13.5 NOAA's NPOESS DATA EXPLOITATION PROJECT

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1. INTRODUCTION

The launch of National Polar-orbiting Operational Environmental Satellite System (NPOESS) Preparatory Program (NPP) in 2006 and the first operational NPOESS in 2009 will begin a new phase in the National Oceanic and Atmospheric Administration's (NOAA) operational polar-orbiting satellite program. The NPOESS Program will continue mission support capabilities established by NOAA's Polar-orbiting Operational Environmental Satellite (POES) program and will provide many new opportunities and technologies to exploit information from polar-orbiting satellites. NPP will provide a risk reduction opportunity for many new NPOESS capabilities and will serve as a proof of concept mission for the NPOESS ground segment architecture and for critical new instruments.

The National Environmental Satellite, Data, and Information Service (NESDIS) is responsible for receiving and processing environmental satellite observations and disseminating the products to NOAA's vast user community. The NPOESS Data Exploitation (NDE) Project has been established to identify and implement all changes within the NESDIS architecture required to process and disseminate NPP and NPOESS data. NDE will therefore provide the critical link between NPOESS and the civilian user community.

2. NPP/NPOESS INSTRUMENTATION

The payload of the NPP satellite consists of three mission critical sensors and an ozone sensing instrument. All four sensors will be proof of concept sensors for NPOESS.

- *Cross-Track Infrared Sounder (CrIS)*: will be used for generating global observations of temperature and moisture profiles in cloud free areas. This sensor also has the potential to estimate greenhouse gases.
- *Advanced Technology Microwave Sounder (ATMS)*: will be used for generating global, all weather observations of temperature and moisture profiles. It is used in conjunction with CrIS to derive enhanced short-medium term weather forecasts and improve warnings.
- *Visible Infrared Imaging Radiometer Suite (VIIRS)*: will be used for generating global observations of land, ocean, and atmosphere parameters, including clouds, aerosols, sea surface temperature, ocean color, low light visible imagery, vegetation health, and marine phytoplankton activity.
- *Ozone Mapping and Profiler Suite (OMPS)*: will be used for generating total ozone and ozone profiles.

The launch of the operational NPOESS satellites will introduce several additional instruments:

- *Conical Scanning Microwave Imager/Sounder (CMIS)*: will be used for atmospheric temperature and moisture profiles, clouds, sea surface winds, and all-weather land/water surfaces.
- *Earth Radiation Budget Sensor (ERBS)*: will be used for measuring the amount of solar energy absorbed, radiated, and reflected from the Earth.
- *Aerosol Polarimeter Sensor (APS)*: will be used for generating aerosol and cloud parameters.
- *RADAR Altimeter (ALT)*: used to measure sea surface topography.
- *Total Solar Irradiance Sensor (TSIS)*: will measure the variability in the sun's solar output.
- *Space Environment Sensor Suite (SESS)*: will collect data related to the space environment, including neutral and charged particles, electron and magnetic fields, and optical signatures of aurora.

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- *Search and Rescue Satellite Aided Tracking (SARSAT)*: will be used for receiving distress signals from emergency beacons and relaying the signal to rescue authorities on the ground.
- *Advanced Data Collection System (ADCS)*: will be used for relaying meteorological, oceanographic, and other data transmitted from *in-situ* ground based sensors.

Table 1 shows the planned instrumentation on NPP and the first three NPOESS satellites, designated C1-C3.

	NPP	C1	C2	C3
Launch	**Oct 2006**	**Dec 2009**	**Jul 2011**	**Jul 2013**
Nodal Time	2230	2130	1330	1730
VIIRS	X	X	X	X
CMIS		X	X	X
CrIS	X		X	X
ATMS	X		X	X
SESS			X	
OMPS	X		X	
ADCS			X	X
SARSAT		X	X	X
ERBS			X	
ALT				X
TSIS				X
APS		X		

Table 1. Planned Instrumentation, Launch Dates, and Equator Crossing Times for NPP and the First Three Operational NPOESS Satellites

3. DATA FLOW

Satellite data from NPOESS will be received by NPOESS ground stations. The Mission Management Center (MMC), also part of the NPOESS ground system, is responsible for the command and control of the NPOESS satellites and instrumentation. The MMC will provide satellite and instrument information, including concerning anomalies, to NDE upon request. The Integrated Data Processing Segment (IDPS) will process the raw satellite data into data records, which will be made available to the NDE system and for archive. The IDPS will send data records as they are created and will have short-term storage to allow for retransmission.

The NDE Project will provide data records and environmental products to archive facilities and a variety of users including government, universities, and the general public by methods such as secure servers and the Internet.

The NPOESS data flows relating to NDE are shown in the context diagram in Figure 1.

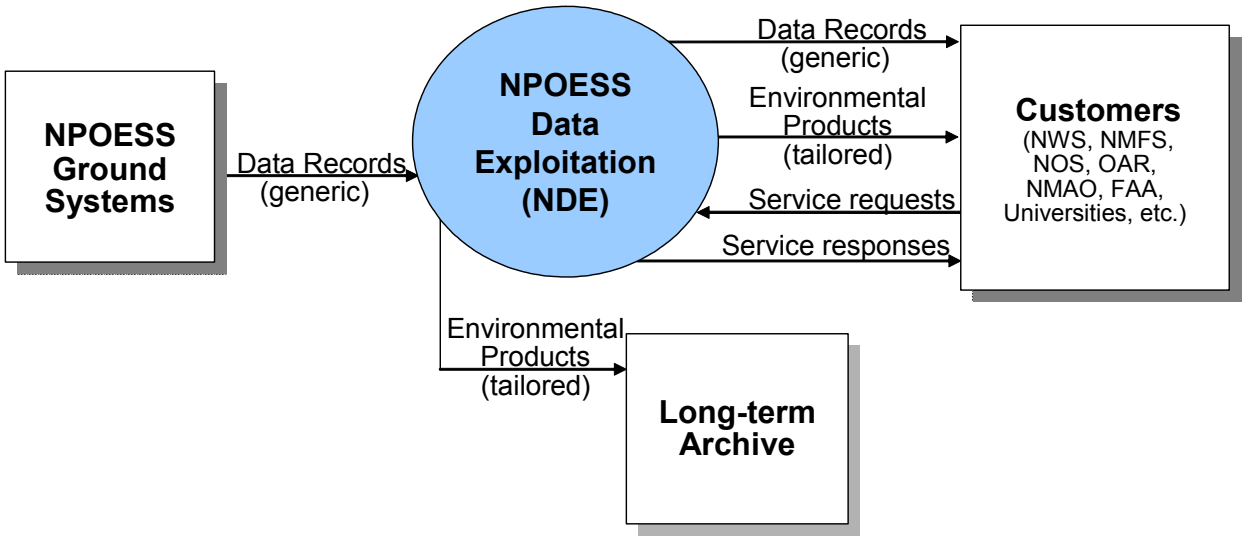

Figure 1. NDE Context Diagram.

4. DATA RECORDS

NESDIS will receive four types of data sets from the NPP and NPOESS IDPS:

- Raw Data Records (RDRs) will be full resolution, unprocessed sensor data that have been time referenced and earth located. Calibration coefficients will be appended to the data.
- Temperature Data Records (TDRs) will be full resolution sensor data that consist of geolocated antenna temperatures with all relevant calibration data counts and ephemeris data. They are created from the application of algorithms to microwave sensor RDRs.
- Sensor Data Records (SDRs) will be full resolution sensor data that have been time referenced and earth located. Calibration coefficients are applied to the data. SDRs also include calibration, ephemeris, and any ancillary data required to convert the sensor units back to raw data. They are created from the application of algorithms to non-microwave sensor RDRs.
- Environmental Data Records (EDRs) will be fully processed sensor data that contain atmospheric, land, oceanic, or solar geophysical environmental parameters or imagery and ancillary data.

Collectively, these are referred to as xDRs.

5. NDE OVERVIEW

The mission of the NDE Project is to process critical environmental products derived from NPP and NPOESS observations and distribute them to NOAA's operational and research community in near real-time. The NPOESS ground systems will package NPP and NPOESS data into intermediate product forms and deliver them to NOAA. NDE will begin at this point by altering the products to satisfy the unique requirements of many different user organizations and distributing the products and services to them in near real-time. NDE has several objectives:

- Continue to meet existing user requirements from NOAA's polar-orbiting mission products
- Provide continuity of service during the transition from the current POES program to NPOESS and avoid any degradation of service to the user community
- Maximize the risk reduction benefits made available by NPP
- Provide customers with near real-time products from NPOESS
- Provide new polar-orbiting products related to the new instruments aboard NPOESS
- Provide services to customers including: operational support regarding near-real time product deliveries, guidance regarding system

requirements for NPOESS product assimilation, and scientific advice about NPOESS product introductions
- Work with NOAA's Line Offices to coordinate integration of NPOESS products into their systems
- Provide for the long term archive of NDE products

To meet these objectives, the NDE Project will commence a number of activities. These include product tailoring and distribution, NOAA-unique product development, instrument characterization, designing architecture and infrastructure, developing new communication capabilities, providing for archive and access, establishing new customer services, and utilizing software engineering in product system development.

5.1 *Product Tailoring and Distribution*

Product Tailoring and Distribution (PTD) involves a number of different activities. NPOESS data will be made available to NOAA Line Offices and other civilian end users, both domestically and internationally, to ensure mission critical products from polar-orbiting satellite programs will continue without an interruption. The NOAA users include: NESDIS, National Weather Service (NWS), National Ocean Service (NOS), National Marine Fisheries Service (NMFS), Office of Oceanic and Atmospheric Research (OAR), and NOAA Marine and Aviation Operations (NMAO).

Details on the changes in data format and data content introduced by the NPP and NPOESS satellites, as well as the plans for data processing tools, are described below.

Data format: Data received from the NPP and NPOESS satellites will be in Hierarchical Data Format 5 (HDF5) format. This format, which supports increased storage requirements as well as improved throughput processing requirements, differs from the current formats provided by NESDIS, which include Binary Universal Form for the Representation of meteorological data (BUFR), gridded/mapped, etc. NESDIS will develop a tool set to process HDF5 data into other formats. NESDIS will use this tool set to repackage data for end users. NESDIS may also make this tool set available to end users so they can more easily ingest data into various applications.

Data content: Pre-defined NPP/NPOESS data sets will be delivered to NESDIS for use in its product processing systems. The data provided in these data sets will differ from data received from the current POES satellites in numerous ways. New instruments, more instrument data, and higher spectral and spatial resolution in the sensor data will impact the current NESDIS product suite as well as make new products available. Integrating these new data sets into existing POES products, producing higher level products as well as blended products (derived from both polar-orbiting and geostationary satellites) is critical to maintain product continuity. All of these product-related activities require new algorithms, new or enhanced processing software, and enhanced processing tools.

Data processing tools: A common set of data processing tools will be developed that can be shared by many internal applications. These enterprise-processing tools will include capabilities to combine orbital data sets to derive daily, weekly, monthly, etc. products and to combine various imagery channels to derive new imagery based products such as fog and stratus detection imagery.

Product development efforts will initially focus on the NPP instruments to take full advantage of their risk reduction benefits. The user community can realize the potential of the NPP sensor data prior to NPOESS and minimize the impact to their processing systems when the NPOESS satellite is declared operational. By satisfying a large portion of the NPOESS requirements with the NPP satellite, users will be able to assimilate the improved products into their systems soon after the launch of the first operational NPOESS.

The PTD system will retrieve, store, process, and distribute the xDRs from the IDPS. Products will be delivered to users in increments, synchronized with instrument payloads and the NPOESS launch schedule. Repackaging of the xDRs for format, coverage, frequency, projection, etc. will depend on user needs. Requirements for repackaged xDRs will be a priority and will initially focus on the Key Performance Parameters (KPPs). KPPs have been designated for the NPOESS Program as those products that are critical to the NPOESS mission. The NPP satellite will be capable of delivering several of these parameters, including atmospheric temperature and moisture soundings, sea surface temperature, and imagery.

Atmospheric Temperature and Humidity: Atmospheric moisture and temperature soundings, such as layer precipitable water, total precipitable water, layer temperatures, and level temperatures, will be provided to the NWS field units via the Advanced Weather Interactive Processing System (AWIPS).

Sea Surface Temperature: Sea surface temperature products beyond the EDR level will include daily, bi-weekly, and monthly analyses. The EDR products will also be reformatted for users, including NWS, NMFS, NOS, and the CoastWatch program which makes environmental satellite products available to marine scientists, coastal resource managers, and the public. Sea surface temperature products from NPP will be derived from the VIIRS instrument although these products will also be derived using the CMIS instrument on NPOESS.

Imagery: NESDIS will receive infrared, visible, and passive microwave specialized imagery in which environmental phenomena can be identified, including cloud types and elements as well as planetary scale weather patterns. This imagery will be used in support of many of the NESDIS product processing areas, such as hazard support (fires, volcanic ash, oil spills) and other product enhancements.

In addition to the KPPs, NESDIS will receive EDRs that will be repackaged based on user requirements. The EDRs fall into the categories of atmosphere, land, ocean, and space. User applications include tropical storm programs, climate applications, environmental monitoring, hydrology, local forecasts and warnings, marine transportation systems, ecosystem research, and space, marine, and aviation weather.

Atmosphere: NESDIS will receive atmospheric EDRs from the NPP and NPOESS satellites such as aerosols and suspended matter, cloud properties, atmospheric pressure profiles, and total ozone and ozone profiles. Atmospheric EDRs that are specific to the NPOESS satellites include precipitation type and rate, radiation budget, and precipitable water. Users for these products include NWS and OAR.

Land: Land EDRs from NPP and NPOESS include active fire detection, ice and land surface temperature, snow cover and depth, surface type and vegetation cover, and soil moisture. Users for these products include NWS, OAR, and NOS.

Ocean: Ocean color and sea ice characterization products will be made available to NESDIS from both the NPP and NPOESS satellites. The launch of NPOESS will introduce new instruments and a wider variety of ocean products that include sea surface winds, ocean wave characteristics, and sea surface height. NOAA line offices that have requirements for ocean products include NWS, NOS, NMFS, and NMAO.

Space: EDRs that describe the space environment will not be available until the NPOESS satellites when the first SESS and TSIS instruments are flown. Examples of space weather products include auroral imagery, plasma temperature and fluctuations, electric fields, and solar irradiance. These products may be repackaged by the NDE Project for NOAA's Space Environment Center.

In some cases, it may be necessary to deny NPOESS products and data when directed by the Department of Defense for matters of national security. During periods of data denial, NDE will limit the distribution of data only to authorized users that have maintained security agreements with NOAA.

The PTD team has developed a matrix to identify NOAA Line Office needs for xDRs produced by IDPS, along with an office priority and mission goal for each product. In addition, the matrix identifies products that will be developed by NOAA. Currently, 146 NPOESS products supporting over 600 NOAA mission needs have been identified. The team will also explore product requirements of non-NOAA users.

5.2 *Product Development and Validation*

NESDIS currently generates many products in support of its user community that will not be delivered under the NPOESS program efforts, but can be produced using NPOESS data. There are plans to produce NOAA-unique products for continuity of data. While requirements for NOAA-unique products have not yet been fully defined, initial efforts may include blended products from polar-orbiting and geostationary satellite data, hazard support for volcanic ash detection and tropical storms, and vegetation and ocean products.

Land Surface Data: The VIIRS instrument will provide the EDR for vegetation index by measuring biomass greenness in Normalized

Difference Vegetation Index (NDVI) units. NESDIS may create more specific vegetation products for users, including real-time green vegetation fraction, leaf area indices, drought indices, and vegetation health.

Snow cover products may also be generated by blending data from several of the NPOESS instruments and with other polar-orbiting and geostationary satellite data.

Ocean Products: Ocean product development efforts are expected to focus on two areas: sea surface temperature and ocean color. Sea surface temperature products beyond the EDR level may include products that are generated in support of coral reef bleaching events and sea surface temperature anomalies. A blended product using data from the VIIRS and geostationary satellite data may also be produced.

The ocean color EDR contains information on water leaving radiances and chlorophyll-α. NESDIS will generate additional ocean color products such as particulate organic carbon and will derive information on harmful algal blooms. These products will also be tailored for the CoastWatch program and for NMFS and NOS.

Hazards: NPP and NPOESS satellite data will be used in support of hazard monitoring. Fire and smoke plume detection and aerosols from volcanic eruptions will be derived from the VIIRS instrument. Tropical rainfall potential and other tropical cyclone parameters, such as tropical cyclone classification and positioning, may be generated. Many of these products will be generated using Geographic Information System (GIS) technologies.

Currently, more than 50 NOAA-unique products have been identified for those instruments aboard NPP. Additional NOAA-unique products will likely be necessary from the NPOESS satellites.

The NDE Product Development and Validation Team will develop the science, software systems, and hardware requirements for generating NOAA-unique products from xDR data. All NOAA-unique and tailored products will also be validated.

5.3 *Instrument Characterization*

The NDE Instrument Characterization team will provide oversight of and support for the NPOESS and NPP sensor characterization and calibration algorithm development, before and after launch. The team will also verify and monitor the accuracy and precision of the SDRs and TDRs delivered from the IDPS. Calibration accuracy determines the quality of most products. High calibration accuracy is required for numeric forecasts and climate studies. Calibration ensures that the SDRs are generated correctly and accurately represent the observed environment.

The Instrument Characterization team will also validate on-orbit sensor performance and calibration quality. Long-term support is needed to ensure calibration accuracy and to develop methods for comparisons of NPOESS data against *in situ* data and other satellites with similar sensors. An extension of the current Earth Observing System (EOS) will be to use the Marine Optical Buoy (MOBY) project to calibrate and validate ocean color data.

5.4 *Architecture and Infrastructure*

The introduction of NPP and NPOESS data into the operational environment will cause a need for changes to the NESDIS architecture and infrastructure. The evaluation, selection, and implementation of infrastructure elements such as computer hardware, communications equipment, and operating systems, as well as application development tools, techniques, and methodologies to be used are required in order for NDE to satisfy its operational performance requirements. The NDE system will be developed to ensure the integrity of the design and conformity to information technology best practices and to government standards. The NDE implementation plans will be reviewed in order to ensure that the NDE information technology architectures are appropriately integrated into the operational environment and that the plans are feasible.

As part of the NDE architecture there will be a development test bed that will permit development of common software, algorithms, and processes for all products, modification to include maintenance, technology refreshment, and upgrades, systems testing, and the transfer of product processing systems to operations without any risk to the operational system.

5.5 *Communications*

NPOESS will provide a 1200-fold increase in data volume over the current POES system. Although NPP will provide a subset of the NPOESS

instrument complement, NPP will still provide 1000 times the amount of satellite data received per day over current data volumes. This massive increase of data volume requires major upgrades to the existing communication infrastructure and development of compression techniques to reduce the volume of disseminated information. The NDE Project will ensure the delivery of tailored NPOESS products and NOAA-unique products to NOAA line offices and other users through the use of Internet and Dedicated Telecommunications Services.

5.6 *Archive and Access*

The Comprehensive Large Array-data Stewardship System (CLASS) is a NESDIS-managed project that captures and securely stores large volumes of environmental observation data and distributes data to users as requested. NDE will utilize CLASS for archive and access. Metadata, ancillary data, processes used to create products including system configurations, and NOAA-unique products will be archived for long-term storage in CLASS. In addition, CLASS will provide support for repackaged xDR utilities and data, implement data access controls, provide notification of anomalies in archive data to users, provide changes to archive products through version control, and provide catalog information for archived products. There are also plans to create and store browse image data files for online access to repackaged xDRs and NOAA-unique data sets.

Because of the increased data volume of NPP and NPOESS data, a more efficient archive and access capability will be required, including greater storage capacity, improved data management, and enhanced telecommunications to distribute the immense data volume to users on request.

5.7 *Customer Service*

NESDIS currently provides customer services on a 24-hour per day, 7-day per week basis. This will continue with NDE with additional plans for customer services. These include cooperating with NOAA users when planning for necessary system upgrades, providing help and training on NDE's data utilities, NOAA-unique products, and format tools, and developing procedures for customers to request services such as placing standing orders or requesting changes to products.

5.8 *Software Engineering*

Software engineering refers to the systematic design, implementation, operation, and maintenance of software. The NDE Project will utilize methods to ensure that the non-scientific components of the product processing software will be developed to reduce risks and maintenance costs. This will be accomplished in order to minimize redundancy of the non-scientific aspects and to manage, isolate, alter, and test the functions within the processing systems.

Prior to coding, diagrams and supporting text will be provided that describe an enterprise NESDIS product processing system which reuses the maximum number of system elements in the greatest possible number of product processing applications. In addition both polar-orbiting and geostationary product generation and distribution systems will be described within the diagrams and supporting text.

Development tools will be selected that are widely supported in the remote sensing software industry and are most likely to be known by future NESDIS support staff. The development tools will include programming languages, integrated Computer-Assisted Software Engineering (CASE) tools, object repositories, database management systems, etc. that will promote the ability to alter executable elements without altering source code.

6. SUMMARY

Historically, operational products have been made available to customers after an average of two to three years following satellite certification. NDE will use data from the NPP satellite to develop product prototypes and enable NESDIS customers to realize the benefits of NPOESS data shortly after the launch of the first operational satellite. The advanced NPOESS data is expected to improve a variety of user applications that ultimately improve science research, the understanding of the Earth's environment, ship and air navigation, environmental policy formulation, and weather forecasts and warnings disseminated to the general public.

The NDE Project will be working with many users to maintain product continuity for atmospheric, oceanic, and land-based products. A systems requirements review was held in June 2004 to ensure that user needs are being addressed in the

areas of product tailoring and distribution, product development and validation, instrument characterization, architecture and infrastructure, communications, archive and access, and customer service. The NDE Project is now in a conceptual design phase and will continue to work with users to determine specific product processing needs.

7. REFERENCES

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