CGMS-46 NOAA-WP-01
May 2019

Prepared by NOAA
Agenda Item: D.5
For information to Plenary

STATUS OF NOAA CURRENT AND FUTURE SATELLITE PROGRAMS – REPORT TO CGMS-47

This document summarizes the status of NOAA current and future LEO and GEO satellite systems. The reporting period for the current satellite operations is 30 April 2018 to 30 April 2019. 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 30 April 2018 to 30 April 2019. 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
Storage	GOES-13 (**L**)	60ºW	05/24/2006		In storage
Standby	GOES-14 (B)	105ºW	06/27/2009	http://www.ospo.noaa.gov/Organization/About/access.html	Backup for GOES-East and GOES-West
Operational	GOES-15 (Op)	128ºW	03/04/2010	http://www.ospo.noaa.gov/Organization/About/access.html	All payloads are operational; providing temporary supplemental operations for GOES-West
GOES East	GOES-16 (Op)	75.2ºW	11/19/2016	http://www.ospo.noaa.gov/Organization/About/access.html	All payloads are operational
GOES-West	GOES-17 (Op)	137.2ºW	03/01/2018	http://www.ospo.noaa.gov/Organization/About/access.html	All payloads are operational

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
- **Space weather monitoring and forecasting**
- **Search and Rescue**

2.2 Status of spacecraft

GOES-13

GOES-13, launched on May 24, 2006 and was stationed at 75^{o}W as GOES-East from April 14, 2010 until December 18, 2017. It was moved to its current station at 60^{o}W in January 2018. 9 rows out of 512 Solar X-ray Imager (SXI) detectors were damaged due to a 2006 flare. X-ray Sensor (XRS) measurements are functioning but may invert unexpectedly. The Sounder filter wheel has stalled in November 2015. GOES-13 Imager is functioning nominally. Star tracker 3 failed in 2015. GOES-13 was commanded to storage mode configuration in February 2018.

GOES-14

GOES-14, launched on June 27, 2009, is located at 105^{o}W as 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. GOES-14 SXI and XRS are primary instruments for SWPC.

GOES-15

GOES-15, launched on March 4, 2010, and is on station at 128^{o}W providing temporary supplemental operations for GOES-West since February 12, 2019. Yaw-flip manoeuvre 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 SWPC.

GOES-16

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

GOES-17

GOES-17, launched on March 1, 2018, is located at 89.5^{o}W. GOES-17 is located at 137.2^{o}W, and is operating as GOES West since February 12, 2019.

2.3 Impact on spacecraft due to space weather

Space weather related spacecraft anomalies (Items in bold are required)

Source: Recommendations for Contents of Anomaly Database for Correlation with Space Weather Phenomena, P. O'Brien, J.E. Mazur, T. Guild, November 2011, AEROSPACE Report No.TOR-2011(3903)-5.

1. Date and Universal Time of the anomaly	**2. Fully specified location of the anomaly (spacecraft location)**	**3. Velocity or orbital elements at time of the anomaly**	4. Eclipse state of the vehicle (full, penumbra, partial, none)	5. Vector to Sun in spacecraft coordinates	6. Velocity vector of spacecraft in spacecraft coordinates	7. Initial guess at type of anomaly (See taxonomy below)	8. Estimated confidence of that guess	9. Anomaly category (e.g., affected system or kind of disruption)	

Taxonomy of Satellite Anomalies Caused by In Situ Charged Particle Environment (to be used for column 7):

1. Electrostatic discharge (charging)
    - 1.1 Surface charging
        - 1.1.1 Plasma sheet (subauroral)
        - 1.1.2 Auroral
    - 1.2 Internal charging
        - 1.2.1 Subsurface charging (e.g., beneath blanket)
        - 1.2.2 Deep charging (e.g., inside a box)
2. Single-Event Effects
    - 2.1 Protons
        - 2.1.1 Solar proton event
        - 2.1.2 Geomagnetically trapped protons
    - 2.2 Heavy ions
        - 2.2.1 Galactic Cosmic Rays
        - 2.2.2 Solar energetic partic
        - 2.2.3 Geomagnetically trap
3. Total Dose
    - 3.1 Long-term dose accumulation (r
    - 3.2 Short-term (days or less) dose a
        - 3.2.1 Solar protons
        - 3.2.2 Geomagnetically trapp
        - 3.2.3 Geomagnetically trapp

2.4 Ground segment matters

The availability of the GOES ground systems was nominal in the reporting period. Two new GOES-R antennas in Wallops CDA have been tested and certified for GOES NOP operations. Four antennas in NSOF had been upgraded to serve both GOES NOP and GOES-R series satellites.

2.5 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 NOAA Satellite Operations Facility at Suitland, Maryland, also provide 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-2 (L)	N/A	1309.5 km	Jun 20, 2008	http://www.ospo.noaa.gov/Organization/About/access.html	CARMEN-2 off, all others Green: Altimeter, DORIS, AMR, GPSP, LRA, , Poseidon-3, T2L2, LPT
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	NOAA-15 (Op)	18:54 as of 4/10/2019	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.
Polar, SSO	NOAA-18 (Op)	20:32 as of 4/10/2019	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-19 (Op)	16:46 as of 4/10/2019	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
Polar, SSO	DMSP-17 (Op)	18:20	848 km	Nov 4, 2006	http://www.ospo.noaa.gov/Organization/About/access.html	OLS, SSMIS, SSIES, SSUSI, SSM, SSJ
Polar, SSO	DMSP-18 (Op)	19:08	850 km	Oct 18, 2009	http://www.ospo.noaa.gov/Organization/About/access.html	OLS, SSMIS, SSIES, SSULI, SSUSI, SSM, SSJ
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, Afternoon	NOAA-20	13:25	834 km	Nov 18, 2017	http://www.ospo.noaa.gov/Organization/About/access.html	VIIRS, ATMS, CrIS, CERES, OMPS

3.1 Mission objectives, payload/instruments, products

The POES spacecraft constellation includes one primary spacecraft for mission services and two secondary spacecraft. These spacecraft are in 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 Nov 18, 2017, declared operational in May 2018. One of NOAA's previous primary satellite, NOAA-19 (launched in Feb 2009), remains the primary PM satellite for services such as SARSAT and the Argos Data Collection System (collecting data from small remote environmental transponders worldwide). Two secondary spacecraft, NOAA-18 and NOAA-15 provide additional payload operational data. In April 2013, NOAA declared EUMETSAT's Metop-B as NOAA's mid-morning primary operational spacecraft.

3.2 Status of spacecraft

Jason-2

Jason-2 was launched in June of 2008, declared operational in December of 2008, and became the backup spacecraft when Jason-3 was declared operational in July of 2016. In July 2017 Jason-2 was maneuvered to a new orbit, 27km below the reference orbit (i.e. at 1309.5km altitude), with the same inclination. This orbit is known as the LRO (Long Repeat Orbit), and is also the graveyard orbit for Jason-2. On this orbit, the cycle is no longer 9.9 days, but approximately 368 days (4736 revs). In order to simplify the continuation of data production, the numbering of cycles and passes stays artificially the same at processing level (254 passes – 9.9 days cycle). Cycles are restarted from cycle 500 on July 10, 2017 at 04:43:08 UTC.

This satellite altimetry mission provides sea surface heights for determining ocean circulation, climate change and sea-level rise. It is operating the Poseidon-3 Radar Altimeter (Poseidon-3), Advanced Microwave Radiometer (AMR), Doppler Orbitography and Radio-positioning Integrated by Satellite (DORIS), Global Positioning System Payload (GPSP), Laser Retroreflector Array (LRA), Environment Characterization and Modelization-2 (Carmen-2), Time Transfer by Laser Link (T2L2), and Light Particle Telescope (LPT). All instruments are operational with the exception of Carman which is off.

Jason-3

Jason-3 was launched in January of 2016, declared operational in July of 2016 and became the primary Jason mission spacecraft in July of 2016. Jason-3 will make highly detailed measurements of sea-level on Earth to gain insight into ocean circulation and climate change. It is operating the Poseidon-3B Radar Altimeter (Poseidon-3B), Advanced Microwave Radiometer-2 (AMR-2), Doppler Orbitography and Radio-positioning Integrated by Satellite (DORIS), Global Positioning System Payload (GPSP), Laser Retroreflector Array (LRA), Environment Characterization and Modelization-3 (Carmen-3), and Light Particle Telescope (LPT).

NOAA-15

NOAA-15 was launched in May 1998 and declared operational in December of the same year. It 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 a Data Collection System payload that allows remote transponders to feed information back to NOAA from equipment all over the world. The SAR unit on NOAA-15 is operating in a degraded mode and the DCS payload is fully operational.

NOAA-18

NOAA-18 was launched in May 2005, and declared operational in August of the same year. It 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 Data Collection System (DCS) payloads of NOAA-15. In contrast to its older sister, NOAA-18's instruments are mostly fully operational, with the SBUV/2, MHS and HIRS are inoperative. SAR and DCS payloads are both fully functional.

NOAA-19

NOAA-19, launched in Feb 2009, is the youngest NOAA/TIROS satellite, and was declared operational in June of the same year. It is currently the primary PM polar environmental satellite for services such as SARSAT and ARGOS Data Collection System (S-NPP 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 Advanced Data Collection System (ADCS), improved over the version in older satellites, allowing two-way communication with remote transponders. NOAA-19's instruments are fully functional, with the exception of its HIRS and MHS payloads, which are operating in a degraded mode.

DMSP F17

DMSP F17 was launched from Vandenberg AFB on Nov 4, 2006. All primary instruments are fully functional, with some degradation of secondary SSMIS, SSI-ES2/3, and SSUSI instruments. The SSULI instrument is non-operational. It provides meteorological data to the US Military.

DMSP F18

DMSP F18 was launched from Vandenberg AFB on Oct 18, 2009. All primary instruments are fully functional, with some degradation of secondary SSMIS, SSI-ES2/3, and SSULI instruments. It provides meteorological data to the US Military.

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, the next generation 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), which have revolutionized forecasters' ability to make longer range forecasts. The vehicle and instruments are all operating within specifications.

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 Mar 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

3.3 Impact on spacecraft due to space weather

Space weather related spacecraft anomalies (Items in bold are required)

Source: Recommendations for Contents of Anomaly Database for Correlation with Space Weather Phenomena, P. O'Brien, J.E. Mazur, T. Guild, November 2011, AEROSPACE Report No.TOR-2011(3903)-5.

1. Date and Universal Time of the anomaly	**2. Fully specified location of the anomaly** (spacecraft location)	**3. Velocity or orbital elements at time of the anomaly**	4. Eclipse state of the vehicle (full, penumbra, partial, none)	5. Vector to Sun in spacecraft coordinate	6. Velocity vector of spacecraft in spacecraft coordinates	7. Initial guess at type of anomaly (See taxonomy below)	8. Estimated confidence of that guess	9. Anomaly category (e.g., affected system or kind of disruption)

1. Electrostatic discharge (charging)
    - 1.1 Surface charging
        - 1.1.1 Plasma sheet (subauroral)
        - 1.1.2 Auroral
    - 1.2 Internal charging
        - 1.2.1 Subsurface charging (e.g., beneath blanket)
        - 1.2.2 Deep charging (e.g., inside a box)
2. Single-Event Effects
    - 2.1 Protons
        - 2.1.1 Solar proton event
        - 2.1.2 Geomagnetically trapped protons
    - 2.2 Heavy ions
        - 2.2.1 Galactic Cosmic Rays
        - 2.2.2 Solar energetic particl
        - 2.2.3 Geomagnetically trapp
3. Total Dose
    - 3.1 Long-term dose accumulation (r
    - 3.2 Short-term (days or less) dose a
        - 3.2.1 Solar protons
        - 3.2.2 Geomagnetically trapp
        - 3.2.3 Geomagnetically trapp

3.4 Ground segment matters

The Polar Ground systems continue to perform well. The NOAA Jason Ground System (NJGS) was installed, tested, and activated over the course of the year and is performing as expected handling a two-spacecraft (Jason-2/3) constellation. The JPSS Common Ground System completed its Block 2.0 upgrade and transitioned to operations in August 2017, to support the November 2017 JPSS-1 launch.

3.5 Data transmission

Data transmission for POES and Jason 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.

4 STATUS OF ADDITIONAL 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 Time (ECT) Ascending	Mean altitude	Launch Date	Details on near real time access to L0/L1 data (links)	Instrument payload and status
Low-orbit (72° inclination), non-SSO?	COSMIC-1 (FM1 – 6) (L)	Varies	700-800 km	Apr 15, 2006	http://www.ospo.noaa.gov/Organization/About/access.html	Integrated GPS Occultation Receiver (IGOR), the Tiny Ionosphere Photometer (TIP), the Coherent Electromagnetic Radio Tomography/Triband Beacon Transmitter (CERTO/TBB)

4.1 Mission objectives, payload/instruments, products

This joint U.S.-Taiwan program is called COSMIC (Constellation Observing System for Meteorology, Ionosphere, and Climate) in the United States and FORMOSAT-3 in Taiwan. The low-orbiting satellites are the first to provide atmospheric data daily in real time over thousands of points on Earth for both research and operational weather forecasting by measuring the bending of radio signals from the U.S. Global Positioning System (GPS) as the signals pass through Earth's atmosphere. Temperature and water vapor profiles derived from the GPS data will help meteorologists observe, research, and forecast hurricanes, typhoons, and other storm patterns over the oceans and improve many areas of weather prediction.

COSMIC relies on a technology known as radio occultation. Just as the water molecules in a glass change the path of visible light waves so that a pencil appears bent, molecules in the air bend GPS radio signals as they pass through (are occulted by) the atmosphere. By measuring the amount of this bending, scientists can determine underlying atmospheric conditions, such as air density, temperature, moisture, and electron density.

The six identical satellites host the Integrated GPS Occultation Receiver (IGOR), the Tiny Ionosphere Photometer (TIP), and the Coherent Electromagnetic Radio Tomography/Triband Beacon Transmitter (CERTO/TBB) sensors.

4.2 Status of spacecraft

FM1 – Degraded Power System (battery degradation), IGOR is powered off, TIP and TBB instruments are powered off due to power situation, currently not providing any downlink data. The spacecraft may provide data in the future in more favourable sun conditions.

FM2 – Degraded Power System (battery degradation), IGOR is powered off, TIP and TBB instruments are powered off due to power situation, currently not providing any downlink data. The spacecraft is not expected to provide any data in the future.

FM3 – Degraded Power System (battery degradation), IGOR is powered off, TIP and TBB instruments are powered off due to power situation, currently not providing any downlink data. The spacecraft is not expected to provide any data in the future.

FM4 – Degraded Power System (battery degradation), IGOR is powered off, TIP and TBB instruments are powered off due to power situation, currently not providing any downlink data. The spacecraft is not expected to provide any data in the future.

FM5 – Degraded Power System (battery degradation), IGOR is powered off, TIP and TBB instruments are powered off due to power situation, currently providing some state of health downlink data only. The spacecraft may provide IGOR data in the future in more favourable sun conditions.

FM6 – Degraded power system causes payload turn off at high battery state of charge IGOR operating with low Signal-to-Noise Ratio, TIP and TBB instruments operating during low sun angle periods.

4.3 Impact on spacecraft due to space weather

Space weather related spacecraft anomalies (Items in bold are required)

Source: Recommendations for Contents of Anomaly Database for Correlation with Space Weather Phenomena, P. O'Brien, J.E. Mazur, T. Guild, November 2011, AEROSPACE Report No.TOR-2011(3903)-5.

1. Date and Universal Time of the anomaly	**2. Fully specified location of the anomaly** (spacecraft location)	**3. Velocity or orbital elements at time of the anomaly**	4. Eclipse state of the vehicle (full, penumbra, partial, none)	5. Vector to Sun in spacecraft coordinates	6. Velocity vector of spacecraft in spacecraft coordinates	7. Initial guess at type of anomaly (See taxonomy below)	8. Estimated confidence of that guess	9. Anomaly category (e.g., affected system or kind of disruption)	

Taxonomy of Satellite Anomalies Caused by In Situ Charged Particle Environment (to be used for column 7):

1. Electrostatic discharge (charging)
    - 1.1 Surface charging
        - 1.1.1 Plasma sheet (subauroral)
        - 1.1.2 Auroral
    - 1.2 Internal charging
        - 1.2.1 Subsurface charging (e.g., beneath blanket)
        - 1.2.2 Deep charging (e.g., inside a box)
2. Single-Event Effects
    - 2.1 Protons
        - 2.1.1 Solar proton event
        - 2.1.2 Geomagnetically trapped protons
    - 2.2 Heavy ions
        - 2.2.1 Galactic Cosmic Rays
        - 2.2.2 Solar energetic partic
        - 2.2.3 Geomagnetically trap
3. Total Dose
    - 3.1 Long-term dose accumulation (r
    - 3.2 Short-term (days or less) dose a
        - 3.2.1 Solar protons
        - 3.2.2 Geomagnetically trap
        - 3.2.3 Geomagnetically trap

4.4 Ground segment matters

Ground Segment support for COSMIC is provided by the Fairbanks Command and Data Acquisition Station (FCDAS) as well as the Wallops Command and Data Acquisition Station (WCDAS), and services were contracted with Kongsberg Satellite Services (KSAT) at their Tromsø Satellite Station through NOAA agreements with the Norwegian Space Center. Since April 2008, NOAA stations have been providing both uplink and downlink services and Tromsø has been providing downlink services only. Ground station support availability for FS-3/C was required to perform at 90% or better. Over the course of FS-3/C operations, ground stations services have performed at 95% or better with only minor interruptions due to occasional equipment issues (hung servers or processors, for example). The MOC (Mission Operations Center) is located at NSPO (National Space Organization) in Taiwan. The MOC is embedded into NSPO's MMC (Multi-Mission Center). The MOC performs all S/C operations.

4.5 Data transmission

All science and some telemetry data is being sent to CDAAC (COSMIC Data Analysis and Archive Center) at the University Corporation for Atmospheric Research (UCAR) in Boulder, CO, and to TACC (Taiwan Analysis Center for COSMIC), a mirror site of CDAAC in Taiwan, located at CWB (Central Weather Bureau) in Taipei. The centers also receive data from a global network of ground GPS receiving sites (the so-called fiducial network). The centers analyze the received data and distribute it to the principal investigators and to the science community for science and research. COSMIC data are also distributed by NOAA for operational use by weather forecast centers globally, and also for space weather prediction services. COSMIC data have demonstrated significant positive impact on medium range weather forecasts.

4.6 Projects, services

The COSMIC-2/Formosat-7 follow-on project will launch six satellites into low-inclination orbits later in 2018.

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)	Instruments and payload status
L-1	DSCOVR (P)	L-1, Lagrangian Point	2/11/2015	http://www.osp o.noaa.gov/Org	All instruments operational.

				anization/About /access.html	

5.1 Mission objectives, payload/instruments, products

Primary mission is to monitor the 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 Space Weather Prediction Center (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 National Institute of Standards and Technology (NIST) Advanced Radiometer (NISTAR).

5.2 Status of spacecraft

DSCOVR spacecraft is in its final orbit and operational with all instruments operating as designed. SWPC switched operations from ACE to DSCOVR on July 27, 2016. ACE is still being utilized as back-up.

5.3 Impact on spacecraft due to space weather

Space weather related spacecraft anomalies (Items in bold are required)

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    - 3.2 Short-term (days or less) dose a
        - 3.2.1 Solar protons
        - 3.2.2 Geomagnetically trap
        - 3.2.3 Geomagnetically trap

5.4 Ground segment matters

There have been some tracking issues with the Wallops (WCDA) 18-meter antenna which has been corrected temporarily with a software fix. We expect to have a permanent repair sometime in May 2016.

5.5 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 SWPC (Space Weather Prediction Center). Terrestrial data and images are distributed by NASA's DSOC (DSCOVR Science Operations Center).

5.6 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-T (P)	TBD	TBD (after Q4 FY2020)	http://www.goes-r.gov/resources/docs.html	ABI, EXIS, SUVI, SEISS, MAG, GLM
TBD	GOES-U (P)	TBD	LCD 1st Qtr FY2025	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) that will extend 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 (HRIT), Search-and-Rescue Satellite Aided Tracking (SARSAT), and Emergency Managers Weather Information Network (EMWIN).

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.

Work on GOES-T continues. The satellite is currently in storage awaiting the return of the ABI instrument sensor unit, which is undergoing design changes to correct a thermal issue discovered on GOES-17. GOES-T will continue mated integration testing in early 2020 upon return of the ABI sensor unit, followed by environmental testing.

Build-up of the GOES-U spacecraft is proceeding well. The propulsion module has completed integration with a planned delivery in April 2019, and the system module integration and testing is well underway. The mate of these two modules is planned for mid-2019. The GOES-U spacecraft will include the addition of a new instrument, a compact coronagraph (CCOR). The critical design review for the CCOR is planned for June of 2019.

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, WV. 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 RBU 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) 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 75Mbps, over 30 times the legacy rate. 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 Joint Status of future 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 Time (ECT) ascending node	Mean altitude	Launch date	Details on near real time access to L0/L1 data (links)	Instrument payload and status
1330	JPSS-2 (P)	1330	824	2022	http://www.ospo.noaa.gov/Organization/About/access.html	ATMS, CrIS, VIIRS, OMPS-N, RBI
1330	JPSS-3 (P)	1330	824	2026	http://www.ospo.noaa.gov/Organization/About/access.html	ATMS, CrIS, VIIRS, OMPS-N, RBI
1330	JPSS-4 (P)	1330	824	2031	http://www.ospo.noaa.gov/Organization/About/access.html	ATMS, CrIS, VIIRS, OMPS-N, RBI

7.1 Mission objectives, spacecraft, payload/instruments, products

The Joint Polar Satellite System (JPSS) is the new generation of 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.

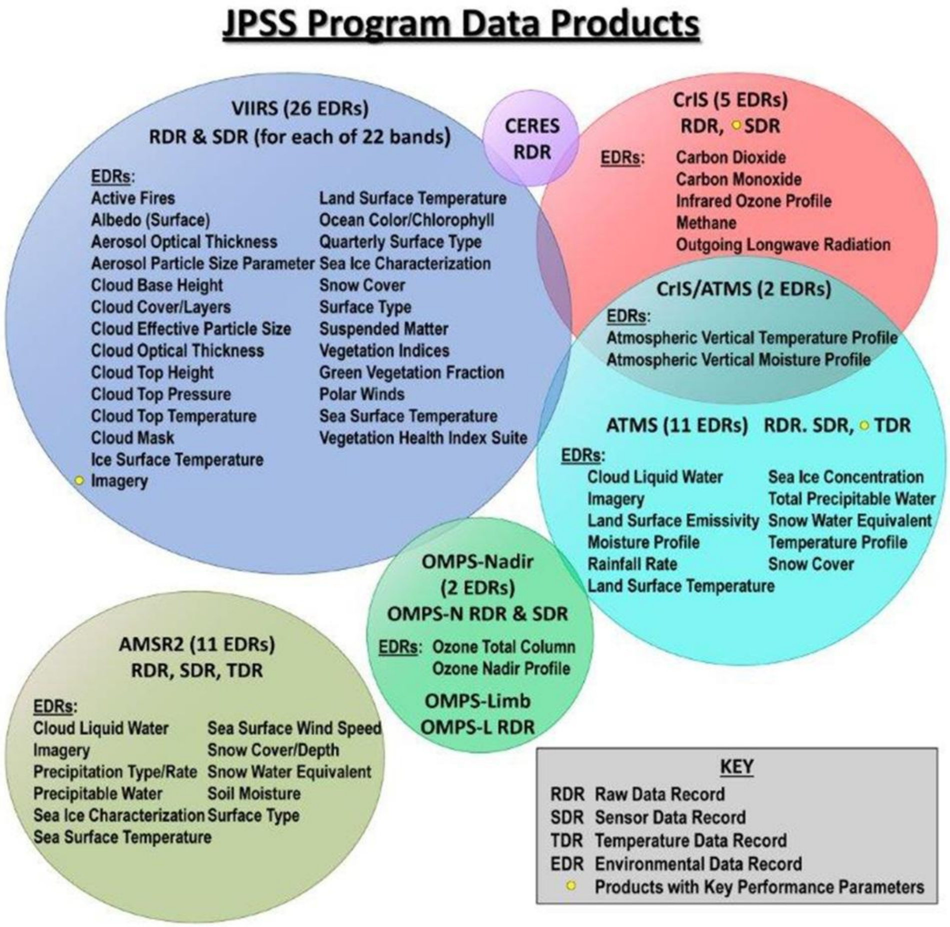
The most important function of polar orbiting operational weather satellites is to feed Numerical Weather Prediction (NWP) models with global three dimensional structures of atmospheric temperature and moisture and other parameters that enable increased forecast skill to produce three to seven day-ahead 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 modellers, 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:



7.2 User Engagement

The JPSS Proving Ground and Risk Reduction (PGRR) Program was established in 2012, following the launch of the Suomi National Polar Partnership (Suomi NPP) satellite, to facilitate Operations to Operations (O2O) through demonstrations of JPSS derived data and products in user environments. It applies the science and technology provided by JPSS to user products and services (applications). The Program focuses on maximizing the benefits and performance of data, algorithms, and products derived from Suomi NPP and JPSS for downstream operational and research users. The PGRR program provides resources and support to peer-reviewed projects which demonstrate improved utilization of JPSS data which enhance NOAA and other agency missions. The PGRR program now contains key data products and applications from other observing systems, including the GOES-R series. For example our the Flood mapping application area now integrates data from GOES-R series Advanced Baseline Imager to provide users with integrated JPSS and GOES-R flood maps.

PGRR supports:

- Enhancements and improvements of user applications
- Education, Training and Outreach
- Facilitation of transition of improved algorithms to operations.
- User feedback to the calibration/validation (cal/val) program

The Proving Ground component consists of demonstration and utilization of data products by end-users in NOAA's LOs in their operational and/or research environments, leading to innovative applications and identification of new capabilities. The Proving Ground also promotes outreach, training, and coordination of new products with the end users.

8 STATUS OF FUTURE EQUATORIAL LEO SATELLITE SYSTEMS

Orbit Type	Satellites in orbit P= pre-operational Op=operational B=back-up L=limited availability	Right Ascension of Ascending Node (RAAN)	Mean Altitude	Launch Date	Details on near real time access to L0/L1 data (links)	Instrument payload and status
Equatorial 24º Inclination	COSMIC-2A 6 satellites (P)	0º, 60º, 120º, 180º, 240º. 300º	520 km	NET June 2019	http://www.ospo.noaa.gov/Organization/About/access.html	TGRS* IVM** RFB***

8.1 Mission objectives, spacecraft, 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 the current FORMOSAT-3/COSMIC mission 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 will be launched into low earth mission orbits with altitude of 520 km and inclination of 24º. Each FORMOSAT-7/COSMIC-2 satellite will carry one primary mission payload, called the TriG Global Navigation Satellite System (GNSS) Radio Occultation (RO) Receiver 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 will 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 will also measure the ionospheric total electron content (TEC) along the ground receiver-satellite line of sight during satellite contacts. The RFB ground receivers will be established by the USAF and may be established by NSPO at ancillary sites.

The six equatorial satellites are fully integrated with instruments, ready to be shipped to the launch site and are planned for launch later in June 2019 2018.

8.2 Ground segment matters

For satellites in the low-inclination orbit, 9 receiving stations are planned to be strategically placed around the equator. The 9 receiving station are located in Taiwan, Hawaii, Honduras, Guam, Kuwait, Australia, Brazil, Ghana, and Mauritius Island. The NSPO Satellite Operations Control Center (SOCC) will provide command and control of the COSMIC-2 constellation as well.

The Mark IV-B antennas in Hawaii, Honduras, Guam, and Kuwait are being provided by the Air Force with signed letters of commitment in place. The Australian Bureau of Meteorology (BoM) is providing an antenna in Darwin for which the Implementing Agreement (IA) was finalized March 29, 2016. The Brazil National Institute of Space Research (INPE) and NOAA concluded an arrangement on June 30, 2015 for the installation of an antenna at INPE's expense at their facility in Cuiaba. NSPO provides antennas in Taiwan as part of the FORMOSAT-7/COSMIC-2 mission. NOAA concluded a Program Implementation Plan with the Norwegian Space Centre for antenna services from a site on Mauritius Island and awarded a contract to Atlas Space Operations, Inc. for antenna services from a site in Ghana. The Ghana and Mauritius Island ground sites now provide backup commanding capability.

8.3 Data transmission

The data collected by FORMOSAT-7/COSMIC-2 will be 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.

9 STATUS OF ADDITIONAL FUTURE LEO SATELLITE SYSTEMS

Orbit Type	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)	Instrument payload and status
Polar, non-SSO	Jason-CS (P)	N/A		CY 2020	http://www.ospo.noaa.gov/Organization/About/access.html	

9.1 Mission objectives, spacecraft, payload/instruments, products

The Sentinel-6/Jason-CS primary mission objective is to provide continuity of ocean topography measurements beyond the TOPEX/Poseidon, Jason, OSTM/Jason-2, and Jason-3 cooperative missions, for determining sea surface height, ocean circulation, and sea level. Accordingly, the Sentinel-6/Jason-CS Mission will utilize the legacy TOPEX/Poseidon precision altimetry orbit.

As a secondary mission objective, it will collect high-resolution vertical profiles of atmospheric temperature using the GNSS-RO sounding technique to assess temperature changes in the troposphere and the stratosphere and to support numerical weather prediction. The secondary mission objective will not become a driver of, or in any way impede, the development and implementation of the Sentinel-6/Jason-CS Mission or delay the launches.

The Sentinel-6/Jason-CS cooperative mission will be implemented by two identical satellites launched in sequence, each with a nominal 5.5 year lifetime. In order to provide continuity, the launch of the Sentinel-6/Jason-CS A satellite is planned for 2020 and the launch of the Sentinel-6/Jason-CS B satellite is planned for 2025.

The Sentinel-6/Jason-CS Project is currently in the Phase “D” of system development with IV&V testing in progress. Systems Engineering Working Group (SEWG), Radio Occultation Working Group (ROWG) and Mission Performance Working Group (MPWG) meetings and reviews are ongoing. Milestones achieved to date for Sentinel-6/Jason-CS Satellite Project is as follows: System Critical Design Review (CDR) completed November 2018, Jason-CS Overall Ground System Key Point Review for the Mission Operations Center (MOC) held in November 2018. The most recent developments have been the selection of the European Mission Data Acquisition, and Tracking, Telemetry and Command services provider, which will be the Swedish Space Corporation with antennas physically located in the Kiruna Esrange facility.

Current status of Sentinel-6/Jason-CS Satellite Project is as follows: Satellite System Validation Test-1 (SSVT-1) was completed in late 2018, with SSVT-2 taking place in March 2019. In addition, taking place this month was the first version of the Payload Data Acquisition Processing which consisted of successful testing and delivery of Level 0 processing and supporting functions, NASA/JPL has shipped and delivered the GNSS-RO and AMR instruments to Airbus for satellite integration.

The next step in the development work of this project is the Satellite Assembly, Integration, and Testing activities, which will commence April 2019 keeping the mission on track for its scheduled launch in late 2020.

10 STATUS OF DEEP SPACE MISSIONS

Orbit Type	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)	Instrument payload and status
L1	Space Weather Follow-On (SWFO)	N/A	1.6×10^9 m	CY 2024	http://www.ospo.noaa.gov/Organization/About/access.html	In definition phase (Phase B)

10.1 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 (L_1), SWFO-L1.

<u>Prediction of Space Weather Effects</u>
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 is comprised 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.

<u>Programmatic Objectives</u>

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, 2015a,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 L_1 libration point with the objective of providing both coronal imaging and in situ measurements of the solar wind and its magnetic field, all of 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 R_{sun}. 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 competed in a NASA research program and will be announced in mid-2019.

SWFO-L1 is planned for launch in 2024 as a rideshare to NASA's Interstellar Mapping and Acceleration Probe (IMAP) mission to L_1.

Mission Support and Program Schedule

Funding provided in FY 2019 and in the President's FY 2020 Budget Request for NOAA will support the SWFO Program in completing formulation activities and initiate development with respect to 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 2021 and 2022; the GOES-U planned launch is in 2024 while the SWFO-L1 rideshare with NASA's IMAP is nominally in 2024.

10.2 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 WCDAS, FCDAS, and the Consolidated BackUp (CBU) facility. NOAA is also investigating the use of ground stations by other agencies (NASA, Air Force) and international partner organizations.

10.3 DATA TRANSMISSION

The coronal images and solar wind data acquired by SWFO-L1 and CCOR on GOES-U will be downlinked to the tracking stations 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.

11 CONCLUSIONS

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

CGMS is invited to take note.