CGMS-50-NOAA-WP-11
1 June 2022

Prepared by NOAA
Agenda Item: 1
For information to Plenary

STATUS OF NOAA CURRENT AND FUTURE SATELLITE PROGRAMS – REPORT TO CGMS-50

Executive Summary

This document summarizes the status of NOAA current and future LEO and GEO satellite systems. The reporting period for the current satellite operations is May 1, 2021 to April 30, 2022. For future satellites, progress to date at the time of writing is included.

Current satellite programs cover the status of the spacecraft, ground segment, space weather effects, and data transmission.

Future satellite programs cover the mission objectives (spacecraft, payload, instruments, products) and program status (space, system and ground segments).

CGMS is invited to take note.

1 INTRODUCTION

This paper reports on the status of NOAA current and future satellite systems. The reporting period for current satellite operation is 1 May, 2021 to 30 April 2022. For future satellites, progress to date at the time of writing is included.

2 STATUS OF CURRENT GEO SATELLITE SYSTEMS

Sector	**Satellites in orbit** P= pre-operational Op=operational B=back-up L=limited availability	**Location**	**Launch Date**	**Details on near real time access to L0- L1 data (links)**	**Environmental payload and status**
GOES-West	GOES-17 (Op)	137.2°W	03/01/2018	http://www.ospo.noaa.gov/Organization/About/access.html	All payloads are operational
GOES-East	GOES-16 (Op)	75.2°W	11/19/2016	http://www.ospo.noaa.gov/Organization/About/access.html	All payloads are operational
Standby	GOES-14 (B) GOES-15 (Storage)	105°W 128°W	06/27/2009 03/04/2010	http://www.ospo.noaa.gov/Organization/About/access.html	Backup for GOES-East and GOES-West
Checkout	GOES-18 (P)	89.5°W (136.8°W)	03/01/2022	http://www.ospo.noaa.gov/Organization/About/access.html	Commissioning

2.1 Mission objectives, payload/instruments, products

The goals of the Geostationary Operational Environmental Satellite (GOES) system program are to:

- Maintain continuous, reliable, operational, environmental, and storm warning systems to protect life and property
- Monitor the earth's surface and space environmental conditions
- Introduce improved atmospheric and oceanic observations as well as data dissemination
- Develop and provide new and improved applications and products for a wide range of federal agencies, state and local governments, and private users

The GOES system functions to accomplish an environmental mission serving the needs of operational meteorological, space environmental, and research users.

- Warnings to U.S. public – detect, track, and characterize - hurricanes, severe storms including flash floods, and winter cyclones
- Imagery for weather forecasting
- Derived products for analysis and forecasting – surface temperatures, wind for aviation and NWS numerical models, sounding and radiances for NWS models, air quality, and rainfall estimates
- Environmental data collection – platforms including buoys, rain gauges, river levels, and ecosystem monitoring

2.2 Status of spacecraft

GOES-18

GOES-18 launched on March 1, 2022. It is currently in post-launch checkout at 89.5°W. It is planned to go into operational service as GOES-West, replacing GOES-17, in early 2023 near 137 °W.

GOES-17

GOES-17, launched on March 1, 2018. GOES-17 is located at 137.2°W, as GOES-West since February 12, 2019. GOES-17 had an ABI performance issue due to the instrument's cooling system. A great deal of progress has been made to optimize the performance of the GOES-17 data and the instrument is currently delivering over 94% of the data.

GOES-16

GOES-16 was launched on November 19, 2016. It has been located at 75.2°W, as GOES-East since December 18, 2017. All of the GOES-16 payload instruments are nominal.

GOES-15

GOES-15, launched on March 4, 2010, and is located at 128°W, as standby spacecraft. Yaw-flip maneuver is required at equinox to mitigate Sounder temperature control blanket anomaly. Star tracker 1 failed in 2014 and star tracker 2 failed in 2015 so that GOES-15 is operating with single star tracker. GOES-15 SXI and XRS are backup instruments for the Space Weather Prediction Center (SWPC).

GOES-14

GOES-14, launched on June 27, 2009, is located at 105°W, as the standby spacecraft. GOES-14 had provided short term GOES-East services while GOES-13 was recovering from anomalies. GOES-14 is in normal configuration, instead of storage mode configuration, to provide quick services as a backup. All of the GOES-14 payload instruments are nominal.

2.3 Ground segment matters

The availability of the GOES ground systems was nominal in the reporting period. There are three GOES-R antennas at the Wallops Command and Data Acquisition Station (WCDA) in Wallops, Virginia, and the Consolidated Backup Facility (CBU) in Fairmont, West Virginia, have been tested and certified for GOES NOP operations. Four antennas at the NOAA Satellite Operations Facility (NSOF) in Suitland, Maryland, were upgraded to serve both GOES NOP and GOES-R series satellites.

2.4 Data transmission

Data transmission for GOES NOP is handled through the Processed Data Relay (PDR) direct broadcast service in the GOES Variable (GVAR) transmission format. The GOES-R series GOES Rebroadcast (GRB) is primary relay of full resolution, calibrated, near-real-time direct broadcast space relay of Level 1b data from each instrument and Level 2 data from the Geostationary Lightning Mapper (GLM). The Environmental Satellite Processing Center (ESPC) collocated with the NSOF also provides data directly to users, including the National Weather Service and field users

3 STATUS OF CURRENT LEO SATELLITE SYSTEMS

Orbit Type ECT=Equator Crossing Time (for sun-synchronous orbits)	**Satellites in orbit** P= pre-operational Op=operational B=back-up L=limited availability	**Equator Crossing Mean Local Time First Ascending Node**	**Mean altitude**	**Launch Date**	**Details on near real time access to L0/L1 data (links)**	**Instrument payload and status**
Polar, non-SSO	JASON-3 (OP)	N/A	1336 km	Jan 17, 2016	http://www.ospo.noaa.gov/Organization/About/access.html	All Green: Poseidon-3B Altimeter, DORIS, AMR-2, GPSP, LRA, CARMEN-3, LPT
Polar, SSO, Afternoon	NOAA-20	13:25	834 km	Nov 18, 2017	http://www.ospo.noaa.gov/Organization/About/access.html	VIIRS, ATMS, CrIS, CERES, OMPS
Polar, SSO, Afternoon	Suomi-NPP (Op)	13:25	833 km	Oct 28, 2011	http://www.ospo.noaa.gov/Organization/About/access.html	VIIRS, ATMS, CrIS, CERES, OMPS
Polar, SSO	NOAA-19 (Op)	19:42 as of 4/24/2022	870 km	February 6, 2009	http://www.ospo.noaa.gov/Organization/About/access.html	MHS, AVHRR are Yellow, AVHRR, AMSU-A1/2, ADCS, SEM and HIRS, SBUV, APT are Green

cont.

Orbit Type ECT=Equator Crossing Time (for sun-synchronous orbits)	**Satellites in orbit** P= pre-operational Op=operational B=back-up L=limited availability	**Equator Crossing Mean Local Time First Ascending Node**	**Mean altitude**	**Launch Date**	**Details on near real time access to L0/L1 data (links)**	**Instrument payload and status**
Polar, SSO	NOAA-18 (Op)	22:11 as of 4/24/2022	854 km	May 20, 2005	http://www.ospo.noaa.gov/Organization/About/access.html	HIRS, MHS, and SBUV are Red, SEM is yellow, and AVHRR, AMSU-A1/2, APT, DCS are Green
Polar, SSO	NOAA-15 (Op)	19:29 as of 4/24/2022	813 km	May 13, 1998	http://www.ospo.noaa.gov/Organization/About/access.html	AMSU-B are red, HIRS is yellow, AVHRR, AMSU-A1, SARR, SEM are Yellow, and AMSU-A2, and DCS, and APT are Green.

3.1 Mission objectives, payload/instruments, products

The POES spacecraft constellation is composed of three satellites that provide mission data services and observation coverage. These spacecrafts are in near circular orbits inclined at approximately 98 degrees (retrograde), allowing them to maintain a constant sun angle as they pass a point on earth (making detection of changed conditions easier). NOAA's primary afternoon operational spacecraft, NOAA-20, was launched on November 18, 2017, declared operational in May 2018. One of NOAA's previous primary satellites, NOAA-19 (launched in Feb 2009), remains the primary PM satellite only for services such as SARSAT and the Argos Data Collection System (collecting data from small remote environmental transponders worldwide). Two of the residual spacecrafts, NOAA-18 and NOAA-15 provide additional payload data and observational capability. In April 2013, NOAA declared EUMETSAT's Metop-B as NOAA's mid-morning primary operational spacecraft.

3.2 Status of spacecraft

NOAA-20

The Joint Polar Satellite System-1 (JPSS-1) was successfully launched and reached polar orbit on November 18, 2017, resulting in its re-designation as NOAA-20. A successful Post-Launch Acceptance Review and Handover Readiness Review were conducted by NASA and NOAA on March 6 and 7, 2019, and the spacecraft and its operations were transferred to NOAA's Office of Satellite and Product Operations. NOAA-20 is part of the Joint Polar Satellite System as one of the next generations of weather satellites. It is operating advanced instruments such as the Visible Infrared Imaging Radiometer Suite (VIIRS), the Advanced Technology Microwave Sounder (ATMS), the Cross-track Infrared Sounder (CrIS), the Clouds and the Earth's Radiant Energy System (CERES), and the Ozone Mapping and Profiler Suite (OMPS) and is contributing to the continuity of observations that are critical for environmental monitoring and prediction. The vehicle and instruments are all operating within specifications. As of February 12, 2019, NOAA-20 is serving as the Primary PM operational satellite.

S-NPP

Suomi National Polar-orbiting Partnership (S-NPP) was launched on Oct 28, 2011, and operated as the Primary PM Weather satellite from May 1, 2014, until February 12, 2019. S-NPP is the precursor of the Joint Polar Satellite System. It is operating advanced instruments such as the Visible Infrared Imaging Radiometer Suite (VIIRS), the Advanced Technology Microwave Sounder (ATMS), the Cross-track Infrared Sounder (CrIS), the Clouds and the Earth's Radiant Energy System (CERES), and the Ozone Mapping and Profiler Suite (OMPS), which have revolutionized forecasters' ability to make longer range forecasts. The vehicle and instruments are all operating within specifications except the CrIS instrument is only providing longwave and shortwave IR information due to a digital signal processor issue.

NOAA-19

NOAA-19, launched in February 2009, remains the primary NOAA polar environmental satellite for SARSAT and Argos Data Collection System (NOAA-20 is the primary environmental data satellite in the PM orbit). Along with Metop satellites, it operates the Advanced Very-High-Resolution Radiometer (AVHRR), the High-resolution Infrared Radiation Sounder (HIRS), the Advanced Microwave Sounding Unit (AMSU) A, the Microwave Humidity Sounder (MHS, in place of the AMSU-B), the Solar Backscatter Ultraviolet Instrument (SBUV/2), and the Space Environment Monitor (SEM), as well as SARSAT and the Argos Advanced Data Collection System (ADCS), improved over the version in older satellites. NOAA-19's instruments are fully functional, with the exception of its HIRS and MHS payloads, which are operating in a degraded mode.

NOAA-18

NOAA-18, launched in May 2005, is currently a secondary PM polar environmental satellite. Along with Metop satellites, it is operating the Advanced Very-High-Resolution Radiometer (AVHRR), the High-resolution Infrared Radiation Sounder (HIRS), the Advanced Microwave Sounding Unit (AMSU) A, the Microwave Humidity Sounder (MHS, in place of the AMSU-B), the Solar Backscatter Ultraviolet Instrument (SBUV/2), and the Space Environment Monitor (SEM), as well as SARSAT and the Argos Data Collection System (DCS) payloads. NOAA-18's instruments are mostly fully operational, though the SBUV/2, MHS and HIRS are inoperative. SAR and Argos DCS payloads are both fully functional.

NOAA-15

NOAA-15, launched in May 1998, is currently a secondary AM polar environmental satellite, along with Metop-A/B. Along with the Metop satellites, it is operating the Advanced Very-High-Resolution Radiometer (AVHRR), the High-resolution Infrared Radiation Sounder (HIRS), the Advanced Microwave Sounding Unit (AMSU) A and B, and the Space Environment Monitor (SEM). Most of the instruments are operating in a degraded mode, with the HIRS and AMSU-B non-operational and the SEM and AMSU-A2 units remaining fully operational. At 20+ years old, it is the oldest of the NOAA satellites. NOAA-15 also carries a SARSAT payload, as well as the Argos DCS payload. The SAR unit on NOAA-15 is operating in a degraded mode and the Argos DCS payload is fully operational.

3.3 Data transmission

Data transmission for POES is handled through the Environmental Satellite Processing Center (ESPC) collocated with the NOAA Satellite Operations Facility at Suitland, Maryland. Data is provided to users, including the National Weather Service, through the ESPC, and to field users directly through the High Resolution Picture Transmission (HRPT) direct broadcast service. S-NPP and NOAA-20 utilize the NPP Data Exploitation (NDE) / Product Distribution and Access (PDA) and the Interface Data Processing Segment to ingest and distribute products to users worldwide as well as High Resolution Data (HRD) direct broadcast service

4 STATUS OF ADDITIONAL CURRENT LEO SATELLITE SYSTEMS

Orbit Type	Satellites in orbit P= pre-operational Op=operational B=back-up L=limited availability	Mean altitude	Launch Date	Details on near real time access to L0/L1 data (links)	Instrument payload and status
Low-orbit, 24º inclination, non-SSO	COSMIC-2	520 km	June 25, 2019	https://www.cosmic.ucar.edu/what-we-do/cosmic-2/data/	All six TGRS instruments are Green. Neutral atmosphere products assimilated into NWS GFS in May 2020 and other global weather prediction centers

4.1 Mission objectives, payload/instruments, products

FORMOSAT-7/COSMIC-2 is a joint U.S.-Taiwan satellite mission being conducted under an agreement between the American Institute in Taiwan (AIT) and the Taipei Economic and Cultural Representative Office in the United States (TECRO). NOAA is AIT's designated representative, and the National Space Organization (NSPO) is TECRO's designated representative. The objective is to continue collecting data similar to FORMOSAT-3/COSMIC mission (decommissioned in May 2020) with important technology advances. The objective of the FORMOSAT-7/COSMIC-2 mission is to demonstrate an operational constellation for the continuous and uniform collection of atmospheric and ionospheric data as inputs to daily near-real-time weather forecasts, space weather research, and climate change studies. For operational numerical weather prediction and space weather monitoring, the Radio Occultation (RO) data profiles from the reliable global constellation system will number approximately 4,000 profiles on average per day.

The 6 FORMOSAT-7/COSMIC-2A satellites launched into low earth parking orbits with altitude of 720 km and inclination of 24º on June 25, 2019. Each FORMOSAT-7/COSMIC-2 satellite carries one primary mission payload, called the TriG Global Navigation Satellite System (GNSS) Radio Occultation (RO) System (TGRS) which tracks GNSS signals and infers the deviations in each signal's straight-line path caused by temperature, pressure, moisture and electron density gradients.

The six equatorial satellites also each carry two U.S. secondary science payloads. The Ion Velocity Meter (IVM) measures in-situ plasma properties using a series of apertures mounted on the ram-facing side of the low-inclination satellites. The IVM also measures the background ionospheric density, ion composition, and ion temperature for ionospheric modelling research.

The Radio Frequency Beacon (RFB) measures the ionospheric scintillation by transmitting phase coherent signals in UHF, L-Band and S-Band RF which are received by ground-based receivers. The ground receivers also measure the ionospheric total electron content (TEC) along the ground receiver-satellite line of sight during satellite contacts. The RFB ground receivers were established by the USAF and by NSPO at ancillary sites.

4.2 Status of spacecraft

The six COSMIC-2 spacecraft completed orbit lowering in February 2021 and are now in their final, evenly spaced mission orbits. The Neutral atmosphere observations are now available through the WMO Global Telecommunications System (GTS) and are used operationally by several Numerical Weather Prediction Centers including at NOAA and ECMWF. The Ionospheric products have been validated and are operational at the USAF 557th Weather Wing, and will be in operational use at NOAA SWPC this fall.

4.3 Ground segment matters

For satellites in the low-inclination orbit, ten (10) receiving stations are strategically placed around the equator in Taiwan, Hawaii, Honduras, Guam, Kuwait, Australia, Brazil, Ghana, Tahiti, and Mauritius Island. The NSPO Satellite Operations Control Center (SOCC) provides command and control of the COSMIC-2 constellation.

The Mark IV-B antennas in Hawaii, Honduras, Guam, and Kuwait are provided by the U.S. Air Force. The Australian Bureau of Meteorology (BoM) provides an antenna in Darwin. The Brazil National Institute of Space Research (INPE) operates an antenna at their facility in Cuiaba, Brazil.

NSPO provides antennas in Taiwan as part of the FORMOSAT-7/COSMIC-2 mission. Mauritius antenna services are provided to NOAA under a Program Implementation Plan with the Norwegian Space Centre, and NOAA has contracted for antenna services in Ghana and Tahiti. The Ghana and Mauritius Island ground sites now provide backup commanding capability.

4.4 Data transmission

The data collected by FORMOSAT-7/COSMIC-2 are downlinked to the tracking stations and then transferred to the U.S. Data Processing Center (USDPC) at UCAR as well as to the Taiwan Data Processing Center (TDPC). The TDPC is the mirror site of the USDPC to serve the users in Taiwan. Several "Day In the Life" (DITL) tests have been completed to demonstrate readiness of the various components of the ground system. These DITL tests have successfully verified the data transmission from the ground antenna sites through the USDPC to the end users at NOAA/NWS.

The main objective of the USDPC is to process all raw mission science data into Environmental Data Record (EDR) products, disseminate the data for operational use by weather and space weather forecast centers and for research by the broad atmospheric science community. The USDPC processes the mission science data in a near real-time mode for operational applications, within 8 weeks of observation in a post-processing mode, and in a re-processing (re-analysis) mode every 2-3 years with consistent software algorithms. The USDPC serves as a complete mission data analysis center for the FORMOSAT-7/COSMIC-2 mission.

4.5 Projects, services

COSMIC-2 data is available for operational use through the WMO GTS. UCAR also provides service to the scientific community through UCAR Data Processing Center https://cdaac-www.cosmic.ucar.edu

5 STATUS OF CURRENT OTHER SATELLITE SYSTEMS

Sector	Satellites in orbit P=pre-operational Op=operational B=back-up L=limited availability	Location	Launch date	Details on near real time access to L0/L1 data (links)	Instrument payload and status

L-1	DSCOVR (Op)	L-1, Lagrangian Point	2/11/2015	http://www.ospo.noaa.gov/Organization/About/access.html http://epic.gsfc.nasa.gov/	Space weather instruments - operational, nominal; terrestrial instruments (EPIC and NISTAR) - nominal; DSCOVR officially returned to active service on 2 Mar 2020 with a flight software update to the attitude control system - the system is nominal and operational

5.1 Mission objectives, payload/instruments, products

The DSCOVR mission monitors solar wind activity from L1 in order to provide early warning for Earth orbiting satellites and ground-based systems that are susceptible to disturbances in solar wind. The PlasMag instrument, which includes a Magnetometer, Faraday Cup (FC), and Electrostatic Analyzer (ESA), collects the solar wind data for downlink to SWPC. The data is downlinked 24/7 through NOAA’s ground stations (WCDA, FCDA) and Real Time Solar Wind Network (RTSWNet) around the globe.

Additionally, DSCOVR collects Earth observations from a pair of Earth-pointing instruments; the Earth Polychromatic Imaging Camera (EPIC) and U.S. National Institute of Standards and Technology (NIST) Advanced Radiometer (NISTAR).

5.2 Status of spacecraft

DSCOVR spacecraft is operational with all instruments operating as intended. DSCOVR was placed in safe-hold due to life limiting issues associated with Z-axis laser gyro in April 2019 and flight software modifications were deployed in January 2020 to utilize star tracker for attitude determination - in early March 2020 DSCOVR resumed full operations. SWPC switched operations from ACE to DSCOVR on July 27, 2016. ACE is still being utilized as back-up.

5.3 Ground segment matters

NESDIS currently does not have any ground segment matters to report.

5.4 Data transmission

DSCOVR Space weather data are collected through NOAA's CDAS (Command and Data Acquisition System) and RTSWNet (Real Time Solar Wind Network) and distributed to U.S. and international users by the NOAA National Weather Service’s Space Weather Prediction Center (SWPC). Terrestrial data and images are distributed by NASA's DSCOVR Science Operations Center (DSOC).

5.5 Projects, services

EPIC images are provided to public through the following web link: http://epic.gsfc.nasa.gov/

6 STATUS OF FUTURE GEO SATELLITE SYSTEMS

Sector	Satellites in orbit P=pre-operational Op=operational B=back-up L=limited availability	Location	Launch date	Details on near real time access to L0/L1 data (links)	Environmental payload and status
TBD	GOES-U (P)	TBD	April 2024	http://www.goes-r.gov/resources/docs.html	ABI, EXIS, SUVI, SEISS, MAG, GLM, CCOR

6.1 Mission objectives, spacecraft, payload/instruments, products

The GOES-R series is NOAA's next generation of satellites within the GOES Mission. The GOES-R series significantly improves the detection and observation of environmental phenomena that directly affect public safety and the protection of property. The satellites provide advanced imaging with increased spatial resolution and faster coverage for more accurate forecasts, real- time mapping of lightning activity, and improved monitoring of solar activity.

The GOES-R series is a four-satellite program (GOES-R/S/T/U) extending the availability of the operational GOES satellite system through 2036. When fully operational, the GOES-R series consists of two satellites at 75 degrees west and 137 degrees west longitude and a spare satellite.

The Space Segment consists of the spacecraft, instruments, auxiliary communications payloads, and launch vehicle. The primary instrument is the Advanced Baseline Imager (ABI) that will provide hemispheric, synoptic, and mesoscale imagery for global and CONUS forecasting and severe weather warning. Secondary instruments include the Extreme ultraviolet and X-ray Irradiance Sensor (EXIS), Solar Ultraviolet Imager (SUVI), Space Environment In-Situ Suite (SEISS), Magnetometer (MAG), and Geostationary Lightning Mapper (GLM). The GOES-U spacecraft will also include a Compact Coronagraph (CCOR) instrument. Additionally, GOES-R will provide a set of communications services (Unique Payload Services) in support of the Data Collection System (DCS), High-Rate Information Transmission and Emergency Managers Weather Information Network (HRIT/EMWIN) and Search-and-Rescue Satellite Aided Tracking (SARSAT), GOES-R will make available 34 meteorological, solar and space weather products. Additional products will be made available over time. Additional information about the baseline and planned future products is available at: http://www.goes-r.gov/products/overview.html

The first GOES-R series satellite (GOES-16) has been operational at the 75.2 degrees west longitude location since December 2017 and is now designated GOES-East. The second GOES-

R series satellite (GOES-17), which was launched on March 1, 2018, has been operational at the 137.2 degrees west longitude location since February 2019 and is now designated GOES-West.

GOES-Twas launched on March 1, 2022 and is currently in operational check-out. . Both GOES-T and GOES-U carry the Goddard Magnetometer, which is a change from GOES-16 and -17.

The GOES-U satellite is nearly integrated and preparing for an environmental test in preparation for its planned launch in April 2024. The GOES-U spacecraft will include the addition of a new instrument, a compact coronagraph (CCOR).

Geostationary Extended Observations (GeoXO)

NOAA has recently initiated formulation for the Geostationary Extended Observations (GeoXO), program, the satellite series that will follow GOES-R. GeoXO completed the Mission Concept Review in June 2021, the Key Decision Point A in July 2021, and the Milestone 1 decision point in November 2021. At these reviews, the program proposed a constellation of three satellites: East and West satellites, at 75W and 137W longitude respectively, will carry an Imager, Lightning Mapper, and Ocean Color instrument. An additional Center satellite at 105W will manifest a Sounder and Atmospheric Composition instrument. The East and West satellites will provide DCS relay capability. Other rebroadcast functions are planned to be accomplished with commercial communications satellites. GeoXO is currently working toward the Milestone 2 decision in December 2022, which will officially approve the program as well as authorize the major acquisitions. The first GeoXO launch is planned for 2032.

6.2 Ground segment

The GOES-R ground system receives the raw data from GOES-R series spacecraft and generates Level 1b and Level 2+ products. The ground system also makes these products available to users in a timely manner consistent with the GOES-R latency requirements. Level 1b data from each instrument and Level 2+ data from the Geostationary Lightning Mapper (GLM) is distributed to direct readout users with antenna receivers by means of spacecraft relay as GOES Rebroadcast (GRB). Level 1b products and Level 2+ products are provided to the Product Distribution & Access (PDA) System for users.

The Ground Segment (GS) operates from three sites. The first is the NOAA Satellite Operations Facility (NSOF). NSOF is responsible for the primary Mission Management (MM) functions which include: Tracking, Telemetry, and Command (TT&C), Product Generation (PG), and Product Distribution (PD) functions of Level 2+ products. The Wallops Command and Data Acquisition Station (WCDAS) in Wallops Island, Virginia provides space communications services and Level 1b product generation. The third site is a geographically isolated Consolidated Backup Facility (CBU) located at Fairmont, West Virginia. It functions as a completely independent backup for designated MM, PG and PD functions for the production and delivery of Level 1b, Key Performance Parameters (KPPs), and GOES Rebroadcast (GRB) data and is capable of remote operation from NSOF and WCDAS. The CBU has visibility to all operational and on-orbit spare satellites. The Enterprise Management (EM) function lies over all ground segment components and locations.

The PD functionality provides for direct distribution of GOES-R product data to the National Weather Service (NWS) Advanced Weather Interactive Processing System (AWIPS) and the Environmental Satellite Processing Center (ESPC). The Environmental Satellite Processing and Distribution System (ESPDS), Product Distribution and Access (PDA) within ESPC receives GOES-R data and distributes the data to users and to the Comprehensive Large Array-data Stewardship System (CLASS). ESPDS and CLASS are co-located at the Environmental Satellite Processing Center (ESPC) at NSOF. CLASS provides long-term archive and access services to retrospective users of GOES-R data. The CLASS system is considered external to the GOES-R Ground Segment and is part of the NOAA infrastructure interface.

The Ground System has been supporting both GOES-16 (GOES-East) and GOES-17 (GOES-West) since their respective launches. The responsibility for operation of GOES-16 was handed over from the GOES-R Series Program to the Office of Satellite and Product Operations (OSPO) in June of 2017, and the responsibility for operation of the GOES-17 was handed over to OSPO in October 2019.

6.3 Data Transmission

The GOES-R communication system supports the higher volume of data and services by using X-band communication links. Data handling efficiency is improved over current missions by using Consultative Committee for Space Data Systems (CCSDS) encoding for raw instrument, telemetry, and command links. CCSDS permits diverse data types to be routed to appropriate applications without intermediate processing and delays associated with unpacking packet contents, while taking advantage of error detection and correction properties inherent in CCSDS design. A precision pointing bus is used to meet instrument pointing and stability requirements. The GOES-R series further improves on the altitude control and image navigation capability of the current missions. Image Navigation and Registration (INR) on GOES–R differs from the previous series in a number of ways. GOES–R has a new allocation of INR responsibility, tighter INR performance requirements, and a new approach to achieving those requirements.

To support the large increase in spatial, spectral, and temporal resolution of the ABI and other instruments, the raw data rate has been increased to an equivalent 31 Mbps. GOES-R data volume drives a large increase in processing requirements for product generation and for distribution of the products to users. Product processing accounts for a much greater part of the GOES-R life cycle cost than the legacy system.

The GOES-R system has a much greater product distribution capability over the legacy missions. The full set of Level 1b instrument data is provided in real time through the GRB link and the Level 2+ products are provided via network services. The Ground Segment has been designed with open and expandable architecture so that additional instrument management and data processing requirements may be accommodated without affecting existing capabilities.

GOES-R data and products are distributed by two primary categories, internal and external interfaces.

There are two primary internal data transport mechanisms: space-based relay through the GRB rebroadcast service, and telecommunications networks. There are two types of external interfaces, which are the GOES-R Access Subsystem (ESPDS PDA) and the National Weather Service interface which allow external user access to the GOES-R System data. ESPDS PDA also distributes GOES-R data to the CLASS system for external long-term storage, archival, and access.

7 The Status of future LEO satellite systems

ECT=Equator Crossing time (for sun-synchronous orbits)	Satellites in orbit P=pre-operational Op=operational B=back-up L=limited availability	Equator Crossing Time (ECT) ascending node	Mean altitude	Launch date	Details on near real time access to L0/L1 data (links)	Environmental payload and status
1330	JPSS-2 (P)	1330	824	2022	http://www.ospo.noaa.gov/Organization/About/access.html	ATMS, CrIS, VIIRS, OMPS-N, RB
1330	JPSS-3 (P)	1330	824	2027	http://www.ospo.noaa.gov/Organization/About/access.html	ATMS, CrIS, VIIRS, OMPS-N, RB
1330	JPSS-4 (P)	1330	824	2031	http://www.ospo.noaa.gov/Organization/About/access.html	ATMS, CrIS, VIIRS, OMPS-N, RB

7.1 Mission objectives, spacecraft, payload/instruments, products

The Joint Polar Satellite System (JPSS) is the new generation of the United States' Polar-orbiting Operational Environmental Satellites (POES) in the early afternoon sun-synchronous orbit of 13:30. JPSS contributes to NOAA's missions to enable a weather ready nation; healthy oceans; climate adaptation and mitigation; and resilient coastal communities and economies by providing timely and global space based weather and environmental phenomena observations for forecasts, monitoring, and impact assessment. The Joint NOAA/National Aeronautics and Space Administration (NASA) Suomi-National Polar Partnership (S-NPP) mission is the first of the JPSS missions and was launched on October 28, 2011 with an inclination angle of 98.79 degrees and an altitude of about 833 km.

The most important function of polar orbiting operational weather satellites is to feed Numerical

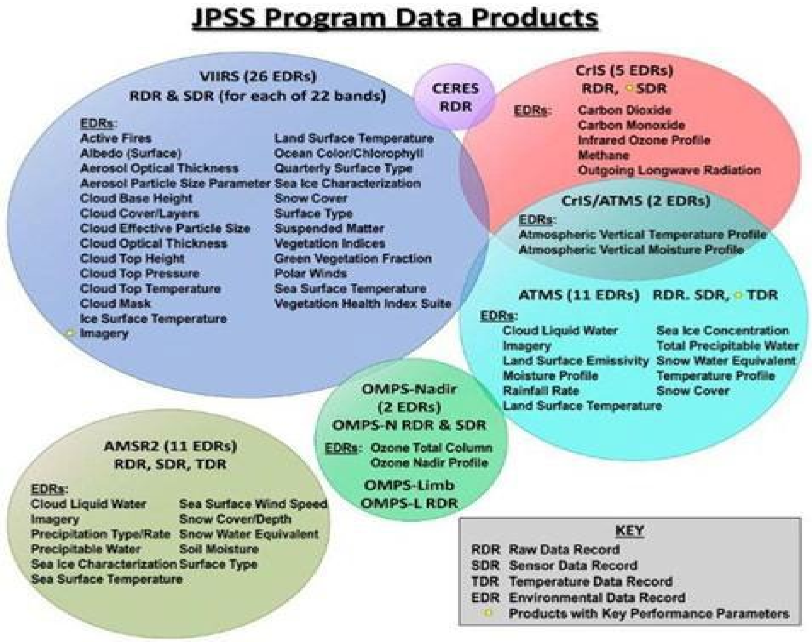
Weather Prediction (NWP) models with global three-dimensional structures of atmospheric temperature and moisture and other parameters that enable increased forecast skill to produce three to seven day-ahead forecasts of impending severe weather, critical to the protection of life, property and economic efficiency. Approximately 85% of all the input data used in NWP global and regional models comes from polar orbiting satellites. Polar orbiters also provide visible, infrared, and microwave imagery, which are the primary observations for situational awareness for Alaska and other regions in proximity to the Arctic and Antarctic. The polar-orbiting capabilities are also important for a wide variety of specialty forecast and monitoring functions such as ozone, aerosols, ice, volcanic ash, wildfires, floods, droughts, vegetation health, algal blooms, and sea surface temperature.

Data from instruments in polar sun-synchronous instruments have provided more than 35 years of continuous observations that have allowed scientists to monitor the climate. These data support modelers, scientists and decision makers concerned with advancing the understanding of global weather dynamics, prediction, mitigation and adaptation strategies, and policies.

JPSS was announced in February 2010 as part of the President's Fiscal Year 2011 President's budget request to be the civilian successor to the National Polar-orbiting Operational Environmental Satellite System (NPOESS). The JPSS program completed formulation in July 2013 with a formal baseline establishing requirements, budget, and top level schedules, to include continued operations and sustainment of the S-NPP development operations and sustainment of JPSS-1 and JPSS-2 missions through September 2028, and sustainment of ground segment capabilities necessary to perform these missions. Polar Follow-On Missions, JPSS-3 and JPSS-4, were approved in 2016 to extend JPSS' capabilities to at least 2038. Each satellite is launched approximately every 5 years with a design life of 7 years. JPSS-1, now designated NOAA-20, was successfully launched November 17, 2017, into the 1330 orbit, separated from S/NPP by one-half orbit (i.e. 50 minutes separation) to maximize the impact on applications.

JPSS hosts five instruments, the Advanced Technology Microwave Sounder (ATMS), the Cross Track Infrared Sounder (CrIS), the Visible Infrared Imaging Radiometer Suite (VIIRS), the Ozone Monitoring and Profiler Suite (OMPS), and an earth radiation budget instrument. The ATMS, CrIS, VIIRS and OMPS Nadir comprise the NOAA provided weather instrument complement. NASA provides the OMPS Limb sensor starting with JPSS-2. S-NPP was developed as a partnership between NASA and NOAA, with NASA providing the spacecraft, ATMS, Clouds and Earth's Radiant Energy Sensor (CERES) radiation budget instrument, and launch; while NOAA provided the CrIS, VIIRS, OMPS Nadir and Limb, the ground and operations. JPSS-1 does not include the OMPS limb, and hosts a NOAA provided CERES radiation budget instrument.

Below figure provides a list of data products:



8 STATUS OF ADDITIONAL FUTURE LEO SATELLITE SYSTEMS

ECT=Equator Crossing time (for sun-synchronous orbits)	**Satellites in orbit** P=pre-operational Op=operational B=back-up L=limited availability	**Equator Crossing Time (ECT) ascending node**	**Mean altitude**	**Launch date**	**Details on near real time access to L0/L1 data (links)**	**Environmental payload and status**
1730	Argos-4 Hosted Payload Solution (HoPS)	1730	750	2022	N/A https://www.nesd is.noaa.gov/OPP A/argos-adcs.php	Argos-4 (“A-DCS”)

8.1 Mission objectives, spacecraft, payload/instruments, products

NOAA/NESDIS is managing the integration, launch, and operation of an Argos Data Collection System (Argos-4) instrument. The Argos-4 instrument is provided under international agreement with the French space agency Centre National d’Etudes Spatiales (CNES).

NESDIS is utilizing the US Air Force Hosted Payload Solution (HoPS) contract to provide a commercial payload hosting solution for the Argos-4 instrument.

The Argos system provides worldwide coverage with the unique ability to independently locate a data source from anywhere on earth. The Argos-4 HoPS mission will collect, process and disseminate environmental data from fixed and mobile platforms worldwide. Each month, Argos provides key environmental data from more than 15,000 active Argos platforms globally.

Argos-4 HoPS is planned for a 2022 launch, for a five-year mission.

9 STATUS OF DEEP SPACE MISSIONS

Sector	Satellites in orbit P=pre-operational Op=operational B=back-up L=limited availability	Location	Launch date	Details on near real time access to L0/L1 data (links)	Instrument payload and status
L-1	Space Weather Follow-On (SWFO) (P)	L-1, Lagrangian Point	2025	http://www.ospo.noaa.gov/Organization/About/access.htm	In final design and fabricationphase (Phase C)

9.1 MISSION OBJECTIVES, SPACECRAFT, PAYLOAD/INSTRUMENTS, PRODUCTS

This section outlines NOAA's plans for the Space Weather Follow On (SWFO) program focusing on its future deep-space mission at Lagrange 1 (L1), SWFO-L1.

Prediction of Space Weather Effects

In-situ measurements of solar wind in the Earth-Sun line provide the sole input for short-term (15-60 minutes) warnings of geomagnetic storms and are widely regarded as the single most important operational space weather capability. The current solar wind continuity program consists of DSCOVR (discussed in Section 5 above) and NASA's ACE. DSCOVR was launched in February 2015 and was designed for a two-year mission with five years of fuel. ACE was launched in 1997, is currently operating well beyond its five-year mission life, and it is fuel-limited to 2026. Thus, there is a high probability of a gap in solar wind data in the near future, which will significantly reduce NOAA's ability to warn of impending space weather storms.

Coronal Mass Ejection (CME) imagery is another critical observation used by SWPC forecasters and their models. CME images are a required input to advanced models for 1- to 4-day advanced warnings for the onset, intensity, and duration of geomagnetic storms. The current CME imagery continuity program consists of the joint NASA/European Space Agency (ESA) Solar and Heliospheric Observatory (SOHO) launched in 1995 and currently operating well beyond the planned three-year mission life. Due to the degradation of its solar panels SOHO is not expected to have adequate power after 2025. Once more, there is a high probability of a gap in CME imagery in the near future, which will cripple NOAA's ability to issue watches of space weather storms.

Programmatic Objectives

Given the multifaceted and urgent need for accurate space weather prediction and the fact that its major events recur at monthly and multi-annual time scales, the federal government has developed a systematic plan of action. The Office of Science and Technology Policy (OSTP) of the White House has formulated a comprehensive strategy for dealing with space weather as well as a plan of action which requires coordination among government agencies and with other stakeholders [NSTO, 2015 a, b, updated 2019]. Space weather effects have been documented, and in several cases explained and predicted, over the 6 decades that humans have undertaken activities in space. The science community has identified several chains of events with most of them originating at the generally unpredictable solar environment. Recent summaries of research findings include several reports by the National Research Council (e.g., [NRC, 2008, 2014]). In collaboration with academia and industry, NOAA has studied the effects of space weather and summarized its findings in NOAA's Consolidated Observational User Requirements List (COURL) [OPPA, 2017].

Within NOAA's mission, space weather forecasting has become prominent, especially since the late 1990s. Thus NWS/SWPC provides forecasts and other alerts against damaging solar activity to a large customer base (the number of individual subscriptions to SWPC services has exceeded 55,000). SWPC provides forecasts, and various alerts (including watches and warnings) against damaging solar and other space activity. NESDIS, NOAA's planning and satellite operational arm, is responsible for developing new missions and operating them for the agency, users, and other stakeholders. NESDIS is responsible for program acquisition in partnership with NASA offices.

NESDIS has developed a space weather strategy to ensure continuity of SWPC forecasting capabilities for the space weather effects outlined above. The NESDIS primary space-weather goals include:

- Provide continuous 24/7 CME imagery to maintain SWPC's required operational effectiveness
- Provide continuous 24/7 data of key solar wind variables to SWPC. The variables include plasma density, bulk velocity, and temperature; vector magnetic field; and suprathermal proton flux at several energies.
- Continue to update and operate a robust space and ground architecture.

In advancing this strategy, NESDIS has recently developed the multifaceted SWFO program which aims to a) add SWFO-L1 to the monitoring spacecraft; and b) place a CCOR telescope on GOES-U so as to continue supplying coronal images and solar wind data essential in SWPC's forecasting capabilities.

Deep Space Mission

SWFO-L1 will operate at the L1 libration point with the objective of providing both coronal imaging and in situ measurements of the solar wind and its magnetic field, all of which are used by SWPC's forecasters and its numerical models. SWFO-L1 will carry the CCOR telescope with a field of view (FOV) of 3-22 Rsun. The CCOR units on GOES-U (section 6) and SWFO-L1 will complement each other to provide a robust and redundant system to provide continuous 24/7 CME imagery.

The spacecraft will also carry a Solar Wind Instrument Suite (SWIS) comprising a plasma instrument to measure the solar wind (Solar Wind Plasma Sensor, or SWiPS), a magnetometer (MAG), and an energetic particle detector (SupraThermal Ion Sensor, or STIS) all of which are specified to be similar to those of DSCOVR. Images of the Sun's corona will be generated at 15-minute intervals while solar wind variables will have a 5-minute cadence. There is an option for an instrument of opportunity which was completed in a NASA research program and will be announced in mid-2019.

SWFO-L1 is planned for launch in 2025 as a rideshare to NASA's Interstellar Mapping and Acceleration Probe (IMAP) mission to L1.

9.2 Mission Support and Program Schedule

Funding provided in Fiscal Years 2019-2022 and in the President's Fiscal Year 2023 Budget Request for NOAA requests support the SWFO Program in completing development of the three key technical components: 1) The Compact Coronagraph (CCOR); 2) the SWFO-L1 spacecraft; and 3) the accommodation of the second CCOR on GOES-U described in Section 6. In a summary schedule, the two CCOR instruments are scheduled for delivery in 2022; the GOES-U planned launch is in 2024 while the SWFO-L1 rideshare with NASA's IMAP is planned in 2025.

9.3 GROUND SEGMENT MATTERS

NOAA will utilize a number of ground station networks for telemetry and data acquisition for SWFO-L1 centered on NOAA's ground station network which includes the Wallops Command and Data Acquisition Station (WCDAS) at Wallops, Virginia, Fairbanks Command and Data Acquisition Station (FCDAS) at Fairbanks, Alaska, and the Consolidated Backup (CBU) facility at Fairmont, West Virginia. NOAA is also investigating the use of ground stations by other agencies (NASA, Air Force) and international partner organizations.

9.4 DATA TRANSMISSION

The coronal images and solar wind data acquired by SWFO-L1 and CCOR on GOES-U will be downlinked to the tracking station of the ground networks and then transferred to OSPO's NSOF. SWPC will process the data and images, generate data products, and distribute them directly to operational users. NCEI will archive data products and make them available to retrospective users.

10 CONCLUSIONS

This document summarizes the status of NOAA current and future satellite systems.

CGMS is invited to take note.