10.1 THE FUTURE OF NOAA's OFFICE OF SATELLITE OPERATIONS

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ABSTRACT

The National Environmental Satellite, Data, and Information Service (NESDIS), part of the National Oceanic and Atmospheric Administration (NOAA), is responsible for the establishment and administration of funding for civil operational environmental satellite systems. As part of its planning to transition to a fully integrated international satellite system, NOAA entered into an agreement with the European Organization for the Exploitation of Meteorological Studies (EUMETSAT) for participation in Initial Joint Polar System (IJPS). In the IJPS Agreement, NOAA and EUMETSAT agree to operate their polar-orbiting satellites in a manner beneficial to both parties, as well as the world's meteorological community. The IJPS system allows NOAA to process and distribute the EUMETSAT satellite information as the NOAA morning operational satellite.

1. INTRODUCTION

NESDIS operates and maintains the Polar-orbiting Operational Environmental Satellite (POES) system as part of the basic architecture for collecting satellite data in support of NOAA's current national and international commitments for providing global environmental data. NESDIS manages and operates the POES system through its operational ground segment while acquiring replacement satellites, launch vehicles, and launch services through interagency agreements with the National Aeronautics and Space Administration (NASA). The POES Ground Segment receives environmental data from satellite instruments, processes and displays satellite health and safety information, generates schedules and commands for control of satellite subsystems, processes information from satellite instruments, generates environmental products, and distributes selected products to users. Since 1978, the POES system has operated with a two-satellite constellation in circular, near-polar, sun-synchronous orbits.

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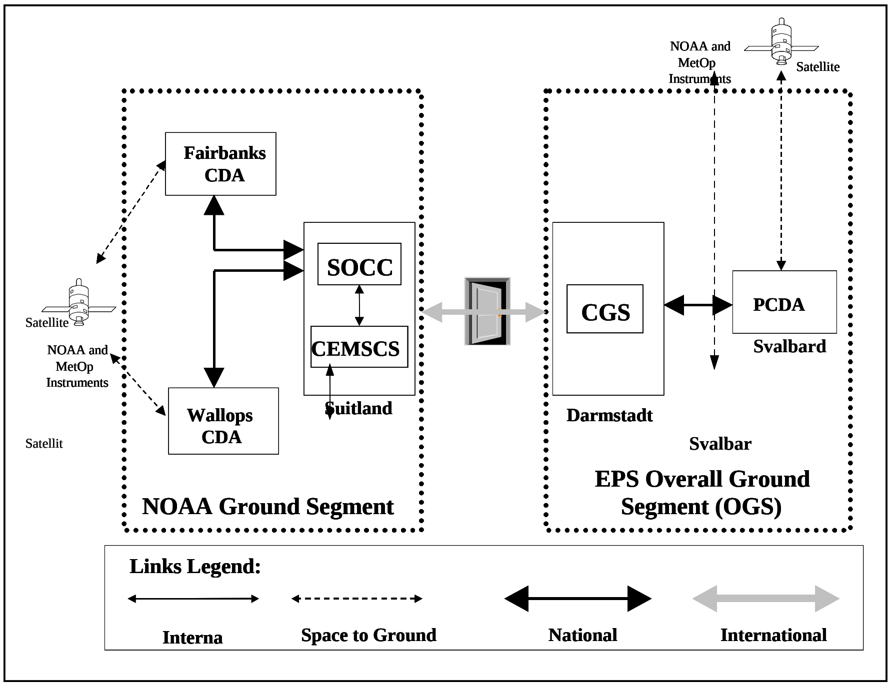
The current system is operating with NOAA-16, an advanced Television Infra-Red Observation Satellite (TIROS)-N satellite launched on September 21, 2000, in the primary afternoon orbit. NOAA-17, a satellite launched on June 24, 2002, is operating in the morning. The remaining fifth-generation satellites that are currently being acquired by NOAA for the POES system are designated as NOAA-N, and -N'. NOAA-N and -N' continue to use the same spacecraft baseline, upgraded with spacecraft solid-state recorders and environmental instruments. To extend the availability of the fifth-generation POES satellites, NOAA has entered into the IJPS Agreement with EUMETSAT to jointly share operational satellite responsibilities and the environmental data collected by the system. The IJPS has two independent but fully coordinated polar-orbiting satellite systems. Each independent system consists of two satellites flown consecutively under the control of its respective ground segment. In support of the IJPS Agreement, NOAA-N and -N' will be flown consecutively in a polar orbit with an afternoon equatorial crossing time. EUMETSAT, working together with the European Space Agency (ESA), will develop a Metop series of satellites to be flown in a polar orbit with a mid-morning equatorial crossing time. The Metop satellites constitute the space segment of the EUMETSAT Polar System (EPS).

2. POES SYSTEM DESCRIPTION

The ground segment for the POES System, illustrated in Figure 1, has five components: the Satellite Operations Control Center (SOCC), located at Suitland, Maryland; two Command and Data



Acquisition (CDA) Stations at Wallops Island, Virginia, and Fairbanks, Alaska; and NOAA internal and external interfaces for both command control and payload distribution. The figure also represents the international communications link used to connect these components to the Core Ground Segment (CGS) and the Polar CDA.

3. SOCC

Figure 2 – New SOCC Building 2005, Suitland MD

The SOCC (Satellite Operations Control Center) is ultimately responsible for health and safety of the satellites. SOCC functionally provides mission planning/scheduling, real-time operations, satellite engineering, and ground-segment management. SOCC equipment includes the following major components:

(1) Communication interfaces that interconnect the CDA stations and the internal and external interfaces

(2) Data handling equipment

(3) Communications control computers

(4) Telemetry and command computers

(5) Polar Imagery Display Engineering System (PIDES)

(6) Test and Training System (TTS)

(7) Computer-controlled switches for equipment configuration and status

(8) Workstations

(9) Local area networks (LAN)

(10) Wide area network interfaces for interconnecting with the CDA stations

(11) Global Positioning System (GPS) receivers and NASA Time-Code Generators

(12) Uninterruptible power supply

The SOCC additional responsibilities for the European Metop satellites are identical to the responsibilities it has for current POES satellites. Additional SOCC capabilities are required to support Metop satellites and to use European Polar System (EPS) resources for POES satellites. POES satellite contacts through the European CDAs will be similar to POES operations today. Telemetry and mission data downlinked during European passes will be delivered to the Darmstadt Germany interface and transported by the NOAA Trans Atlantic link to Suitland. The SOCC can command through the Darmstadt interface to the European CDA during such satellite contacts.

Command loads are usually generated by the SOCC well in advance of a commanding session. During the satellite contact the CDAs do the final command processing and transmit commands to the POES satellite. Real-time commands can be generated either at the SOCC or at the CDAs.

The European Core Ground Segment will command the Metop satellite using the Suitland Interface and the Fairbanks CDA. The Fairbanks CDA will have the capability to create the NRZ-L-PSK command bit stream for uplink to the Metop satellite. The Fairbanks CDA will also acknowledge receipt of Metop commands and return the acknowledgment to the Suitland Interface in real time.

4. CDA Stations

The CDA Stations (CDAS) implement spacecraft commands and schedules that are normally generated and executed at the SOCC; acquire, archive, and distribute a continuous flow of POES satellite data; and manage, operate, and maintain their facilities. Each CDA has the following major equipment components:

(1) Antennae and antenna controllers including the NOAA Polar Antenna System (NPAS)

(2) Radio frequency (RF) equipment

(3) Signal distribution equipment

(4) Data-handling equipment (command generators, command encryptors, frame and bit synchronizers)

(5) Communications control computers

(6) Telemetry and command computers

(7) Computer-controlled switches for equipment configuration and status

(8) Workstations

(9) Local area network

(10) Wide area network interfaces for interconnecting with the SOCC

(11) A time-and-frequency system

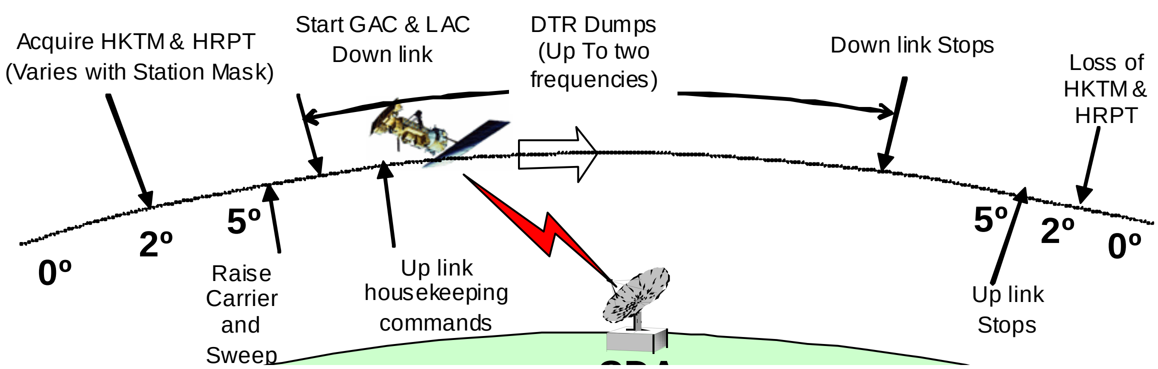
(12) Uninterruptible power supply

(13) Data storage equipment, including redundant multiplexing systems with Redundant Array Inexpensive Disk (RAID) array storage and digital tape drives for the long-term storage of data

(14) Backup power generators that are automatically enabled and switched during a power failure

Fairbanks CDA Station (FCDAS) has six antennae normally used for POES: three 13-meter antennae, two VHF uplink antennae, and one Very High Frequency (VHF) downlink antenna slaved to a 13-meter antenna.

Figure 3 Typical POES Pass Activities



The 13-meter antennae have S- and L-band uplink and X-, S- and L-band downlink capability with autotrack at S- and L- band frequencies. X-band down conversion to S-band and corresponding tracking receivers is in place. The 13-meter antennae at Wallops CDA Station (WCDAS) and FCDAS can be remotely controlled from SOCC.

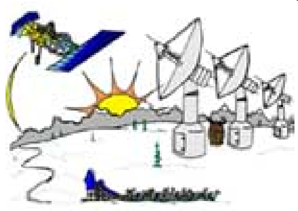
Each CDAS can provide a short-term backup to the SOCC for telemetry, command, and payload data management operations. With some limitations, the WCDAS can serve as a backup for extended outages at SOCC. The POES backup functionality includes spacecraft health and safety and limited payload data management capabilities. All scheduling, control, navigation, and sustaining engineering can be provided by the WCDAS. The WCDAS would rely on the User Ephemeris File (UEF) from the Central Environmental Satellite Computer System (CEMSCS). As a backup SOCC, CEMSCS can generate the UEF using the Generic Space software. The SOCC distributes wideband (payload) data to CEMSCS and the NESDIS product processing facility located organizationally in the NESDIS Office of Satellite Data Processing and Distribution (OSDPD) in Suitland, Maryland.

Even though the NOAA CDAs will not be providing nominal acquisition support to Metop, the CDAs will continue to be staffed to support telemetry, command, and antenna control functions as if it were a POES pass to ensure Metop HRPT (MHRPT) acquisition. The MHRPT will be broadcast from the satellite with the NOAA instrument data in the clear and the EUMETSAT instrument data encrypted. The NOAA instrument data can also be encrypted. The MHRPT data will be filtered at the CDAs and broadcast over the existing 1.33 Mbps DOMSAT link to Suitland for processing by CEMSCS. The NOAA CDAs will acquire no GDS or telemetry data during nominal Metop passes.

During nominal POES satellite passes, CDAs activities will continue as today. During IJPS, the NOAA-N and N' satellites will continue to provide the same data downlinks provided by the current POES satellites: GAC (or Stored Advanced Microwave Sounding Unit Information Processor [SAIP] or Stored TIROS Information Processor [STIP]), LAC, and HRPT (or Advanced Microwave Sounding Unit Information Processor [AIP] or TIROS Information Processor [TIP]). Currently, for approximately two orbits a day, data from the current satellites cannot be acquired due to the lack of antenna coverage from FCDAS and WCDAS. The GAC data from these blind-orbits are stored on the satellite for later downlink. In the IJPS period, the EUMETSAT CDAS in Svalbard (a Norwegian Territory 78 00 N, 20 00 E) or SVL will acquire the GAC data from these blind orbits and provide this data to NOAA. Under Metop contingency operations, the Fairbanks CDA will provide GDS, and TM data acquisition and bent-pipe commanding from Darmstadt. The CDAs will not be required to oversee Metop health and safety or satellite control. TM data will be provided real-time to on a backup T1 link Darmstadt. Commands will be received from Darmstadt via Telecommand (TC). Both Fairbanks and Wallops CDAs have the capability to serve as operational backup facilities to the SOCC for satellite command and control functions. Only Wallops will have a command capability through Darmstadt to POES satellites. This makes Wallops a backup SOCC to IJPS.

4. FCDAS OPEATIONS

In IJPS, all POES FCDAS passes will continue to operate as before. During a scheduled Metop FCDAS pass, the satellite will downlink a 70 Mbps GDS at X-Band and 4.096 kbps telemetry bit stream at S-Band. For commanding support the FCDAS will uplink to Metop a command bit stream at 2 kbps in S-band. The commands will be sent in throughput mode as received from the CE. Blind-orbit GDS will be ingested at FCDAS at least twice a year and as required for contingency operations. New FCDAS capabilities include the following:



(1) Autotracking of X-band signals during Metop passes

(2) Demodulation of the GDS datastream

(3) Bit synchronization of the GDS datastream

(4) Frame synchronization of the GDS datastream

(5) RF modulation for the Metop command uplink

(6) Demodulation of the Metop telemetry (TM) stream

(7) Bit Synchronization of the Metop TM stream

(8) Frame Synchronization of the Metop TM stream

Satellite data from the EPS satellite (Metop) will be processed by the POES system and distributed to users in lieu of the data from a POES morning satellite. With the CSU the POES system will also process and distribute the environmental data received from the additional instruments onboard the EPS and POES satellites. The priority of the data received at the Fairbanks ground station from the METOP and POES (MHRPT or HRPT) data will be identical. If there is a conflict between POES and METOP resources at Fairbanks, SOCC scheduling will have an established precedence of resource allocation coordinated with the OSD program office. Likewise, POES and METOP satellites at Svalbard will have an identical priority and established precedence.

4. WCDAS OPEATIONS

In IJPS, the WCDAS will serve as the Backup SOCC. Full TM/TC interface connectivity between Wallops Communication Controllers and Suitland Interface will be in place. This will allow Wallops to perform POES contact using EPS CDA during extended SOCC outage. GAC/STIP/SAIP transfers to EPS CGS will not be supported when Wallops is operating as primary SOCC. GAC/STIP/SAIP telemetry can be played back from Wallops to SOCC once SOCC has returned to operational status. HRPT will not be supported due to CE bandwidth limitations. MHS telemetry requests will not be supported when Wallops is operating as primary SOCC. Current design only supports MHS telemetry extraction and transfer from the SOCC. Wallops CDA currently do not have archive system or a SRAS system. As such, the WCDAS capabilities will include the following:

(1) Coordination with CGS for IJPS POES cross-support

(2) POES commanding through Darmstadt

(3) Receiving blind POES TM from Darmstadt

(4) Receiving POES command echoes from Darmstadt

Managing CE resources for IJPS operations

5. SOCC INTERFACES

The SOCC provides payload data to the CEMSCS, the NOAA central processing facility at Suitland. In addition, the CEMSCS provides the SOCC with the spacecraft ephemeris data and orbital elements. Three NOAA affiliated university research contractors (University of Wisconsin, Colorado State University, and the University of Miami) receive payload data over the same Domestic Satellite (DOMSAT) system used by SOCC. Payload data is also provided to several Department of Defense (DoD) DOMSAT receive sites: Air Force Weather Agency (AFWA), Naval Oceanographic Office (NAVOCEANO) and Fleet Numerical Meteorology and Oceanography Center (FNMOC). (Note: any suitably equipped user can receive raw payload data as long as that the data is not sold.)

High-resolution picture transmission (HRPT) data from both WCDAS and FCDAS are sent from CEMSCS to the Service’s Advanced Data Collection and Location System (DCS) Argos facility in Largo, Maryland. To support planning and scheduling, OSDPD provides the SOCC with the spacecraft ephemeris data and orbital elements derived from orbital data generated by the DoD sites.

6. INITIAL JOINT POLAR-ORBITING SYSTEM

The IJPS will be a joint European/U.S. endeavor; EUMETSAT assumes responsibility for the "mid-morning" orbit, and NOAA is responsible for the "afternoon" orbit. To maintain compatibility, the operational meteorological payload will, as far as possible, be common to both the "mid-morning" and "afternoon" spacecraft. Furthermore, the respective NOAA and EUMETSAT Ground Segments will, to the extent possible, be compatible regarding data exchange and processing. The ground segment is comprised of the CSU (CDAS and SOCC Upgrade) and the CE (Communications Element). In support of IJPS operations, the POES and EPS satellites—including the instruments they carry—will be operated and controlled by NOAA and EUMETSAT through their respective ground segments. IJPS operations are to be conducted continuously 24 hours a day, seven days a week in support of on-orbit satellites. This requires that adequate capability exist to adapt to anomalous satellite performance and to provide backup capability for ground segment elements in case of failures or downtime for maintenance or repair. Global and housekeeping data received by the POES and EPS ground segments during operations with their respective satellites will be archived and made available to NOAA and EUMETSAT as required to implement the IJPS mission. In addition to operating and controlling their own satellites, POES and EPS ground segments will provide blind orbit cross-support for commanding access and housekeeping telemetry acquisition to/from operational satellites not in view of their respective ground segments. At the altitude for Polar satellites, the orbital period is nominally 102 minutes, permitting just over 14 complete earth orbits per day. Of these orbits, not all satellite orbital passes will be within the field of view of its dedicated ground stations. While each satellite provides direct broadcast of real-time environmental data as it passes in view of ground stations worldwide, it also stores mission data to be downloaded as scheduled by its dedicated ground station when in its field of view. In the IJPS era, NOAA and EUMETSAT will provide blind orbit support to each other for both satellite commanding and telemetry operations. When providing blind orbit cross-support, the ground segment will be operated in a communications throughput (bent-pipe) mode. Also provided during blind orbit operations will be the collection, storage, and timely exchange of global data between NOAA and EUMETSAT. The POES Ground Segment (CSU) will continue to receive, process, and distribute direct broadcast satellite information from both the POES and the EPS satellites (with the operational Metop satellite functioning as the morning NOAA satellite). A single-point communications interface for each system will be established by a communications link (CE) between the POES and EPS satellite systems. This link will be defined and implemented by NOAA and EUMETSAT to meet IJPS mission operations requirements. The governing document for all these operations is the Joint Operations Rules and Procedures (JORP). The IJPS controls, receives, processes, and transmits data from two independent polar-orbiting satellite systems. The polar-orbiting satellites operated by EUMETSAT and NOAA will carry a set of jointly provided instruments in orbits that will provide both parties and the world's meteorological community with improved data. IJPS CE provides the design, procurement, installation, and operations of a communications network to tie the EUMETSAT headquarters in Darmstadt, Germany, to the NOAA facilities in Suitland, Maryland.

IJPS CE is providing international data connectivity and end equipment at Darmstadt, Germany, and Suitland, Maryland. All equipment and services are managed and controlled by the IJPS Network Operations Center (NOC) under the direction of the NOAA SOCC Operations. Specifically, the contractor shall provide an IJPS Network having commercial-grade data communications capabilities within the network using industry-standard network components and protocols. The design of the IJPS Network will allow for growth with a flexible and extensible architecture. The IJPS Network will be built on a completely dedicated network. The unique features of the CE are commercial-off-the-shelf solutions using industry-standard equipment and interfaces. The system is isolated from the public Internet. Data connectivity is accomplished using a Digital Signal Level 3 (DS3) International Private Line provided by Sprint's fiber-optic network (excess of two times the required bandwidth) and a fully redundant Synchronous Optical Network (SONET) ring. Network Management is provided by Sprint using an International Frame Relay Network; this allows Network management to be isolated from data network, a modem backup in case of frame relay failure and support for NOAA Telecommanding (NTC) and NOAA Telemetry (NTM) for Wallops. NOAA-owned equipment was chosen with 99.8 percent availability requirement in mind. The network uses a Cisco 6509 High Availability/Redundant Architecture Catalyst switch/router at Suitland and Darmstadt, with redundant Dell data buffering servers. The NOC will have total remote control of the following functions:

(1) Operational configuration

(2) Startup/shutdown

(3) Power on/off

(4) Environment monitoring and alarms

NOC functionality will be provided at three geographically separated facilities:

(1) Remote NOC Maritime Communication Services (MCS) Melbourne, Florida (Two Personal Computer [PC]-based workstations)

(2) Alternate NOC collocated at Suitland, Maryland (Two PC-based workstations)

(3) Quick Look Terminal Harris Technical Services Corporation (HTSC) Omaha, Nebraska (One PC-based workstation)

The equipment located at EUMETSAT and SOCC will be in locked equipment racks with electronic monitoring; this will provide a physical barrier to prevent unauthorized access. There will be a door contact sensor, a web camera to authenticate access attempts, and temperature, humidity, audio, and airflow sensors to warn of environmental hazards.

7. POES MISSION MANAGEMENT ACTIVITIES

There are seven operational phases for the POES Satellite: pre-launch, launch and early orbit, on-orbit performance verification, on-orbit, on-orbit residual (partial operation), on-orbit residual (standby), and deactivation. On the ground system, the particular activities required for each of these POES Mission operations phases can be grouped into four operational phases managed with SOCC: control, support, software, and engineering.

Real-time activities depend on the particular satellite phase of each satellite. Under most circumstances, these activities are concerned with the operation of the two POES satellites in full mission operation and several satellites in partial operation or standby. Since launches have historically occurred within periods of just under two years, real-time support is also frequently required for spacecraft in the pre-launch phase, launch and early orbit phase, or on-orbit performance verification phase.

Operations are done 24/7 predominantly by personnel from the SOCC Control Branch, the Wallops Operations Branch, and the Fairbanks Operations and Management (O&M) contract staff. During satellite passes, the CDAs are staffed to support overall CDA direction and telemetry, command, and antenna control functions. SOCC is staffed for overall POES direction, satellite health and safety, data acquisition, and satellite control for each CDA.

A number of system tools are available to allow real-time operations personnel to monitor satellite and ground systems and manage data acquisition schedules. Examples include displays of satellite subsystem telemetry values and status, significant ground system events, and real-time execution of satellite and ground activities. These tools are provided by a part of the PACS. The PACS is a network of various levels of computers located at the SOCC and both CDAs (Figure 3-1). Each location consists of individual operator workstations connected to mid level systems concerned with telemetry and command activities. Communications Control Computers switch data between these computers and other system data handling devices such as bit and frame synchronizers and electronic switches. The Communications Controller software controls the set up of the equipment needed to configure the correct data path for telemetry and command. The software also monitors the status of the equipment on a regular basis.

SOCC and CDAs connect their internal elements using an Ethernet Wide Area Network (WAN). SOCC is connected to each CDA via WAN for narrow-band data flow; telemetry, command, status and control. SOCC is also connected to each CDA via a simplex DOMSAT link for wide-band data. Wide-band data consists of both satellite payload data and satellite housekeeping data (HRPT).

Real-time monitoring primarily involves the use of the system tools provided by the PACS applied in accordance with defined operational procedures. Its purpose is to define system performance, compare and contrast performance to expectations, take procedurally appropriate action, and report results.

The system requires near real-time voice as well as e-mail and Fax coordination between the POES command control and user segments in order to supplement information provided by the automated tools or to obtain data not otherwise available.

The ground segments monitored during the normal POES satellite phases involving the full, partial or standby operation of several satellites are the CDAs, SOCC, CEMSCS, AFWA and their connecting communications. Real-time operators use workstations to assess ground status during all three pass phases. The tools used include the PACS system schedules, PACS hierarchical events software, and PACS equipment status displays. Some data are provided automatically in response to operator-initiated activities, while some information is available only in response to direct operator queries.

The Aerospace Engineering Technician (AET) and Satellite Controller at the SOCC primarily monitor satellite state of health and command activities during pass operations. At acquisition a top-level check of the satellite's subsystems state and performance is made using predefined procedures called AET Monitor Guidelines. The control system also automatically performs a comprehensive comparison of satellite state at acquisition to the state of the satellite at loss of signal on its last pass. The resulting report of state differences describes both planned and unplanned changes.

Throughout the pass, background telemetry limit check software automatically and continuously performs an even more detailed review of satellite state of health. The software compares received telemetry with a database that describes both normal and abnormal satellite subsystem responses. It encompasses spacecraft bus and instrument subsystems and all types of POES telemetry (digital, analog and bi-level). The database is user defined and allows the user to select 'Cautionary' (yellow) and 'Immediate Attention/Action' (red) high and low limits.

After the satellite health is assessed, satellite state becomes important to command operations and the recovery of scheduled payload data. In addition, these activities require continuous knowledge of the state of CDA, SOCC, CEMSCS and AFWA during Pass and Post-Pass. This knowledge is essential for efficient command operations, for data playback and data transfer, and for the real-time troubleshooting of problems.

7. CONCLUSION

The next few years will see an extreme change in operations for NOAA and its European counter part Eumetsat. As the launch of NOAA N (first quarter 2005) and Metop 1 (last quarter 2005) gets closer, these ground systems will have completed a very thorough test and validation. Joint sharing of weather data will have many challenges left to overcome although relatively minor ones overall. Polar weather will now have to communicate between control centers to accomplish many tasks usually accomplished at one node. Standard voice communication between centers will will be used so as to not confuse each other. Planning products for each others programs will need to be shared to deconflict resources previous owned by one entity. Configuration control policies affecting the ground system baseline will need to have approval from both American and European counterparts before implementation. Joint procedures will also need to be worked out ahead of time and with the proper urgency to not interrupt the flow of operations. Data delivery problems prompting a change in primary and secondary ground systems will need to adhere to special protocols established ahead of time. We will accomplish all this on a daily basis to assure all our national and international weather customer's continue to receive the vital weather data necessary for their proper products to be accomplished. NOAA and Eumetsat's excellent spirit of teamwork and professional service in past years continues with this new partnership and promises to keep the customer need for weather data first and foremost in mind.

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BIOGRAPHY

Keith Amburgey is the Suitland Operations Control Center (SOCC) Manager for the National Oceanic and Atmospheric Administration (NOAA). His has an extensive background of over 20 years managing and operating several key critical Department of Defense (DoD) Air Force satellite programs to include Global Positioning Satellite (GPS), and the Defense Meteorological Satellite Program (DMSP). He also served on the Air Staff's Directorate of Space Integration responsible for providing guidance and resolution of critical issues and recommendations for enhancing space support across the spectrum of national instruments of power. Mr. Amburgey holds a BS degree from The Ohio State University and has a MBA in Information Technology from the University of Colorado.