Appendix A: Existing U.S. Operational Meteorological Satellite Programs

Geostationary Operational Environmental Satellite Program

NOAA has been operating GOES satellites since 1974. GOES satellites maintain orbital positions over the same Earth location along the equator at about 36,000 km (22,300 miles) above Earth, giving them the ability to make continuous observations of weather patterns over and near the United States. Continuous measurements are necessary to monitor the formation of severe storms, which can develop in less than 30 minutes. GOES satellites provide both visible-light and infrared images of cloud patterns, as well as "soundings," or indirect profile measurements, of the temperature and humidity throughout the atmosphere. NOAA has been operating GOES satellites since 1974. Data from these spacecraft provide input to meet the forecasting responsibilities of the National Weather Service. Among other applications, the GOES data assist in monitoring storms and provide advance warning of emerging severe weather. The vantage point of GOES satellites allows for the observation of large-scale weather events, which is required for forecasting small-scale events. They have a crucial role in monitoring hurricanes. Images from GOES provide a visual summary of weather conditions across the United States and are used routinely by television weather forecasters to inform the public about impending weather conditions.

To supply complete coverage of the continental United States, Alaska, and Hawaii, the GOES program requires two satellites, one nominally placed at 75º west longitude and one at 135º west longitude. GOES-7, which was launched in 1987, and has already exceeded its five-year design life, is currently located at 135º west longitude. GOES-8, the first in the GOES-Next series of satellites, became operational in October 1994 and is located at 75º west longitude. GOES-J (now GOES-9) was launched on May 23, 1995, and will take the place of GOES-7, which will be retired. GOES satellites are designed to last about five years. NOAA plans to launch replacements as needed (table 1).

Polar-orbiting Operational Environmental Satellite Program

The POES satellites follow orbits that pass close to the north and south poles. They orbit at about 840-km altitude, providing continuous, global coverage of the state of Earth's atmosphere. Data gathered by POES includes data essential for assimilation into weather prediction models. Specific data collected include atmospheric temperature, humidity, cloud cover, ozone concentration, and Earth's energy budget, as well as important surface data such as sea-ice and sea-surface temperature and snow and ice coverage. In order to maintain continuity of data delivery, NOAA will replace POES satellites as needed, nominally on a three-year schedule (table 2).

POES satellites carry several instruments:

1. The *Advanced Very High Resolution Radiometer (AVHRR)*, which determines cloud cover and

Earth's surface temperature, including sea surface temperature and vegetation cover.

2. The *High Resolution Infrared Radiation Sounder (HIRS)*, which measures energy emitted by the atmosphere in 19 spectral bands in the infrared region of the spectrum, and one spectral band at the far-red end of the visible spectrum to infer the temperature structure of the atmosphere in cloud-free regions.
3. The *Microwave Sounding Unit (MSU)*, which detects energy in the troposphere in four areas of the microwave region of the spectrum to infer the temperature structure of the atmosphere in cloudy regions.
4. The *Stratospheric Sounding Unit (SSU)*, a three-channel instrument that has flown on all NOAA POES satellites except NOAA-12. It measures the intensity of electromagnetic radiation emitted from carbon dioxide at the top of the atmosphere, providing scientists with the necessary data to estimate temperatures through the stratosphere.
5. The *Space Environment Monitor (SEM)*, a multichannel charged-particle spectrometer that measures the flux density, energy spectrum, and total energy deposition of solar protons, alpha particles, and electrons.
6. The *ARGOS Data Collection System (DCS)*, which consists of approximately 2,000 platforms (buoys, free-floating balloons, remote weather stations, and even animal collars) that transmit temperature, pressure, and altitude data to the POES satellite.
7. The *Solar Backscatter Ultraviolet Radiometer/2 (SBUV/2)*, which measures concentrations of ozone at various levels in the atmosphere and total ozone concentration. This instrument is flown on all POES satellites that cross the equator in the afternoon.
8. The *Search and Rescue Satellite Aided Tracking System (SARSAT, or S&R)*, which locates signals from emergency-location transponders on board ships and aircraft in distress and relays these data to ground receiving stations.
9. The *Earth Radiation Budget Experiment (ERBE)*, which was flown only on NOAA-9 and NOAA-10. ERBE measures the monthly average radiation budget on regional to global scales and determines the average daily variations in the radiation budget.

Beginning with NOAA-K, the MSU and SSU will be replaced with the Advanced Microwae Soundings Unit (AMSU)-A and AMSU-B. The AMSU-A is a 15-channel microwave temperature sounder that will greatly increase the ability to infer the temperature structure of the atmosphere in cloudy regions. The AMSU-B is a five-channel microwave humidity sounder that will allow data users to infer the water vapor structure of the atmosphere.

Defense Meteorological Satellite Program

The DMSP program collects and disseminates global environmental information for the U.S. Department of Defense. Sensors on DMSP view most of Earth twice per day. The primary sensor aboard DMSP satellites is a visible and infrared imager. Data from this sensor are also supplemented with atmospheric and oceanographic data. The current Block 5D-2 satellites are being replaced with upgraded 5D-3 satellites.

Each DMSP satellite contains the following sensors:

1. The *Operational Linescan System (OLS)*, a visible and infrared imager that monitors cloud cover. The OLS also uses photomultipliers to enable observations at very low light levels.
2. The *Special Sensor Microwave/Imager (SSM/I)*, a radiometer used for determining soil moisture, precipitation, and ice cover, has four channels and a spatial resolution of 25 to 50 km. It also provides data used to determine sea-surface wind speed, but not direction.
3. The *Special Sensor Microwave/Temperature Sounder (SSM/T1)*, used for vertical temperature sensing, has seven frequency ranges.
4. The *Special Sensor Microwave/Water Vapor Sounder (SSM/T2)*, used for determining humidity through the atmosphere, has five channels and spatial resolution of 40 to 120 km.
5. *Space Environment Sensors*: SSB/X-2, a gamma- and X-ray spectrometer; SSM, a magnetometer; SSJ/4, a precipitating charged particle spectrometer; and SSI/ES-2, a plasma and ion/electron scintillation monitor. Information from these sensors is used to predict and plan for the impact of the space environment on space systems.

The Integrated Program Office

In order to support the transition from the existing DOD DMSP and NOAA POES satellite systems to the single, converged system of the 21st century, DOD, NOAA, and NASA have set up an Integrated Program Office (IPO), composed of representatives from each

agency. The IPO is funded by NOAA, DOD, and NASA.[1] Each agency has the lead on one function of the operational system—acquisition (DOD), operations (NOAA), and technology transition (NASA)—but each functional office includes representatives of all agencies. This arrangement is designed to institutionalize each agency's incentive to support the overall system.

The IPO has begun planning for replacing the existing DOD and NOAA operational polar-orbiting systems of four satellites and associated support systems with a three-satellite U.S.-European system beginning around the year 2005. The United States will fly one satellite with an early morning equator crossing to support DOD's need for cloud observations and other early morning data, and one satellite with an afternoon equator crossing. The European Organisation for the Exploitation of Meteorological Satellites (Eumetsat) plans to contribute a similar satellite to the converged system, which would cross the equator in mid-morning.

[1] NASA provides personnel only.

Appendix B: Workshop Participants

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