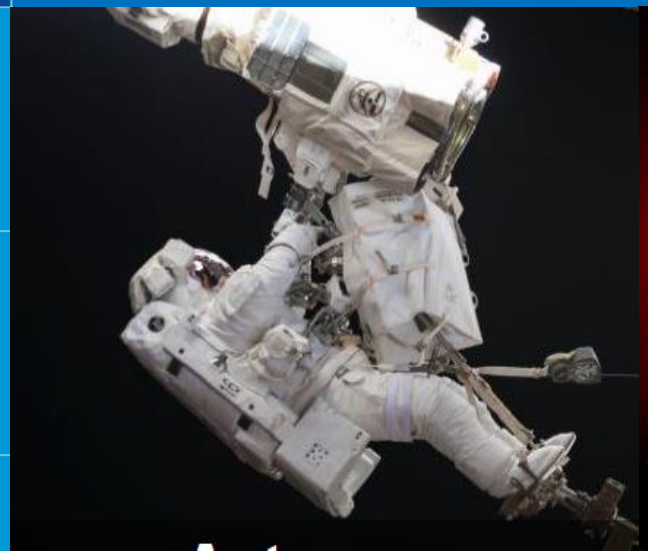
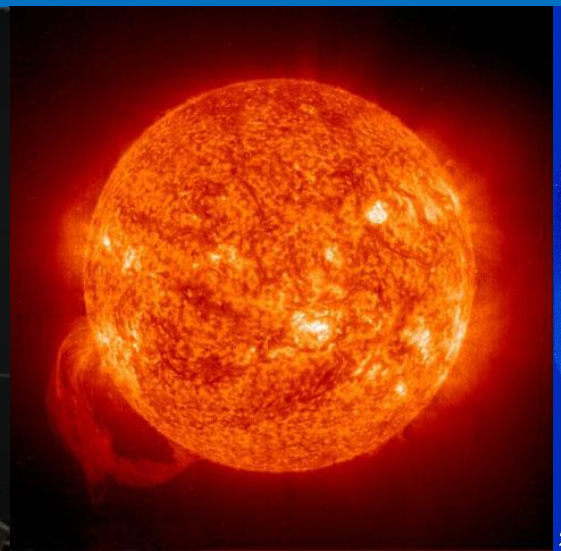
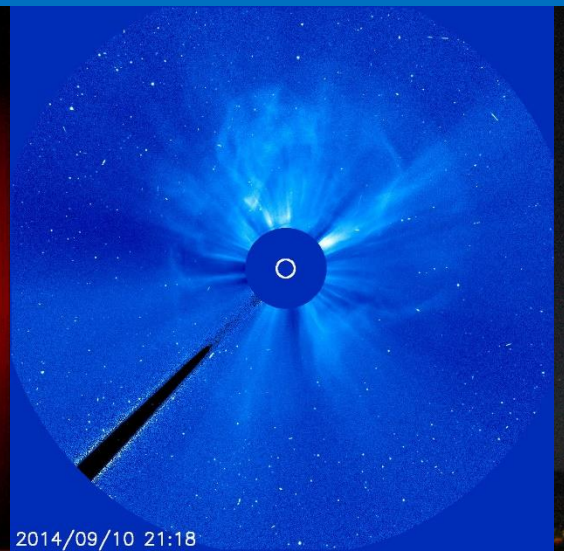
Space Weather Overview & Space Weather Program Introduction

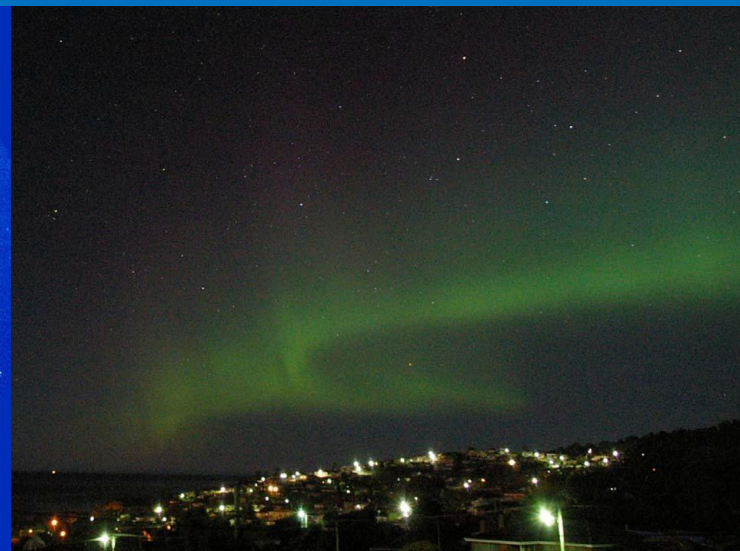
Elsayed Talaat, NESDIS/OPPA Director

September 30, 2020







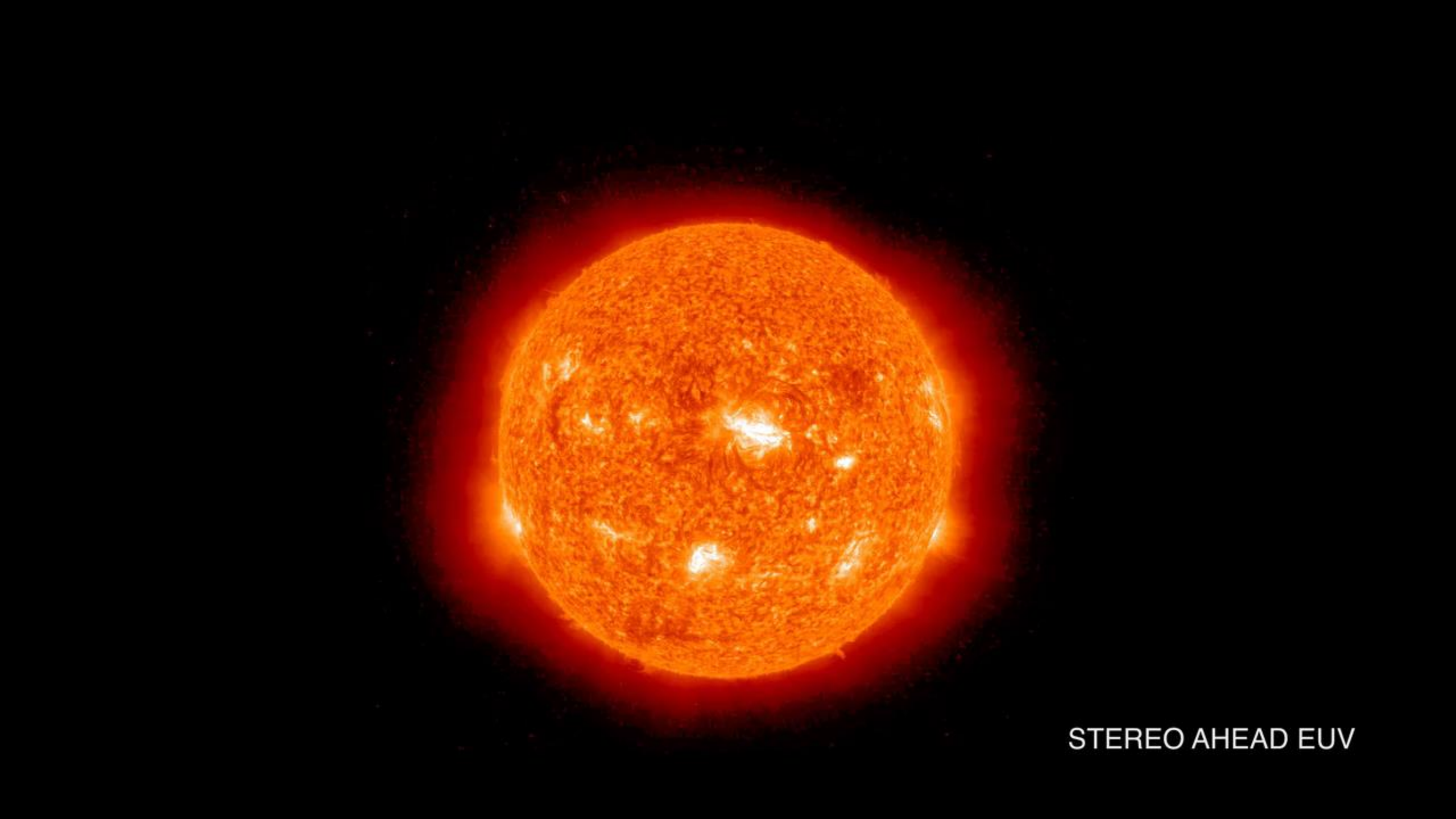


Agenda

- Bottomline up front
- Background
- SXX program overview
- Notional SWFO to SWX timeline
- SWX formulation drivers and assumptions
- SWX program formulation plans
- SWX project formulation plans
- Formulation Studies
- Summary

Bottomline upfront

- SWFO – L1 will continue to provide operational service into late 2020's
  - Continuing to evolve data products based on user input
- SWX was initiated by Dr. Volz, March 2020
  - New program is the third pillar in the NESDIS Observing Systems
  - Mission will encompass all space weather observational needs including LEO, GEO, HEO and extended orbits
- SWX program planning has started
- Currently formulation studies underway:
  - User needs assessments
  - Observational value assessments
  - Requirements development
  - Initial instruments and constellation options
  - Partnership development
  - Commercial data buy research
- MS1/KSP0: Phase A notionally planned for April 2021
- Preparing for formal program initiation following MS2/KDP 1 decision gate notionally in 3Q FY22


STEREO AHEAD EUV

Achieving the NESDIS Vision in Space Weather

NESDIS Vision:

A truly integrated digital understanding of our earth environment that can evolve quickly to meet changing user expectations by leveraging NOAA's own capabilities and partnerships.

Space Weather Strategic Objective:

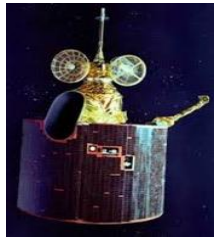
Advance Space Weather observational leadership in LEO, GEO, and extended orbits consistent with the agency's responsibilities within the National Space Weather Strategy and Action Plan.

Space Weather Roles:

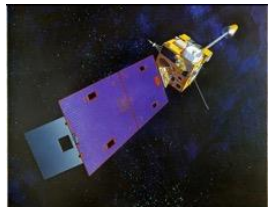
- *Maintain and extend space weather observations from LEO, GEO, HEO and extended orbits (Lagrange 1 and beyond)*
- *Improve and expand our product suite*
- *Collaborate with partners to collect, process, and deliver relevant data to our users*
- *Interpret and provide data in a manner that users can readily access and understand*

Space-Based Space Weather at NOAA and Partners

NASA SMS
GOES 1-3



GOES 4-7



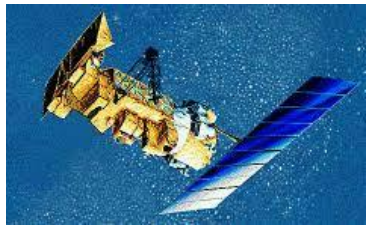
GOES 8-12

GOES-NOP

NASA SDO

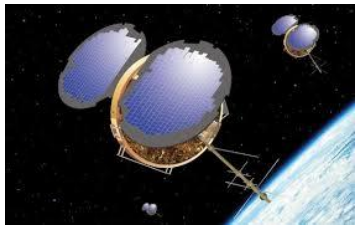
GOES-R Series

TIROS-N



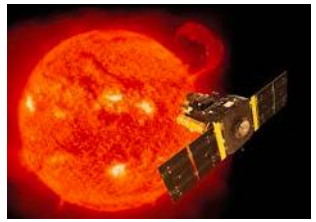
POES

EUMETSAT Metop

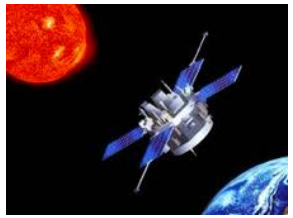


COSMIC-1

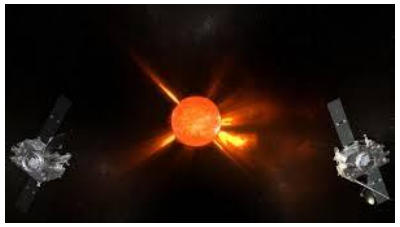
COSMIC-2



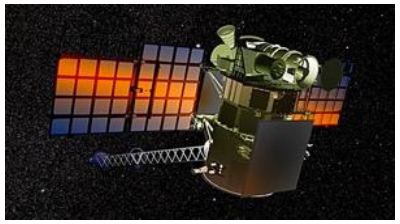
ESA/NASA SOHO



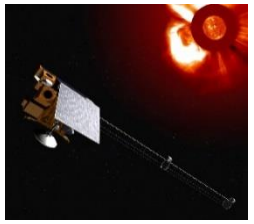
NASA ACE



NASA STEREO



DSCOVR



SWFO-L1

Legend:
Historical
Operational
In development

Uses of Space Weather Products

Electric Power Grid

- Adjust/reduce system load
- Disconnect components
- Postpone maintenance

Airlines

- Divert polar flights
- Change altitude

GPS/Navigation

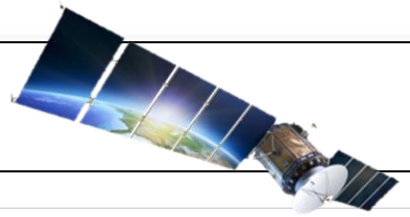
- Postpone activities
- Redo survey
  - Use backup systems

Space Operations

- **Postpone launch of satellite**
  - **Turn off/safe instruments and/or spacecraft in orbit**

SECTIONS HOME SEARCH **The New York Times** *Nov 2015*

Solar Storm Knocks Out Flight Control Systems in Sweden



Solar Flares Knock Out LightSquared Satellite
As Run of Bad Fortune Continues

by Karl Bode Friday 16-Mar-2012 tags: satellite · business · wireless · alternatives wireless

MOTHERBOARD

Solar Flares Interfered With Radio Network's Ability to Warn People About Hurricane Irma

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General: Recent solar storm interfered with Air Force satellite

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Huge Solar Flare Delays Private Rocket Launch to Space Station until Thursday

by Tariq Malik, Managing Editor | January 08, 2014 08:10am ET

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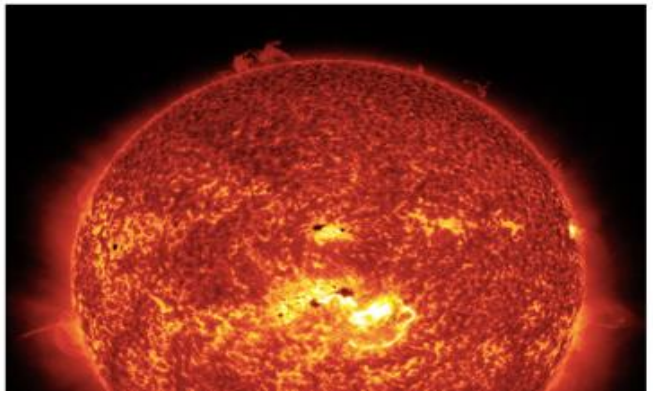
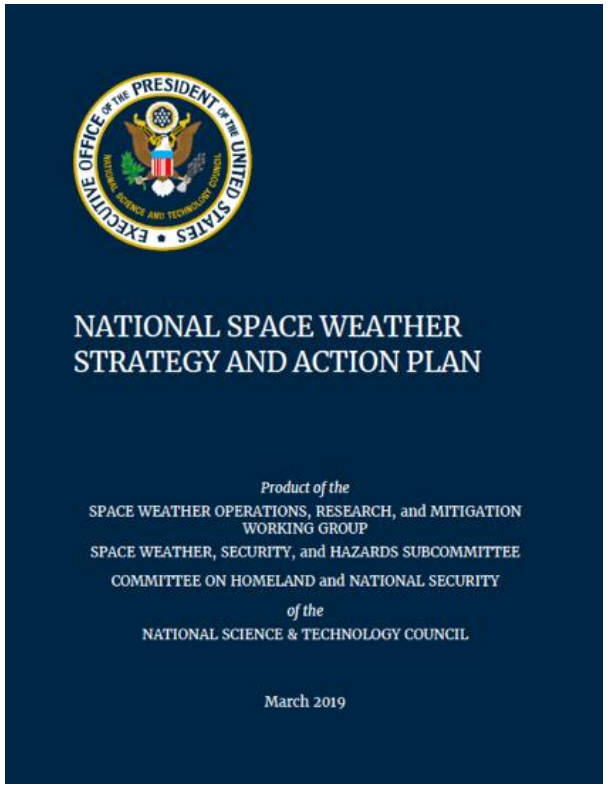


Space Weather as a National Priority

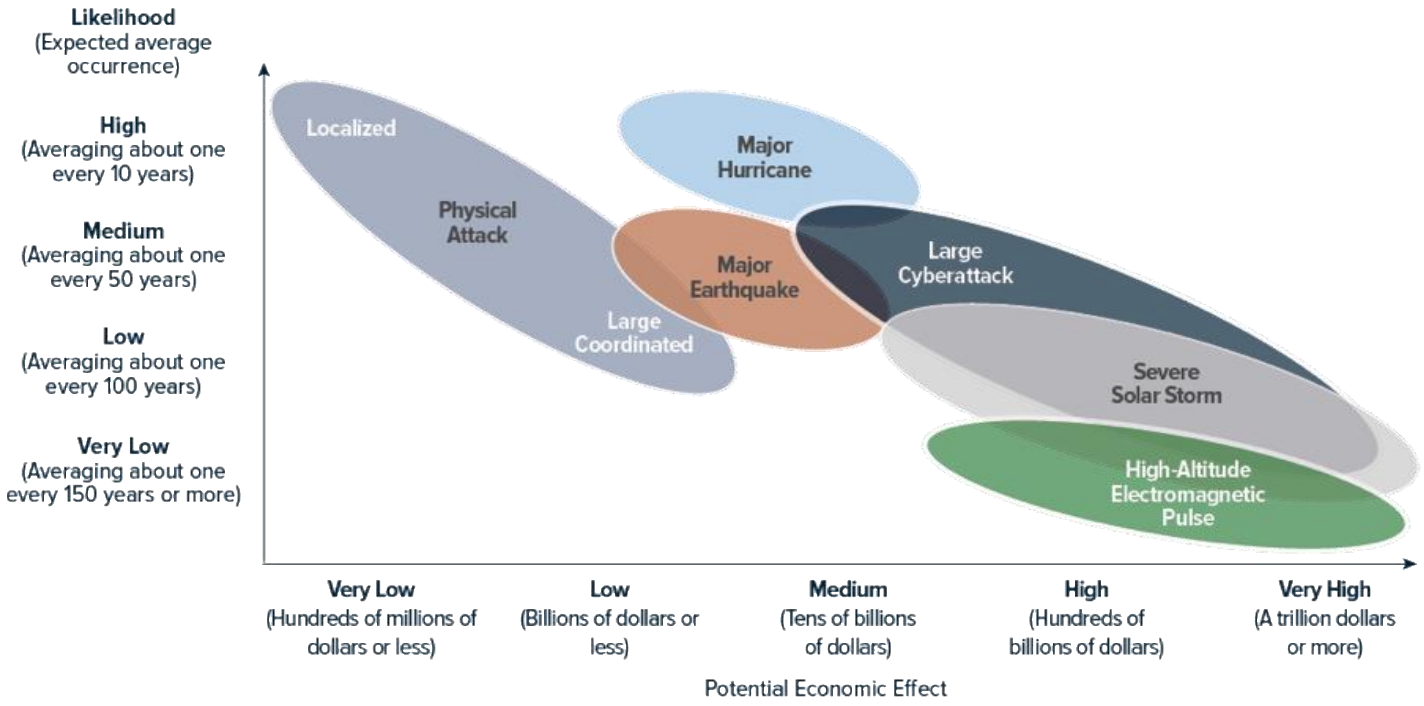


2020 Enhancing the Security of the North American Electric Grid

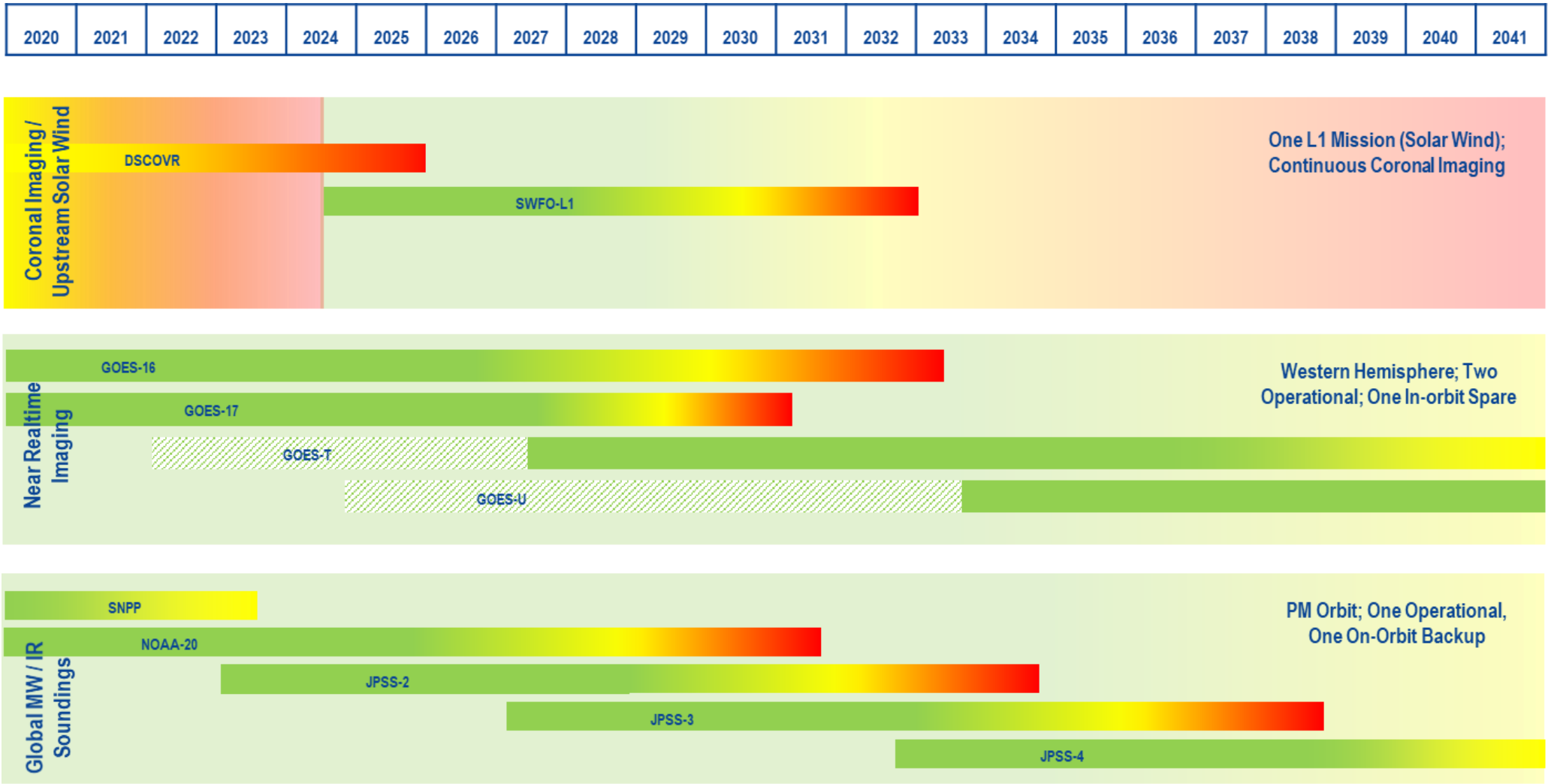
Congressional Budget Office

2019 Space Weather Strategy and Action Plan

Space Weather Operations, Research, Mitigation Working Group, National Science & Technology Council



Constellation Risk for Key NESDIS Observations (Programs of Record)



CME Imagery and In-situ Solar Wind Measurements are Key for Timely Space Weather Forecasts

NOAA's National Weather Service Space Weather Prediction Center (SWPC) is the nation's official source of Alerts, Watches, and Warnings

Coronal Mass Ejection (CME) Imagery

- CME imagery (visible-light imagery of the most destructive global events) are used for 1-4-day warnings of geomagnetic storm conditions
- Currently provided by ESA/NASA Solar and Heliophysics Observatory (SOHO) mission, which launched in 1995

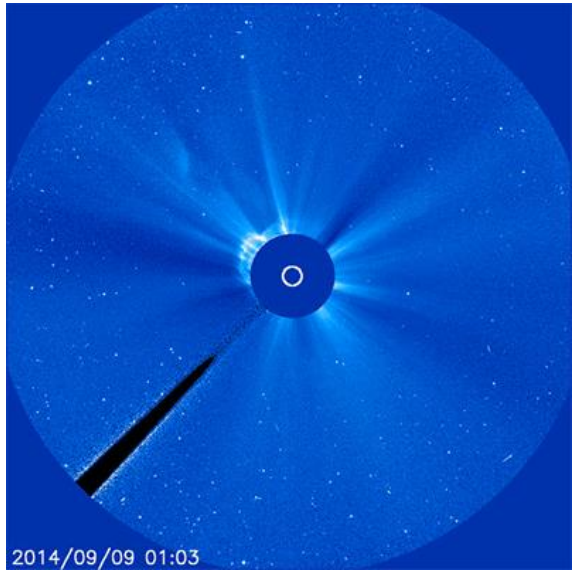
Upstream Solar Wind Data

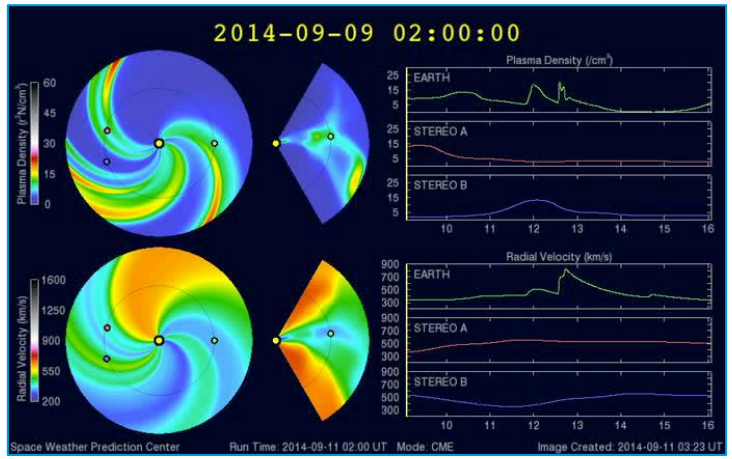
- Solar wind plasma and magnetic field measurements provide 15-60-minute notice for geomagnetic storm conditions
- Primary Source: NOAA's Deep Space Climate Observatory (DSCOVR), launched in 2015

– Safe hold since June 2019. Expected return to operations in Q2 FY20

- Current backup: NASA Advanced Composition Explorer (ACE) launched in 1997

NESDIS provides NWS/SWPC with essential observations to meet these requirements





SWPC's Models Require Reliable Real Time Space Weather Data

Pillars of NESDIS Observing System Implementation

Integrated, Adaptable and Affordable: Orbits, Instruments & Systems

GEO

Continuous real-time observations supporting warnings and watches of severe weather and hour-by-hour changes. High-inclination orbits to observe northern latitude & polar regions.

LEO

Miniaturized instruments on small, affordable and proliferated satellites and partner data improving forecasts through better and additional data. Better precipitation forecasts, wave height predictions, ocean currents, and more.

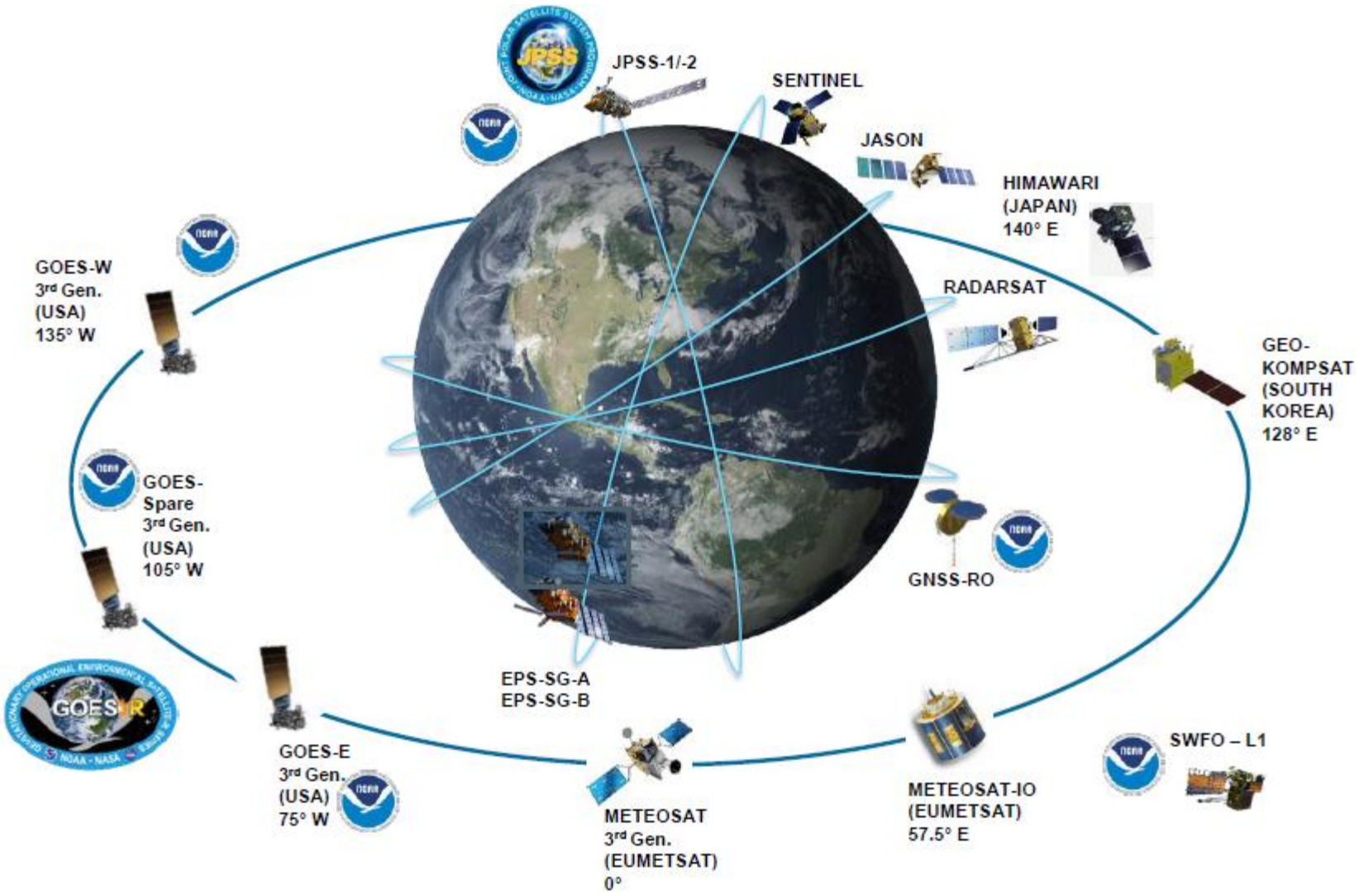
Space Weather

Reliably monitoring space weather from L1, GEO and LEO can protect the nation's valuable, vulnerable infrastructure. New capabilities at L5 and HEO can provide additional insight and improve forecasts.

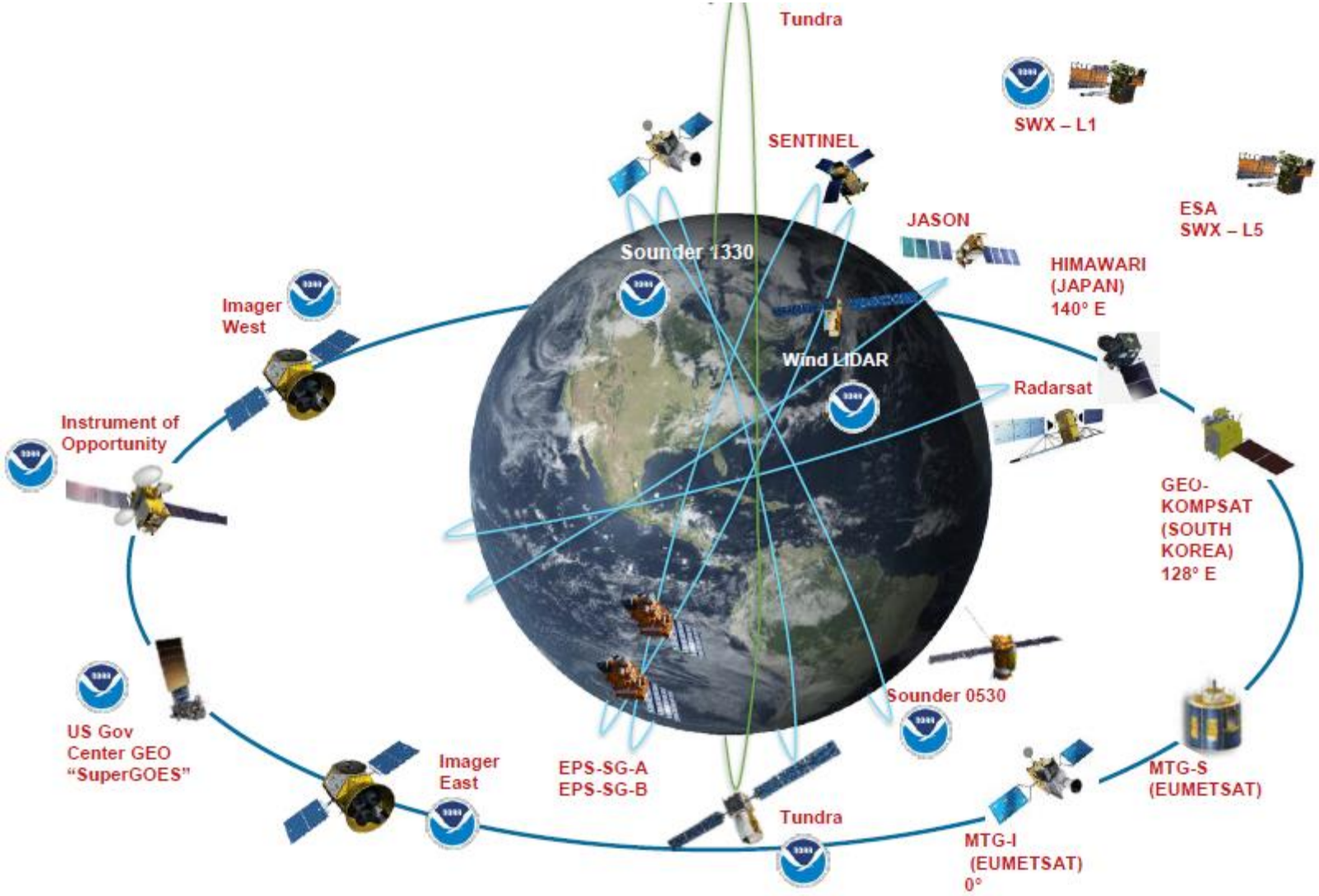
Common Ground Services

Secure ingest of data in different formats from different partners requires a flexible, scalable platform. Common Services approach integrates Cloud, AI and machine-learning capabilities to verify, calibrate and fuse data into new and better products and services.

Near-Term Observational Capability

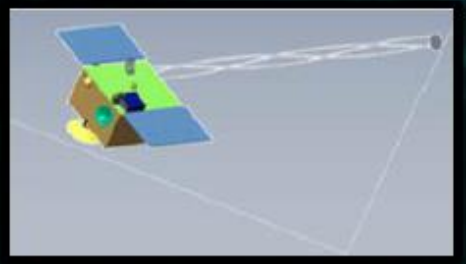


Evolution of NOAA and Partner Space Architecture



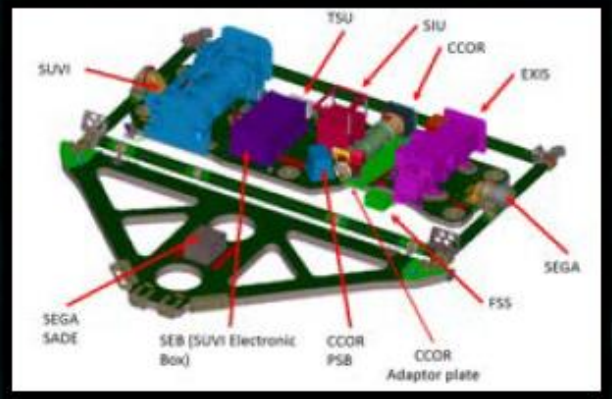
Starting Point – Program of Record 2025

3-Axis
Stabilized ESPA
Class
Spacecraft



Compact
Coronagraph
(CCOR)

GOES-U Solar Pointing Platform (SPP)



CCOR +
SUVI +
EXIS

2025 NOAA Space Weather
Observing Program of Record
Starting point for Infrastructure Workshop

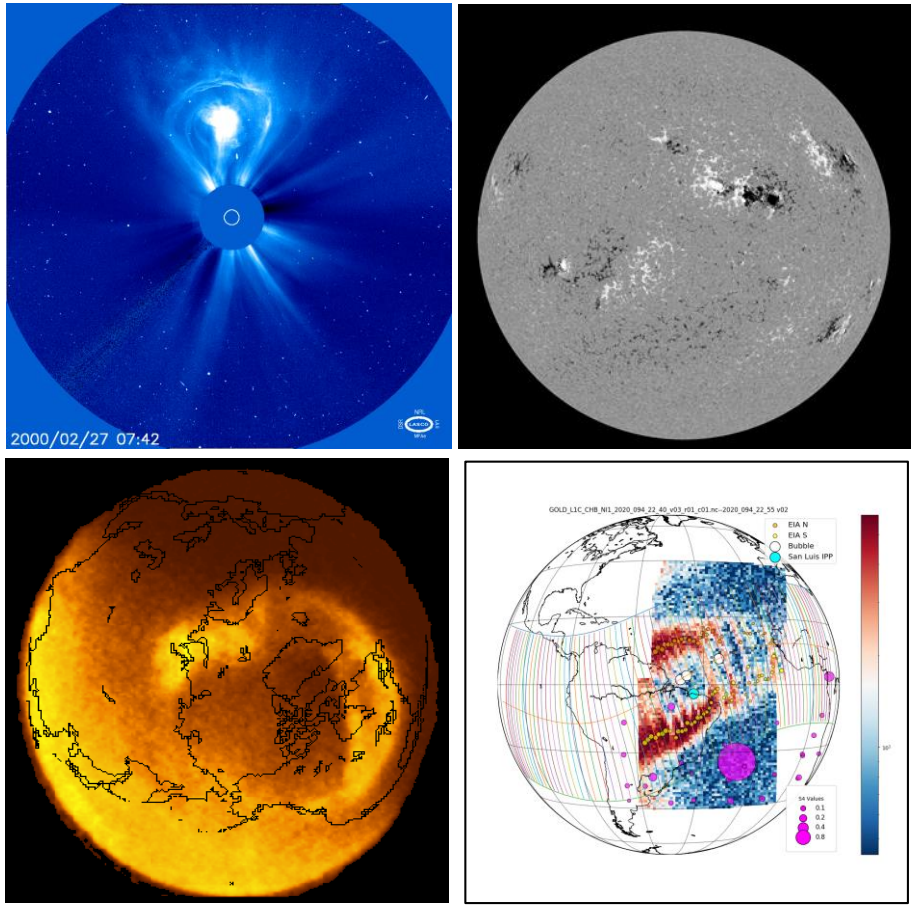
SWFO – L1 platform
GOES – U
COSMIC-2 →
GOLD
Metop – C, SG A1, SG B1
ESA – L5 (2027)

What's next for 2030 and beyond?

Space Weather Program Overview

- *SWX = Space Weather Program*
  - The mission to subsumes the Space Weather Follow-on program and provides continuity for hosted space weather instruments hosted on GOES-R, JPSS, COSMIC-2 satellites.
  - Includes continuity for L1 observations, off-Sun Earth Line (L5)
  - Considering expanding to include observations from "Tundra" to Lagrange points and beyond L1
  - Ground services for Space Weather mission
- SWX includes all space weather-observing assets deployed at LEO, GEO, HEO and extended orbits:
  - Government spacecraft
  - Instruments or payloads hosted on commercial/partner spacecraft
  - Potential use of commercial services and observational data
  - Potential partnerships, interagency and international
- Operational in the 2024 -2040 timeframe
  - Currently in pre-formulation:
    - Instrument and constellation studies underway
    - User needs assessment underway
    - Requirements definition underway
  - Notional Program Schedule
    - System Requirements Review, 2021
    - Milestone 1, 2021
    - System Definition Review, 2022
    - Milestone 2, 2022
    - SWFO-L1 launch, 2024
    - SWX L1-1 launch, 2027

Data Continuity and Potential New Observations

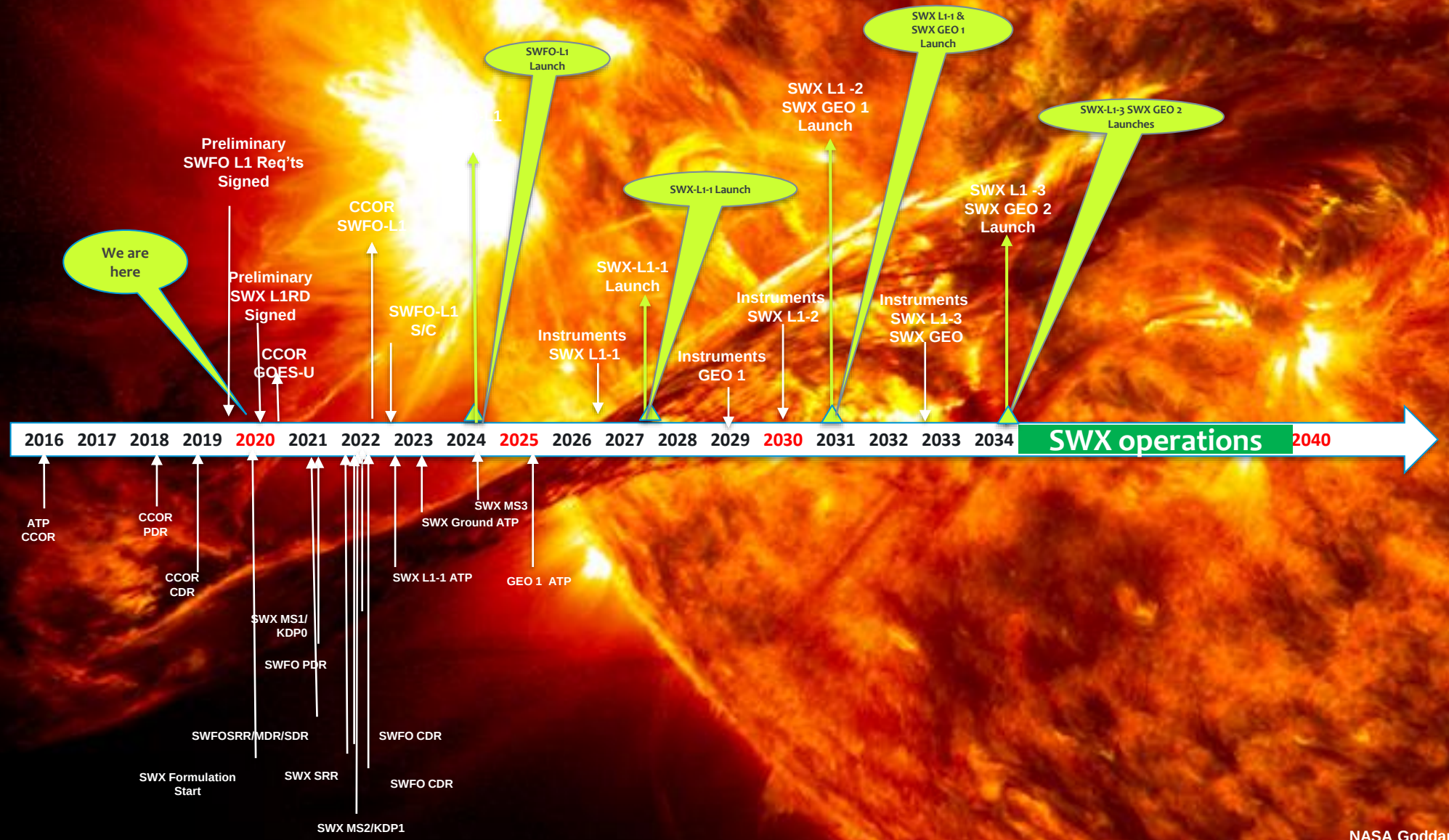


Clockwise from top left:
a) Coronal imagery (LASCO),
b) Magnetograph imagery (HMI),
c) Thermospheric imagery (GOLD),
d) aurora (POLAR).

SWX formulation drivers and assumptions for planning

- Approach to formulation process development
  - Program process for formulation
  - Project process
- Requirements Process
  - XORWG
  - User Needs
  - Benefits analyses
  - DOC/NASA according to NOAA/NASA MCP, DOC docs, NASA NPR 7120.5E
- Objectives and Requirements
  - Driven by need date to maintain Imager continuity
  - Key Performance Parameter: Solar geomagnetic storm warning, etc….
  - Low risk tolerance for **KPP** (NASA Class B)
  - More risk tolerance for other elements (Class C or D)
  - Requirements are observations (L1b data); data products (L2) will be developed separately (NCEI, STAR, SWPC?)
  - More autonomous operations and lower operational cost
  - Ground will employ NESDIS enterprise ground system and mission unique elements

Notional SWFO to SWX Timeline



NASA Goddard SFC

Program Pre-Phase A: Concept Development

- Define Program and Requirements leading up to System Requirements Review
- Defined at System Requirements Review :
  - Initial Program Level 1 Requirements
    - Understanding of User needs and space weather value
  - Observations planned, from NOAA systems and commercial sources
    - Instrument performance baseline and options
  - Space architecture
    - Observational needs from orbital domains
    - Detailed trades with number of observatories, their orbits and payload complements.
    - Use of NOAA satellite hosting, commercial hosts, free flyer trades
    - Cost, schedule and risk assessment
  - Ground system roles and feasible system concepts
  - Technology Readiness Assessment with rough cost and schedule estimates
- Mission Needs Statement
  - User Engagements, Societal and Economic Benefits Studies, Previous and new requirements studies
- MS1/KDP0 Review: Program Initiation Approval

Notional SWX Formulation thru 2 Qtr. FY21

SWX Pre-Formulation Event/Activity	Timeframe	Status
Initial trade Studies (SWPC, NCEI, GSFC, MITRE, Aerospace, ASTRA)	4Q FY20	Completed
User Needs Studies (NASA, SWPC, MITRE, GEO-XO,)	4Q FY20	Underway; ECD 2Q FY21
Initial AOA (NASA, SWPC, NCEI, GSFC, MITRE, AEROSPACE, ASTRA)	4Q FY20	Underway; ECD 1Q FY21
Requirements Working Group	2Q FY20	Work Underway
GEO Broad Agency Announcement Study Contracts	3Q FY20	Awarded; ECD 2Q FY21
Interagency and International Partnership development	1Q FY21	Underway; ECD 3Q FY21
Requirements Definition Plan then briefed to NOSC	2Q FY21	Underway; ECD 2Q FY21
Formulation Authorization Document	1Q FY21	ECD 2Q FY21
NOAA-NASA Inter-Agency Agreement	3Q FY21	Planned
User Needs Workshops	2Qt FY21	3Q FY21
Program Level 1 Requirements	1Q FY21	Drafted; ECD 3Q FY21
System Requirements Review	3Q FY21	ECD 3Q FY21
MS1/KDP0	3Q FY21	ECD 3Q FY21

Program Phase A: Concept Definition

- Defined at Mission Definition Review :
  - Initial Program Level 1 Requirements
  - Observations planned, from NOAA systems and commercial sources studies
    - Instrument concept and performance baseline studies
  - Detailed space architecture studies
    - Number of NOAA spacecraft, their orbits and payload complements
    - Use of NOAA satellite or commercial hosts
    - Detailed communication architecture concepts
  - Detailed ground system roles and feasible system concept studies
  - Technology Readiness Assessment with rough cost and schedule estimates
  - Program Management Plan
- Acquisition Strategy
- Architecture societal and economic benefits studies
  - User engagements and use of STAR ASPEN tool
- MS2/ KDP1
  - Acquisition approval for program to proceed
- Project acquisition cycle for each project

Notional SWX Formulation thru 2 Qtr. FY21 MS2

SWX Pre-Formulation Event/Activity	Timeframe	Status
Detailed concept studies, instruments, S/C, architecture	2Q FY20	ECD 2Q 2021
Detailed AOA	2Q FY21	ECD 2Q FY22
Requirements Societal and Economic Benefits	2Q FY21	ECD 3Q 2021
Continuing Interagency and International Partnership development	1Q FY20	ECD 2Q 2022
Formulation Agreement	1Q FY21	ECD 2Q FY22
NOAA-NASA Inter-Agency Agreement completion	2Q FY21	ECD 2Q FY21
Independent Review	2Q FY21	ECD 2Q FY21
System Definition Review	2Q FY22	ECD 2Q FY22
MS2/KDP1 Review	3Q FY 22	ECD 3Q FY22

Project formulation: Pre-phase A and Phase A

- For each candidate project, pre-phase A
  - Conduct competitive industry studies for each candidate concepts
  - Prioritizing the instrument studies ahead of spacecraft and ground, as they are expected to be critical path
  - Identify project risks, costs, and schedules
  - Hold a Mission Concept Review prior to MS1/KDP A
  - Prepare for MS1/KDPA review, approval for phase A start
- For each candidate Project, the Phase A study will:
  - Detailed studies to develop baseline concept
  - Evaluate concepts against program measures of effectiveness, cost, schedule and risks
  - Develop Concept of Operations and next level requirement documentation
  - Finalize initial project requirements with System Requirements Review
  - Prepare for MS 2 DOC project.
  - Develop Project Management Plan and System Engineering Plan
  - Hold an Acquisition Strategy Meeting
- User needs assessments will continue for possible instrument concept changes.
- Projects under consideration include observational requirements at Low Earth Orbits, Geostationary Orbits, Highly Elliptical Orbits and extended orbits on Sun-Earth Line and off- Sun Earth Line.

User Requirements Studies

- ***Economic Benefit Analysis of NOAA's Space Weather Products and Services to the Electric Power Industry***, Eastern Research Group, Inc. (ERG), August 2020

- ***Customer Needs and Requirements for Space Weather Products and Services***, *Abt Associates, Inc., March 2019*

- ***Social and Economic Impacts of Space Weather in the United States, Abt Associates, Inc***, *September 2017*

- *Space Weather Prediction Center study on user uses of space weather products and potential enhancements with improvements in space weather products. Ongoing as part of the SWX formulation effort*

- *Future focus user engagements anticipated to fill in the gaps*

Partnership Development Activities

- Formalizing partnership effort with European Space Agency (ESA)
  - Presently working the hosting of NESDIS Compact Coronagraph (NRL) on ESA L5 mission
  - Investigating additional potential collaborations
    - Held an initial ESA/NOAA workshop where several other collaborative opportunities were identified
    - Future workshops planned to discuss potential details
- Investing potential collaboration and partnerships with the Department of Defense Space Weather group
  - DoD space weather plans were briefing at the SWX requirements working group
  - Continuing to work with DoD representatives to coordinate formulation efforts.
- Plan to continue data product research activities with joint NOAA-NASA technology studies
  - Global Dynamics Constellation
  - Polarimeter to Unify the Corona and Heliosphere, (PUNCH)
  - Global-scale Observations of the Limb and Disk (GOLD)
- Participating in study with Environment Canada on potential arctic mission
- Continue user needs assessments including partner inputs

Architectural Studies

- Prioritizing observations
  - Prioritizing the observations against societal and economic benefits
  - Prioritizing observations at different orbital domains options
- Investigating potential partnerships and commercial space weather data
- Initial AOA Objectives
  - Identify architecture drivers
    - Requirements
    - Technologies
    - Costs
    - Risks
  - Scope a feasible architecture to implement in the next 15 years
  - Develop a rough order of magnitude cost estimate for planning purposes only
  - Identify critical technologies and risks
- Phase A studies will go into much more detail and define the program architecture and elements
  - Detailed instrument, Spacecraft, and architecture concepts
  - Architecture impact analyses, use of STAR ASPEN tool
  - Societal and Economic Benefits analyses

SWX Summary

- SWFO – L1 will continue to provide operational service into late 2020's
  - Continuing to evolve data products based on user input
- SWX was initiated by Dr. Volz, March 2020
  - New program is the third pillar in the NESDIS Observing Systems
  - Mission will encompass all space weather observational needs including LEO, GEO, HEO and extended orbits
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- Preparing for formal program initiation following MS2/KDP 1 decision gate notionally in 3Q FY22