NPOESS: Improving Operational Global Earth Observations from Space

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In the next decade, weather forecasters, climate researchers, and global decision-makers will rely on the National Polar-orbiting Operational Environmental Satellite System (NPOESS) to meet many of their needs for remotely-sensed, Earth science data and information. Beginning in 2013, NPOESS spacecraft will be launched into two different orbits to provide significantly improved operational capabilities and benefits to satisfy critical civil and national security requirements for space-based, remotely sensed environmental data. NPOESS will observe more phenomena simultaneously from space and deliver a data volume significantly greater than its operational predecessors with substantially improved delivery of data to users. Higher (spatial, temporal, and spectral) resolution and more accurate imaging and atmospheric sounding data will enable improvements in short- to medium-range weather forecasts. NPOESS will support the operational needs of meteorological, oceanographic, environmental, climatic, and space environmental remote-sensing programs and provide continuity of data for climate researchers. With the development of NPOESS, we are evolving operational "weather" satellites into integrated global environmental, operational observing systems by expanding our capabilities to observe, assess, and predict the total Earth system - atmosphere, ocean, land, and the near-Earth space environment.

I. Introduction

The tri-agency Integrated Program Office (IPO), comprised of the Department of Commerce's (DOC) National Oceanic and Atmospheric Administration (NOAA), the Department of Defense (DoD), and the National Aeronautics and Space Administration (NASA), is working with prime contractor Northrop Grumman Space Technology (NGST), principal teammate Raytheon, and instrument subcontractors to jointly develop and acquire the next-generation operational weather and environmental satellite system - the National Polar-orbiting Operational Environmental Satellite System (NPOESS). NPOESS will replace NOAA's current Polar-orbiting Operational Environmental Satellites (POES) and DoD's Defense Meteorological Satellite Program (DMSP) spacecraft that have provided global data for weather forecasting and environmental monitoring for over 45 years. NPOESS will acquire

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and deliver critical Earth observation measurements to NOAA and DoD central processing facilities through an innovative global SafetyNet™ communications network of 15 unmanned ground stations that will provide significantly improved data latency. NPOESS will enable high-quality, space-based, remotely-sensed data to be used faster and more frequently in numerical weather prediction (NWP) models for improved environmental forecasts and warnings. NPOESS will employ platforms and instruments that incorporate technological advances from NASA's Earth Observing System (EOS) satellites in an integrated mission serving the nation's civilian and military needs for space-based, remotely-sensed environmental data.

II. Status of NPOESS Development

The NPOESS program was restructured in 2006 as a result of technical problems with new sensor development, associated cost growth, and schedule delays incurred in previous years. The NPOESS constellation will now consist of four spacecraft (C1 – C4) and manifested sensors in two key orbital planes (1330 local time ascending node – LTAN and 1730 LTAN) to meet the operational needs of NOAA and DoD. The NPOESS program provides for the initial acquisition of two spacecraft (C-1 and C-2). The government may exercise its option under the existing contract with NGST in 2010 to procure two additional NPOESS satellites (C-3 and C-4).

As a precursor to NPOESS, the NPOESS Preparatory Project (NPP) is scheduled to be launched in 2010. The first operational NPOESS spacecraft (C-1) is now scheduled for launch in 2013. The last satellites (C-3 and C-4) in the two-orbit NPOESS constellation are expected to be operational well into the 2023-2026 time period.

The first operational NPOESS spacecraft (C-1) is expected to be launched in 2013 into a sun-synchronous, afternoon polar orbit (1330 LTAN) at an altitude of 828 km to replace the last of NOAA's POES. Data collected from imaging and atmospheric sounding instruments in this afternoon orbit are critical for global NWP models. The NPOESS C-2 satellite is being planned for launch in 2016 to replace the last of the DMSP spacecraft that currently occupy either an early morning (1730 LTAN) or mid-morning orbit to support military operations worldwide. Satellite imagery and atmospheric data from this orbit are critical to support DoD global NWP models and short-term local and regional forecasts that are used for tactical planning on the battlefield.

NOAA depends on data from the afternoon orbit (1330 LTAN) for critical input into global and regional weather forecast models. The afternoon NPOESS spacecraft will carry advanced technology visible, infrared, and microwave imagers and sounders to deliver higher spatial, temporal, and spectral resolution data enabling more accurate short-term weather forecasts and severe storm warnings. The early morning orbit (1730 LTAN) will provide critical visible and microwave imagery for global cloud forecast models to support DoD's tactical decisions for air, sea, and ground operations. A mid-morning orbit (2130 LTAN) will be occupied by the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) Meteorological Operational (MetOp) spacecraft that carries advanced instruments similar to those that will fly on NPOESS. EUMETSAT successfully launched the first in the series of MetOp satellites in October 2006 to permanently replace NOAA POES in the mid-morning orbit as part of the NOAA/EUMETSAT Initial Joint Polar-orbiting Operational Satellite System (IJPS).

III. NPOESS Space Segment

Validated user requirements for atmospheric, oceanic, terrestrial, climatic, and solar-geophysical parameters are guiding the development of advanced technology visible, infrared, and microwave imagers and sounders that will provide enhanced capabilities to users and improve the accuracy and timeliness of observations. While these sensors are the "business" end of the overall system, other critical space and ground segment components are needed to transform raw data collected in space into processed data products that can be delivered easily and quickly to end users on the ground. As the prime contractor for NPOESS, NGST is responsible to the IPO for delivering the "end-to-end" system consisting of: the spacecraft; sensors and instruments on the spacecraft; launch support capabilities; the command, control, communications, and data routing infrastructure; and data processing hardware and software.

In recent years, the operational weather forecasting and climate science communities have levied more rigorous operational requirements on space-based observations of the Earth's system, in part as a result of NASA's successful EOS missions. These requirements have significantly increased demands on performance of the instruments, spacecraft, and ground systems required to deliver NPOESS data, products, and information to end users. NPOESS instruments will observe significantly more phenomena simultaneously from space than its POES and DMSP predecessors. NPOESS will deliver more accurate measurements at higher spatial (horizontal and vertical), spectral, and temporal resolution to support operations and research. User demands for faster delivery of more real-time data from NPOESS are driving the space and ground-based architectures for data routing and retrieval that will dramatically shorten data latency (time from observation by the satellite to availability of processed data). NPOESS will deliver data from its advanced technology visible, infrared, and microwave imagers and sounders at higher data rates with more frequent space-to-ground data communications.

Most of the NPOESS sensors are considerably more complex than the instruments carried on either DMSP or POES. NPOESS is expected to deliver a total data volume of approximately 8 terabytes per day which is significantly greater than the current POES and DMSP systems. This significant increase in data volume will necessarily increase demands on the front-end processors and data assimilation systems used to initialize and update global and regional NWP models. The orders of magnitude increase in data volume will also demand significant upgrades to the satellite data archive and distribution systems operated by NOAA.

Instrument payloads will be flown on NPOESS spacecraft in two different configurations, depending upon orbit. NPOESS payloads will include instruments to profile the atmosphere, probe the near-Earth space environment, monitor the Earth's radiation budget, and observe atmospheric, terrestrial, and oceanic phenomena globally. The afternoon (1330 LTAN) NPOESS spacecraft will carry the following four primary instruments: Visible/Infrared Imager Radiometer Suite (VIIRS); Cross-track Infrared Sounder (CrIS); Advanced Technology Microwave Sounder (ATMS), and Ozone Mapping and Profiler Suite (OMPS). In addition, the afternoon NPOESS spacecraft will carry the Microwave Imager/Sounder (MIS – C3 only), Space Environment Monitor (SEM), Clouds and the Earth's Radiant Energy System (CERES – C1 only), and Total Solar Irradiance Sensor (TSIS – C1 only). Currently, the early-morning spacecraft (1730 LTAN) will fly with a reduced complement of instruments: VIIRS and MIS (C2 and C4). Both early-morning and afternoon spacecraft will also be equipped with the Advanced Data Collection System (ADCS) and Search and Rescue Satellite Aided Tracking System (SARSAT). The current orbit manifest for the NPOESS and NPP sensor payloads is shown in Table 1. Flight units for the primary instruments are nearing completion for integration onto the NPP spacecraft.

Table 1. NPOESS and NPP Sensors by Orbit

Afternoon Orbit	Morning Orbit	NPP
VIIRS	VIIRS	VIIRS
CrIS		CrIS
ATMS		ATMS
MIS (C-3)	MIS	
OMPS (Nadir)		OMPS
SEM		
CERES (C-1)		CERES
TSIS (C-1)		
SARSAT	SARSAT	
A-DCS	A-DCS	

The 22-channel VIIRS will collect calibrated visible/infrared radiances to produce about 20 different Environmental Data Records (EDRs) including imagery, cloud and aerosol properties, albedo, land surface type, vegetation index, ocean color, and land and sea surface temperature to fulfill functions similar to what the Moderate Resolution Imaging Spectroradiometer (MODIS) does for NASA's EOS Terra and Aqua missions. VIIRS will provide complete daily global coverage over the visible, short/medium-infrared, and long-wave infrared spectrum at horizontal spatial resolutions of 370 m and 740 m at nadir. VIIRS will image at a near constant horizontal resolution across its ~3000 km swath (i.e., from 370 m at nadir to ~800 m at edge of scan) a significant improvement over NOAA's Advanced Very High Resolution Radiometer (AVHRR) and NASA's MODIS instruments. VIIRS also has a day/night band to detect low levels of visible-near infrared radiance at night from sources on or near the Earth's surface, such as low clouds and fog illuminated by moonlight, snow cover, and lightning flashes. VIIRS will produce low-light imagery at a higher horizontal resolution than the Operational Linescan System (OLS) on DMSP. A preview of the capability of the VIIRS day/night band is provided in Ref. 1.

The VIIRS flight sensor for NPP is now undergoing final characterization and calibration. Instrument performance has been assessed by comparing VIIRS calibration and characterization Sensor Data Records (SDRs) to equivalent Level 1 products from MODIS. Predictions demonstrate that cloud products, land EDRs (land surface temperature, surface type, surface albedo, and vegetation index), and sea surface temperature (SST) from VIIRS will be equivalent in quality to products from MODIS[2,3,4]. However, aerosol EDRs and ocean color/chlorophyll products will be degraded with respect to MODIS performance due to cross-talk problems in the filter assemblies on the first VIIRS flight sensor[5,6].

The Cross-track Infrared Sounder (CrIS) and the Advanced Technology Microwave Sounder (ATMS) will provide vertical profiles of atmospheric temperature, humidity, and pressure from the surface to the top of the atmosphere. CrIS senses upwelled infrared radiances from 3 to 16 µm at very high spectral resolution (~1300 spectral channels) to determine the vertical atmospheric distribution of temperature and moisture from the surface to the top of the atmosphere across a swath width of 2200 km. CrIS will succeed the Atmospheric Infrared Sounder (AIRS) which is on NASA's EOS Aqua spacecraft and fly in a complementary orbit with the Infrared Atmospheric Sounding Interferometer (IASI) on the EUMETSAT MetOp satellites. ATMS has 22 microwave channels in the 23-

183 GHz range to provide vertical temperature and moisture soundings. Data from CrIS and ATMS will be used to construct atmospheric temperature profiles at 1° K accuracy for 1 km layers and moisture profiles accurate to 15 percent for 2 km layers to approximate the accuracy of data obtained from radiosondes.

The tri-agency NPOESS Integrated Program Office (IPO) has defined a less complex passive microwave radiometer sensor and acquisition strategy to replace the Conical-scanning Microwave Imager/Sounder (CMIS) that was demanifested when the NPOESS program was restructured. The Microwave Imager/Sounder (MIS) will fly on NPOESS C2-C4 to perform key, “all weather” measurements including soil moisture and sea surface winds, as well as other environmental parameters including atmospheric temperature and moisture profiles, and integrated atmospheric moisture and precipitation. MIS will be the primary instrument for satisfying 16 EDRs. The design for MIS is based on heritage conically-scanning microwave radiometers that are currently flown on DMSP spacecraft and on the Naval Research Laboratory’s WindSat/Coriolis mission. MIS will use a 1.8 m rotating main reflector to cover a 1,700 km swath width while measuring over a range of 6 GHz to 183 GHz. Details on MIS are provided in Ref. 7.

The Ozone Mapping and Profiler Suite (OMPS) on NPP will use nadir and limb scanning ultraviolet (UV) instruments to collect atmospheric total column and vertical profile ozone data and continue the daily global data produced by the current ozone monitoring systems, the Solar Backscatter Ultraviolet radiometer (SBUV)/2 and Total Ozone Mapping Spectrometer (TOMS), but with higher fidelity. The OMPS limb scanner is expected to provide vertical profiles of ozone concentrations for 3 to 5 km thicknesses of the atmosphere as compared to the 7 to 10 km thicknesses obtained from the SBUV/2 on NOAA POES. The OMPS on NPOESS C-1 may be a nadir sensor only.

The Space Environment Monitor (SEM) is a multi-channel, charged particle spectrometer that measures the population of the Earth’s radiation belts and the particle precipitation phenomena resulting from solar activity. SEM is currently flown on NOAA’s POES.

NPOESS is on track to deliver more than 35 essential measurements for operational weather and ocean nowcasting and forecasting, land use, and space weather while providing continuity of data for 14 of 26 essential climate variables. Although several NPOESS climate sensors were de-manifested as a result of restructuring in 2006, the NPOESS spacecraft is designed to handle the re-manifest of all de-manifested sensors, including climate monitoring sensors. In fact, as a result of recent tri-agency (DOC, DoD, and NASA) decisions, CERES was added to NPP and both CERES and TSIS will be flown on NPOESS C-1. NOAA and NASA are currently working on other options to meet requirements for long-term climate monitoring from space that may include NPOESS.

The Cloud and Earth Radiant Energy System (CERES) instrument consists of three broadband radiometers, covering the spectral regions from 0.3 to > 50 µm, which scan the Earth from limb to limb. CERES will provide measurements of the space and time distribution of the Earth’s Radiation Budget (ERB) components. CERES will continue a nearly 30-year record of measurements of the Earth radiation budget by instruments on NASA spacecraft. Data from CERES will be used in conjunction with VIIRS to study changes in the Earth's energy balance and key changes in clouds and aerosols to determine the effect of changing clouds on the Earth's energy balance from space. It is this balance between the incoming energy from the Sun and outgoing energy back to space that determines Earth's temperature and climate.

The Total Solar Irradiance Sensor (TSIS) will measure variability in the sun's solar output, including total solar irradiance. TSIS consists of two instruments: the Total Irradiance Monitor (TIM) that measures the total light coming from the sun at all wavelengths; and the Spectral Irradiance Monitor (SIM) that will measure how the light from the sun is distributed by wavelength. These measurements are needed to understand how solar radiation interacts with the Earth's surface and atmosphere. TSIS is an important climate sensor that will help maintain continuity of the climate data record for space-based solar irradiance measurements that now spans over three decades.

NPOESS spacecraft are being designed for precise orbit control to maintain altitude, nodal crossing times to within ±10 minutes throughout the mission lifetime, and repeat ground tracks. These design criteria are particularly important for climate measurements such as tropospheric temperatures that will be made with CrIS and ATMS. For example, drift in the orbits of the 20+ year series of afternoon POES spacecraft coupled with instrument intercalibration issues have resulted in controversial results with respect to trends in tropospheric temperatures. These types of problems should be remedied on NPOESS.

The spacecraft instruments are designed for autonomous operations for up to 60 days without commanding from the ground. On-board data handling capabilities will be sufficient to store data at instrument resolution globally, so there will be no need to schedule special higher-resolution imagery products (i.e., as currently occurs with POES Local Area Coverage-LAC and DMSP Fine Mode). Fault tolerant designs for each of the instrument payloads will enable long mission life (up to 8 years storage and 7 years operation) to ensure mean mission durations exceeding five years for each of the NPOESS spacecraft over the operational life of the program (2013 to ~2026). This is a significant improvement over the average on-orbit life of POES or DMSP spacecraft (36-48 months) and comparable to what NASA is currently achieving in its EOS missions. Longer on-orbit life also means that fewer spacecraft will be required to provide coverage over the 10+ year span of NPOESS operations.

IV. NPOESS Preparatory Project

To ensure a successful transition from current research to future operations, the NPOESS IPO and NASA are partners in the NPP that is scheduled for launch in 2010 as a precursor to NPOESS. NPP will accomplish two key objectives: (1) reduce final development risks for NPOESS by providing on-orbit testing, calibration, and validation of sensors, algorithms, and ground-based operations and data processing systems prior to the launch of NPOESS-C1 in 2013; and (2) provide continuity of calibrated, validated, and geo-located NASA EOS Terra, Aqua, and Aura global imaging and sounding observations.

NPP will carry the four primary NPOESS sensors (VIIRS, CrIS, ATMS, and OMPS) and CERES to provide on-orbit testing and validation of sensors, algorithms, ground-based operations, and data processing and distribution systems prior to the launch of the first operational NPOESS satellite. The NPP satellite will be launched into the 1330 LTAN orbit to reduce the risk of a data gap between the last POES and the first NPOESS satellite. The satellite will be commanded from the NPOESS Mission Management Center at NOAA’s Satellite Operations Facility (NSOF) through a ground station located at Svalbard, Norway. Svalbard is located at high enough latitude (78 degrees north) to be able to “see” and downlink data from all 14 daily NPP satellite passes. The global stored mission data from NPP will be transmitted from Svalbard within minutes to the U.S. via a fiber-optic cable system that was completed in January 2004 as a joint venture between the IPO, NASA, and the Norwegian Space Center (NSC). The Svalbard ground station and fiber-optic link will improve data latency (time from observation by the satellite to availability of processed data) from NPP compared to the ~120-180 minute data latency from POES and DMSP. NPP will generate approximately 1.5 terabytes of data per day that will be processed into about 25 separate EDRs and higher level products at the NSOF and the Air Force Weather Agency (AFWA). NOAA, DoD, and NASA will have real-time access to data from NPP for use and critical evaluation, ensuring that NPOESS products will be incorporated into operations soon after launch.

NPP will also support real-time Direct Broadcast (DB) services via an X-band downlink. There are currently over 150 ground stations worldwide that are being used to acquire real-time, DB data (i.e., imagery) from the X-band downlinks on NASA’a EOS Terra and Aqua satellites. These users will be able to receive real-time data from NPP after it launches in 2010 by using the International Polar Orbiter Processing Package (IPOPP) that is being developed by the IPO through a collaborative arrangement with the Direct Readout Laboratory at NASA’s Goddard Space Flight Center and the Cooperative Institute for Meteorological Satellite Studies at the University of Wisconsin-Madison.

A key component of NPP is NASA's Science Data Segment (SDS). The SDS evaluates key NPP/NPOESS EDRs in the following discipline areas: oceans, land, ozone, atmospheric sounding, and atmospheric composition. The SDS will assess NPP EDR quality and performance, and test the suitability of EDRs for climate research. Details on the NPP SDS are provided in Ref. 8.

V. NPOESS Ground System

The NPOESS Ground System has three key components that will ensure the timely and efficient delivery of NPOESS data once operational: Command, Control, and Communications Segment (C3S), Interface Data Processing Segment (IDPS), and the Field Terminal Segment (FTS). NPOESS will be an end-to-end system to acquire, process, and deliver meteorological, oceanographic, terrestrial, climatological, and solar-geophysical observations of the Earth, atmosphere, and space to NOAA and DoD central processing facilities through an innovative global SafetyNet™ communications network of 15 unmanned ground stations that will provide significantly improved data latency over current systems. The NPOESS C3S will deliver global stored mission data to four U.S. Operational Processing Centers (OPCs) for processing and distribution to end users: NOAA’s National Environmental Satellite, Data and Information Service (NESDIS) that will serve the National Centers for Environmental Prediction (NCEP); AFWA; Fleet Numerical Meteorology and Oceanography Center (FNMOC); and the Naval Oceanographic Office (NAVOCEANO).

The NPOESS ground system architecture is expected to deliver 95% of the data within 28 minutes from the time of collection. This capability of SafetyNet™ to reduce data latency (or speed up data delivery) is critical and is the key benefit of the system for NPOESS. Today, data collected by NOAA’s POES are stored on board and delivered to a single ground antenna once per orbit. The current ground processing system adds another delay of up to two hours. In fact, the existing POES ground stations at Fairbanks, Alaska and Wallops Island, Virginia cannot "see" all 14 orbits per day and data from three "blind" POES orbits are processed considerably later in a delayed mode. Antennas at Svalbard are currently being used to receive data from the NOAA-18 (POES) "blind" orbits as part of IJPS. Notably, this "blind" orbit problem will not exist at all with the NPP and NPOESS ground systems that will rely on the site at Svalbard for a primary data downlink. SafetyNet™ will use up to 15 multiple sites around the world where data will be downloaded and delivered in some cases within 2 minutes of acquisition on orbit.

This dramatic, four-to-five fold improvement in data latency from NPOESS will lead to significant improvements in forecasts produced by numerical weather prediction (NWP) models by delivering data updates much earlier and more frequently than provided by today's satellites. Dr. Louis Uccellini, Director of NOAA's National Centers for Environmental Prediction has stated that "lowering data latency rates ensures that we will be able to process NPOESS data quickly and deliver more timely, higher resolution forecasts to decision makers." Improvements in data latency should provide a tremendous benefit to modelers as well as to users of model output.

In addition to the space-to-ground transmission of stored mission data, NPOESS will simultaneously broadcast two continuous real-time data streams, at high (X-band) and low (L-band) rates, to suitably equipped field terminals worldwide. The NPOESS High Rate Data (HRD) broadcast will be a complete, full resolution data set containing all sensor data and auxiliary/ancillary data necessary to generate all NPOESS EDRs (except some Earth Radiation EDRs) and is intended to support users at fixed, regional hubs. The NPOESS Low Rate Data (LRD) broadcast will be a subset of the full NPOESS sensor data and is intended for U.S. and worldwide users of field terminals (land and ship-based, fixed and mobile environmental data receivers operated by DoD users and surface receivers operated by other U.S. government agencies, worldwide weather services, and other international users). Future communications capabilities (e.g., rebroadcast of processed imagery/data and delivery via the Internet or "commercial" services) may allow other-than-direct satellite-to-ground data transmission to follow-on field terminal systems.

The NPOESS IDPS features high-speed, symmetric, multi-processing computers that will rapidly convert and process large streams of NPP and NPOESS Raw Data Records (RDRs) (on the order of 8 Terabytes per day when NPOESS is fully operational) into 38 distinct EDRs at the four OPCs. The IDPS equipment for the NSOF is already installed and the equipment is currently being installed and tested at AFWA to serve the NPP mission. The IDPS equipment for NAVOCEANO and FNMOC will be installed in ~2012 to complete the full-up system for NPOESS operations. NOAA's NESDIS will maintain the long-term archive of NPOESS data. NESDIS will also be responsible for providing access to the worldwide user community for near real-time processed NPOESS data and higher-level products, as well as access to archived NPOESS data via other distributed servers at the NESDIS Data Centers.

Key components of the NPP and NPOESS command, control, and communications system have already been installed and have passed preliminary tests at the Svalbard Satellite Station (SvalSat) and at NOAA's Satellite Operations Facility. Communications capabilities from Antarctica are being upgraded to support NPOESS. NOAA and EUMETSAT are currently exploring opportunities to receive MetOp data from an Antarctic ground station, thereby substantially improving data latency in the mid-morning orbit. Installation and testing of the NPOESS Integrated Data Processing system at NOAA and DoD facilities will continue throughout 2008. In the future, NPOESS and MetOp will provide essential real-time data to the international community to support weather forecasting, as well as continuity of critical data for monitoring, understanding, and predicting climate change.

VI. NPOESS Applications and User Training

The visible and near-infrared channels on VIIRS will be used to generate high resolution cloud imagery, sea ice, aerosols, vegetation, and land surface type products. The short- to long-wave infrared channels will provide data to derive cloud properties (cloud type, cloud particle size, cloud top height, cloud top temperature), snow cover, sea surface temperature, and fires. Multi-channel algorithms will combine visible and infrared data to generate measurements such as albedo that is important in measuring and understanding the Earth's energy balance. These multi-spectral capabilities will allow users to accurately detect phenomena such as volcanic ash plumes and discriminate low clouds from fog that may significantly impact aircraft operations.

Higher (spatial, temporal, and spectral) resolution and more accurate sounding data from CrIS and ATMS will support continuing advances in data assimilation systems and NWP models to improve short- to medium-range weather forecasts. Assimilation of high-spectral resolution radiance data from AIRS into NWP models at NOAA's National Centers for Environmental Prediction (NCEP) has already resulted in a several hour increase in forecast skill/range at five to six days in both northern and southern hemispheres, a significant improvement that normally takes several years to accomplish[9]. CrIS will produce operational sounding data comparable to AIRS. VIIRS will deliver high resolution, radiometrically accurate data on surface albedo, land surface type, sea surface temperature, snow cover, and ice extent for ingesting into global and regional models. OMPS will profile ozone vertically in 3 km layers to provide better specification of stratospheric ozone that is now being used as a tracer in global NWP models.

High resolution, multi-spectral instruments on NPP and NPOESS will provide image and sounding products useful to the forecaster that aren't available from geostationary satellites. NASA's Short-term Prediction Research and Transition (SPoRT) Center has been demonstrating the utility of higher resolution measurements from polar-orbiting satellites by providing real-time data and products from NASA's MODIS and AIRS instruments to National Weather Service (NWS) forecasters on an experimental basis to improve short-term weather forecasts. NPP will maintain continuity of high-resolution data from NASA's EOS missions during the transition to NPOESS. NPP data will be available in a timeframe consistent with the projected installation of the next generation Advanced Weather Information Processing System (AWIPS) at NWS forecast offices.

Even as data from NASA's MODIS and AIRS instruments are being used to support current operations, weather forecasters and other users of remote sensing data are being prepared to exploit NPP and NPOESS data as soon as these new systems are launched. Over the past six years, the Cooperative Program for Operational Meteorology, Education and Training (COMET) has focused its satellite training on the capabilities, applications, and relevance of NPP and NPOESS to operational weather forecasters and other user communities[10]. A complementary training effort is hosted by Naval Research Laboratory (NRL) in Monterey, California on their NRL/NPOESS Next Generation Weather Satellite Demonstration Project (NexSat) website. NexSat uses real-time imagery from current operational (e.g, POES and DMSP) and research (e.g., NASA's EOS Terra and Aqua) satellites to highlight the expected capabilities of comparable sensors on the future NPP and NPOESS[11]. The goal of these efforts is to ensure that forecasters and other users will be prepared to use data and products from NPP and NPOESS on "Day 1" of operations.

VII. Conclusion

NPOESS will support the operational needs of the civilian meteorological, oceanographic, environmental, climatic, and space environmental remote-sensing programs, and will provide global military environmental support, including geophysical and space support. In addition, NPOESS data will be available to over 120 different nations around the world in support of their environmental forecasting capabilities. The advanced technology visible, infrared, and microwave imagers and sounders that will fly on NPOESS will deliver higher spatial and temporal resolution oceanic, atmospheric, terrestrial, climatic, and solar-geophysical data, enabling more accurate short-term weather forecasts and severe storm warnings. These data will be assimilated into NWP models to improve short- (3-5 day) to medium- (7-15 day) range weather forecasts.

The NPOESS architecture will enable high-quality, space-based, remotely-sensed data to be used faster and more frequently in numerical weather prediction models for improved environmental forecasts and warnings. As a key component of the Global Earth Observation System of Systems (GEOSS), NPOESS data will contribute to the "Nine Societal Benefits Areas." NPOESS will provide essential real-time data to the international community to support weather forecasting, as well as continuity of critical data for monitoring, understanding, and predicting climate change and assessing the impacts of climate change on seasonal and longer time scales.

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