CGMS-XXIX
USA-WP-02
USA-WP-03
Agenda Item: B.1
Discussed in Plenary

CGMS - Satellite Constellation Status
WP-02- Polar Operational Environmental Satellite (POES)
WP-03 Geostationary Meteorological Satellite Systems

The National Oceanic and Atmospheric Administration (NOAA) manages a constellation of seven geostationary and eleven polar orbiting meteorological spacecraft, including five military satellites, from the Satellite Operations Control Center (SOCC) in Suitland, Maryland. These satellites provide continuous observations of weather conditions and environmental features of the western hemisphere, monitor global climate change, verify ozone depletion and land surface change, monitor the critical space environmental parameters, and support search and rescue efforts across the globe. Upcoming launches include a new polar orbiting civilian satellite in March 2002 and a new military polar-orbiting spacecraft in November 2001. This document briefly addresses the status of the geosynchronous and low-earth-orbiting spacecraft constellations as of August 10, 2001.

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B. Report on the Status of Current Satellite Systems

B.1 Polar Orbiting Meteorological Satellite Systems

Polar Operational Environmental Satellite (POES)

The POES spacecraft constellation includes two primary, one secondary and two standby spacecraft. These spacecraft are in circular orbits inclined at approximately 98 degrees (retrograde). The primary operational spacecraft, NOAA-16 and NOAA-15, are in sun-synchronous afternoon and morning orbits, respectively. One secondary spacecraft, NOAA-14 provides additional payload operational data. NOAA-12 and NOAA-11 are standby spacecraft supporting additional user data requirements.

The next POES launch, NOAA-M is slated for launch in March 2001. This spacecraft, which will be renamed NOAA-17 once it achieves orbit, will replace NOAA-15 as the operational morning spacecraft.

NOAA-16

NOAA-16 was launched on September 21, 2000. By March 2001, NOAA-16 was designated as the operational replacement for NOAA-14. As such, it operates in an orbit with a 13:53 p.m. ascending node (afternoon orbit) and utilizes a similar set of instruments as NOAA-14. On November 13, 2000 the VHF transmitter (VTX) failed which does not allow the broadcast of Automatic Picture Transmission (APT). Data Recorder DTR#5 failed February 2, 2000 and is no longer used due to a failure within its electronics.

The NOAA-16, or afternoon mission, instrument payload includes:

X The Advanced Very High Resolution Radiometer (AVHRR/3), a six channel imaging radiometer which detects energy in the visible and near-IR portions of the electromagnetic spectrum. This data is used to observe vegetation, clouds, lakes, shorelines, snow, aerosols and ice.

X The High Resolution Infrared Radiation Sounder (HIRS/3), which detects and measures energy emitted by the atmosphere to construct a vertical temperature profile from the Earth's to an altitude of about 40 km. These measured energy profiles are used to determine ocean surface temperatures, total atmospheric ozone levels, precipitable water, cloud height and coverage and surface radiance

X The Advanced Microwave Sounding Unit-A (AMSU-A), which measures scene radiance in the microwave spectrum. The data from this instrument is used in conjunction with the HIRS to calculate the global atmospheric temperature and humidity profiles from the Earth's surface to the upper stratosphere, approximately a 2 millibar pressure altitude (48 km or 28 miles). The AMSU-A

is also complemented by the AMSU-B, which is designed to allow the calculation of the vertical water vapor profiles from the Earth's surface to about a 200 millibar pressure altitude (12km or 7.5 miles). The data from these instruments is used to provide precipitation and surface measurements including snow cover, sea ice concentration, and soil moisture.

X The Space Environmental Monitor (SEM/2) provides measurements to determine the intensity of the Earth's radiation belts and the flux of charged particles at the satellite altitude. It provides the knowledge of solar terrestrial phenomena and also provides warnings of solar wind occurrences that may impair long-range communication, high-altitude manned operations, or disrupt satellite operations.

X The Search and Rescue (SAR) instruments are part of the international COSPAS-SARSAT system designed to detect and locate Emergency Locator Transmitters (ELTs), Emergency Position-Indicating Radio Beacons (EPIRBs), and Personal Locator Beacons (PLBs) operating at 121.5, 243, and 406 MHz. The NOAA-15 spacecraft carries two instruments to detect these emergency beacons; the Search and Rescue Repeater (SARR) provided by Canada, and the Search and Rescue Processor (SARP-2) provided by France.

X The Data Collection System (DCS) collects and processes measurements from remote data collection platforms for on-board storage and subsequent transmission from the satellite. Data collection platforms in the form of buoys, free-floating balloons, and remote weather stations transmit their data on a 401.65 MHz uplink to the spacecraft. The DCS is used to gather environmental measurements such as atmospheric temperature and pressure, rainfall and snowfall, and velocity and direction of the ocean and wind currents.

X The major addition to the afternoon suite of instruments is the addition of the Solar Backscatter Ultraviolet Spectral Radiometer (SBUV). The SBUV is used to measure solar irradiance (backscattered solar energy), total ozone concentrations, and the vertical ozone profile in the atmosphere.

NOAA-15

NOAA-15 was launched on May 13, 1998. By July 1998, NOAA-15 was designated as the operational replacement for NOAA-12. As such, it operates in an orbit with a 7:30 am descending node (morning orbit) and utilizes the same set of instruments as NOAA-16 except the SBUV. NOAA-15 has anomalous instrument behavior in the HIRS and AVHRR and the on-orbit failure of three high gain downlink antennas. The AVHRR is re-phased once a day to assist the scan motor to maintain synchronization.

NOAA-14

NOAA-14, which was launched in December 1994, is the secondary operational afternoon (ascending node) spacecraft. One of the two on-board processors (OBP) is unusable due to the malfunction of an associated command demodulator.

Except for the failure of the on-board Search and Rescue Processor (SARP), all instrument subsystems are

currently providing usable data. On two different instruments, the Microwave Sounding Unit (MSU) and the Solar Backscatter Ultraviolet Spectral Radiometer (SBUV), drive motors for different movable assemblies have been observed to seize (the MSU scanner and the SBUV grating drive). As a result, command sequences have been coded into the on-board software that shuts off the appropriate instrument drive when elevated temperatures are observed that would be indicative of drive seizure.

The afternoon instrument payload on NOAA-14 is similar to the functionality of the NOAA-16 instruments except for:

X NOAA-14 uses the Microwave Sounding Unit (MSU) and Stratospheric Sounding Unit (SSU) to support atmospheric sounding data collection. These instruments are the predecessors to the two Advanced Microwave Sounding Units (AMSU-A and AMSU-B) on the NOAA-15 (and later) spacecraft.

Standby Spacecraft

NOAA-12 was launched in May 1991. Its AVHRR could be used to satisfy morning mission user data requirements.

NOAA-11, launched in September 1988, is an afternoon spacecraft providing SBUV instrument data in a very limited range due to continual degradation of the instrument.

NOAA-10, launched in September 1986, is non-operational status and is only contacted once per week.

Defense Meteorological Satellite Program (DMSP)

Over the last three years, NOAA and the US Air Force successfully completed the safe and efficient convergence of the five Defense Meteorological Satellite Program (DMSP) military satellites into the NOAA meteorological constellation. Initiated via Presidential Decision Directive in 1994, this convergence capitalizes on many of the shared resources and mission requirements of the civilian and military polar-orbiting spacecraft. The transfer of operations convergence is an interim step toward development of a single, integrated environmental satellite system designed to meet civilian and military needs. The first satellite in the new system will be available for launch in July 2007.

Similar to the civilian POES program, the DMSP program designs, launches, and maintains several near polar orbiting, sun synchronous satellites monitoring the meteorological, oceanographic, and solar-terrestrial physics environments. The visible and infrared sensors collect images of global cloud distribution across a 3,000-kilometer swath during both daytime and nighttime conditions.

The current DMSP constellation consists of two primary, two secondary, and one backup operational spacecraft.

B.2 Geostationary Meteorological Satellite Systems

The current Geostationary Operational Environmental Satellites (GOES) are three-axis stabilized spacecraft in geosynchronous orbits. The current primary satellites, GOES-8 and GOES-10, are stationed over the east and west coasts of the United States. These satellites are used to provide simultaneous images and soundings of the Western Hemisphere. GOES-12 was launched in July of 2001 and will be placed in the storage mode in December 2001 after post-launch checkout. The GOES-12 spacecraft will be stored in orbit near GOES-11 and GOES-9 and will be ready for the replacement of the older operational spacecraft if necessary. GOES-3 and GOES-7, spin-stabilized satellites from the previous GOES series, continue a track record of more than 55 years of combined service via continued support of non-NOAA users in a data relay mode (non-imaging).

The primary instrument payload for the current series of GOES spacecraft consists of:

X The Imager, a multi-channel instrument designed to sense radiant and solar reflected energy. The GOES-12 spacecraft a new 13.3 micron channel, which replaces the 12 micron channel on earlier satellites. It will provide data for upper level wind predictions.

X The Sounder, which provides data for atmospheric temperature and moisture profiles, surface and cloud top temperature and ozone distributions.

The Imager and Sounder both have the capability to sense stars during non-imaging times for use in Image Navigation and Registration (INR). In addition, the spacecraft can apply compensation signals to the instrument servo motors to compensate for repeatable long-term orbit and attitude effects.

The GOES spacecraft also have Space Environmental Monitor (SEM) systems to measure magnetic fields, solar x-ray flux and high energy electrons, protons and alpha particles. All the three axis GOES spacecraft SEM subsystems are operating nominally. GOES-12 has the new Solar X-Ray Imager (SXI) instrument which will provide real-time images (once per minute) of the sun in the X-Ray band.

A data collection system on the GOES spacecraft receives and relays environmental data sensed by widely dispersed surface platforms such as river and rain gauges, seismometers, tide gauges, buoys, ships and automatic weather stations. Platforms transmit sensor data to the satellite at regular or self-timed intervals, upon interrogation by the satellite, or in an emergency alarm mode whenever a sensor receives information exceeding a preset level.

GOES-8

GOES-8, launched in April 1994, is stationed over the East Coast of the United States at 75EW. The first of the series, GOES-8 retains the ability to provide the full range of products, although with some loss of redundancy of backup systems.

Both of the GOES-8 primary instruments are providing operational data, however one of the servo motor windings in the Sounder instrument failed in August 1994. The winding failure is believed to be a result of stresses induced by a combination of motor material incompatibilities and elevated temperatures, which occur primarily at spacecraft midnight. Data products are unaffected due to the use of a redundant coil, but due to a similar failure on GOES-9, the servo motors have been redesigned for all future GOES spacecraft.

The GOES-8 spacecraft bus continues to operate nominally with some loss of redundancy. Due to the location and mechanical mounting of the Attitude and Orbit Control Electronics (AOCE), the two AOCEs are susceptible to electrostatic discharge (ESD) events at specific times each year. Since launch, six ESD events have occurred on GOES-8. These events usually manifest themselves as soft (i.e. correctable) upsets to RAM locations, but on one occasion in April of 1996, a hard error occurred where the ability to address a quarter of the RAM locations on the primary AOCE was lost. Operations have been nominal on the backup AOCE since the anomaly. As a result of some of the earlier ESD events, some design modifications were made to all future GOES spacecraft before launch. To date, no ESD events have been experienced on GOES-9, GOES-10, or GOES 11. On January 9, 1997, the tachometer output from one of the two primary momentum wheels (Momentum Wheel #1) was lost. As a result, the AOCE lost the ability to control the wheel, and on January 10, a redundant reaction wheel was activated. Since that time, the spacecraft has operated nominally in the backup control mode and investigations are underway to recover some limited usage of Momentum Wheel #1. On October 27, 1998 the GOES-8 earth sensor # 2 failed. As a result, a spacecraft loss of attitude lock occurred and the safe hold mode was entered. Subsequent analysis revealed that the earth sensor was generating erratic error signals and was isolated to the earth sensor component. Within 24 hours, the spacecraft was recovered using the redundant earth sensor (earth sensor # 1) and has continued to provide nominal performance.

GOES-10

GOES-10 is the operational West Coast satellite at 135E W. Shortly after launch in April 1997, GOES-10 suffered a near-fatal anomaly when it's solar array stopped moving, either due to a gear train jam or due to an external jam. The anomaly was studied over a period of months, and it was decided to invert the satellite (180 degrees in relation to the Earth) and run the array drive in the reverse direction to track the sun. This operational strategy was coupled with extensive ground and spacecraft software modifications to allow the imagery to look "non-flipped" to the users.

GOES-11

The GOES-11 spacecraft was successfully launched on May 3, 2000 and will be used as the primary replacement in the event of a failed operational spacecraft. The GOES-11 orbit raising sequence was executed flawlessly and entered the operational mode on May 14, 2000. The first full disk visible image was taken on May 18, 2000. This was followed by the standard post launch characterization and performance tests. In addition, one month of special science testing was performed for the National

Weather Service. The checkout period has demonstrated that the spacecraft is ready to provide products when necessary. On August 14, 2000, GOES-11 was placed in a passive spin stabilized storage mode at 105 degrees west. In the event that GOES-8 or GOES-10 should fail or run out of fuel, GOES-11 could be activated and be made operational within 48 hours.

GOES-9

Launched in May 1995, GOES-9 is now in a Z-axis Precession (ZAP) mode, a spin-stabilized storage mode that minimizes use of life-limited spacecraft components and requires little operator intervention. In the summer of 1998, GOES-9's momentum wheels started to show signs of significant lubrication starvation. GOES-9 was put into storage mode in anticipation of imminent wheel failure. Currently located at 105 degrees W, GOES-9 has limited capability due to attitude limitations and imager visible noise.

GOES-7, GOES-3 and GOES-2

Launched in February of 1987, GOES-7 completed almost nine years of operational service with a final operational image on January 11, 1996 (after GOES-9 was declared fully operational). GOES-7 was last called into service to support the relay of operational weather data during the GOES-8 wheel tachometer failure in January 1997. GOES-7 is currently located over the Pacific to support data relay requirements for the University of Hawaii's Pan-Pacific Educational and Cultural Satellite (PEACESAT) Program as a replacement to GOES-2.

Due to a highly inclined geostationary orbit (approximately 12E), GOES-3 is currently able to support data relay requirements to the South Pole Station for the National Science Foundation (NSF). GOES-3 no longer has any remaining imaging capabilities.

On May 5 and after 24 years of service, GOES-2 was placed in to a super-synchronous orbit (186 km above geo-synchronous) and is no longer operating.