INTRODUCTION

The past few decades have seen a tremendous growth in the use of weather satellites for both civilian and military applications. The maturation of visible-infrared imagery from geosynchronous and polar orbits have become familiar to vast television audiences and military planners as well as a wide array of geophysical, oceanographic, and atmospheric scientists.

After the early TIROS (Television and Infrared Observation Satellite) civilian weather satellites in the 1960s, the military developed and operated their own distinct military operational satellites starting in 1965 under the Defense Meteorological Satellite Program (DMSP) for exclusive use by the DoD. The NOAA civilian polar orbiting satellites also evolved over time to become the POES (Polar-orbiting Operational Environmental Satellite) program. During the Cold War, a dual system was required out of military necessity and differences between military and civilian user community needs.

During the last decade, the two systems, POES and DMSP, have evolved to use a somewhat similar spacecraft bus, but have different instrument suites. Many government studies had been conducted to assess the value of converging the two systems into a single system, but were unsuccessful in achieving convergence. A 1993 tri-agency study by DoD, NOAA, and NASA recommended that a single converged system should replace the current separate systems. With the end of the Cold War and Congressional interest in saving money, the converged system was included as an initiative in the Vice President's National Performance Review. A Presidential Decision Directive, signed in May of 1994, directed the convergence of the polar orbiting weather satellites systems into a single national system to serve both civil and national security needs. The Integrated Program Office (IPO) within NOAA was established in October 1994 as a result of the signing of a tri-agency Memorandum of Agreement (MOA) in May 1994. The new converged system was identified as NPOESS. The IPO is staffed with representatives of NOAA, Department of Defense and NASA.

NPOESS ATTRIBUTES

Mission

The IPO is responsible for the development, acquisition, management, and operation of the NPOESS with a first launch as early as 2007. The NPOESS will remain operational for at least ten years and provide global data for meteorological, oceanographic, environmental, climatic, and solar-geophysical users by disseminating the data to worldwide users. These data will be delivered in the form of Environmental Data Records (EDRs) in compliance with the Integrated Operational Requirements Document (IORD) [1] which incorporates the NOAA and DoD operational mission requirements.

The NPOESS has four major segments: space, launch support, C3 and interface data processor (IDP).

The space segment is comprised of three spacecraft each with a complement of various sensors designed to provide the data to satisfy the data product requirements and refresh as directed by the IORD for both the civilian and military user community. Two will be U.S. spacecraft while the third is planned to be provided by the EUMETSAT METOP.
Development Approach for NPOESS

The NPOESS acquisition approach is phased to allow a logical progression of development milestones to complete and field each segment of the NPOESS. During the first phase for the space segment, sensor development will lower technology risks early in the program. Modifications to the current POES and DMSP spacecraft will then provide potential improved performance while NPOESS design and engineering work continues. During this same period, NPOESS spacecraft accommodation issues will also be addressed and resolved as sensor designs mature. It is planned that a Total System Performance Responsibility (TSPR) contractor will then perform the spacecraft design, fabrication, and integration with the sensors as developed earlier. By the use of open architecture interfaces between the spacecraft and sensors [2], it will be possible to avail NPOESS of rapidly evolving technologies being developed by such programs as NASA’s EOS, ESSP, and New Millennium and DoD programs. The intent of this open architecture interface is to facilitate system integration and use of the best commercially available products and to discourage proprietary or “closed” architectures which lead to unique system interfaces and increased costs and schedule risks.

SENSOR DEVELOPMENT

The Requests for Proposal (RFP) were released in April 1997 for the NPOESS sensor development effort. The IPO awarded nine sensor development efforts in July 1997. Because of the technical complexity and risk involved with these five particular payload suites below, two competitive contracts per sensor (one for GPSOS) were awarded to begin sensor development and risk mitigation.

VIIRS - Visible/Infrared Imager / Radiometer Suite
CMIS - Conical Microwave Imager/Sounder
CrIS - Cross-track Infrared Sounder
OMPS - Ozone Mapper/Profiler Suite
GPSOS - Global Positioning System Occultation Sensor

These sensors and six others are required by the IPO to meet both the EDR threshold values, as a minimum, published in the IORD which was written and approved by the user communities and particular requirements stated in the Sensor Requirements Document (SRD) [3]. This will require each sensor contractor to develop not only the sensor design but the algorithms necessary to deliver the EDRs assigned to that sensor.

The competitive contracts will continue to the preliminary design review (PDR) at which point a Call for Improvement (CFI) will be issued and a single contractor per sensor will be selected to continue to develop both sensor and algorithms, fabricate flight hardware, and provide support for integration, deployment, and operations.

The Visible/ Infrared Imager /Radiometer Suite

The two winning contractors for VIIRS announced in July 1997 were ITT Defense & Electronics, Ft. Wayne, IN and Santa Barbara Remote Sensing, Santa Barbara, CA. Each contractor will be involved in performing a requirements flowdown in the design of their sensor, identifying technical risk and risk mitigation approaches, developing the best approach to satisfy the EDRs with a cost effective, low risk sensor design and algorithm basis, and, finally, producing a preliminary design for the VIIRS and its associated retrieval algorithms. Because of the competitive nature of the VIIRS contracts, no specific details of either contractor’s approach will be discussed.

VIIRS is to be the next generation operational visible and infrared radiometric instrument. There has been a long history of visible and infrared imager designs for both the civilian and military. The USAF OLS (Operational Line Scanner) has been the primary sensor on DMSP ever since Block 5D-1 in 1976. [4] The OLS has the primary mission of day and night cloud cover imagery. It is a cross-track scanning instrument operating in the visible (0.4 to 1.1 microns) and infrared (10.5 to 12.6 microns). A high resolution photomultiplier tube provides the nighttime visible imagery.

The current POES imager, AVHRR (Advanced Very High Resolution Radiometer), first flew on TIROS-N in 1978 [4]. The AVHRR has the mission of measuring cloud coverage, sea surface temperature, vegetation, and aerosols. The AVHRR is also a cross-track scanning sensor currently operating in the spectral ranges of 580 - 680 nm, 725 -1100 nm, 3550 - 3930 nm, 10.3 - 11.3 microns, and 11.4 - 12.4 microns. The radiometric resolution of the AVHRR is 11 bit with a spatial resolution of 1.1 km at nadir. NASA has been developing the scientific MODIS (Moderate Resolution Imaging Spectroradiometer) instrument for the EOS program. It has 36 spectral bands with 21 from 0.4 to 3.0 microns and 15 bands from 3 to 14.5 microns. Its spatial resolution will be as small as 250 meters at nadir in some bands. MODIS will have a ± 5% absolute radiometric accuracy in the visible and near infrared with 1% in the thermal bands. MODIS is now scheduled to fly on EOS AM 1 in September of 1998. MODIS will provide long term data for the climate and oceanographic communities. Given the operational heritage and the developing scientific instruments, like MODIS, VIIRS has a very firm basis on which to proceed in satisfying the IORD. Table 1 lists the twenty six VIIRS EDRs as assigned by the SRD. Most of the EDRs listed in Table 1 are already being retrieved.
TABLE 1. VIIRS EDRs

<table>
<thead>
<tr>
<th>Imagery</th>
<th>Sea Surface Temperature</th>
<th>Soil Moisture</th>
<th>Aerosol Optical Thickness</th>
<th>Aerosol Particle Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albedo (Surface)</td>
<td>Cloud Cover/Layers</td>
<td>Cloud Effective Particle Size</td>
<td>Cloud Optical Thickness</td>
<td>Cloud Top Height (Derived)</td>
</tr>
<tr>
<td>Cloud Top Pressure (Derived)</td>
<td>Cloud Top Temperature</td>
<td>Ocean Currents</td>
<td>Fresh Water Ice</td>
<td>Ice Surface Temperature</td>
</tr>
<tr>
<td>Land Surface Temperature</td>
<td>Littoral Sediment Transport</td>
<td>Net Heat Flux</td>
<td>NDVI</td>
<td>Ocean Color/Chlorophyll</td>
</tr>
<tr>
<td>Sea Ice Age / Edge Motion</td>
<td>Snow Cover/Depth</td>
<td>Suspended Matter</td>
<td>Mass Loading</td>
<td>Vegetation /Surface Type</td>
</tr>
<tr>
<td>Cloud Base Height (Derived)</td>
<td></td>
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**System Design Trade Considerations**

The following design considerations do not necessarily reflect the IPO's position regarding the VIIRS final design. They are offered as examples of the complexity of the VIIRS. Due to the large number of VIIRS EDRs and their attributes, as stated in the IORD, a critical factor facing designers is to determine a nominal set of visible and infrared bands to provide data to meet the threshold values of the EDRs. As the number of bands increases, the data rate of the VIIRS instrument must be maintained to prevent an increase in power, volume, and weight due to increased on-board data storage for down linking to ground stations.

The overall system architecture of the VIIRS sensor suite is also a critical issue. Should the bands selected be implemented in a single or multiple instrument configuration? Optical design which would allow for requirements growth and also accommodate new technology is another sensor trade. Stray light issues as well as polarization sensitivity for ocean color and optical cross talk represent daunting challenges for the designer. Each of these approaches offer advantages and disadvantages. Calibration on board is another design feature which, while assuring accuracy for EDR products, will impact overall sensor weight, power, and volume requirements. Several approaches have been proposed, but no approach will be acceptable which might impact the operation of other NPOESS instruments on board the spacecraft. The VIIRS contractor is required to evaluate these architectures, develop the required algorithms, and validate that their design is a cost effective design utilizing the best set of algorithms that ultimately produce the EDR product in a timely manner.

These sensor design trades are bounded by another critical factor: spacecraft accommodation. The SRD currently allows VIIRS a mass of 132 kg, a power consumption of 215 watts, a volume of (1.29 m (velocity direction) x .65 m (nadir direction) x 1.38 m (anti-solar direction), and a data rate of 3.4 megabits per second (compressed data).

**VIIRS Technical Evaluation**

The government must also be prepared to eventually evaluate the VIIRS design at PDR along with the supporting algorithms. For that reason, the IPO is in the process of developing a Weather Products Test Bed (WPTB) to aid in the evaluation of VIIRS design at PDR and CDR. It is expected that this approach will produce the “best value” for the government when combined with Life Cycle Cost (LCC) data.

**REFERENCES**