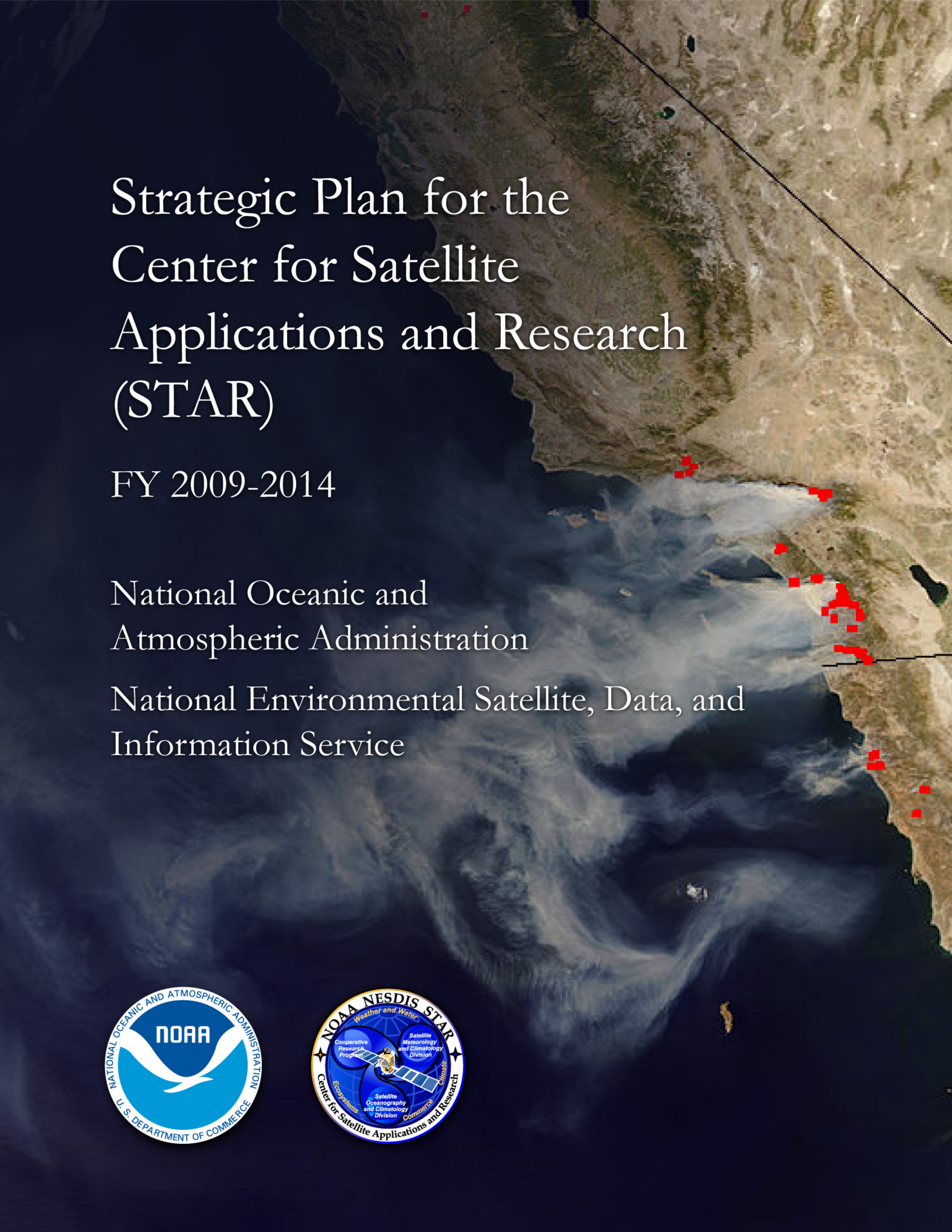
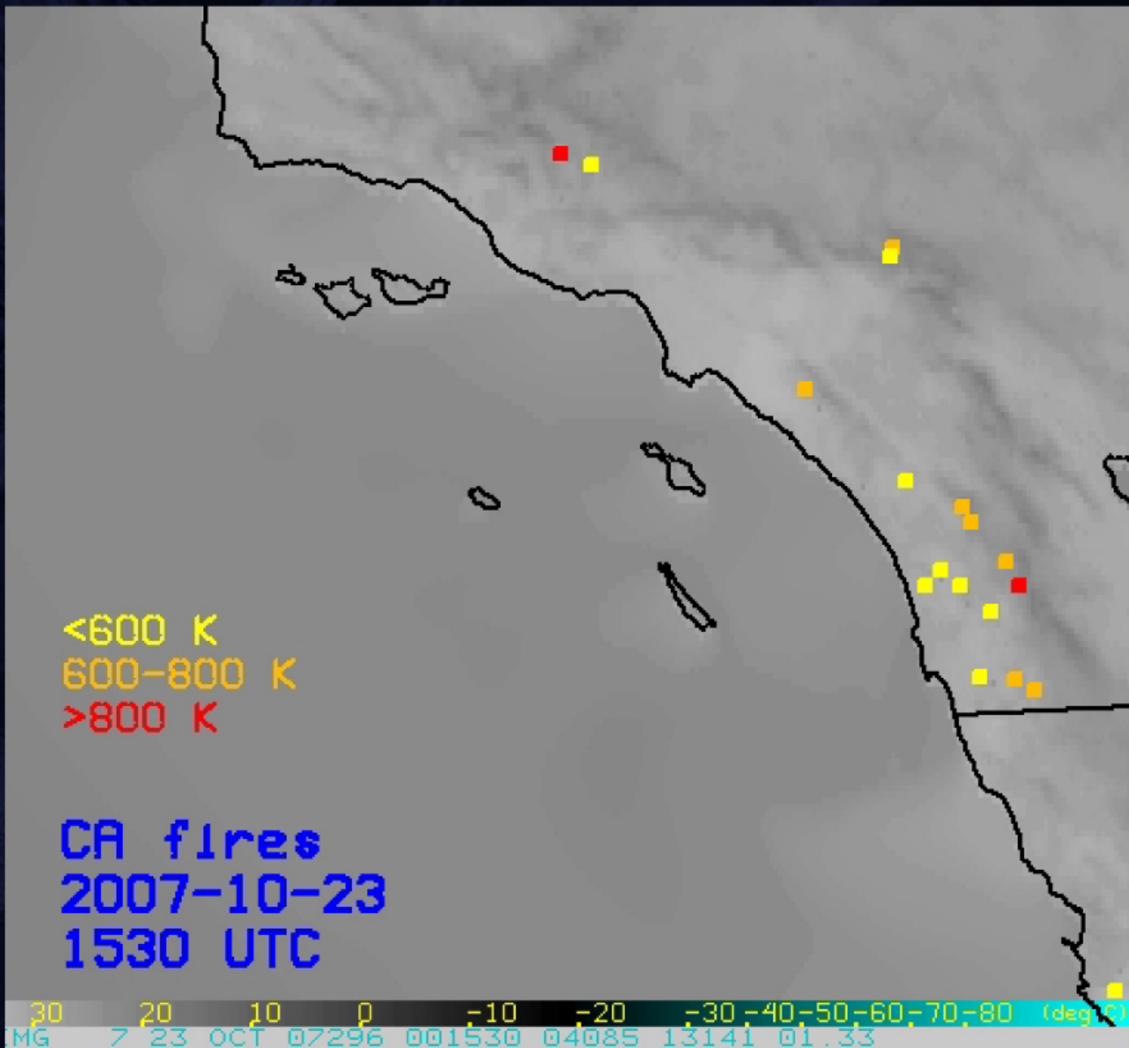


Strategic Plan for the Center for Satellite Applications and Research (STAR)

FY 2009-2014

National Oceanic and Atmospheric Administration

National Environmental Satellite, Data, and Information Service



Synthetic ABI 3.9 µm Image produced by CIRA's RAMM Branch.
Date/time: 2007/10/23 15:30 UTC

This STAR/CIRA/RAMM Branch fire product is part of the GOES-R AWG proxy data sets produced in support of GOES-R Advanced Baseline Imager (ABI) algorithm development. The fire proxy data sets are produced by applying a radiative transfer model to a high-resolution regional weather prediction model (400 m spatial resolution, 5 min data over a 6-hour period). The fire locations come from a CIMSS data set based on a GOES-12 image. An ABI-like satellite image is then created by applying an ABI wavelength-specific point spread function considering the actual ABI footprint for the area of Southern California.

Credit goes to NASA for this MODIS image of the southern California fires on October 23, 2007

STAR's Mission

To provide NOAA with scientific research and development to accelerate the transition of state-of-the-art satellite products, data systems, and services to operations for use by land, atmosphere, ocean, and climate user communities

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A Message from the Director

In its January 2007 report, the National Research Council gave an overarching recommendation that "the U.S. government, working in concert with the private sector, academia, the public, and its international partners, should renew its investment in Earth observing systems and restore its leadership in Earth science and applications." At the National Oceanic and Atmospheric Administration (NOAA), the National Environmental Satellite, Data, and Information Service (NESDIS) has charged its Center for Satellite Applications and Research (STAR), formerly the Office of Research and Applications, to play an integral role in this new commitment.

STAR collaborates with the private sector and academia to develop new instruments and products. The Center also interacts with the public and international partners to deliver global information that will help them better understand and predict changes in the Earth's environment. In the years ahead, new satellite systems with advanced sensing technology will generate new measurements that will significantly increase the volume and precision of environmental data; this increased capability will provide both the opportunity and the challenge to develop "blended products"—products that combine multiple data sets to achieve greater accuracy or greater coverage for critical environmental measurements. STAR is also investing in the future by training young scientists and users of remote-sensing data who will be ready to meet the challenges of this ever-changing field.

The United States and the international community are changing the way we provide remote-sensing data. Instead of separate satellites serving the needs of individual organizations, government agencies, and international organizations, these groups now collaborate to define requirements for the integrated satellite observing systems of the future. Future satellites will meet global requirements for information on Earth's environment—its atmosphere, land, and oceans. Nations are pooling their resources to produce better satellite systems with an increasing number of enhanced instruments. Working with national and international research partners, STAR will support NESDIS in conducting research and developing satellite data applications and products that fully use the expanded capabilities of our increasingly global Earth observing system. STAR's research support is—and will continue to be—necessary for driving NOAA/NESDIS into the future, achieving the strategic goals needed to realize important societal benefits.

This Strategic Plan describes STAR's approach for providing the scientific support necessary to maintain NOAA's leadership in the international community of Earth observing systems. STAR's dedication to research support will advance sensor technology, products, and applications to meet NOAA's expanding requirements for accurate, reliable, and comprehensive environmental data sets.

Alfred M. Powell, Jr., Ph.D.
Director, NOAA/NESDIS Center for Satellite Applications and Research

Introduction to the Center for Satellite Applications and Research

The United States invests billions of dollars annually in environmental satellites in order to monitor the Earth's environment. The Center for Satellite Applications and Research (STAR) is the science arm of the National Environmental Satellite, Data, and Information Service (NESDIS), which acquires and manages the nation's environmental satellites for the National Oceanic and Atmospheric Administration (NOAA). STAR plays an essential role in the development and application of science and technology for current and future satellite observing systems that contribute to the nation's ability to monitor our environment, in particular:

- Assessing current conditions;
- Predicting future changes on the earth; and
- Understanding long-term changes in the environment

STAR research activities, integral to the implementation of the research priorities established in the *NOAA 5-Year Research Plan* and *20-Year Research Vision*, as well as directly supporting the *NOAA Strategic Satellite Plan* (see Figure 1), are aligned with and carried out in direct support of NOAA and NESDIS programs, strategic goals, and performance objectives.

As depicted in Figure 2, STAR supports four phases of the life cycle of satellite hardware, data, and products:

- The life cycle begins with the *Creating* stage of products and systems. STAR helps identify new requirements for satellite data and environmental information; the Center addresses the important science questions that need to be answered in order to meet those requirements. STAR scientists then conduct the research in support of new sensor technology, products, and applications to meet these requirements.
- During the *Producing* phase, STAR develops and tests products that meet the customer's requirements. After an extensive evaluation, the products that satisfy the requirements are transferred to operations for customer use.
- Once a product is operational, customer feedback guides the selection of products for improving or enhancing existing capabilities. The next phase—*Enhancing*—consists primarily of two techniques to improve current products:
  - Refining the formulas used to produce operational products
  - Combining data from other sensors to improve the products
- In the *Mastering* phase, quality and excellence are instilled into the routine methods used to process data.

Throughout all four phases, STAR shares its findings with partners and stakeholders to promote creative thinking about methods that would use satellite data to obtain better information about the Earth and its environment.

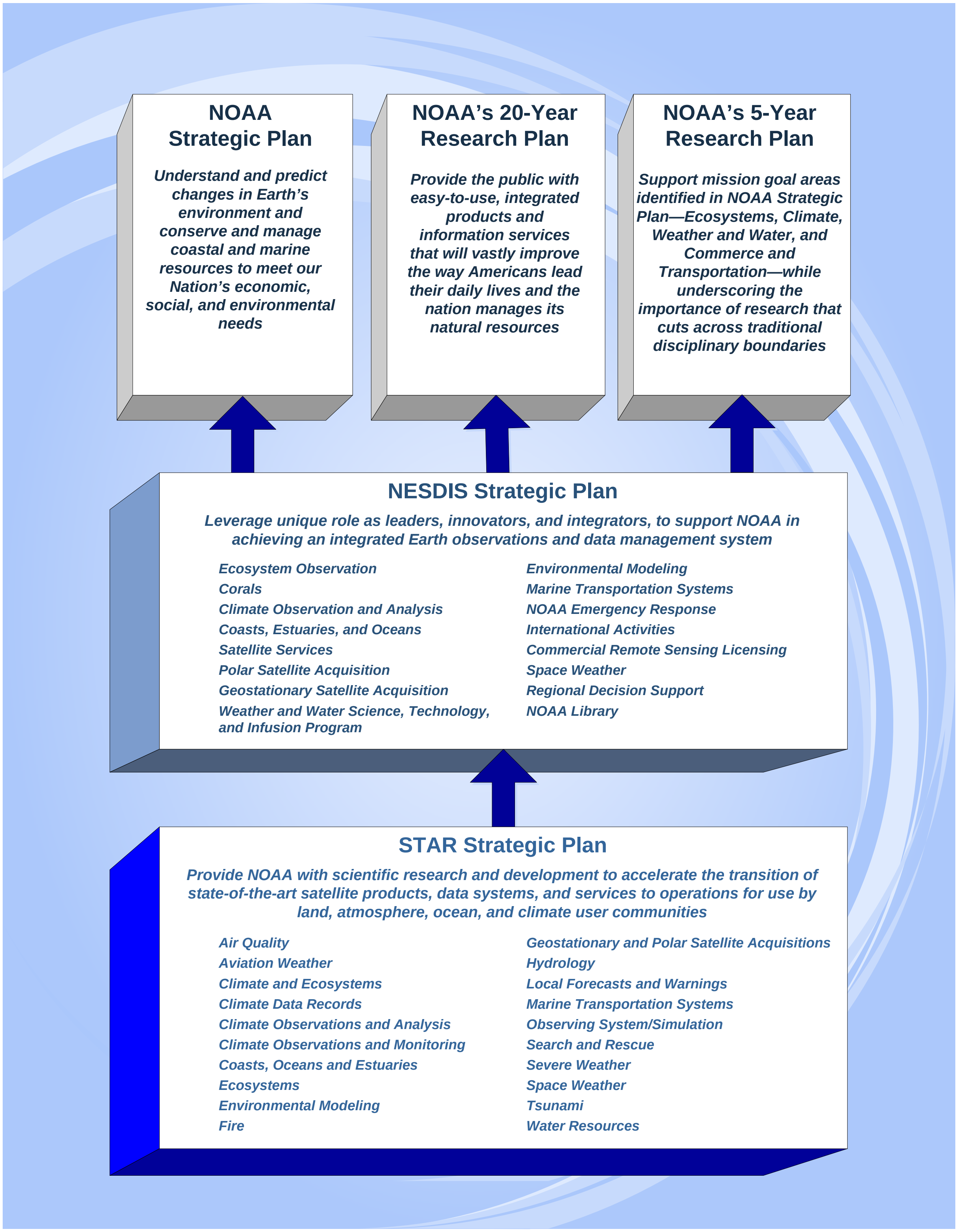


Figure 1. Relationship between the STAR Strategic Plan and the NESDIS and NOAA Strategic Plans

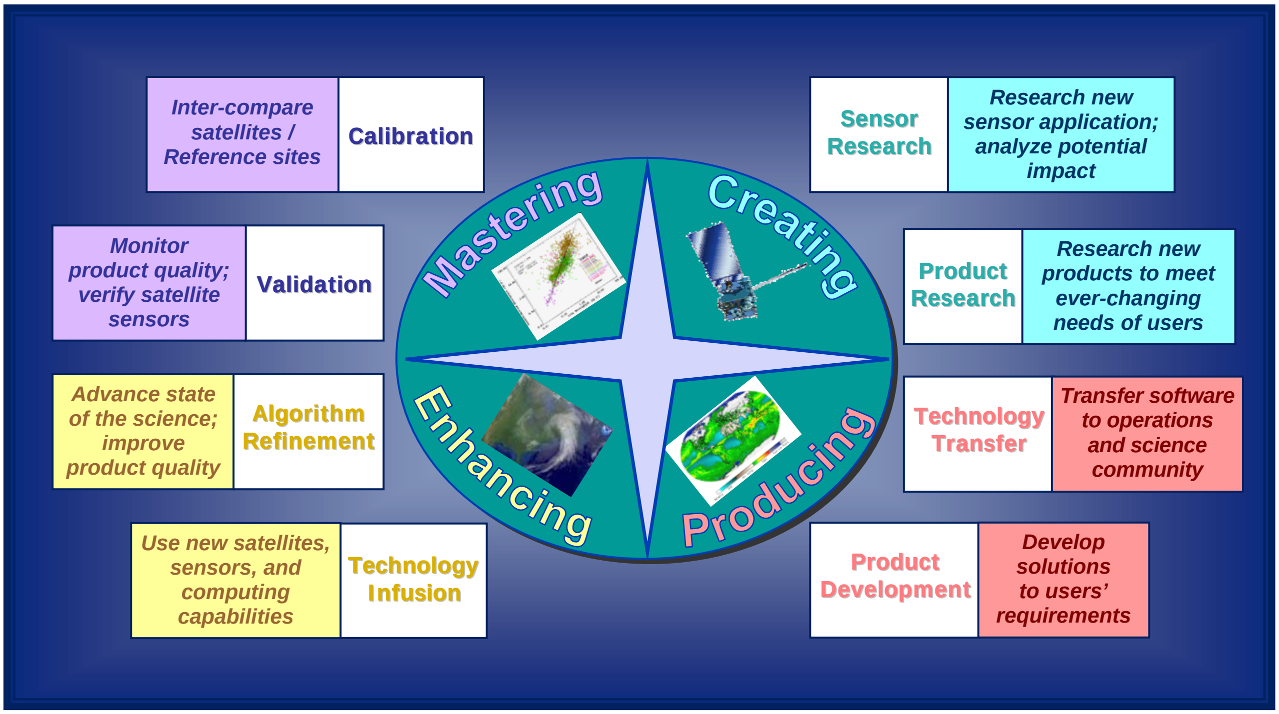


Figure 2. Life Cycle of Satellite Hardware, Data, and Products

STAR supports the calibration and validation of all data in NOAA's satellite operations. In addition to maintaining existing calibration sites, STAR develops new methods for intercalibrating data from NOAA polar and geostationary satellites with other satellites in the evolving international system. STAR scientists lead efforts to develop, test, validate, and refine the science algorithms needed to drive user-defined products. STAR also investigates both enhanced and new sensor technology for future NOAA satellite missions. STAR research examines which products users will need—including ocean, ecosystem, climate, and weather products—to carry out NOAA's mission goals. In addition, STAR collaboratively develops efficient methods and technology to transfer new products from research to operations.

Table 1 summarizes the links between STAR's scientific activities and research and related NOAA programs. STAR's strategy for future satellite applications and research activities has been mapped to support specific elements of the NOAA/NESDIS missions, strategies, and policies. This strategic plan describes the major areas of STAR's work in the context of NOAA's current and future requirements for satellite systems and products. It also provides some representative examples of the types of satellite applications and products that STAR has already developed for its NOAA customers.

Table 1. Links Between STAR's Scientific Support and Research and NOAA Programs

STAR Outcomes *What do we want to achieve in six years?*	**STAR Strategy** *How do we get there? What do we need to do to achieve this outcome?*	**STAR Scientific Support and Research**	**NOAA Programs Supported**
New satellite products and applications needed to meet the NOAA mission	• Support generation of blended/merged products and multidisciplinary algorithms for Global Earth Observation System of Systems (GEOSS) applications • Contribute to NOAA and NESDIS decision making regarding high-impact systems, programs, and applications	• Advance new sensor and product research (satellites, instruments, and processing systems) • Measurement concepts • Alternative trade studies • Hurricane Forecast Improvement Project	• Geostationary and polar satellite acquisitions • Hydrology • Aviation weather • Local forecasts and warnings • Coasts, oceans, and estuaries • Science, technology, and infusion • Climate data records
Timely, successful transition of new or updated satellite product algorithms from research to operations	• Apply resource allocation to risk-managed, high-payoff opportunities, and reduce risks for future satellites (e.g., Satellite Algorithm Test Bed) and quasi-operational data from non-NOAA satellites • Develop a collaborative environment to expedite transition of algorithms/products from research to operations • Leverage resources for future systems development and demonstration missions to meet projected shortfalls by developing, maintaining, and enhancing outside links and collaborations (e.g., other NOAA Line Offices, NASA, USGS, and EPA) through an operational instrument improvement program	• Advance technology transfer and product development • Develop new products and proxy data sets from NASA research missions • Participate on decadal survey mission science teams • Develop and enhance products for National Polar-orbiting Observation Environmental Satellite System (NPOESS) and Geostationary Operational Environmental Satellite (GOES-R) data exploitation	• Local forecasts and warnings • Air quality • Space weather • Environmental modeling • Climate and ecosystems • Science, technology, and infusion • Ecosystem Observations • Coasts, oceans, and estuaries
Optimal accuracy and continuity of NOAA satellite data	• Provide calibration services for all NOAA satellite data sources and validation of satellite data products and applications • Develop a satellite intercalibration system • Develop an integrated validation system • Provide services to ensure accurate instrument data, algorithms, and products using a collaborative environment • Maintain surface reference sites	• Ensure highest satellite data quality (calibration and validation)	• Local forecasts and warnings • Climate data records • Marine transportation systems • Science, technology, and infusion
Advancement of satellite technology	• Develop methodologies, software tools, and infrastructure improvements for assimilating the data from next-generation, advanced satellite instruments • Conduct Observing System Experiments (OSEs) • Conduct Observing System Simulation Experiments (OSSEs)	• Advance algorithm refinement and technology infusion (better formulas, combine data sources) • Enhance Community Radiative Transfer Model (CRTM)	• Climate observations and monitoring • Ecosystems • Air quality • Local forecasts and warnings • Science, technology, and infusion • Environmental Modeling
Blended data and products across satellites and data processing systems	• Develop data reduction techniques for assimilation of new observing capabilities (e.g., hyperspectral) and creation of climate data records (support for the proposed National Climate Service)	• Advance new sensor and product research (design of satellites, instruments, and processing systems) • Enhance Microwave Integrated Retrieval System (MIRS)	• Coasts, oceans, and estuaries • Climate observations and analysis • Local forecasts and warnings • Science, technology, and infusion
Expansion of international remote-sensing capabilities	• Foster strong working relationships with the interagency and international partners (e.g., ESA/EUMETSAT, CNES, JAXA, CSA, CMA, InPE, ISRO, CEOS, WMO) and the user community both locally and globally • Jointly evaluate planned observing and applications capabilities and projected gaps and work to meet shortfalls in observing, modeling, and distribution	• Expand the NOAA/NESDIS role in the international satellite community – GSICS – CEOS – WMO – GEO	• Environmental modeling • Tsunamis • Climate observations and analysis • Local forecasts and warnings
A well-educated user community	• Continue development and upgrade of the Virtual Institute for Satellite Integration Training, the International Virtual Laboratory Satellite Training, and Satellite Hydrology and Meteorology (SHyMET), GOES-R Proving Ground	• Empower the user community • Host demonstrations of satellite products and training	• Local forecasts and warnings • Coasts, estuaries, and oceans • Geostationary and polar satellite acquisitions

STAR Divisions and Affiliates

An understanding of processes on land and in the atmosphere is key to good stewardship of the environment. The ***Satellite Meteorology and Climatology Division*** (SMCD) provides the primary research, development, and transition-to-operations support for NOAA's atmospheric and land remote-sensing activities. SMCD scientists work in the areas of operational product development (e.g., soundings, winds, clouds, hazards, aviation weather, validation), satellite calibration and data assimilation (e.g., radiative transfer, sensor calibration, sounding algorithms, trace gas retrievals, air quality, new satellite instrument development) and environmental monitoring and climate (e.g., vegetation, snow, ice, aerosols, radiation budget, clouds, precipitation, temperature). Applications developed by SMCD assist weather prediction modelers and forecasters in predicting aviation hazards, floods, hurricanes, and severe weather. These predictions play a vital role in reducing the loss of lives and property during such events. SMCD also supports the generation of satellite-based climatological data sets for essential climate variables, providing society and decision makers with a global, regional, and historical perspective of climate change and variability.

Since more than 70 percent of the earth's surface is covered by water, satellites are sensing the surface of the ocean most of the time. The ***Satellite Oceanography and Climatology Division*** (SOCD) provides primary research and development and research-to-operations support for oceanic remote sensing within NOAA. SOCD scientists work in the primary areas of ocean remote sensing (e.g., ocean color, ocean surface winds, sea surface temperature, satellite altimetry, and ocean surface roughness), marine ecosystems and climate (e.g., sea ice, coral reefs, water quality), and ocean physics (surface currents and sea-floor topography). Because the ocean plays a fundamental role in determining both weather and climate conditions, observations of ocean properties directly support weather and climate modeling and forecasting and contribute to the immense social and economic value of forecasting efforts. The same observations also play important roles in managing ocean ecosystems, protecting endangered species, and measuring the role of the oceans in climate.

To more fully realize the societal benefits of increased exploitation of data from NOAA satellites, STAR teams with academic partners across the country at four cooperative institutes and one cooperative center. Cooperative research programs (1) develop methods for remote sensing Earth from satellites, (2) make accuracy assessments of the satellite observations and derived products, (3) transfer technology to operations, and (4) provide science support, training, and outreach. The three branches of STAR's ***Cooperative Research Program*** (CoRP)—consisting of federal government scientists—are collocated with a cooperative institute managed by a university.

Partnerships with these five ***cooperative institutes or centers*** enable CoRP to conduct innovative research with current and future remote-sensing specialists:

- Cooperative Institute for Climate Studies (CICS), University of Maryland, College Park, Maryland
- Cooperative Institute for Meteorological Satellite Studies (CIMSS), University of Wisconsin, Madison, Wisconsin
- Cooperative Institute for Oceanographic Satellite Studies (CIOSS), Oregon State University, Corvallis, Oregon
- Cooperative Institute for Research in the Atmosphere (CIRA), Colorado State University, Fort Collins, Colorado
- Cooperative Remote Sensing Science and Technology Center (CREST), City College of City University of New York, New York, New York, and participating institutions: Bronx Community College (NY), Bowie State University (MD), Columbia University (NY), Hampton University (NY), Lehman College (NY), University of Maryland Baltimore County, and the University of Puerto Rico-Mayaguez.

STAR is also a part of and a fundamental contributor to the activities of the ***Joint Center for Satellite Data Assimilation*** (JCSDA). The JCSDA—collocated with STAR—was established to improve and accelerate the quantitative use of research and operational satellite data in weather, ocean, and climate modeling, analysis, and prediction. The JCSDA provides a focal point for the development of common software and infrastructure for its partner agencies: the National Aeronautics and Space Administration (NASA), NOAA, and the Department of Defense (DoD). The Joint Center enables these agencies to fully prepare for the upcoming flood of data from the advanced satellite instruments that will be launched during the next five to ten years and to better achieve their mission goals. JCSDA research and development directly supports NOAA and DoD in their operational environmental prediction responsibilities at home and abroad and supports NASA in its quest to improve our understanding of Earth's climate and in transferring its research to operational weather and climate forecasting.

STAR's Scientific Support and Research

In the next 15 years, NOAA will develop, implement, and collaborate on a series of new satellite programs: the Initial Joint Polar-orbiting Satellite system (IJPS), a cooperative effort with European Organization for the Exploitation of Meteorological Satellites (EUMETSAT); the National Polar-orbiting Operational Environmental Satellite System (NPOESS), a collaboration with NASA and the Department of Defense; and the Geostationary Operational Environmental Satellite Series R (GOES-R), a collaboration with NASA. NOAA will also help integrate a global system of environmental observation data, which will require integration of data from international satellites and other Earth observations. This worldwide program of shared environmental data and resources is called the Global Earth Observation System of Systems (GEOSS). GEOSS is designed to characterize the global Earth system through various environmental measurements and to monitor changes to address societal benefits. Satellites will generate the largest source of data by volume in this global system.

Satellites traditionally used to monitor daily weather must be intercalibrated before they can be used in longer-term monitoring of the regional or global environment. A major challenge of the intercalibration effort will be to compare the radiation measurements from the constellations of geostationary and low Earth-orbiting (LEO) satellites.

STAR will work with its national and international research partners to better exploit satellite data, to evaluate capabilities and gaps, and to use these enhanced assets to advance the science of remote sensing. STAR has identified five focus areas for scientific support and research that are needed to achieve these goals:

- Promote new sensor and applications research (design of satellites, instruments, and processing systems)
- Ensure the highest-quality satellite data (calibration and validation)
- Advance algorithm refinement and technology infusion (better formulas, combined data sources)
- Expand the NOAA/NESDIS role in the international satellite community
- Empower the satellite data user community

The priority for the transition of research missions to operations will be determined by user benefits and its ability to meet NOAA performance objectives. The highest priority operational and research missions for NESDIS/STAR are shown in Figure 3.

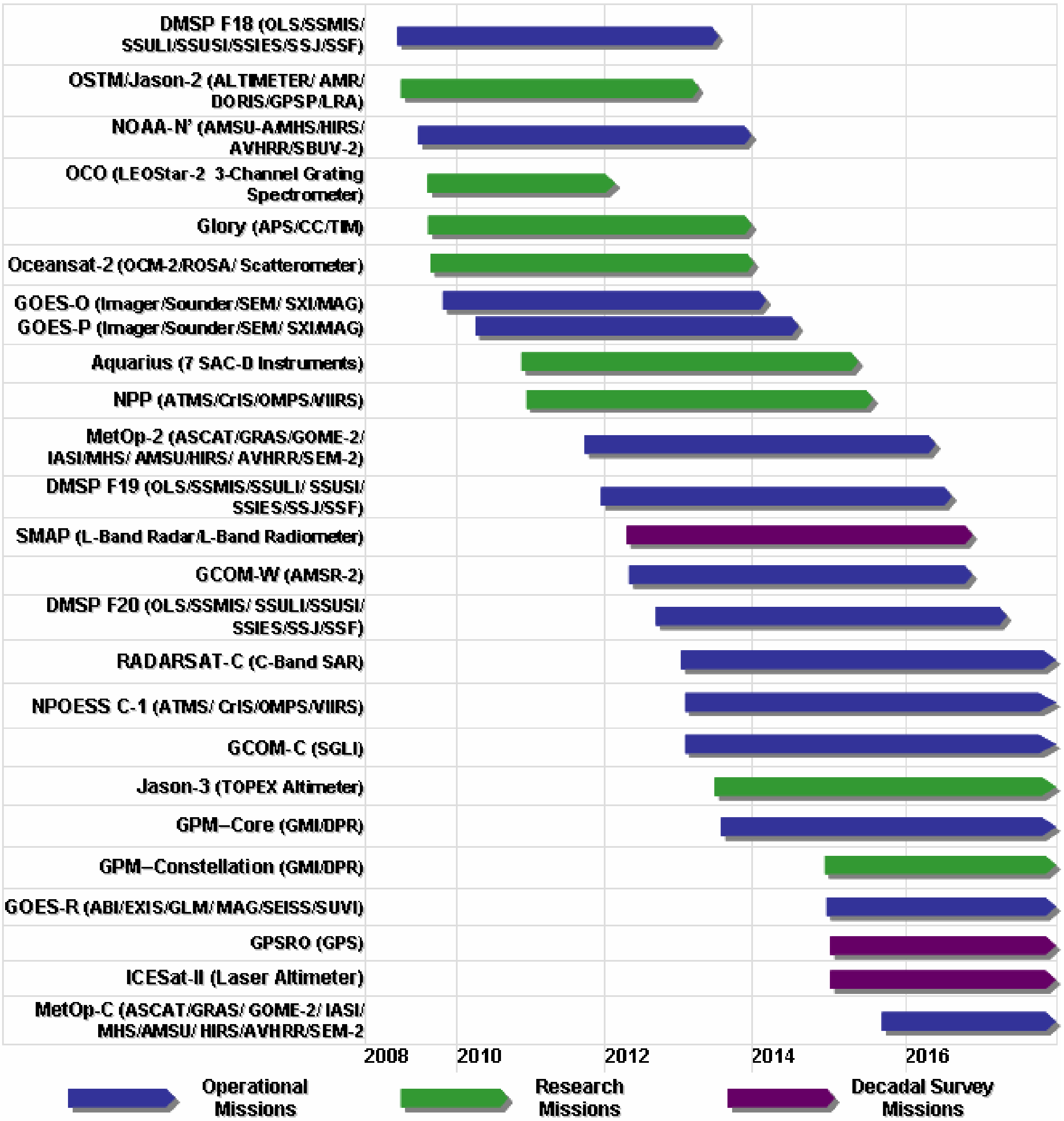


Figure 3. Highest Priority Satellite Mission for Planned Launch Dates of 2016 or Earlier

In Appendix A, each mission's alignment with NOAA performance outcomes, objectives and the important benefits are described. Through this mission alignment, this information will help NOAA match user requirements with improved measurement capability.

In the years ahead, these advanced sensing technology satellite systems will generate new measurements and enhanced products that will significantly increase the volume and accuracy of environmental data. These increased capabilities will provide both opportunities and challenges to develop "blended products"—products that combine data sets from multiple sensors or platforms to achieve greater accuracy or greater coverage for critical environmental measurements.

STAR’s research strategy for each of its focus areas is described in the following sections. The descriptions include examples of how STAR’s work supports and expands the development and use of current and future NOAA, NASA, and international Earth observing systems (see satellite fly-out schedule in Appendix B), as well as NOAA’s international leadership in building integrated systems, such as GEOSS.

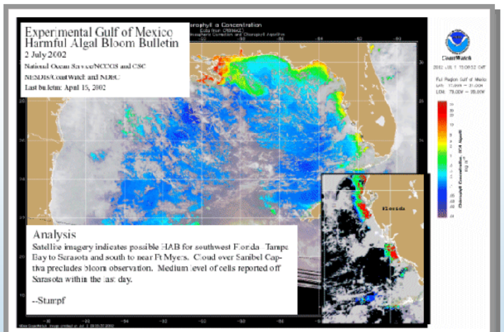
Promote New Sensor and Applications Research (Satellites, Instruments, and Processing Systems)

To ensure measurement continuity, NOAA routinely plans for new satellites to replace old satellites, utilizing technology breakthroughs to enhance subsequent missions. STAR scientists—often working with National Aeronautics and Space Administration (NASA) scientists—participate in designing new instruments to be flown on the next-generation geostationary and LEO satellites. Notable improvements include increased spectral, spatial, and temporal resolutions. During the design phase of new satellites, STAR helps identify the trade-offs in cost and risk for new instruments. STAR evaluates system requirements for spatial coverage, temporal sampling, ground-truthing methods, and the need for blended products (a mix of data sources). STAR scientists also help determine the best way to use the new/enhanced data to meet the specific needs of end users.

A number of important trends in instrument technologies will be implemented in the next generation of operational satellites. A few of these trends are identified below:

- Hyperspectral instruments for monitoring the earth's environment in greater detail than ever before possible will measure the atmosphere, land, and oceans with unprecedented information content, frequency, and timeliness; this information will significantly improve nowcasting, as well as short- and medium-range forecasts.
- Active sensors such as radar, lidar, and microwave instruments will add new capabilities for measuring—with unprecedented resolution—the vertical structure of the atmosphere, including temperature, moisture, clouds, precipitation, winds, and aerosols.
- Radar instruments will measure surface properties of the ocean directly and in fine spatial detail, providing information on ocean surface winds, water roughness, sea level, sea ice, and ocean currents.
- New instruments will provide the first space-based information on ocean salinity, soil moisture, and aerosol properties. They will also ensure that NOAA has robust observations of ocean color, solar radiation, and the radiation budget of Earth.

Detection of Harmful Algal Blooms



Chlorophyll concentration (above) and possible HAB areas shown in red (inset). Cell concentration sampling data from May 9, 2002 shown as red filled circles (medium to high), yellow filled circles (low), unfilled circle (present), and black "X" (not present).

STAR and its partners use satellite imagery, field observations, and buoy data to provide the large spatial scale and high frequency of observations required to assess bloom location and movement.

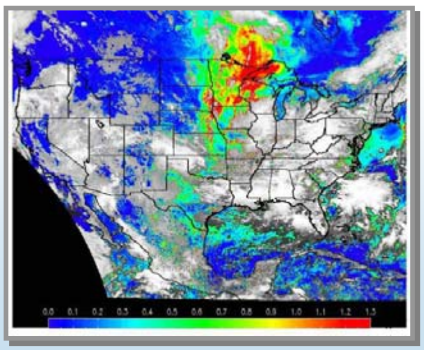
Beyond the traditional function of predicting hurricanes and severe weather events, geostationary imaging can serve a number of emergency response applications, providing vital information for such concerns as oil spills, harmful algal blooms, and hazardous agents introduced into the environment. This new information will be used for improved weather prediction, study of trace gases and aerosols, land-use applications, ocean prediction, and climate change. Blended products from multiple measurement sources—such as satellites and surface or airborne observations— will provide notably enhanced information.

STAR scientists chair and participate in technical advisory committees, which guide the development of new sensors and applications on geostationary satellites. STAR also leads the development of GOES-R algorithms through its representation on the GOES-R Algorithm Working Group and its close cooperation with international partners, such as EUMETSAT.

NOAA's NPOESS Data Exploitation (NDE) project will provide products derived from NPOESS observations to NOAA's operational community in near–real-time. STAR will work with the NDE project to develop new, NOAA-unique products derived from NPOESS data. Initially, these products will be developed from data transmitted from the NPOESS prototype satellite, the NPOESS Preparatory Program (NPP). These products will include sea surface temperature, snow cover, cloud liquid water, and precipitable water.

Atmospheric chemistry, aerosol and transport models, and their applications are increasingly important components of environmental monitoring and forecasting systems, which the U.S. Congress recognized by recently directing NOAA to issue nationwide hourly air quality forecasts. Satellite data provides information about aerosol loading and about atmospheric constituents, such as ozone, sulfur dioxide, carbon dioxide, carbon monoxide, and methane. STAR will develop an advanced algorithm for current satellite sensors to retrieve ozone profiles and small particle concentrations. The products will be used to directly monitor air quality in real time. The resulting products can also be directly used to initialize air quality models and to diagnose the model outputs. Using modern multivariate data assimilation methods, STAR's work has the potential to significantly improve aerosol and weather forecasts in general. Atmospheric chemistry models—when integrated with weather prediction and climate models—provide powerful tools for analyzing and predicting the evolution and distribution of greenhouse gases, quantifying the earth's carbon cycle, and forecasting air quality, visibility, and ultraviolet (UV) exposure indices. STAR, having undertaken air quality and aerosol data assimilation efforts, will play an important role in developing applications for atmospheric chemistry, the carbon cycle, and the link between atmospheric aerosol and the climate system. The ultimate goal is to effectively monitor and enhance the understanding of human interaction with global air quality. As a partner in the Joint Center for Satellite Data Assimilation (JCSDA), STAR will play a significant role in improving forecasts of the passive transport of aerosols and gaseous pollutants.

Aerosol Monitoring for Air Quality and Forecasting



STAR provides the near–real-time aerosol optical depth product for air-quality monitoring and the weather-forecasting community. The Environmental Protection Agency (EPA), the National Weather Service (NWS), and other stakeholders use this product to track the movement of pollution plumes, to monitor particulate pollution, and to verify particulate pollution forecasts.

NOAA needs more capability to monitor atmospheric, land, and ocean properties related to public health and safety, such as atmospheric pollutants, harmful algal blooms, and West Nile virus. Health and economic effects of extreme weather and poor atmospheric conditions are primary drivers for NOAA's responsibilities in warning and forecasting. Stakeholders increasingly expect more lead time and accuracy in weather forecasts in order to support disaster services, search and rescue, and military operations. The GOES-R Geostationary Lightning Mapper (GLM) is an example of a significant new instrument that will map all lightning flashes day and night in a storm, aiding forecasters in increasing the warning lead-time for severe storms.

Examples of STAR Research Support

- Develop prototype and first-generation active sounder algorithms
- Demonstrate the applicability of satellite-derived products for air quality monitoring and forecasting
- Develop a reliable surface ultraviolet irradiance product derived from Geostationary Operational Environmental Satellite (GOES) that will provide much-needed data for research in the fields of climate, biology, agriculture, fishery, and industry
- Investigate the potential of new products or techniques derived from GOES or polar multispectral data to improve the detection and short-range forecasting of aviation hazards, including fog, low clouds, aircraft icing, turbulence, volcanic ash, and convective wind gusts
- Exploit advanced infrared and microwave sounder to extend the useful range of weather predictions and provide critical information on greenhouse gases associated with global climate change
- Evaluate the potential of GOES Imager to develop first sea-surface temperature (SST) climatology with diurnal cycle resolved
- Monitor lightning detection and flash rate trending to provide advance warning of severe and hazardous storms
- Develop climate quality algorithms to measure the atmospheric components of the carbon cycle, ozone trends, aerosol properties, and the Earth radiation budget from the advanced observations of MetOp and the NPOESS Preparatory Program (NPP)
- Blend infrared geostationary and polar data with microwave SST data and evaluate the operational impact
- Develop blended microwave precipitation products from multiple satellites for weather and climate
- Develop capabilities to provide quantitative information relating to oceanic biological parameters, e.g. phytoplankton biomass and productivity, biogeochemical processes, coral bleaching, ocean acidification, and the state and magnitude of human activities in oceanic and coastal waters
- Develop and sustain a new generation of high-resolution, high-accuracy satellite SST, using improved cloud screening and radiance inversions

Ensure the Highest Satellite Data Quality (Calibration and Validation)

NOAA's mission for the next century includes a new goal to understand climate variability and change. STAR will provide sustained support for this effort by better characterizing satellite observations through reduced measurement uncertainties by using detailed pre-launch and post-launch data analyses, including leading the international effort, through the Global Satellite InterCalibration System (GSICS). The GSICS will foster LEO-LEO and LEO-GEO intercalibration activities to ensure overall consistency of data sets for GEOSS applications, including climate and Numerical Weather Prediction (NWP). The primary focus of GSICS is the intercalibration and improved characterization of passive measurements (infrared [IR]–visible–microwave [MW]) from operational satellites using research and development instruments as a benchmark. Improving the accuracy of the fundamental measurements will allow STAR and other science groups to develop improved Climate Data Records (CDRs) of essential climate variables, allowing better assessments of climate change. In this manner, STAR will contribute to NOAA's newly planned National Climate Service.

GSICS Quarterly

Global Space-based Inter-Calibration System

No. 1, Spring 2007

• CMA • CNES • EUMETSAT • JMA • KMA • NOAA • WMO •

Introducing GSICS

For most of the history of the earth sciences, weather and climate phenomena such as severe thunderstorms, blizzards, hurricanes, droughts, and monsoon floods have been studied as isolated regional-scale events using simplified theoretical or numerical models and limited observations. Furthermore, atmospheric, oceanographic, and geological scientists rarely crossed the boundaries of their own disciplines, and they scarcely thought of interacting with biological and social scientists. In the past decade or so, earth scientists have been summoned to mostly abandon this "pure research" mode of activity in favor of applying earth science principles to solve very complex environmentally-related societal problems. These problems, which are outlined within the Global Earth Observation System of Systems (GEOSS) concept, include:

- Reducing loss of life and property from disasters;
- Understanding environmental factors affecting human health;
- Improving management of energy resources;
- Understanding, assessing, predicting, mitigating and adapting to climate variability and change;
- Enhancing water resources management through better understanding the water cycle;
- Improving weather information, forecasting and warning;
- Improving the management and protection of terrestrial, coastal and marine ecosystems;
- Supporting sustainable agriculture and combating desertification; and
- Understanding, monitoring and conserving biodiversity.

In order to make tangible steps toward these goals, using space-based observations of the dynamic earth-ocean-atmosphere system is an essential part of the process.

The original concept of space-based observations was to provide snapshots of the state of our environment over large regions of the globe, especially in areas where conventional measurement systems are impractical. Highly accurate agreement between snapshots taken by different satellite instruments, or by the same instrument at different times, was not part of the concept. More recently, concerns about global climate change and the advent of more powerful methods of data assimilation and numerical weather prediction have forced satellite measurements to take on roles that they were not originally designed for. An example of this is the mid-tropospheric temperature time series created from several NOAA Polar-Orbiting Environmental Satellite (POES) Microwave Sounding Unit (MSU) instruments, which contain brightness temperature biases and bias drifts that must be removed to make a coherent climate data record. A perspective of the MSU time series over ocean, before and after bias correction, is given in Figure 1, which was taken from an analysis of Zou et al. (2006). This demonstrates that in order to make use of observations from the international constellation of satellite instruments to monitor and understand weather and climate phenomena that impact society, these instruments must be carefully inter-calibrated. This is the role of the Global Space-based Inter-Calibration System (GSICS), which has been established to foster collaboration and cooperation amongst the satellite data providers of the world.

Figure 1. Global tropospheric temperature trends revealed by NOAA-10, -11, -12, and -14 Microwave Sounding Unit (MSU) data before (top) and after (bottom) intersatellite calibration bias correction.

The concept and strategy for GSICS (GSICS-IP, 2006) were submitted by the World Meteorological Organization (WMO) and endorsed by the Coordination Group of Meteorological Satellites (CGMS) at its 33rd meeting (CGMS-XXXIII) held in Tokyo, Japan on 1-4 November 2005. The initial goal of GSICS is to achieve operational inter-calibration of satellite instruments within the space-based component of WMO's World Weather Watch/Global Observing System (WWW/GOS). The GSICS organizational chart given in Figure 2 also depicts how GSICS fits into the structure of WWW/GOS, whose purpose is to address climate, weather

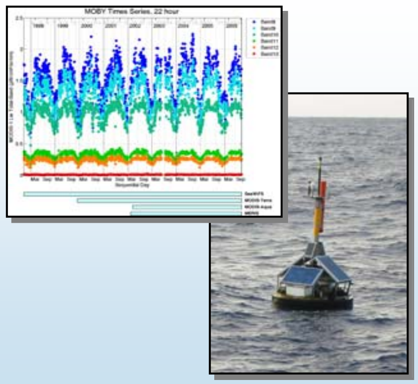
To ensure long-term confidence in the accuracy and quality of Earth observation data and products, the Working Group on Calibration and Validation (WGCV) and GSICS, in which NESDIS/STAR plays a central role, provides a forum for calibration and validation information exchange, coordination, and cooperative activities. The WGCV promotes the international exchange of technical information/documentation, and joint experiments, as well as the sharing of facilities, expertise, and resources. To this end, WGCV addresses the need to standardize ways of combining data from different sources to ensure the interoperability required for effective use of existing and future Earth observing systems.

STAR teams calibrate instruments on one satellite against instruments on another (inter-satellite calibration) and link the original calibration of the satellite's IR sensor to the reference on NOAA satellites to the standard of the National Institute of Standards and Technology (NIST). In the future, the Climate Absolute Radiance and Refractivity Observatory (CLARREO) mission will become a key component of our climate mission by providing "irrefutable" climate records through the use of exacting on-board traceability of the instrument accuracy. Spectral visible and IR radiances, along with Global Positioning System Radio Occultation (GPSRO) refractivities measured by CLARREO, will be used to detect climate trends and to test, validate, and improve climate prediction models.

STAR has already developed a powerful method to quantify the inter-satellite calibration biases for radiometers on polar-orbiting satellites. If the method were applied to all historic observations from NOAA polar-orbiting satellites, it would be possible to construct the more precise CDRs needed for climate monitoring and reanalysis. The method is based on observations of a Simultaneous Nadir Overpass (SNO), where nadir is the point on the earth directly beneath a satellite. A SNO occurs when the nadir points of two polar-orbiting satellites cross each other within a few seconds, usually in polar regions. For each SNO, the radiometers on the pair of satellites view the same place at the same time at nadir, thus eliminating uncertainties associated with the atmospheric path, view geometry, and time differences. The measurements should be identical; consequently, it is possible to determine the bias of one instrument with respect to the other.

In 2007, STAR scientists assumed responsibility for the Marine Optical Buoy (MOBY), an ocean color reference site operating in Hawaiian waters for the past decade, supporting vicarious calibration of the world's ocean-color satellites. Continued uninterrupted data from this reference site is essential to cross-referencing data and to maintaining the highest-possible-quality environmental data from the evolving constellation of international ocean-color satellites, including the Visible Infrared Imager Radiometer System (VIIRS) on NPP and NPOESS. This ten-year time series (previously funded by NASA) represents a successful research-to-operations effort that draws on both NASA and NOAA strengths and requirements.

Ocean Color Vicarious Calibration

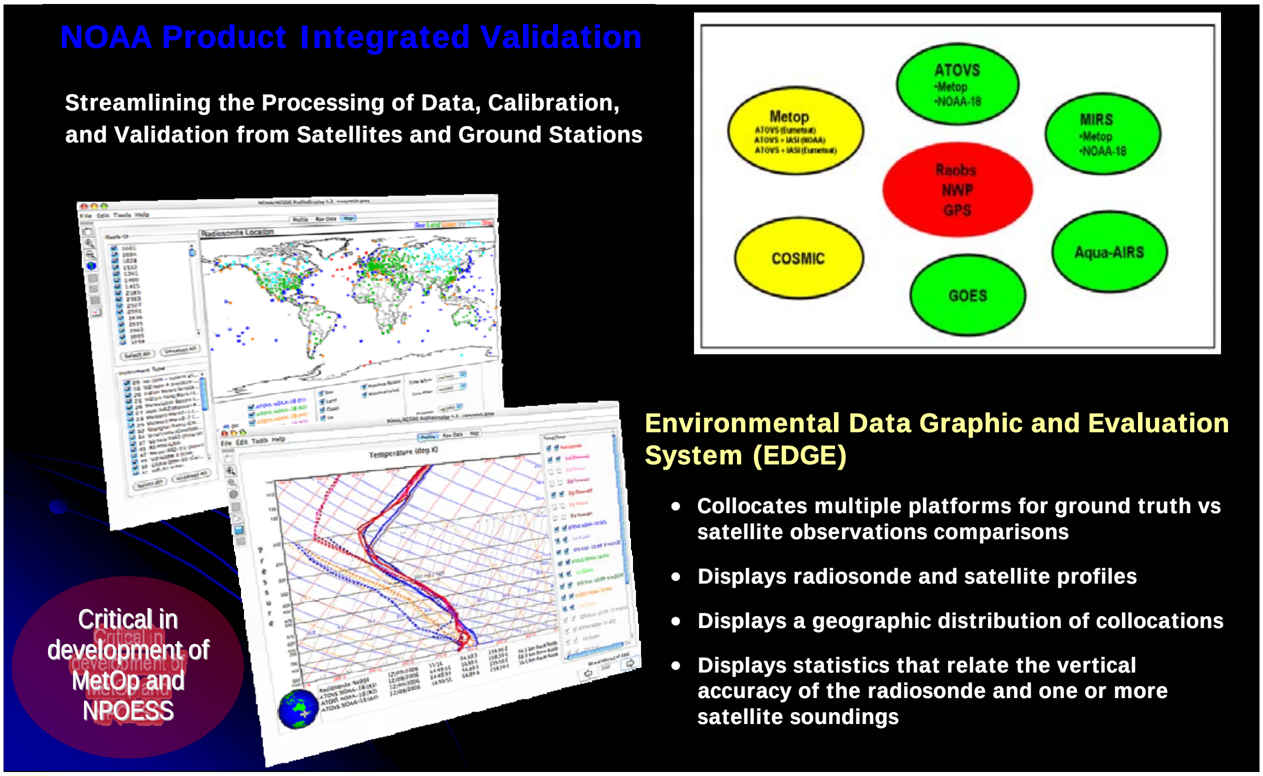


STAR and its partners use have been providing vicarious calibrations for ocean color sensors since 1998 with the Marine Optical BuoY (MOBY). MOBY, located ten miles off the coast of Hawaii, measures daily water leaving radiances at times corresponding to ocean color satellite overpasses. The in situ-satellite data matchups are then used to adjust the sensor gain factors to fine tune calibrations.

STAR has created a standard of quality control for sea surface temperature (SST). The team runs statistical checks to ensure that SST products are self-consistent, cross-calibrated and validated against ground truth data observed by buoys and ships.

NESDIS has been responsible for the generation and validation of satellite-based surface and atmospheric weather products since the deployment of the Television and Infrared Observation Satellite (TIROS) Operational Vertical Sounder (TOVS) in 1979. These systems have expanded over the past 25-plus years to include products from multiple polar and geostationary space platforms, leading up to the current advanced microwave and hyperspectral IR sounders that will be the mainstay of next-generation NPOESS systems.

The inter-sensor and product validation challenge has become a growing concern for the scientific community tasked with utilizing these observations to provide the public with real-time weather and long-term climate information. The lack of a centralized, consistent approach to monitoring and validating respective suites of satellite observations has led to ambiguous, even conflicting, results, as well as costly duplication of effort amongst NOAA's satellite and product programs. The NOAA Product Integrated Validation System (NPIVS), a tool developed for the Integrated Program Office (IPO), is establishing an integrated satellite data and ground-truth collocation system with the goal of providing consistent monitoring and validation of NOAA space-based weather products. NPIVS protocols include carefully designed strategies for collocating satellite observations from both polar and geostationary platforms with selected sets of ground-truth observations. The program screens the ground truth used for validation and provides graphical evaluation systems for complete scientific monitoring, analysis, and research support.



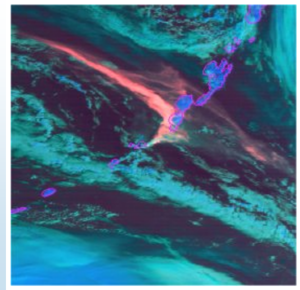
Examples of STAR Research Support

- Develop a satellite intercalibration system to support the generation of high-quality climate data records
- Provide to the operational and science communities improved characterization of satellite observations along with defined and documented uncertainties
- Develop integrated validation systems for monitoring and assessing the quality of sounder products from multiple sensors, such as the Advanced Television and Infrared Observation Satellite (TIROS) Operational Vertical Sounder (ATOVS), the Atmospheric Infrared Sounder (AIRS), the Infrared Atmospheric Sounding Interferometer (IASI), the Cross-track Infrared Sounder (CrIS), and the Global Positioning System (GPS) Radio Occultation system
- Operate the Marine Optical Buoy (MOBY) in support of the Visible Infrared Imager Radiometer System (VIIRS) and the evolving international constellation of ocean color satellites
- Provide validation data sets to NOAA and external researchers
- Develop unified methods for quality control of global satellite and ground-truth data, and their near-real-time monitoring for stability and cross-platform consistency

Advance Algorithm Refinement and Technology Infusion (Better Formulas, Combine Data Sources)

Monitoring Volcanic Ash

Recent experiments conducted by STAR, using multispectral data from the Moderate-resolution Imaging Spectro-radiometer (MODIS) on NASA's Terra/Aqua satellite, have shown that significant improvements in volcanic ash detection can be obtained using multi-spectral techniques. STAR plans to develop similar products to improve aviation safety using data from the next generation of NOAA satellites, including NPOESS and GOES-R.

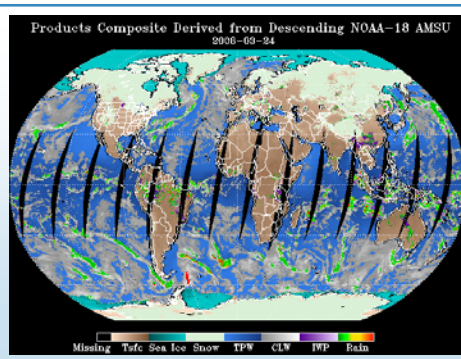


Trends in end-user requirements reflect increasing pressures to improve NOAA's environmental hazards, weather, and climate prediction capabilities. STAR's research support will increase lead time and accuracy for weather and water warnings, as well as for forecasts by improving the predictability of the onset, duration, and impact of severe weather and water events. Satellite data, together with improvements in data assimilation, NWP models, and computer power, have enabled forecast skill to improve at a rate of about one day per decade over the last few decades. Today's five-day forecasts are as accurate as four-day forecasts were just 10 years ago.

STAR scientists will support and maintain current operational satellite products while simultaneously introducing and enhancing more advanced versions at the same time. STAR will use synthetic (proxy) and simulated data as part of its risk reduction activities. Numerical models, in combination with advanced radiative transfer codes, will be used to generate synthetic radiances that are similar to what will be available from future satellites (see the fire image on the cover of this plan). Current operational and research satellites can be used to develop proxy data similar to that from planned future systems. Although Moderate-resolution Imaging Spectroradiometer (MODIS) and Atmospheric Infrared Sounder (AIRS) remotely-sensed data originate from polar satellites, their more-advanced information provide the basis for preliminary product development for the next-generation geostationary operational satellite systems, such as GOES-R. STAR will use synthetic (proxy) and simulated data as part of its risk reduction activities.

Microwave Products

N-18 AMSU/MHS derived product composite from 24 March 2008 (descending orbits). The various colors correspond to the wide array of products derived from the microwave measurements (land surface temperature, sea-ice concentration, snow cover, total precipitable water, cloud liquid water, ice water path, and rain rate), while the different shading indicates the different intensities of the individual products.



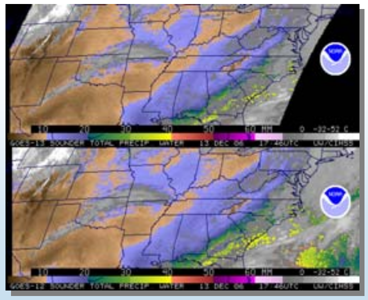
Satellite microwave instruments play vital roles in improving weather and climate prediction since microwave measurements are less affected by clouds than IR, visible, and UV observations; they are also directly related to geophysical parameters and are less affected by clouds than IR, visible, and UV observations. These improvements allow greater forecast accuracy. Additionally, important global time series of 20 years or longer can be derived from passive microwave sensors, such as tropospheric temperature, precipitation, snow and sea-ice cover, and atmospheric moisture. Major challenges being addressed by STAR scientists include the development of improved satellite calibration and intercalibration of satellite data to ensure a seamless time series and merging of measurements from a variety of passive microwave sensors (e.g., Microwave Sounding Unit [MSU], Advanced Microwave Sounding Unit [AMSU], Special Sensor Microwave Imager [SSM/I], Special

Sensor Microwave Imager /Sounder [SSMIS], etc.), as well as the development of merged, multispectral and in-situ data sets and time series.

Hyperspectral observations provide finer temporal, spatial, and spectral resolution, which makes them especially well suited for improving land surface and coastal ocean products. Hyperspectral data and multisensor data availability will make it possible to enhance current satellite products.

The Advanced Baseline Imager: A Next-Generation Sensor

The ABI improves the spectral, temporal, spatial, and radiometric performance over the current GOES Imager, in include missing spectral bands due to eclipses and related outages illustrated in this figure.



The methodology and products developed by STAR for monitoring vegetative conditions are used routinely to warn the global community about long-term drought. Future instruments will have better resolution and different spectral bands to extract better information than current instruments; for instance, current vegetation algorithms will need to be modified for the new instruments. Properties of vegetation, such as leaf area index and advanced indicators of vegetation stress, are not currently available in a satellite product. STAR will develop these advanced products for operational use.

Increased spatial resolution of the Advanced Baseline Imager (ABI) planned for GOES-R will depict a wider range of phenomena by scanning faster to improve temporal sampling and by adding spectral bands to create and improve products, such as aerosol detection and visibility estimation.

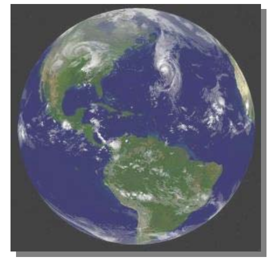
Efforts continue to develop new and improved atmospheric correction techniques for satellite ocean color observations, particularly in turbid coastal waters. This will lead to more robust and accurate products in support of coastal research, management, and decision-making.

STAR supports weather forecasters and water-management agencies with precipitation products from satellite data. Rainfall estimates, covering wide areas of the earth's surface, still require greater accuracy. STAR has begun to merge data from polar satellites and geostationary satellites by blending the data from different instruments to take advantage of the strengths while avoiding the limitations of each.

Examples of STAR Research Support

- Improve vegetation products to provide more accurate surface conditions for Numerical Weather Prediction (NWP) models and drought monitoring
- Improve snow products to allow more accurate boundary conditions in NWP and construction of a long-term climate data record for snow
- Improve the accuracy of satellite-based estimates of rainfall for hurricanes and severe storm events
- Develop outgoing long-wave radiation (OLR) retrieval algorithms from sounder channels (High-Resolution Infrared Radiation Sounder [HIRS], Atmospheric Infrared Sounder [AIRS], Cross-Track Infrared Sounder [CrIS]) to provide a time series of OLR compatible with the Earth Radiation Budget Satellite (ERBS) instrument on NPOESS
- Develop an improved integrated GOES sounder product system that will provide the National Weather Service (NWS) with full resolution GOES sounder products for use in Numerical Weather Prediction (NWP) and the Advanced Weather Interactive Processing System (AWIPS)
- Exploit the enhanced microwave observing capabilities of the Conically Scanning Microwave Imager/Sounder (CMIS) on NPOESS
- Develop GOES-R proxy data sets from synthetic Advanced Baseline Imager (ABI) channels to simulate new products (fire weather, atmospheric structure)

Expand the NOAA/NESDIS Role in the International Satellite Community

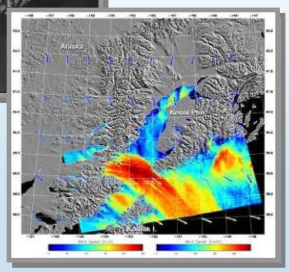


STAR has a leading role in the expansion of national and international remote-sensing capabilities. In collaboration with its partners in NASA and DoD, STAR participates in and advises various teams that are planning the next generation of polar-orbiting satellites.

STAR participates with the Committee on Earth Observation Satellites (CEOS; see www.ceos.org) and the CEOS Strategic Implementation Team (SIT) to identify associated Earth observing (EO) needs, issues, and requirements; gaps in existing and planned capabilities; and priorities for future EO missions and capabilities. STAR currently chairs the CEOS Working Group on Calibration and Validation and is coordinating CEOS activities. STAR scientists are significantly involved in the Integrated Global Observing Strategy (IGOS) Partnership, leading and contributing to development, refinement, and implementation of the IGOS Coastal, Cryosphere, and Ocean Themes (see http://igospartners.org/Theme.htm). The IGOS themes are now being transitioned into the GEOSS in concert with the Group on Earth Observations (GEO; see http://earthobservations.org). In this context, STAR scientists will continue to support satellite-based coastal, cryospheric, and ocean (among other) observations under the auspices of GEOSS and associated GEO work plans. These activities will include leading the development of the GEO Coastal Zone Community of Practice and supporting the World Meteorological Organization's (WMO's) Global Cryosphere Watch Program and the WMO's Space Task Group (STG) for the International Polar Year (IPY), March 2007 to March 2009.

STAR plays an important role in the Coordinated Group on Meteorological Satellites (CGMS) through representing NESDIS research and coordinating future collaborative international research activities at the annual CGMS meetings. STAR is leading GSICS, a new international program of the WMO proposed and endorsed by CGMS. The overarching objective of GSICS is to improve the calibration and characterization of space-based measurements through satellite intercalibration of the international satellite observing system. GSICS will provide the accurate satellite observations needed for early detection of climate change and for modern-day weather forecasting. The GSICS program currently includes participation from the United States (NOAA, NASA, NIST), Europe (CNES/France, EUMETSAT), China (China Meteorological Administration [CMA]), Japan (Japan Meteorological Agency [JMA]) and Korea (Korea Meteorological Administration [KMA]). These agencies have agreed to take steps to ensure better comparability of satellite measurements made by different instruments and to tie these measurements to absolute standards. NOAA/NESDIS chairs the GSICS Executive Panel, operates the GSICS Coordination Center (GCC), and is one of the GSICS Processing and Research Centers.

Using Satellite Wind Data to Improve Navigation



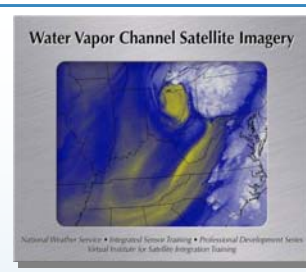
Using algorithms developed by STAR, images from the Canadian satellite RADARSAT-1 (left) are processed for wind speed and wind direction (right) to identify areas of potential danger. STAR will be developing other synthetic aperture radar ocean products for vessel detection, marine oil spill mapping, coastal change detection, sea/lake/river ice variables, severe storm morphology, and other purposes.

Empower the User Community

Advances in satellite and sensor technology will offer greatly increased data rates and enhanced observations, but it is information technology (IT) that will enable society to benefit from the satellite data. STAR will migrate towards computational technology that can process, reprocess, and interpret the data from the next generation of satellites. Tomorrow's sensors will require a significant increase in networking and data storage. In order to transfer the results of research into operations more quickly, it will be necessary to simulate complex data sets and utilize multiple processors for complex operations. STAR will test developmental algorithms and products in its Collaborative Testing Environment. STAR's IT specialists must also anticipate the growing problem of information security to ensure that the center's computers retain their integrity and data remain available.

Scientists worldwide use the data sets developed by STAR to study Earth and its environment. As satellites are launched with new instruments aboard, the availability of hyper-spectral observations, and the development of multi-sensor products in the NPOESS and GOES-R era will present a new challenge for the users of this information. STAR will continue to play a major role in training activities helping users understand and master new satellite products and tools as they become available. Much of the training activity will be conducted in collaboration with STAR's cooperative institutes.

VISIT Teletraining



This VISIT teletraining lesson reviews remote sensing aspects of the water vapor channel, highlights changes made to the water vapor channel on the GOES-12 and GOES-13 imager, and discusses basic applications of water vapor channel imagery to weather analysis and forecasting.

This VISIT teletraining lesson highlights water vapor satellite signatures associated with dynamical structures using the framework of potential vorticity thinking and anomalies, as well as dynamic tropopause. The lesson reviews remote sensing aspects of the water vapor channel, highlights changes made to the water vapor channel on the GOES-12 and GOES-13 imager, and discusses basic applications of water vapor channel imagery to weather analysis and forecasting.

VISIT

The Virtual Institute for Satellite Integration Training (VISIT) program will educate NWS and other operational forecasters on new satellite data types. Synthetic and simulated data sets will be used to educate forecasters before GOES-R and NPOESS come on line. A Satellite Hydrology and Meteorology (SHyMET) training program is being developed for this reason; this program uses web-based training methods, but it may include an on-site component in the future. The SHyMet course will be expanded in the coming decade to include training on future satellite systems.

STAR cooperates with NOAA's Coral Reef Conservation Program, The World Bank/Global Environment Facility, and others to train resource managers and local scientists on the application of satellite remote sensing to address the impacts of climate change on valuable coral reef ecosystems. STAR organized thirteen domestic and international training workshops in 2005-2008, and these will continue into the future.

STAR is also supporting the development of the GOES-R Algorithm Proving Ground. This is a joint effort by the GOES-R Program Office, STAR, and its cooperative institute partners to leverage existing testbeds in Norman, Oklahoma; Huntsville, Alabama; Boulder, Colorado; and elsewhere. The offices will incorporate simulated GOES-R products under local field conditions. Objectives of the proving ground include the following:

- Preparing forecasters for Advanced Weather Interactive Processing System (AWIPS)-focused GOES-R products
- Providing real-world experience by leveraging existing resources in preparation for the GOES-R era
- Providing product tailoring for NOAA operations
- Establishing critical coordination with NWS Weather Forecast Offices (WFOs), River Forecast Centers (RFCs), and national centers (e.g., Storm Prediction Center)

STAR administers the NESDIS Environmental Visualization Program (EVP). The goal of the EVP is to facilitate the use of satellite data through advanced techniques of visualization. Most products in STAR consist of layers of information taken from the various channels of data from GOES and Polar-orbiting Operational Environmental Satellite (POES) satellites. EVP uses geographic information system (GIS) technology to project images from satellites; this approach enhances the overall value by integrating data and information that complements the image.

Examples of STAR Initiatives to Empower the User Community

- Continue updates of Virtual Institute for Satellite Integration Training (VISIT) training for GOES and POES
- Enhance first version of Satellite Hydrology and Meteorology (SHyMet) training
- Continue International Virtual Laboratory satellite training
- Upgrade VISIT, Virtual Laboratory, and SHyMet for GOES-R and NPOESS
- Demonstrate Synthetic Aperture Radar (SAR)-derived products in an operational environment to operational users
- Conduct satellite training and respond to climate change workshops to train coral reef managers, resource managers and local scientists in the US and internationally
- Provide GOES-R Proving Ground training of forecasters and decision makers
- Develop forecast and research demonstration projects and assessments in collaboration with NOAA testbeds

STAR Cross-Cutting Activities

STAR has identified four cross-cutting activities fundamental to achieving its vision in a manner that will move NOAA forward into a new era of remote-sensing science and technology utilization, enhance STAR's contributions to NOAA's programs, and prepare NOAA for the future generation of environmental satellites and sensors:

- Provide algorithm support across remote-sensing programs
- Support instrument and mission development
- Encourage an integrated approach
- Accelerate the transfer of research into operations

Provide Algorithm Support across Remote-Sensing Programs

A major activity of STAR will be to provide support for algorithm development across various remote-sensing programs. STAR will provide the scientific algorithms for implementation and will retain important oversight for development, calibration, validation, and quality assurance during all phases of deployment and operation for both programs. For NPOESS, STAR will have a key role in providing enhancements and validation for the NOAA user community.

STAR will design a collaborative environment for algorithm development and applications research in support of current GOES and POES efforts, as well as GOES-R, NPOESS, and foreign missions for blended products, as envisioned by GEOSS. In this collaborative environment, STAR will work closely with the NESDIS Office of Satellite Data Processing and Distribution (OSDPD) to develop, test, and improve algorithms and products with a computing capability that is parallel to the operational processing environment, an approach which will expedite the transition of products and algorithms to operations.

Support Instrument and Mission Development

User demands for satellite data products are growing rapidly as climate, ocean, and land-use issues gain world attention and as demand increases for greater precision and accuracy of measurements. Scientists around the world realize that there is a need to build a comprehensive and integrated system for Earth observation. Because the volume and coverage of satellite data are growing exponentially and the ways to use the data have diversified, Earth observation systems should be increasingly versatile to meet these diverse needs and allow more data to be integrated into environmental products. STAR scientists and NOAA will work with its global partners to deploy the emerging integrated observing system.

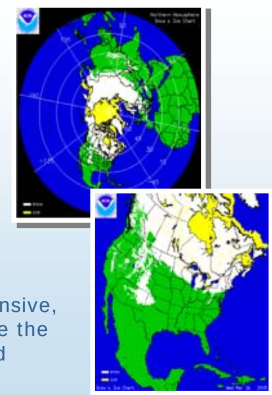
Encourage an Integrated Approach

While different technologies may be used to monitor the environment, the same underlying scientific principles should be employed. When data from multiple instruments can be plugged into the same science code, the resulting information will provide better calibrated and validated products, resulting in improved assessments, understanding, and prediction of key climate and weather parameters. In the past, science software and algorithms were tailored to specific satellite data streams (for example, GOES and POES). For GEOSS to become a reality, software and algorithms must interface with a multiple satellite and in-situ data streams. For example, the NESDIS Hyperspectral Processing Suite generates advanced sounding products from multiple platforms using AIRS, Infrared Atmospheric Sounding Interferometer (IASI), and CrIS, all of which are based on heritage science established by the internationally recognized AIRS Science Team.

The NESDIS Microwave Integrated Retrieval System (MIRS) generates “microwave only” products from several different instruments (SSMIS, AMSU-A/B, Microwave Humidity Sounder [MHS], and eventually the Advanced Technology Microwave Sounder [ATMS]). The resulting integrated processing system will result in significant cost savings compared to stand-alone product generation systems for each sensor type. An additional by-product will be improved science productivity from the reuse of the software for the basic equations of physics.

Generating Snow Cover Maps for Weather Forecasting and Climate Records

STAR introduced the current NESDIS snow-mapping technology, and over the past 10 years, it has developed a multisensor, multiplatform snow product. The resulting snow maps are based on a conglomerate of data—an analyst draws and edits the snow map using multiple sources of data that contain snow information (e.g., animated geostationary and polar satellite imagery, ice maps from the National Ice Center, microwave retrievals of snow cover, and conventional weather station observations). Because analyst-drawn maps are labor-intensive, STAR is investigating ways to fully automate the snow maps while retaining the accuracy and reliability of the current product.



STAR’s Coral Reef Watch has been working with resource managers, decision-makers, and scientists to deliver satellite remote-sensing products focused on the impact of rising ocean temperatures on coral reef ecosystems. In collaboration with NOAA’s Coral Reef Conservation Program, STAR has developed applications that use satellite-derived sea surface temperatures to predict the onset of coral bleaching events. This has been transitioned to an operational system that alerts users around the world of impending impacts of high temperatures on coral reef resources. In turn, local managers are using this information to make management decisions in marine protected areas. STAR is both improving these products by increasing their resolution and expanding into new areas including wind and solar insolation products for coral bleaching, prediction of coral disease, and the development of the first application of satellite and observations to model changes in ocean acidification. Modeling ocean acidification requires the use of data from multiple NOAA and NASA satellites and data from various NOAA and Navy observing systems. Additionally, STAR is working with climate modelers to extend the coral bleaching products from satellite-based observations to forecasting seasons in the future.

Cloud-Drift and Water Vapor Winds in the Polar Regions from NASA Instruments

NESDIS/STAR developed a method to generate wind vectors over the polar regions from polar-orbiting satellites, using the Moderate Resolution Imaging Spectroradiometer (MODIS) instrument on NASA’s Terra and Aqua satellites. This image shows wind vectors derived by tracking clouds and water-vapor features from successive MODIS passes over the Arctic.

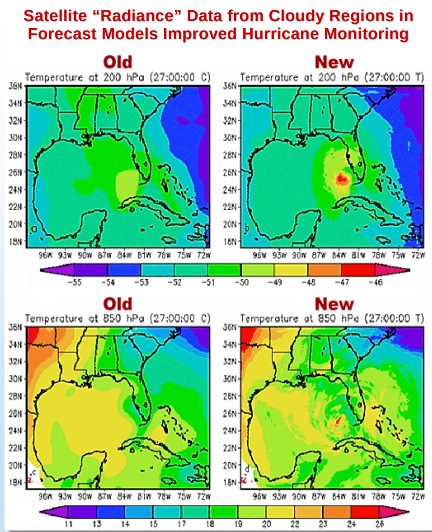
Accelerate the Transfer of Research into Operations

STAR plays a major role in transferring advances in science into NESDIS operations for both geostationary and polar-orbiting satellites. It also provides training support to NWS and DoD forecasters on how to correctly utilize and interpret satellite products. For example, STAR accelerated the transition of the science algorithms it developed for atmospheric soundings and for wind and storm-intensity products to operational processing systems in OSDPD. One important programmatic goal for STAR is to develop and maintain a robust, repeatable technology transition process that results in the timely and successful transition of new or updated product algorithms from the research and development environment to the operational production environments.

Radiative transfer models facilitate the direct assimilation of satellite observed radiances in the NWP initialization process. To date, the models have only been implemented for clear skies, which means that observations of cloudy areas, where much of the weather occurs, are not assimilated..

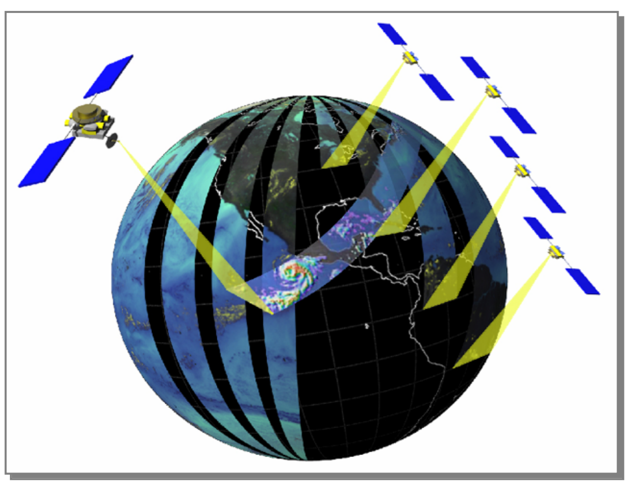
Developing a radiative transfer model for cloudy skies is a significant challenge. STAR researchers, working through the JCSDA, have initiated a project to add a modeling capability for radiative transfer in cloudy or precipitating atmospheres to the current Community Radiative Transfer Model. Additionally, current radiative transfer models have no component for modeling surface properties. Once completed, this project will make it possible to assimilate observations for the half of the globe that is usually cloud-covered. It will also permit more effective use of observations of the surface boundary layer.

Satellite “Radiance” Data from Cloudy Regions Improves Hurricane and Severe Storm Forecasts



Numerical weather prediction (NWP) depends on quality satellite-based observations on a global scale to create both short-term and long-term forecasts. Up to this point, remote-sensed observations or radiances have been limited to regions of clear skies. STAR has led the development of a Community Radiative Transfer Model that allows assimilation of observations in cloudy regions, facilitating significantly improved forecasts of hurricanes, winter storms, and other severe weather

STAR is designing an integrated, flexible, and secure networked environment that improves the flow of data from satellites, through data processing, to customers. STAR will work with its partner office, the OSDPD, to ensure that its requirements are met for operational, developmental, and test environments in the Environmental Satellite Processing Center (ESPC).



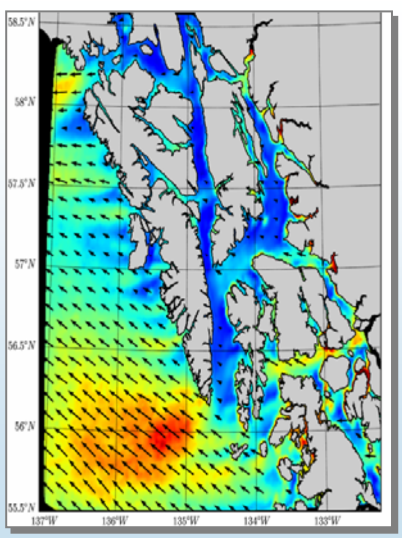
Similarly, through the Operational Instrument Improvement Program (OIIP), STAR, its NESDIS partners, and NASA will work together to develop new sensors for operational services and transition research measurements to operational applications and services. A good example is NASA’s Global Precipitation Measurement (GPM) mission, which will consist of a core satellite having a passive microwave radiometer and a dual-frequency precipitation radar, as well as a “constellation” of passive microwave imagers consisting of both operational (NOAA POES, Defense Meteorological Satellite Program [DMSP], NPOESS, etc.) and research satellites (e.g., Megha-Tropiques). The figure above presents a schematic of GPM. NASA and NOAA are engaged in a wide range of activities on GPM including research and development, application scenarios, and potentially NOAA's development of a future operationally based precipitation radar.

Near–real-time measurements of ocean surface vector winds (OSVWs), including both wind speed and direction, are being widely used in critical operational NOAA forecasting and warning activities. STAR scientists successfully lead the effort to transition different satellite OSVW data from the non-NOAA research and operational satellites into NOAA operations. Among available instruments, the active SeaWinds scatterometer on QuikSCAT provides OSVW measurements with the highest available accuracy, spatial resolution, and coverage.

The impacts of QuikSCAT OSVW data have been significant in meeting societal needs for weather and water information and in supporting the nation's commerce with information for safe, efficient, and environmentally sound transportation and coastal preparedness. Although QuikSCAT OSVW data have revolutionized operational marine weather warnings, analyses, and forecasts, critical but solvable gaps in OSVW capability remain, leaving life and property at risk. QuikSCAT is well beyond its design life, making its ability to continue providing critical data for use in operations uncertain. Therefore, the marine community needs an improved OSVW retrieval system.

This project sets out to establish an operational satellite OSVW data stream and close the OSVW capability gaps, which will result in more accurate warnings, watches, and short-term forecasts; improved analyses, model initializations, and atmospheric forcing of ocean models; and a better understanding of coastal and oceanic phenomena. These results will yield significant improvements in NOAA's operational weather forecasting, warning, and analysis capabilities.

Next Generation Scatterometer Ocean Surface Wind Speed and Direction Measurements



STAR successfully transitioned ocean surface vector wind (OSVW) research measurements from the QuikSCAT satellite into NOAA operations. During eight years of use, near–real-time QuikSCAT data revolutionized National Weather Service (NWS) weather forecast and warning operations. The use of these winds encompasses the warning, analysis, and forecasting missions associated with tropical cyclones, extra-tropical cyclones, fronts, localized coastal wind events, and sea conditions driven by ocean surface winds.

STAR is now working with the Jet Propulsion Laboratory (JPL) to design a next-generation Extended Ocean Surface Vector Wind Mission (XOVWM) that will provide coastal and open ocean, all-weather, all-wind, high-resolution measurements to enable significantly improved severe storm and coastal hazard forecasts. This instrument concept now defines an Extended Ocean Surface Vector Wind Mission (XOVWM) as proposed by the National Research Council's Decadal Survey.

STAR also leads the NOAA CoastWatch Program, partnering with OSDPD and NODC within NESDIS and the other NOAA line offices (NMFS, NOS, OAR, NWS) to facilitate the development and transition of satellite ocean remote sensing products (e.g., ocean color, SST, OSVWs) from research into operations in support of a diversity of national (e.g., Integrated

Ocean Observing System) and regional (e.g., Chesapeake Bay, southern California) coastal activities and applications.

Addressing the Challenges

Over the next 15 years, satellite technology for Earth observation will experience three major upgrades: a new generation of polar-orbiting satellites (NPOESS), a new generation of geostationary satellites (GOES-R), and a new generation of atmospheric sounding instruments based on hyperspectral sensors like the AIRS. Furthermore, civilian and military technologies that were formerly separate are being combined, and the programs of individual nations are increasingly evolving into international partnerships. Data collected from satellite platforms will increase in data volume, quality, and detail.

The increased focus on climate change has resulted in proposed new government initiatives to monitor changes and effects. Congress has proposed a Climate Change Research Amendment in recent energy bills that calls for the Secretary of Commerce to establish an atmospheric monitoring and verification program using aircraft, satellite, ground sensors, and modeling capabilities to monitor, measure, and verify atmospheric greenhouse-gas levels, dates, and emissions. Data from satellites will enable scientists to better understand shifts in global ecosystems and to identify how these changes may impact public health—for example, how changes in the distribution patterns of mosquito vectors may affect the incidence of malaria worldwide.

To address these challenges, STAR will need: additional computing power to handle the anticipated increases in data volume and resolution; scientific talent in some new instrument areas; more comprehensive ground-truth measurements for the land, sea, and air; and succession planning to stem the loss of knowledgeable senior scientists as a result of retirement. STAR's strategy to address these gaps will include developing new tools and more efficient processes to ensure faster transition of research to operations, as well as increasing national and international collaboration in remote sensing.

STAR plans to improve its science management and technical infrastructure, which will facilitate faster transition of research to operations. As noted earlier, one of STAR's research priorities is to develop a collaborative testing environment and algorithm testbed to expedite the transition of algorithms and products from research to operations. STAR will continue to work with its cooperative institute partners to prioritize research activities in needed instrument areas and with other satellite community partners to promote the development of in-situ measurements for validation of satellite observations. STAR will upgrade its computing infrastructure, exploit three-dimensional visualization programs, and use advanced GIS techniques to enhance the utility and understanding of satellite products.

STAR will engage in initiatives to reach out to NOAA's new satellite partners, the satellite user community, and the potential future workforce. Through the JCSDA, STAR works closely with NASA and DoD to identify common critical needs for accelerating the assimilation of satellite data into operational prediction models. Leveraging international activities through its collaboration with countries such as China, India, Malaysia, Morocco, and the Ukraine, STAR will work with its international partners and users to identify remote-sensing requirements and to help develop solutions to ensure that the planned and projected products will meet those future needs.

Appendix A Priority Satellite Mission Alignment with NOAA Objectives and Benefits

Mission Name	Meets NOAA Outcome, Performance Objective	Primary Benefits
Current GOES (GOES-13, etc.)	• Increase lead time and accuracy for weather and water warnings/forecasts • Improve predictability of the onset, duration, and impact of hazardous and severe weather/water events	• Monitors (via imager and sounder) the pre-convective atmosphere for severe weather conditions and monitors the development and evolution of hazards such as tornadoes, flash floods, hail storms, and hurricanes. • Provides atmospheric motion vectors derived from cloud and moisture feature tracking to improve numerical weather prediction model forecasts • Provides maps depicting rainfall, snow, fires, volcanic ash, sea surface temperature
Current POES (DMSP F15-F18) (NOAA-15-18)	• Improve winter storm warning accuracy/lead time • Reduce hurricane track and intensity forecast errors	• Provides comprehensive view of the atmospheric vertical and horizontal structure of temperature and water vapor • Provides high resolution monitoring of global sea surface temperature, precipitation and clouds, snow cover, sea ice concentration , and land emissivity and temperature • Contributes applications including weather analysis and forecasting, climate reanalysis and prediction, climate research and prediction, volcanic eruption monitoring, forest fire detection, global vegetation analysis, search and rescue and ocean dynamics research
MetOp/IJPS (Current and Future)	• Increase lead time and accuracy for weather and water warnings/forecasts • Improve predictability of the onset, duration, and impact of hazardous and severe weather/water events	• Provides higher resolution temperature and moisture profiles • Provides new R&D/Applications via blended retrievals (i.e., AVHRR, AMSU, MHS, etc.) • Contributes to GPM Constellation • Provides for polar winds (VIIRS), global cloud properties (VIIRS), snow and ice (microwave), temperature and moisture profiles • Provides higher resolution temperature/moisture profiles for improved weather forecasts • Provides estimates of trace gases like ozone, methane or carbon monoxide on a global scale
OSTM Jason-2 (2008)	• Sea surface height change • Precision monitoring of sea level rise	• Provides altimetry data to the public with continued sea level, wave height, and surface winds over the global ocean. • Provides important indicators of global warming assessments
Oceansat-2 (2008)	• Improves marine weather forecasting and warning • Improves the marine transportation system, recreational boating and fishing activities	• Mitigates impact of data flow reductions, through availability of alternative sources, from US sources on operational and research users of ocean color data and products • Improves our knowledge of how the ocean and atmosphere interact which is important for understanding the longer-term (climate) and shorter-term (weather) changes of the global ecosystem
OCO (2009)	• Reduce uncertainty in climate projections through timely information on the forcing and feedbacks contributing to changes in the Earth's climate • Improve the accuracy of climate change predictions	• Assesses the carbon budget via biospheric modeling (e.g., NOAA/ESRL CarbonTracker Model) • Provides for data assimilation of the intermediate product of surface pressure • Provides discrimination of lower and upper tropospheric measurements that would enhance the value of OCO to carbon cycle studies (i.e., climate goal)

Mission Name	Meets NOAA Outcome, Performance Objective	Primary Benefits
Glory (2009)	• Reduce uncertainty in climate projections through timely information on the forcing and feedbacks contributing to changes in the Earth's climate • Understand and predict the consequences of climate variability and change on marine ecosystems	• Provides a global distribution of natural and anthropogenic aerosols (black carbons, sulfates, etc.) with accuracy and coverage sufficient for reliable quantification of the aerosol effect on climate, the anthropogenic component of the aerosol effect, and the potential secular trends in the aerosol effect caused by natural and anthropogenic factors • Provides an assessment of the direct impact of aerosols on the radiation budget and its natural and anthropogenic components, and the effect of aerosols on clouds (lifetime, microphysics, and precipitation) and its natural and anthropogenic components; • Allows for an investigation into the feasibility of improved techniques for the measurement of black carbon and dust absorption to provide more accurate estimates of their contribution to the climate forcing function
NPP (2010) *NPOESS C-1* (2013)	• Improve predictability of the onset, duration, and impact of hazardous and severe weather/water events • Accurate observations of the Earth's radiation	• Makes available essential climate variables, extending climate data records • Provides for product continuity for MIRS, risk reduction; contributes to GPM Constellation • Provides for polar winds (VIIRS), global cloud properties (VIIRS), snow and ice (microwave), temperature and moisture profiles • Monitors ozone layer and interaction between the ozone layer and climate change (OMPS) • Provides for improved forecasts of diurnal atmospheric temperature and hydrological cycles uncertain, validation of some climate change hypotheses (CrIS/ATMS) • Provides for high resolution vertical profiles of atmospheric temperature and moisture (CrIS)
Aquarius (2009)	• Improves marine weather forecasting and warning • Reduce uncertainty in climate projections through timely information on the forcing and feedbacks contributing to changes in the Earth's climate	• Provides global assessment of the horizontal sea-surface salinity distribution, a crucial parameter for assessing and modeling the ocean-atmosphere moisture fluxes critical for weather and climate prediction and the density fluxes for ocean circulation • Provides a significant component for assessing marine ecosystems and the evolution of habitats
DMSP F19/F20 (2011/2012)	• Increase lead time and accuracy for weather and water warnings/forecasts • Improve predictability of the onset, duration, and impact of hazardous and severe weather/water events	• Provides comprehensive view of the atmospheric vertical and horizontal structure of temperature and water vapor • Provides high resolution monitoring of global precipitation and clouds, snow cover, sea ice concentration, and land emissivity • Contributes applications including weather analysis and forecasting, climate reanalysis and prediction, and ocean dynamics research
GCOM-W (2012) *GCOM-C* (2013)	• Improve the accuracy of climate change predictions • Increase lead time and accuracy for weather and water warnings/forecasts	• Provides soil moisture products and applications • Makes available merged SST products; CDRs for all variables • Allows for assimilation in cloudy atmospheres • Contributes to GPM Constellation
GPM (2013)	• Improve quantitative precipitation estimation • Improve flash flood lead time	• Provides precipitation type and phase, 3-D assimilation of precipitation (DPR) • Identifies cold season precipitation; precipitation CDRs • Assists with calibration for GOES-R/ABI retrievals • Provides global, 3-hourly precipitation rates (GMI)

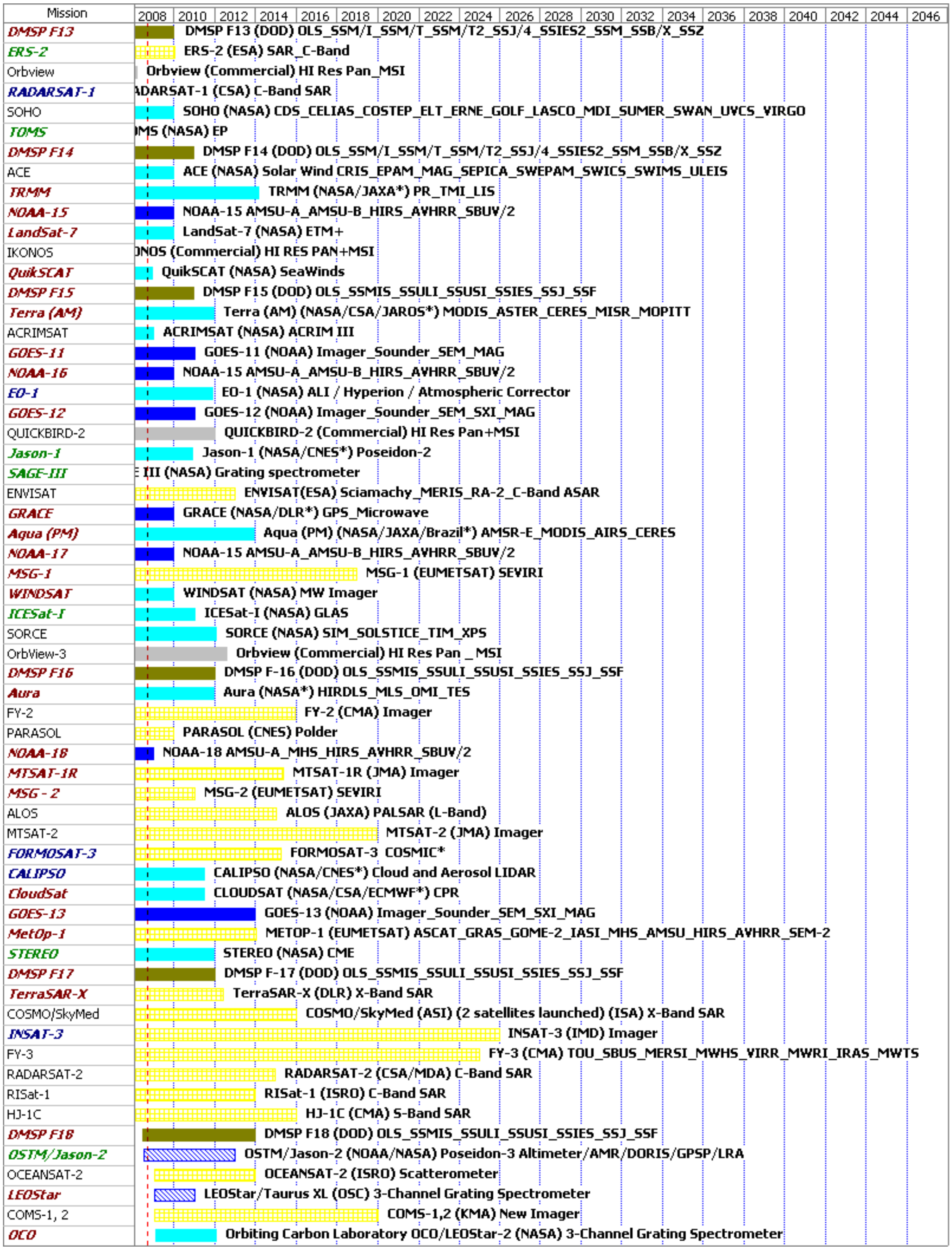
Mission Name	Meets NOAA Outcome, Performance Objective	Primary Benefits
Jason-3 (2013)	• Improve precision monitoring of sea level rise for climate change • Improve predictability of long-term sea level rise • Improve wave forecast accuracy • Improve hurricane intensity forecasts	• Provides the public with continued sea level, wave height, and surface winds over the global ocean • Provides important indicator of global warming • Provides basis for improving long-term projections of sea level rise • Provides improved upper ocean heat content
GOES-O/P (2008/2009)	• Increase lead time and accuracy for weather and water warnings/forecasts • Improve predictability of the onset, duration, and impact of hazardous and severe weather/water events	• Provides greater temporal, spatial, spectral resolution • Provides for an improved cloud, snow/ice, soil moisture product
GOES-R (2014)	• Increase lead time and accuracy for weather and water warnings and forecasts. • Improve predictability of the onset, duration, and impact of hazardous and severe weather/water events	• Provides, via ABI, 3x temporal, 4x spatial, and 5x spectral performance improvements to produce more timely, accurate, new, and enhanced suite of products • GLM detects all lightning (in-cloud, cloud-to-round) and provides information to increase severe storm warning lead time and accuracy • Improved accuracy of tropical cyclone formation and intensity
Decadal Survey Missions – Tier #1		
SMAP (2012)	• Increase lead time and accuracy for weather and water warnings/forecasts • Improve predictability of the onset, duration, and impact of hazardous and severe weather/water events	• Improves knowledge of soil moisture which controls the water, energy and carbon exchanges between land surface and the atmosphere • Provides more accurate soil moisture initialization and data assimilation for numerical weather, seasonal climate and hydrological prediction models will improve their forecast skills
GPSRO (2013)	• Enhance navigational safety and efficiency by improving informational products and services • Realize national economic, safety, and environmental benefits of improved, accurate positioning capabilities	• Significantly improves vertical, horizontal resolution in lower troposphere and stratosphere • Provides improved vertical profiles of ionospheric electron densities • Alerts customers of degradation of activities , such as loss of GPS, HF and VHF radio communication, false targets in radar observations, and communications with satellites; detailed information of these observations allows respond, work around to find alternatives

Mission Name	Meets NOAA Outcome, Performance Objective	Primary Benefits
XOVWM (2014)	• Reduce hurricane track and intensity forecast errors • Understand and predict the consequences of climate variability and change on marine ecosystems • Improves the marine transportation system, recreational boating and fishing activities	• Makes available OSVW data much closer to the coast (1.5–3 miles) than is currently available (12–18miles); important for meteorological and oceanographic applications for numerous reasons: nearly 50% of the U.S. population lives within 50 miles of the coast; coastal fisheries depend on wind-driven nutrient upwelling; shipping and fishing industries need to know wind conditions near the coast • Provides for more reliable estimates of tropical and extratropical cyclones' intensity through all stages of development (currently capped at Category 1 out of 5). • Allows more accurate tracking of tropical cyclone (TC) centers and earlier identification of developing systems, ensuring more accurate initial motion estimates as input into numerical weather prediction model for identification of global trends in extreme wind events • Improves analysis of the TC wind field structure (34, 50, and 64 kt wind radii) which will yield more refined watch/warning areas for the coast and marine areas
ICESat-II (2015)	• Improve precision monitoring of sea level rise for climate change • Enhance navigational safety and efficiency by improving informational products and services	• Monitors ice mass loss contribution to global sea level rise • Helps to test climate models • Provides for monitoring of sea ice for navigation in the Arctic Ocean
CLARREO (2017)	• Enhance navigational safety and efficiency by improving informational products and services • Reduce uncertainty in climate projections through timely information on the forcing and feedbacks contributing to changes in the Earth's climate	• Establishes on-orbit absolute calibration accuracy and traceability for operational instruments and products, which are critically needed for climate change detection from satellites • Characterizes the uncertainty for operational products such as atmospheric temperature and water vapor profiles, land and sea surface temperatures, cloud properties, radiation budget including Earth albedo, vegetation, surface snow and ice properties, ocean color, aerosols, as well as greenhouse gas monitoring • Uses the GPS component from CLARREO in numerical prediction models to improve forecasts
DESDynI (2017)	• Enhance navigational safety and efficiency by improving informational products and services • Improves the marine transportation system, recreational boating and fishing activities	• Provides for operational marine, sea/lake/river ice, and hazard information • Provide access to the only U.S. SAR instrument; U.S. contribution to foreign SAR constellation partnerships
Decadal Survey Missions – Tier #2		
ACE (2020)	• Reduce uncertainty in climate projections through timely information on the forcing and feedbacks contributing to changes in the Earth's climate • Improves the marine transportation system, recreational boating and fishing activities	• Identifies aerosol and cloud profiles for climate and water cycle • Provides for ocean color for open ocean biogeochemistry

Mission Name	Meets NOAA Outcome, Performance Objective	Primary Benefits
HyspIRI (2020)	• Understand and predict the consequences of climate variability and change on marine ecosystems • Increase lead time and accuracy for weather and water warnings/forecasts	• Improves characterization of (1) coastal, marine and inland water ecosystems; (2) land surface and vegetation conditions; (3) active fires and burned areas • Provides for reference data for calibration and validation of coarse resolution products from VIIRS and GOES-R ABI; C. multi-platform observing system (sensor web)
ASCENDS (2020)	• Understand and predict the consequences of climate variability and change on marine ecosystems • Increase lead time and accuracy for weather and water warnings/forecasts	• Provides assessments of carbon budget via biospheric modeling (e.g., CarbonTracker Model) • Data assimilation of the intermediate product of surface pressure; CO2 product itself may be of some benefit to weather goal by eliminating regional and temporal biases in IR radiances • Measurements with co-located infrared sounder hyper-spectral radiances could provide discrimination of lower and upper tropospheric measurements that would enhance the value of OCO to carbon cycle studies
SWOT (2020)	• Improve wave forecast accuracy • Improve precision monitoring of sea level rise for climate change	• Provides for measurement of sea surface height anomalies; fills in gaps and provide greater spatial resolution to observe warm and cold core eddies that may fuel or cool tropical cyclones, and should be important inputs to marine environmental forecasting • Furnishes the spatial resolution needed to tackle coastal currents, something not yet done well with conventional altimeters
GEO-CAPE (2020)	• Understand and predict the consequences of climate variability and change on marine ecosystems • Increase lead time and accuracy for weather and water warnings/forecasts	• Helps NOAA better monitor and manage valuable coastal ecosystems which provide numerous socio-economic benefits (areas where people live, work and recreate, are sites of important commercial and sport fisheries and other valuable natural resources; provide habitat for a broad diversity of organisms, etc.) • Supports the NOAA Ecosystem, Weather & Water, Climate, and Commerce & Transportation Goal Teams and associated mandates of line offices (NOS, NMFS, OAR, NWS), as well as support state, regional and local coastal managers and decision-makers. • Supports various national mandates by providing atmospheric chemistry parameters (tropospheric trace gases and aerosols) at high temporal resolution to monitor environmental disasters and air quality • Supports NOAA and EPA air quality forecasting efforts by measuring short-lived trace gases such nitrogen dioxide, formaldehyde, sulfur dioxide etc. to track emissions sources • Supports NOAA climate mission by observing aerosols and UV flux • Complements NOAA GOES-R mission (example products: aerosols, fires, and total ozone)
Decadal Survey Missions – Tier #3		
3-D Winds (2020)	• Reduce uncertainty in climate projections through timely information on the forcing and feedbacks contributing to changes in the Earth's climate • Increase number and use of climate products and services to enhance public and private sector decision making.	• Extends improved prediction of such important parameters as hurricane track and 5-day mid-latitude cyclone genesis – both high-visibility NOAA issues • Sends an important message to NASA;, by placing high priority on a Global Winds mission, NOAA will be letting NASA know of it's support NASA's efforts to develop the order in which it intends to move forward to implement the missions specified in the decadal survey • Expresses NOAA's strong need and desire to obtain global wind observations and use them operationally for weather forecasting and other purposes

Mission Name	Meets NOAA Outcome, Performance Objective	Primary Benefits
LIST (2025)	• Increase lead time and accuracy for weather and water warnings/forecasts • Reduce uncertainty in climate projections through timely information on ice volume changes. • Improve earthquake hazard assessment	• Provides high resolution land topography for earthquake and landslide hazard assessment, and estimation of water runoff • Potential follow-on to ICESat-1 and ICESat-2 • Provides ability to monitor time variations of continental ice sheet volume, a significant contributor to global sea level rise
PATH (2025)	• Increase lead time and accuracy for weather and water warnings/forecasts • Improve predictability of the onset, duration, and impact of hazardous and severe weather/water events	• Provides key atmospheric environment data records (EDRs) such as vertical temperature and water vapor profiles, cloud ice water, hail detection, rainfall rates are obtained under all weather conditions • Advances significant capabilities for NOAA's prediction of severe weather events (e.g. hurricane and winter storms) through uses of high temporal information from PATH measurements in numerical weather prediction models
GRACE-II (2025)	• Understand and predict the consequences of climate variability and change on marine ecosystems • Improve wave forecast accuracy	• Provides high-temporal-resolution gravity fields for tracking large-scale water movement • Benefits to NOAA include its unique ability to monitor all variations in water mass stored on the continents, variations in global ocean mass associated with eustatic sea-level change, and variations in the mass of the Greenland and Antarctic ice sheets • Assists in constraining and validating ocean circulation and climate models. It would be a vital component of NOAA's sea level rise budget observations, along with satellite radar altimetry and the Argo Project's array of profiling floats • Helps NOAA produce a new generation of land-surface models that would better represent subsurface moisture variations and the recycling of moisture to the atmosphere
SCLP (2025)	• Reduce uncertainty in climate projections through timely information on the forcing and feedbacks contributing to changes in the Earth's climate • Understand and predict the consequences of climate variability and change on marine ecosystems	• Improves measurement of snow water equivalent (SWE) for flood forecasting, water resources management, and climate change monitoring
GACM (2025)	• Increase lead time and accuracy for weather and water warnings/forecasts • Reduce uncertainty in climate projections through timely information on the forcing and feedbacks contributing to changes in the Earth's climate	• Continues the atmospheric chemistry and composition work started with the EOS Aura with even more emphasis on the troposphere • Adds important greenhouse gas measurements complementing and expanding those in the IR sounder line (from EOS AIRS, MetOp IASI, and NPOESS CrIS) • Supports an agreement with the EPA in its Air Quality forecasts; this mission is designed to push the limits of space-based measurements in those applications • Complements and improves on the products under development for MetOp GOME-2 series

Appendix B Satellite Fly-Out Schedule

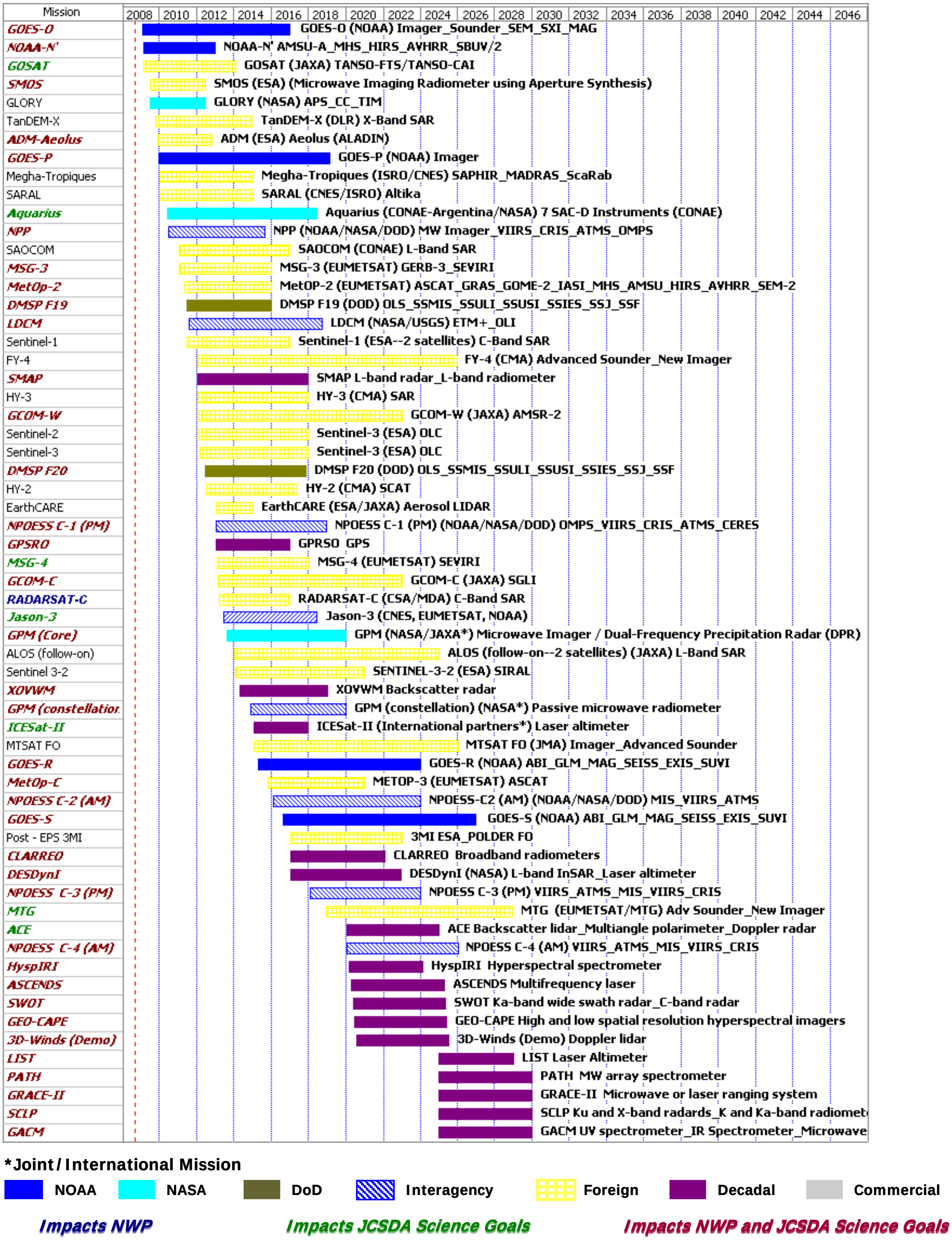


***Joint/International Mission**

NOAA NASA DoD Interagency Foreign Decadal Commercial

Impacts NWP   *Impacts JCSDA Science Goals*   *Impacts NWP and JCSDA Science Goals*

Satellite Flyout Schedule (Concluded)



List of Acronyms

ABI	Advanced Baseline Imager
AIRS	Atmospheric Infrared Sounder
AMSU	Advanced Microwave Sounding Unit
ATMS	Advanced Technology Microwave Sounder
ATOVS	Advanced TIROS Operational Vertical Sounder
AWIPS	Advanced Weather Interactive Processing System
CDR	Climate Data Record
CEOS	Committee on Earth Observation Satellites
CGMS	Coordinated Group on Meteorological Satellites
CICS	Cooperative Institute for Climate Studies
CIMSS	Cooperative Institute for Meteorological Satellite Studies
CIOSS	Cooperative Institute for Oceanographic Satellite Studies
CIRA	Cooperative Institute for Research in the Atmosphere
CLARREO	Climate Absolute Radiance and Refractivity Observatory
CMA	China Meteorological Administration
CMIS	Conically Scanning Microwave Imager/Sounder
CNES	Centre National d'Etudes Spatiales (French Space Agency)
CoRP	Cooperative Research Program
CREST	Cooperative Remote Sensing Science and Technology Center
CrIS	Cross-Track Infrared Sounder
CRTM	Community Radiative Transfer Model
CSA	Canadian Space Agency
DMSP	Defense Meteorological Satellite Program
DoD	Department of Defense
EO	Earth observing
EPA	Environmental Protection Agency
ERBS	Earth Radiation Budget Satellite
ESA	European Space Agency
ESPC	Environmental Satellite Processing Center
EUMETSAT	European Organization for the Exploitation of Meteorological Satellites
EVP	Environmental Visualization Program
GCC	GSICS Coordination Center
GEO	Group on Earth Observations
GEOSS	Global Earth Observation System of Systems

GIS	Geographic Information System
GLM	Geostationary Lightning Mapper
GOES	Geostationary Operational Environmental Satellite
GPM	Global Precipitation Measurement
GPS	Global Positioning System
GPSRO	Global Positioning System Radio Occultation
GSICS	Global Space-based InterCalibration System
HIRS	High-Resolution Infrared Radiation Sounder
IASI	Infrared Atmospheric Sounding Interferometer
IGOS	Integrated Global Observing Strategy
IJPS	Initial Joint Polar System
InPE	Instituto Nacional de Pesquisas Espaciais (Brazilian Space Agency)
IOOS	Integrated Ocean Observing System
IPO	Integrated Program Office
IPY	International Polar Year
IR	Infrared
ISRO	Indian Space Research Organisation
IT	Information Technology
JAXA	Japan Aerospace Exploration Agency
JCSDA	Joint Center for Satellite Data Assimilation
JMA	Japan Meteorological Agency
JPL	Jet Propulsion Laboratory
KMA	Korea Meteorological Administration
LEO	Low-earth orbit
MetOp	Meteorological Operational
MHS	Microwave Humidity Sounder
MIRS	Microwave Integrated Retrieval System
MIS	Microwave Imager/Sounder
MOBY	Marine Optical Buoy
MODIS	Moderate-resolution Imaging Spectroradiometer
MW	Microwave
NASA	National Aeronautics and Space Administration
NDE	NPOESS Data Exploitation
NESDIS	National Environmental Satellite, Data, and Information Service
NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration

NPIVS	NOAA Product Integration Validation System
NPOESS	National Polar-orbiting Operational Environmental Satellite System
NPP	NPOESS Preparatory Project
NWP	Numerical Weather Prediction
NWS	National Weather Service
OIIP	Operational Instrument Improvement Program
OLR	Outgoing Long-wave Radiation
OSDPD	Office of Satellite Data Processing and Distribution
OSE	Observing System Experiments
OSSE	Observing System Simulation Experiments
OSVW	Ocean surface vector winds
POES	Polar-orbiting Operational Environmental Satellite
RFC	River Forecast Center
SAR	Synthetic Aperture Radar
SHyMet	Satellite Hydrology and Meteorology
SIT	Strategic Implementation Team
SMCD	Satellite Meteorology and Climatology Division
SNO	Simultaneous Nadir Overpass
SOCD	Satellite Oceanography and Climatology Division
SST	Sea Surface Temperature
STAR	Center for Satellite Applications and Research
STG	Space Task Group
TIROS	Television and Infrared Observation Satellite
TOVS	TIROS Operational Vertical Sounder
USGS	U.S. Geological Survey
UV	Ultraviolet
VIIRS	Visible Infrared Imager Radiometer System
VIS	Visible Imaging System
VISIT	Virtual Institute for Satellite Integration Training
WFO	Weather Forecast Office
WGCV	Working Group on Calibration and Validation
WMO	World Meteorological Organization
XOVWM	Extended Ocean Surface Vector Wind Mission