The National Polar-orbiting Operational Environmental Satellite System Capabilities for Operational Ocean Remote Sensing

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***Abstract*- Over the last decade, the tri-agency Integrated Program Office (IPO), comprised of the National Oceanic and Atmospheric Administration (NOAA), the Department of Defense (DoD), and the National Aeronautics and Space Administration (NASA), has been managing the development of the National Polar-orbiting Operational Environmental Satellite System (NPOESS). Once operational, NPOESS will replace NOAA's Polar-orbiting Operational Environmental Satellite (POES) and DoD's Defense Meteorological Satellite Program (DMSP) systems. Ocean measurements comprise one-fourth of the 55 user-validated requirements for geophysical measurements that will be made by NPOESS sensors. Ocean requirements have directly and substantially "driven" the design and acquisition strategy for three NPOESS sensors: the Visible/Infrared Imager Radiometer Suite (VIIRS); the Conical-scanning Microwave Imager/Sounder (CMIS); and the Altimeter. With these instruments, NPOESS will deliver higher resolution (spatial and temporal) and more accurate measurements of sea surface temperature (SST), ocean surface wind vectors/stress, ocean color and derived parameters, sea ice (edge motion, age, surface temperature, thickness), oceanic heat flux, significant wave height, and sea surface topography. NPOESS spacecraft will be launched into three orbital planes beginning later this decade to provide significantly improved operational capabilities and benefits to satisfy the critical civil and national security requirements for space-based, remotely sensed environmental data. NPOESS will transform today's relatively short-term, space-based ocean research missions into a sustained, operational ocean remote sensing observation program.**

I. INTRODUCTION

Over the last nine years, 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), has been managing the development of the National Polar-orbiting Operational Environmental Satellite System (NPOESS). Once operational later this decade, NPOESS will replace the current NOAA Polar-orbiting Operational Environmental Satellite (POES) and DoD's Defense Meteorological Satellite Program (DMSP) systems, each with over a 40-year heritage of successful service. With the development of NPOESS, we are evolving the existing "weather" satellites into an integrated environmental observing system by expanding our capabilities to observe, assess, and predict the total Earth system – ocean, atmosphere, land, and the space environment. Data from the advanced NPOESS sensors will enable more accurate short-term "nowcasts" and forecasts as well as serve the data continuity requirements for improved global climate change assessment and prediction. NPOESS will transform today's space-based ocean research missions into a sustained, operational ocean remote sensing observation program.

The IPO, through its Acquisition and Operations (A&O) contractor, Northrop Grumman Space Technology (NGST), will begin in 2009 to launch NPOESS spacecraft into three orbital planes (1330, 1730, and 2130 equatorial ascending nodal crossing times) to provide a single, national system capable of satisfying both civil and national security requirements for space-based, remotely sensed environmental data. NGST, with its teammate Raytheon, is responsible for developing, integrating, deploying, and operating NPOESS satellites to meet the tri-agency requirements for NPOESS over the 10-year operational life of the program. Reference [1] provides additional details on the early phases of the NPOESS program.

II. REQUIREMENTS

The NPOESS development and acquisition plan is designed to make best use of production and existing POES and DMSP assets, to reduce risk on critical sensor payloads and algorithms, and to leverage civil, governmental, and international payload and spacecraft developments. The planned evolution from the current POES and DMSP programs to NPOESS will take place over the next six to ten years. Currently the U.S. is operating two primary POES and two primary DMSP satellites. The first launch of NPOESS is planned for 2009 to begin replacing the last of the current POES and DMSP satellites. When NPOESS reaches full operational capability (circa 2013), three satellites will provide global coverage with a data refresh rate of approximately four hours for most observations.

The tri-agency partners in the NPOESS program agreed upon a fully defined set of integrated operational requirements that will meet the needs of the nation's civil and military users for satellite data in the next decade. The military and civilian user communities jointly defined Environmental Data Records (EDRs), as well as the required performance characteristics for each of these data products. The 55 NPOESS Environmental Data Records (Fig. 1) fully encompass the Earth science disciplines. When operational, NPOESS will truly be an "environmental observing system."

☆ Atmos Vert Moist Prof	Dn Lwave Rad (Sfc)	Ozone-Tot Col/Profile
☆ Atmos Vert Temp Prof	Electric Field	Precipitable Water
☆ Imagery	Electron Density Prof	Precip Type / Rate
☆ Sea Surf Temp	Aero Refractive Index	Pressure (Surf/Profile)
☆ Sea Surf Winds	Geomagnetic Field	Sea Ice Age Char
☆ Soil Moisture	Ice Surface Temp	Sea Surface Hgt/Topo
Aero Opt Thickness	Energetic Ions	Snow Cover/Depth
Aerosol Particle Size	In-situ Plasma Fluct	Solar Irradiance
Albedo (Surface)	In-situ Plasma Temp	ST- Auroral Particles
Auroral Boundary	Downward Swave Rad	Surface Wind Stress
Auroral Imagery	Med Energy Particles	Suspended Matter
Cloud Base Height	Ionospheric Scint	Auroral Energy Depos
Cloud Cover/Layers	Land Surface Temp	Out Lwave Rad (TOA)
Cloud Eff Particle Size	Surface Type	
Cloud Ice Water Path	Net Heat Flux	Atmospheric
Cloud Liquid Water	Net Solar Rad (TOA)	Oceanic
Cloud Opt Thickness	Neutral Density Profile	Terrestrial
Cloud Top Height	Total Water Content	Space Environment
Cloud Top Pressure	Vegetation Index	Climate
Cloud Top Temp	Ocean Color / Chlor	
Cloud Part Size / Dist	Ocean Wave Char	

☆Environmental Data Records (EDRs) with Key Performance Parameters

Fig. 1. NPOESS Environmental Data Records (EDRs)

Performance characteristics for each of the 55 EDRs were defined and bounded between threshold values that represent minimally acceptable performance for an attribute and objective levels that represent performance that would have significant added value to users. In many cases, threshold values were set to meet or exceed what can be achieved from instruments on current operational satellites (i.e., POES, DMSP). The specific attributes include horizontal (vertical) resolution, mapping accuracy, measurement range, measurement precision, measurement uncertainty, refresh rate, data latency, and geographic coverage. Long-term stability requirements have also been set for key parameters (e.g., atmospheric vertical temperature, sea surface temperature, sea surface winds) to ensure temporal consistency and continuity of data over the life of NPOESS that will support improved global climate change assessment and prediction.

A. Ocean Requirements

Ocean observations comprise approximately one-fourth of the 55 user-validated requirements for geophysical measurements that will be made by NPOESS sensors. These ocean requirements were established based on current uses and applications of ocean remote sensing data (Table I), projected needs for higher resolution data to support operations in coastal and open ocean regions, and existing capabilities of operational and research instruments and satellites (e.g., Advanced Very High Resolution Radiometer [AVHRR-3] on POES, Sea-viewing Wide Field-of-view Sensor [SeaWifs], Moderate Resolution Imaging Spectroradiometer [MODIS] on NASA's Terra and Aqua spacecraft).

TABLE I
APPLICATIONS OF OCEAN REMOTE SENSING DATA

OCEANOGRAPHIC MEASUREMENTS	**EXAMPLE APPLICATIONS**
Images of Ocean Surface Features	• Surface circulation • Essential fish habitat mapping • Fisheries management • Ship detection • Floating oil rig stabilization
Surface Temperature	• Surface circulation • Climate change analysis • Marine weather forecasts • Essential fish habitat ranges • Fisheries management • Sea ice and navigation
Surface Water Color	• Biological productivity • Essential fish habitat mapping • Harmful algal bloom detection • Pollution detection & monitoring • Coastal erosion & runoff
Surface Wind Speed	• Severe weather forecasts • High sea state warnings • Biological productivity zones • Ship routing
Surface Wind Direction	• Severe weather forecasts • Biological productivity zones • Ship routing
Sea Surface Heights	• Ocean currents • Sea level change analysis • Climate change forecasts
Ocean Wave Heights	• Ship routing • Ship and ocean platform design studies

Although NPOESS will carry only one instrument designed specifically for ocean observations (i.e., a radar altimeter), ocean requirements have directly and substantially "driven" the design and acquisition strategy for several multi-disciplinary NPOESS sensors and have set constraints on certain aspects of the total system performance (e.g., orbital characteristics, payload configurations, and spacecraft navigation). With these instruments, NPOESS will deliver higher resolution (spatial and temporal) and more accurate measurements of sea surface temperature (SST), ocean surface wind vectors/stress, ocean color and suspended matter, sea ice (edge motion, age, surface temperature, thickness), oceanic heat flux, significant wave height, and sea surface topography. Table II lists primary attributes for the principal ocean parameters.

TABLE II
ATTRIBUTES FOR OCEAN PARAMETERS

	Thresholds		**Objectives**	
	Resolution	Accuracy	Resolution	Accuracy
Imagery	0.4 km	1.0 km	0.1 km	0.5 km
Sea Surface Temperature	1.0 km	±0.5°C	0.25 km	±0.1°C
Sea Surface Winds	20 km	±2 ms^{-1} & ±20°	1.0 km	±1 ms^{-1} & ±10°
Surface Wind Stress	20 km	±0.02 Nm^{-2}	1.0 km	±0.01 Nm^{-2}
Ocean Wave Characteristics	2.5–20 km	±0.2 m	2.5 km	±0.2 m
Sea Surface Height*	15 km	6 cm	2 km	4 cm
Ocean Color & Chlorophyll	0.75 km	10% & 40%	0.1 km	5% & 20%
Ice Surface Temperature	1 km	±1.0°C	0.1 km	±1.0°C
Sea Ice Concentration & Age	20 km	10%	0.05 km	5%
Net Heat Flux	20 km	±10 Wm-2	5 km	±1 Wm-2

* Accuracy defined separately for meso-, basin, and global scales

An example of the complete set of performance attributes for measurement of SST is shown in Table III. The requirements for the complete set of 55 EDRs, including the ocean parameters, are fully documented in [2].

TABLE III
ATTRIBUTES FOR SEA SURFACE TEMPERATURE (SST)

Systems Capabilities	**Thresholds**	**Objectives**
a. Horizontal Cell Size Nadir, clear Worst Case, clear All Weather	 1 km 1.3 km 40 km	 0.25 km 20 km
b. Mapping Accuracy Nadir, clear Worst Case, clear All Weather	 1 km 1.3 km 5 km	 0.1 km 3 km
c. Measurement Range	-2° to 40°C	-2° to 40°C
d. Measurement Precision Clear All Weather	 0.2°C 0.3°C	 0.1°C 0.1°C
e. Measurement Uncertainty Clear All Weather	 0.5°C 1.0°C	 0.1°C 0.5°C
f. Refresh	6 hours	3 hours
g. Long-Term Stability	0.1°C	0.05°C
h. Latency	90 minutes	15 minutes
i. Geographic Coverage	Global Ocean	Global Ocean

III. Instruments and System Development

The established requirements for 55 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. In 1997, the IPO initiated a robust sensor risk reduction effort that was focused on early development of the critical sensor suites and algorithms necessary to support NPOESS. In August 2001, preliminary design efforts were completed for the last of five critical imaging/sounding instruments for NPOESS. Final design, prototype development, and fabrication of these instruments have begun, with delivery of the first flight units for four sensors scheduled for 2005. In 2000, the IPO initiated a program definition and risk reduction program to define the requirements for the NPOESS total system architecture, including space, ground processing, and command, control, and communications components, as well as to develop specifications for sensor/spacecraft integration. This phase of the early development program was concluded in August 2002 with the award of a single prime contract to Northrop Grumman Space Technology to accomplish the Acquisition and Operations of NPOESS.

Thirteen different instrument payloads will be flown on NPOESS spacecraft in three different configurations, depending upon orbit. These payloads include instruments to: 1) profile the atmosphere (Cross-track Infrared Sounder [CrIS], Advanced Technology Microwave Sounder [ATMS], Ozone Mapping and Profiler Suite [OMPS], and Aerosol Polarimetry Sensor [APS]); 2) probe the space environment (Global Positioning System Occultation Sensor [GPSOS] and Space Environment Sensor Suite [SESS]); 3) monitor the Earth's radiation budget (Total Solar Irradiance Sensor [TSIS] and Earth Radiation Budget Sensor [ERBS]); 4) map the ocean surface (radar altimeter [ALT]); and 5) observe atmospheric, terrestrial, and oceanic phenomena globally (Visible/Infrared Imager Radiometer Suite [VIIRS] and Conical-scanning Microwave Imager/Sounder [CMIS]). In addition, NPOESS will carry forward the current capabilities on POES for search and rescue and surface data collection/location (Search and Rescue Satellite Aided Tracking System [SARSAT] and ARGOS/Data Collection System [A-DCS]) that are important to the ocean community.

Details on each of the 13 instrument payloads are available in [3]. Here we focus on those NPOESS instrument payloads that will provide operational ocean remote sensing capabilities in the future:

- <u>Visible/Infrared Imager Radiometer Suite (VIIRS):</u> The VIIRS will combine the radiometric accuracy of the Advanced Very High Resolution Radiometer (AVHRR/3) currently flown on POES with the high (0.65 km) spatial resolution of the Operational Linescan System flown on DMSP. The VIIRS will have 22 channels grouped into the panchromatic day/night band, visible and near-infrared (IR), short and mid-wave IR, and long-wave IR, with additional spectral capabilities that can be used to determine ocean color. VIIRS spectral bands are characterized as either fine resolution or moderate resolution. Fine resolution bands will have (nearly constant) horizontal sampling intervals (HSIs) of about 400 m (at nadir) to 800 m (at edge-of-scan) across the ~3000 km swath and moderate resolution bands will have HSIs of twice this size. VIIRS will provide measurements of sea surface temperature, atmospheric aerosols, snow cover, cloud cover, surface albedo, vegetation index, sea ice, and ocean color. VIIRS is expected to perform similarly to MODIS on NASA's Terra and Aqua missions in many of the spectral bands. VIIRS represents a significant step in transforming NASA's state-of-the-art research sensors into operational sensors to meet the needs of both the operational and research communities. See [4] for additional details on VIIRS and [5] for comparisons of key properties between the MODIS and VIIRS sensors.
- <u>Conical-scanning Microwave Imager/Sounder (CMIS):</u> The CMIS will combine the microwave imaging capabilities of Japan's Advanced Microwave Scanning Radiometer (AMSR) on NASA's Earth Observing System (EOS) Aqua satellite and the atmospheric sounding capabilities of the Special Sensor Microwave Imager/ Sounder (SSMI/S) on the remaining series of DMSP satellites that will begin launching in late-2003, with the passive, polarimetric capabilities of the WindSat sensor on the Coriolis mission that was recently launched in January 2003. The CMIS uses a dual-primary rotating reflector with an aperture of ~2.2 m to make "all-weather" measurements across a large frequency range of 6 to 190 GHz. Polarization for selected imaging channels will be used to passively derive ocean surface wind vectors similar to what has previously been achieved with active scatterometers. CMIS data will be used to derive a variety of parameters, including all-weather sea surface temperature, surface wetness, precipitation, cloud liquid water, cloud base height, snow water equivalent, surface winds, atmospheric vertical moisture profile, and atmospheric vertical temperature profile. See [6] for details.
- <u>Radar Altimeter (ALT):</u> The IPO is planning to fly a dual frequency radar altimeter (TOPEX/Jason-class) on the early-morning (0530 descending) NPOESS satellite. The altimeter will measure sea surface height, significant wave height, and wind speed. Altimetry measurements will be used to derive ocean circulation parameters to satisfy monitoring requirements for both operations and research purposes. The altimeter will be acquired as a leveraged payload for flight on the NPOESS spacecraft. We recognize that the near-polar orbit of the NPOESS spacecraft will not be ideal for replicating the series of long-term measurements of global and regional mean sea level change that have been initiated with the TOPEX/Poseidon and Jason missions. However, we do expect to be able to meet operational requirements for mapping mesoscale ocean variability. We are also working with our NOAA, NASA, and international partners to define a future constellation of altimeters to meet both real-time operational and long-term research requirements for measuring sea surface height.
- <u>Search and Rescue Satellite Aided Tracking System (SARSAT):</u> The SARSAT receives distress signals from emergency position indicating radio beacons (EPIRBs) on international distress frequencies and retransmits them to local user terminals for action by appropriate government agencies. The redesigned SARSAT subsystems on NPOESS will only support EPIRBs transmitting at 406 MHz.
- <u>ARGOS/Data Collection System (A-DCS):</u> The A-DCS relays meteorological and other data transmitted from in-situ ground-based data collection platforms including buoys, free floating balloons, and remote weather stations. NPOESS will carry the upgraded ARGOS-3/4 data collection system that will provide two-way messaging capabilities for users to command and manage platform transmitters and sensors, as well as receive data efficiently from their platforms.

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 10-year operational life of the program (2009-2018).

The current operational concept for NPOESS consists of a constellation of spacecraft flying at an altitude of 833 km in three sun-synchronous (98.7 degree inclination) orbital planes with equatorial ascending nodal crossing times of 1330, 1730, and 2130 local solar time respectively. NPOESS spacecraft are being designed for precise orbit control to maintain altitude, nodal crossing times to within $\pm$10 minutes throughout the mission lifetime, and repeat ground tracks to $\pm$1 km for certain measurements (e.g., sea surface height). Because the user-specified requirements for data refresh are different for the 55 environmental parameters, not all instrument payloads are required in each orbit. In addition, certain orbital characteristics (e.g., the terminator orbit is not conducive to certain measurements), as well as considerations of instrument field of view on the spacecraft have determined the payload configurations for each orbit. The afternoon (1330 ascending) spacecraft will carry a full complement of instruments. The early-morning (0530 descending) and mid-morning (0930 descending) NPOESS spacecraft will carry reduced complements of instruments, including VIIRS and CMIS that are required to meet the stringent U.S. horizontal resolution and data refresh (four hours) requirements for "all-weather" imaging (visible/infrared and microwave) and ocean surface wind field mapping in these orbits. The current orbit manifest for the NPOESS sensor payloads is shown in Table IV.

TABLE IV
NPOESS INSTRUMENT PAYLOADS BY ORBIT
EQUATORIAL ASCENDING NODAL CROSSING TIME

1330	1730	2130
VIIRS	VIIRS	VIIRS
CrIS	CrIS	
ATMS	ATMS	
CMIS	CMIS	CMIS
OMPS		
GPSOS		
SESS	TSIS	
ERBS	ALT	APS
SARSAT	SARSAT	SARSAT
A-DCS	A-DCS	

Table V maps each of the ocean parameters to the instruments that will contribute to the measurement.

TABLE V
NPOESS SENSORS FOR OCEAN PARAMETERS

	Sensor			
	VIIRS	CMIS	CrIS	Altimeter
Imagery	X	X		
Sea Surface Temperature	X	X	X	
Sea Surface Winds		X		X
Surface Wind Stress		X		X
Ocean Wave Characteristics				X
Sea Surface Height				X
Ocean Color & Chlorophyll	X			
Ice Surface Temperature	X	X		
Sea Ice Concentration & Age	X	X		
Net Heat Flux	X	X	X	

Note that data from multiple instruments will be required to derive certain parameters. In particular, "all-weather" requirements will be met by combining near-simultaneous infrared (from VIIRS) and microwave (from CMIS) measurements to derive global and regional products (e.g., SST).

IV. Early Flight Testing

Early flight-testing of instruments is a critical part of the NPOESS program to reduce development risk and to demonstrate and validate global imaging and sounding instruments, algorithms, and pre-operational ground systems prior to the first NPOESS launch in 2009. The joint DoD/IPO Coriolis/WindSat mission was launched in January 2003 to provide a space-based test and demonstration of passive microwave polarimetric techniques to derive measurements of ocean surface wind speed and direction. Preliminary results from the first five months of on-orbit operations have demonstrated excellent radiometric functionality and improved spatial resolution over SSM/I. This planned three-year mission continues the development of improved microwave measurement capabilities from the Special Sensor Microwave Imager and Sounder (SSMI/S) on the remaining DMSP spacecraft to CMIS on NPOESS.

The joint IPO/NASA NPOESS Preparatory Project, that will be launched in 2006, will carry four of the critical NPOESS sensors (VIIRS, CrIS, OMPS, and the NASA-developed ATMS) to provide on-orbit testing and validation of sensors, algorithms, and ground-based operations and data processing systems while the current operational POES and DMSP and the NASA EOS Aqua research satellite systems are still in place. In addition to ATMS, NASA is providing the NPP spacecraft that is being built by Ball Aerospace and Technologies Corporation, as well as the launch vehicle. The IPO is responsible for the VIIRS, CrIS, and OMPS instruments, NPP spacecraft operations, and ground processing systems. More detailed information on NPP is provided in [7].

The NPP mission will provide operational agencies early access to the next generation of operational sensors, thereby greatly reducing the risks incurred during the transition from POES and DMSP to NPOESS. NPP will demonstrate the utility of the improved imaging and radiometric data in short-term weather "nowcasting" and forecasting and in other oceanic and terrestrial applications, such as harmful algal blooms, volcanic ash, and wildfire detection. In addition to serving as a valuable risk reduction and prototyping mission for the IPO and users of NPOESS data, NPP will provide continuity of the calibrated, validated, and geo-located NASA EOS Terra and Aqua systematic global imaging and sounding observations for NASA Earth Science research. With a five-year design lifetime, NPP will provide a "bridge" from NASA's EOS research missions (Terra and Aqua) to the operational NPOESS mission. NPP will extend the series of key measurements in support of long-term monitoring of climate change and of global biological productivity.

V. Ground Systems

A. Global Data

To meet U.S. user-validated requirements for 55 geophysical parameters, including specific DoD and NOAA user requirements for data latency, the NPOESS C^3S will deliver global Stored Mission Data (SMD) to four U.S. Operational Processing Centers (Centrals) for processing and distribution.

These Centrals are: NOAA's National Environmental Satellite, Data, and Information Service (NESDIS) and National Centers for Environmental Prediction (NCEP); the Air Force Weather Agency (AFWA); Fleet Numerical Meteorology and Oceanography Center (FNMOC); and the Naval Oceanographic Office (NAVOCEANO). Global SMD will be down-linked to 15 globally-distributed, low-cost, unmanned ground stations that will be tied to Centrals via commercial fiber-optic networks. This innovative ground system will deliver 75% of the SMD (daily average) to Centrals within 15 minutes and 95% of the data (daily average) within 26 minutes from the time of on-orbit collection. SMD will be the complete, full resolution data set containing all sensor data and auxiliary data necessary to generate all NPOESS Environmental Data Records at the Centrals. Each Central will be equipped with an Interface Data Processing (IDP) segment consisting of the necessary data ingest and computational hardware/software to process NPOESS Raw Data Records (RDR) into EDRs, using auxiliary and ancillary data as necessary.

NPOESS data will be distributed through the data routing and retrieval component of the NPOESS Command, Control, and Communications Segment (C^3S) to the four U.S. Centrals and to the two NPOESS mission management/control centers. NOAA's NESDIS will maintain the long-term archive of NPOESS data. NESDIS will also be responsible for providing the worldwide user community access to near real-time processed NPOESS data and higher-level products.

B. Direct Broadcast Services

In addition to the space-to-ground transmission of SMD, NPOESS will simultaneously broadcast two continuous real-time data streams, at high and low rates, to suitably equipped field terminals worldwide. These direct broadcast/real-time field terminals will be capable of processing NPOESS RDRs into EDRs by using IDP software appropriate for the type of field terminal. 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 set 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). The LRD broadcast will include data required to satisfy the U.S. user-specified, eight highest priority EDRs for real-time broadcast: imagery (from VIIRS) at 800 m HSI from at least one visible and one infrared channel and nighttime imagery at 2.7 km HSI from the day/night band; atmospheric vertical temperature and moisture profiles (from CrIS, ATMS, and CMIS); global sea surface winds (from CMIS); cloud base height, cloud cover/layers; pressure (surface/profile), and sea surface temperature. Fifteen additional lower priority EDRs will also be included in the LRD broadcast. Additional details on the NPOESS direct broadcast services are provided in [3] and [8].

VI. SUMMARY

The development of NPOESS represents a significant and exciting change in the way the United States acquires, manages, and operates environmental satellites. 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 and improved real-time monitoring of coastal and open ocean phenomena. NPOESS will also provide continuity of critical data for monitoring, understanding, and predicting climate change and assessing the impacts of climate change on seasonal and longer time scales. The improved accuracy in atmospheric temperature and humidity soundings from these instruments, in combination with other observations expected to become available over the next ten years, will enable the current 3- to 5-day short-term weather forecasts to be improved from 70 to 80 percent to better than 90 percent and to be extended to 5 to 7 days with 80-percent accuracy. Equally important for the ocean community, NPOESS will transform today's relatively short-term, space-based ocean research missions into a sustained operational remote sensing observation program. The NPOESS team (IPO, NGST/Raytheon and their subcontractors) is well along the path to creating a high performance, polar-orbiting satellite system that will be more responsive to user requirements, deliver more capability at less cost, and provide sustained, space-based measurements as a cornerstone of an Integrated Global Observing System.

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