CGMS-XXIX
USA-WP-08
Prepared by USA
Agenda Item: C.1

FUTURE POLAR ORBITING METEOROLOGICAL SATELLITE SYSTEMS

The USA discussed its future polar-orbiting meteorological satellite system. NOAA addressed the plan launch schedule for NOAA-m, n and N'. Further, information was provided on the international polar program coordination between EUMETSAT and NOAA. The goal of this cooperation is to provide continuity of measurement from polar orbits, cost sharing, and improved forecast and monitoring capabilities through the introduction of new technologies. An agreement is in place between NOAA and EUMETSAT on the Initial Joint Polar-orbiting Operational Satellite System (IJPS). This program will include two series of independent but fully coordinated NOAA and EUMETSAT satellites, exchange of instruments and global data, cooperation in algorithm development, and plans for real-time direct broadcast.

The USA discussed the NPOESS development and implementation plan 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 NPOESS will provide significantly improved operational capabilities and benefits to satisfy the critical civil and national security requirements for space-based, remotely-sensed environmental data. These activities represent a sound beginning for achieving the planned national and international programmes in the new millennium and ensuring continuous support to a variety of users.

FUTURE POLAR ORBITING METEOROLOGICAL SATELLITE SYSTEMS

1. INTRODUCTION

Since 1960, polar-orbiting satellites have collected environmental data from space in support of preparing informed weather forecasts. The Polar-orbiting Operational Environmental Satellite (POES) system evolved from the experiences gained in space from ten experimental Television Infrared Observation Satellites (TIROS) and four generations of operational polar satellites. Since 1978, the POES system has operated with a two-satellite constellation in circular, near-polar, sun-synchronous orbits.

The POES program is managed by the National Environmental Satellite, Data, and Information Service (NESDIS), part of the National Oceanic and Atmospheric Administration (NOAA). During the 1980s, budgetary concerns guided program decision makers to study convergence of the POES mission with the military's Defense Meteorological Satellite Program (DMSP) and investigate cooperative international programs to reduce overall space system costs. The results of these activities are now reflected in a Presidential decision directive and memorandums of agreement to implement new architectures for national and international polar satellite systems by the end of the first decade in the new millennium. Until the new operational satellite systems are available, the current POES and DMSP programs will provide continuous satellite coverage from space to support user needs.

2. STRATEGIC GOAL

The need to acquire environmental data from space is reflected in NOAA's strategic goals and objectives for the years 1995-2005. As part of the portfolio for "Environmental Assessment and Prediction," NOAA's Strategic Plan includes program elements for Advanced Short-Term Warning and Forecast Services, the implementation of Seasonal to Interannual Forecasts, the Prediction and Assessment of Decadal to Centennial Change, and the Promotion of Safe Navigation. One of the specific objectives of the Advanced Short-Term Warning and Forecast Services program elements is to "maintain continuous operational satellite coverage critical for warnings and forecasts."

3. POLAR MISSION

The primary mission of the POES system is to provide daily global observations of weather patterns and environmental measurements of the Earth's atmosphere, its surface and cloud cover, and the proton and electron flux at satellite altitude; and to establish long-term data sets for climate monitoring and change predictions. Since the beginning of the POES program, environmental data and products acquired by its satellites have been provided to users around the globe.

The POES system comprises on-orbit remote-sensing satellites, and satellite command and control and data processing facilities. The current constellation includes NOAA-15 and

NOAA-16, the first two of five fifth-generation Advanced TIROS-N satellites with updated instruments, operating in a morning and afternoon orbit, respectively. To support the Polar mission, these satellites carry the following instruments:

- AVHRR/3: Through modifications to the current AVHRR/2 instrument, a sixth channel has been added for near-IR data. This channel, referred to as 3A, will provide users with the ability to discriminate between clouds and snow and ice. It will be time shared with the previous channel 3 now referred to as 3B. Operationally, channel 3A will be active during the daytime part of each orbit and 3B will be active during the nighttime part of each orbit.
- HIRS/3: Through changes in the routine use of cold targets in the calibration sequence for HIRS/2, HIRS/3 will have one additional scan line of earth data collected by the instrument during a complete scan cycle.
- Advanced Microwave Sounding Unit (AMSU-A and -B): The AMSU suite is a 20-channel scanning passive microwave radiometer. AMSU-A uses 15 channels to provide data for vertical temperature profiles and information on surface water and precipitation for enhancing sounding measurements. AMSU-B, provided by the U.K. Meteorology Office, is a five-channel microwave radiometer for measuring atmospheric water vapor. AMSU instruments will provide the capability for remote sensing of atmospheric and surface properties on a global basis as well as improving the detection of precipitation and surface features such as ice and snow cover.
- Solar Backscatter-Ultraviolet Spectral Radiometer (SBUV): The SBUV provides estimates of the global ozone distribution by measuring back-scattered solar radiation in the ultraviolet Hartley-Huggins bands. The SBUV is flown only on satellites in afternoon orbits.
- Space Environment Monitor (SEM): The SEM is a multi-channel, charged particle spectrometer that measures the population of the Earth's radiation belts and the particle precipitation phenomena resulting from solar activity.
- Search and Rescue Satellite Aided Tracking System (SARSAT): The SARSAT receives distress signals from emergency beacons on international distress frequencies and retransmits them to local user terminals for action by appropriate government agencies.
- ARGOS/Data Collection System (DCS): The DCS relays meteorological and other data transmitted from *in-situ* ground-based data collection platforms including buoys, free floating balloons, and remote weather stations.

4. FUTURE PROGRAM PLANS

4.1 Follow-on Satellites

NOAA has in place a follow-on polar satellite program to replace current satellites as they reach the end of their operational life. The new fifth-generation POES ATN follow-on satellites are designated NOAA-K, -L, -M, -N, and –N'. NOAA-K, -L, and -M have been upgraded with new primary environmental instruments, followed by NOAA-N and N' updated to a later instrument baseline. The major changes to the environmental instrument baseline for the NOAA-K, -L, and -M satellites, described above, include the AVHRR/3, the HIRS/3, and the AMSU-A and -B. Instrument changes for NOAA-N and –N' include the HIRS/4 which will provide 10 Km field of view versus 20 Km on the previous model, and the Microwave Humidity Sounder, provided by the European Organisation for the Exploitation of Meteorological Satellites, which will replace the AMSU-B.

NOAA-K, now designated NOAA-15, was successfully launched into a morning orbit in May 1998. NOAA-L, now designated NOAA-16, was successfully launched in September 2000 into an afternoon orbit to replace the aging NOAA-14. The planning launch dates for the remaining ATN follow-on satellites are as follows:

NOAA-M	March 2002
NOAA-N	June 2004
NOAA-N'	March 2008

To support the new satellites, elements of the ground segment have also been updated to accommodate the new and updated satellite data formats, generate S-band commands, ingest new satellite environmental data, product processing, and product distribution and archiving. To provide the latest information on the specifics of these changes, NOAA has prepared a user guide for the new POES satellites. This information is available on the Internet at the following URL: http://www2.ncdc.noaa.gov/POD/intro.htm.

4.2 International Program Cooperation

In the 1980s, NOAA needed to balance the high cost of space systems and the growing need to provide a complete and accurate description of the atmosphere at regular intervals as inputs to numerical weather prediction and climate monitoring support systems. This led NOAA to enter into discussions and agreements at the international level with the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT). The goal of this cooperation is to provide continuity of measurement from polar orbits, cost sharing, and improved forecast and monitoring capabilities through the introduction of new technologies.

Building upon the POES program, an agreement is in place between NOAA and EUMETSAT on the Initial Joint Polar-orbiting Operational Satellite System (IJPS). This program will include two series of independent but fully coordinated NOAA and EUMETSAT satellites, exchange of instruments and global data, cooperation in algorithm development, and plans for real-time direct broadcast. Under terms of the IJPS agreement, NOAA will provide NOAA-N and NOAA-N' satellites for flight in the afternoon orbit while EUMETSAT makes available Metop-1 and Metop-2 satellites for flight in the mid-morning orbit. In addition, a common core of instruments will be flown on these satellites that includes the AVHRR/3, HIRS/4, AMSU-A, DCS, SARSAT, SEM, and the Microwave Humidity Sounder (MHS). In addition, NOAA will fly a SBUV instrument on its satellites, while EUMETSAT's additional payloads include an infrared interferometer sounder, a scatterometer, an ozone instrument and a GPS occultation sounder.

Coordination on associated ground segments is also included in this agreement, which ensures the sharing of all mission data, blind-orbit data capture support, and telecommunications paths through each other's ground stations for back-up command and control functions. The first Metop satellite is currently planned for launch in 2005.

4.3 National Polar-orbiting Operational Environmental Satellite System

On May 5, 1994, President Clinton made the decision to merge the United States' military and civil operational meteorological satellite systems into a single, national system capable of satisfying both civil and national security requirements for space-based remotely sensed environmental data. This joint program, known as the National Polar-orbiting Operational Environmental Satellite System (NPOESS), is expected to provide approximately $1.8 billion in savings through the System Life Cycle of the program compared to the cost of continuing the previously planned separate satellite systems.

In October 1994, NOAA, the Department of Defense (DoD) and the National Aeronautics and Space Administration (NASA) created an Integrated Program Office (IPO), organizationally within NOAA, to develop, manage, acquire, and operate NPOESS. NOAA has overall responsibility for the converged system, including satellite operations, and NOAA is also the primary interface with the international and civil user communities. DoD is responsible for major systems acquisitions, including launch support. NASA has a primary responsibility for facilitating the development and incorporation of new cost-effective technologies into the converged system.

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. In 1997, the IPO initiated a robust sensor risk reduction effort that has been 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 three sensors scheduled for late 2004. 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 will be concluded in late 2002, with the award of a single contract for the Engineering and Manufacturing Development of NPOESS.

To support the converged civil and military requirements for space-based, remotely sensed environmental data, the NPOESS spacecraft (depending upon orbit) will carry the following sensor payloads:

- Visible/Infrared Imager Radiometer Suite (VIIRS): The VIIRS will combine the radiometric accuracy of the AVHRR currently flown on the NOAA polar orbiters with the high (0.65 kilometer) spatial resolution of the Operational Linescan System flown on DMSP spacecraft. The VIIRS will have 22 channels with additional spectral capabilities that can be utilized to determine ocean color. VIIRS will provide measurements of sea surface temperature, atmospheric aerosols, snow cover, cloud cover, surface albedo, vegetation index, sea ice, and ocean color.
- Conical-scanning Microwave Imager Sounder (CMIS): The CMIS will combine the microwave imaging capabilities of Japan's Advanced Microwave Scanning Radiometer (AMSR) on NASA's Earth Observing System (EOS) Aqua mission, 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 November 2001. Polarization for selected imaging channels will be utilized to derive ocean surface wind vectors similar to what has previously been achieved with active scatterometers. CMIS data will be utilized 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.
- Cross-track Infrared Sounder (CRIS): The CrIS is a Michelson Interferometer that is designed to enable retrievals of atmospheric temperature profiles at 1 degree accuracy for 1 km layers in the troposphere, and moisture profiles accurate to 15 percent for 2 km layers.
- Advanced Technology Microwave Sounder (ATMS): The ATMS is being designed to be the next generation cross-track microwave sounder and will combine the capabilities of microwave temperature sounders (AMSU-A) and microwave humidity sounders (MHS/HSB) that fly on NOAA's POES, EUMETSAT's Metop, and NASA's EOS Aqua spacecraft.
- Ozone Mapping and Profiler Suite (OMPS): The OMPS will consist of a nadir scanning ozone mapper similar in functionality to NASA's Total Ozone Mapping Spectrometer (TOMS) and a limb scanning radiometer that will be able to provide ozone profiles with a vertical resolution of 3 km as compared to the present 7 to 10 km for the SBUV on POES.
- Global Positioning System Occultation Sensor (GPSOS): The GPSOS will be used operationally to characterize the ionosphere and to determine tropospheric temperature and humidity profiles.
- Space Environment Sensor Suite (SESS): The SESS will provide information about the space environment necessary to ensure reliable operations of current space-based and ground-based systems, to facilitate the analysis of system anomalies that are the result of space environmental effects, and to guide the design and efficient operations of future systems that may be affected by the space environment.

- Cloud and Earth's Radiant Energy System (CERES): CERES will provide data on the Earth's radiation budget and atmospheric radiation from the top of the atmosphere to the surface. The first CERES is currently flying on NASA's Tropical Rainfall Measuring Mission (TRMM), that was launched in November 1997.
- Total Solar Irradiance Sensor (TSIM): The TSIM will measure variability in the sun's solar output, including total solar irradiance in the 200 to 300nm and 1500 nm spectral ranges.
- Radar Altimeter (ALT): The IPO is planning to fly a dual frequency radar altimeter on the morning NPOESS satellite. The altimeter will measure sea surface topography, significant wave height, and wind speed, and altimetry measurements will be used to derive ocean circulation parameters monitoring requirements for both operations and research purposes.
- Search and Rescue Satellite Aided Tracking System (SARSAT): The SARSAT receives distress signals from emergency beacons on international distress frequencies and retransmits them to local user terminals for action by appropriate government agencies.
- ARGOS/Data Collection System (DCS): The DCS relays meteorological and other data transmitted from *in-situ* ground-based data collection platforms including buoys, free floating balloons, and remote weather stations.

As a critical part of the NPOESS development strategy, early flight-testing of instruments is planned 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 flight late in this decade. The joint DoD/IPO WindSat/Coriolis mission will be launched in 2002 to provide a space-based test and demonstration of passive microwave polarimetric techniques to derive measurements of ocean surface wind speed and direction. This three-year mission will continue the development of improved microwave measurement capabilities from SSMI/S on DMSP to CMIS on NPOESS. The NPOESS Preparatory Project (NPP), a joint IPO/NASA mission that is being planned for launch in late 2005, will carry three of the critical NPOESS sensors: VIIRS, CrIS, and ATMS. In addition to serving as a valuable instrument and system risk reduction and prototyping mission for the IPO and the users of NPOESS data, NPP will provide continuity of the calibrated, validated and geo-located EOS Terra and Aqua systematic global imaging and sounding observations for NASA Earth Science research.

The first converged NPOESS satellite is expected to be available for launch by 2008 to back-up the last launches of the current DMSP and POES satellites. The current operational concept for NPOESS consists of a constellation of spacecraft in three sun-synchronous orbital planes with equatorial nodal crossing times of 0530, 0930, and 1330 local solar time (LST), respectively. The early morning (0530) and afternoon (1330) spacecraft will carry full complements of instruments. The mid-morning (0930) NPOESS-"Lite" spacecraft will carry a reduced complement of instruments, including VIIRS and CMIS that are required to meet the stringent U.S. horizontal resolution and data refresh requirements for all-weather imaging in this orbit. The IPO plans to continue cooperation with EUMETSAT for a Joint Polar System (JPS). While in a transition phase to a future international polar satellite program, the NPOESS-"Lite" spacecraft will complement EUMETSAT's third Metop satellite flying in the 0930 orbit. Use of data from EUMETSAT's Metop satellite will increase the global coverage and refresh rate of the U.S. polar satellite system.

In addition, the European meteorological community will receive valuable data from instruments on both the Metop and NPOESS series of satellites.

5. SUMMARY

Plans and programs are in place to provide continuous polar-orbiting satellite coverage well into the new millennium. In the near-term, progress towards implementing these plans can be measured with the completion of the NPOESS concept definition phase, the start of the acquisition of the key NPOESS instruments, the start of the development phase for the Metop spacecraft, and the successful launch of NOAA-L (NOAA-16) in 2000. NPOESS will provide significantly improved operational capabilities and benefits to satisfy the critical civil and national security requirements for space-based, remotely sensed environmental data. The more accurate measurements from the NPOESS instruments are expected to yield significant improvements in the skill of short-to-long range weather forecasts and long-term climate predictions. 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. These activities represent a sound beginning for achieving the planned national and international programs in the new millennium and ensuring continuous support to a variety of users.