

Evolving Ground System Architecture Requirements for the National Polar-orbiting Environmental Operational Satellite System (NPOESS)

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Abstract—The Integrated Program Office (IPO) is developing a ground system architecture for the National Polar-orbiting Environmental Satellite System (NPOESS) because requirements cannot be accommodated by current technology. Increased data rates, increased processing complexity, and more stringent latency requires another approach. In this paper, we discuss the rationale behind the challenging requirements, in which direction the requirements are evolving, and how the NPOESS ground system architecture might be related to the NASA Vision of a Web of Sensors.

I. INTRODUCTION

NPOESS merges U.S. polar-orbiting satellite programs previously operated by the Air Force and the National Oceanic and Atmospheric Administration (NOAA). Established by Presidential Directive, NPOESS is a tri-agency program with NOAA, DoD, and NASA contributions. NPOESS will work in partnership with space agencies in Europe (EUMETSAT) and Japan (NASDA) and will leverage appropriate technologies from NASA programs to provide continuous global coverage of the Earth.

The IPO is initiating a program of convergence projects (sensors, concept demonstrations, and with NASA, the NPOESS Preparatory Project). In the future, NPOESS will carry out a broad program of satellite transition and sensor development. By converging U.S. satellite systems and partnering with EUMETSAT, NPOESS will reduce the number of polar-orbiting systems from four U.S. satellite groups to three (two U.S. and one European). The programmatic savings and benefits are manifold. NPOESS requirements include Environmental Data Records (each with multiple performance levels and attributes), Launch Services, Command, Control, and Communications (C³), Interface Data Processing, and Field Terminals. The focus of this paper is the Interface Data Processing Segment (IDPS).

The IDPS is a state-of-the-art, integrated, automated information system for NPOESS end users, scientists, and operational administrative personnel, providing for near real time information products, exchange, advanced processing, analysis, short term storage and retrieval. IDPS requirements are documented in the Integrated Operational Requirements Document (IORD) II dated December 10, 2001.

The IDP Segment shall have the ability to receive raw mission data from the C³ or Space Segments (as appropriate for Centrals or field terminals), process the RDRs into EDRs, and temporarily store Raw Data Records (RDRs), Sensor Data Records, (SDRs), Environmental Data Records (EDRs), and surface data collection/location data in a database management system. The design of the IDP Segment will not preclude, but will minimize the use of other external data sources in generating EDRs. The IDP Segment shall have sufficient temporary storage capacity to store the RDRs/SDRs/EDRs and ancillary data until the data can be delivered to the IDP Segment/Central interface for use in the Central's application (24 hour minimum). Therefore, the IDP Segment needs to have the capacity to store multiple passes. At final design, the IDP Segment shall be designed to permit 100% growth of the projected Full Operational Capability (FOC) storage and processing capacity.

The IDPS has evolved from the current distributed information system composed of several Centrals, to address the need to accommodate telemetry data rates that are an order of magnitude higher than today's Polar-orbiting Operational Environmental System (POES) and Defense Meteorological Satellite Program (DMSP), plus stringent latency demands, and increased processing complexity. A Summary of Key Requirements is presented in Table 1 below.

TABLE 1
SUMMARY OF KEY REQUIREMENTS

Driving Factor	Key Requirements	Comments
Telemetry Rates	20 Mbps	700 kbps for current polar-orbiting systems
Latency	90 min. threshold, 15 min. objective (for most products)	Quality of forecasts improved
Processing Complexity	Fourier Transforms	FTS Spectrometers on LEO and GEO
User Base	Weather and Military have urgent needs	International base increasing
Onboard Data Processing	Increasing	Will require ability to accurately recreate Raw Data Records

II. IDPS Requirements Evolution

The IDPS design is influenced by two driving requirements. The first is the significant increase in data volume resulting from increased spectral and spatial resolution for the new generation sensors. As an example, the current AVHRR has 6 channels, of which only 5 are broadcast at a given time, compared to the VIIRS instrument which will have 22. The best spatial resolution for the AVHRR is 1.1 km (nadir), where VIIRS will have different resolutions for its channels as low as 0.25 km resolution at nadir.

The second driving factor is improved data latency requirements. Current operational (soundings) products have a latency requirement of 3 hours from observation. User requirements for data latency for most NPOESS environmental data records have dropped to 90 minutes or less (preferably 15 minutes).

Future NPOESS data rate requirements will be affected by Pre-Planned Product Improvement (P³I) initiatives. An order of magnitude increase in data rates and processing could face the IDPS when the currently unaccommodated EDRs are made possible by technological advancements. These advancements include active sensors such as synthetic aperture radar, multi-spectral Vis/IR, and scatterometers. These sensors will be added to NPOESS when they are able to cost-effectively meet mass, volume, and power constraints on the NPOESS spacecraft. Environmental Data Records of interest to weather, national security, and science include Sea and Lake Ice Concentration, Age, Motion, Edge Location, Coastal Sea Winds (Speed and Direction) and Wind Stress, coastal imagery, Ocean Wave Characteristics - Ocean Wave Direction and Wavelength, surf conditions, Location of Surf Zone, Breaking wave height, surf zone currents and bathymetry, Bathymetry (Deep Ocean and Near Shore) "outside of surf zone," and salinity. Adding tropospheric wind profiles will require active lidar. Continued improvements to spatial resolution for imagery is expected owing to greater demand by users once this technology is in place.

In addition to P³I, the NPOESS will have increased data rates as a result of performance improvements to current EDRs. One such EDR is soil moisture where the minimum requirement (threshold) is surface wetness. The threshold for soil moisture is surface wetness (skin layer at -0.1cm) whereas the objective is a profile from the surface to -80cm. Such soil moisture measurements are needed to derive trafficability information useful for the deployment of amphibious and ground forces as well as for surface hydrology. Measurements include moisture in the soil within the zone of aeration, including water vapor present in soil pores. With current technology (CMIS and VIIRS) the

NPOESS can provide the threshold for soil moisture, but would prefer a profile. For that, new technology is required. NASA and NOAA scientists need soil moisture measurements for hydrology, climate change, and ecology.

A new technology, aperture synthesis, will make possible passive microwave remote sensing from space at the low frequencies (e.g. L-band) needed to measure soil moisture and sea surface salinity.

Aperture synthesis is an interferometric technique which has the potential to improve the resolution of future passive microwave instruments in space. This technology will add significantly to the data rate burden for the IDPS.

Other increases to data rates could be occasioned by improvements to current onboard sensors, such as focal plane arrays. Upgrading a 3x3 array to a 6x6 array would increase data rate by 400% for that device. Processor complexity would also be increased by a substantial amount. Also, changes in sampling schemes could increase data rates. Other improvements or changes to current NPOESS sensors also could increase the workload for ground processing.

III. SCIENCE DATA REQUIREMENTS (SDS)

The Earth Science Community, to the maximum extent practical, will be relying on the products generated by the IDPS. Climate users need multi-date products that are averaged over time or composites from cloud-free images, provided weekly, monthly and annually. Climate users want spatial resolution that includes: physics at the pixel level, data products at fine resolution for process and regional studies, and multi-date products at reduced resolution for modeling studies, as well as for trending. Such users require a high percentage of completeness (99%) for their data. Timeliness is not critical for Climatologists. NPP climate data products are called "Climate Data Records" (CDR) in comparison to the operational NPOESS "Environmental Data Records" (EDR).

The Science Data Segment (SDS), being built by NASA, complements the IDPS. The SDS will provide a means for the Earth Science Community to influence the products generated by the operational IDPS and to provide the unique processing capabilities required for climate research including multi-day composite products, multi-sensor products, long-time series and global (retrospective) calibration parameters, and products incorporating these parameters.

The SDS will be utilized during the NPP mission to demonstrate improvements to algorithms, refinements to calibration parameters for incorporation into the products, and new processing techniques. To support this, the SDS will provide the capabilities to generate refined, retrospective calibration parameters, Level 1 processing to incorporate these parameters, and generation of select higher level data

products. Determination of which higher level products will be produced will be accomplished via a NASA Research Announcement (NRA). As appropriate these capabilities will be transitioned to the IDPS during the course of the NPP mission. In addition, the SDS will provide the capabilities to produce higher level products required by the Earth Science Community that go beyond those provided by the IDPS and for which there is no operational interest. These products will also be determined through that aforementioned NRA.

The IDPS products along with the products produced by the SDS will ensure that NPP fully supports the generation of consistent long-term, multi-mission measurement sets.

IV. Common Philosophies of IDPS and Earth Science

The philosophy of the Earth Science Vision is to provide a single, logically integrated database to support any number of distributed applications in order to provide sound, timely, and consistent data for easy access worldwide. A desired objective for the Earth Science Vision is to establish the architecture and infrastructure that will provide many users and many applications, distributed around the world, with information on what data are located where, as well as when the data would be needed. Such an architecture will provide services in an efficient and effective manner that allows for incremental evolution to whatever future requirements may unfold as the system matures, as new technology provides new capabilities at lower costs, and as resources in time, people, and budgets permits.

V. Earth Science Web of Sensors

The IDPS is a precursor to the Earth Science Vision. That is, as applied to the Earth Science Vision, the IDPS will provide a timely and consistent view of near real time data acquisition, processing, and distribution, and a model or approach to hardware and software developers and utilization planners. The Earth Science Vision must successfully converge a variety of technologies into an integrated system of workstations and host computers, software systems, network communication systems, and analysis tools. A monumental variety of data from NPOESS, other Low Earth Orbiting (LEO) Systems, Geostationary Earth Orbit (GEO), land based radar, in situ data collection, field campaigns, and airborne systems are major integrating factors for the architecture of an Earth Science Vision. The IDPS will provide the rules and tools to effectively acquire and process in a timely manner 20 MBPS of data containing raw data records, sensor data records, and supporting 55 environmental data records for real time users for weather, national security, and science. The data rate is likely to increase as EDRs are added. Specific goals of the Earth Science Vision information system and IDPS are:

- Provide automated rules and tools to facilitate management of data acquisition, delivery, and management

- Minimize life-cycle costs
- Enhance user access and productivity
- Provide a common, user-friendly interface to measurements and services
- Maximize use of sound information system engineering processes

VI. CONCLUSIONS

The IDPS could very well be a part of, as well as precursor to, the Earth Science Vision of a world wide information network. This vision is based on shared experience dealing with widely distributed, large-scale data systems relating to demands for near real time access and data volumes of huge proportions and complexity. The Earth Science Vision is complex in many ways. It is complex in terms of the number of public and private sector organizations involved. It is complex in terms of its distributed, international character; the diversity of computer facilities, networks, and software participants are currently using across the world; and it is complex in terms of the planned multi-decade life span and broad spectrum of planned uses of measurements for numerical weather prediction, earth science, climatology, and technology.

A mature information systems architecture will feature a "single-stop-shopping" approach to data access, via a dynamic and responsible single, logically integrated database, supported by an efficient and effective information system infrastructure, a Data Records Dictionary to locate and manage the information assets of the global weather and climate measurement system, and a measurement data flow template to determine where and when data are needed

Partnerships between NASA and interagency, international, commercial and academic organizations will be essential to achieving this vision. The economic benefits will be shared across the globe.

VII. References

Integrated Operational Requirements Document (IORD) II, December 10, 2001, National Polar-orbiting Operational Environmental Satellite System (NPOESS).