NESDIS Satellite Programs: Briefing to the Space Studies Board

Dr. Stephen Volz, NOAA Assistant Administrator for Satellite and Information Services

National Environmental Satellite, Data, and Information Service

20 November 2024

NOAA Mission Requirements

NESDIS' future mission requirements are a direct response to implementation of **NOAA's mission needs** and in response to:

- Weather Act Weather Research and Forecasting Innovation Act of 2017 (P.L. 115-125) - **Better observations for NWP; Increased Interactions with Commercial Sector in Satellite Acquisitions**
- National Integrated Drought Information System Reauthorization Act of 2018 (P.L. 115-423) - **Better drought observations for detection, duration prediction & mitigation**
- Promoting Research and Observations of Space Weather to Improve the Forecasting of Tomorrow Act of 2020 (P.L. 116-181) **- More structure for interagency partnerships; Increased interactions with stakeholders; Resilience in Space Weather observation**
- Executive Order on Tackling the Climate Crisis at Home and Abroad (EO 14008) & Executive Order on Protecting Public Health and the Environment and Restoring Science to Tackle the Climate Crisis (EO 13990) **- Foundational data to provide retrospective analysis (NESDIS), monitoring (OAR), and forecasting (NWS, NMFS, and NOS)**

NOAA's mission continues to evolve in order to help the Nation monitor and respond to climate change, atmospheric weather, ocean variability, space weather, and more. NESDIS requirements evolve with it.

NOAA Priorities

Science, Service, and Stewardship

CLIMATE

Building a Climate Ready Nation by establishing NOAA as the federal authoritative provider of climate information and services in the whole-of-government response to tackling the climate crisis

BALANCE

Advance NOAA's complementary work on environmental stewardship and economic development with a particular focus on the New Blue Economy.

EQUITY

Exhibit equity in how NOAA builds and provides services. Promote diversity, equity, inclusion, and accessibility in the workforce. Provide equitable access to NOAA products and services.

Although these priorities in their current form were not specifically included in the requirements that informed the development of our next generation satellite systems, we have the agility in our product development to address them.

NESDIS Approach to Observing System Management

- NESDIS develops and deploys observing systems and ground/data systems to bring data and information to meet our customer and partner needs.
- We must **meet U.S. National Primary Mission Essential Functional (PMEF) requirements**, which drives us to meet high system assurance levels, both for everyday service provision and for long term system continuity, including 10 and 20 years down the road.
- Our observing system elements are executed within a **small number of portfolios**, but the overall system is **interconnected and co-dependent, and dependent upon partner observations,** for NOAA mission success.
- We manage the recapitalization of these interconnected systems seeking to **avoid overlap of peak budget needs**, and we work to control the overlap of those individual element budget peaks.
- NESDIS' success depends fundamentally on our ***users' ability to satisfy their missions***. Close connections, partnerships and co-development with intermediate and end users is a necessity through all our system development activities.

NOAA NESDIS' Earth Observation Strategy

Integrated, Adaptable, and Affordable: Orbits, Instruments & Systems

LEO

Maintain critical global observations and partnerships yielding high accuracy long-range forecasts, including storms, floods and fires. New systems will utilize next-generation instruments launched on single payload satellites, embracing agile, "new space" commercial processes.

GEO

Continuous real-time observations supporting warnings and watches of severe weather and hour-by- hour changes. Monitoring of oceans, atmosphere, and climate to improve productivity and health outcomes.

SWO

Reliably monitoring coronal mass ejections from L1, GEO, and LEO can protect the nation's valuable, vulnerable infrastructure. New capabilities at L5 and high earth orbit 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 a Common Cloud Framework, providing new and better products and services.

OSPO - Operations

24-Hour Operations for GEO, LEO, & Space Weather satellite systems. 24-Hour Support for Severe Weather and Environmental Forecasting Near-Real-Time Products For the User

STAR – Applied Research

Operations-focused research, development, validation, and maintenance of products and applications based on end user needs. **Develops** the science to make raw satellite data useful. **Improves** data quality, products, and services. **Supports** development of next-generation NOAA satellites and missions.

NCEI – Archives & Services

National archive of environmental data. Produces monthly and annual climate reference data reports. Produces National Climate Assessments, Billion Dollar Disaster and other reports. Provides informa services for multiple users.

Geostationary Earth Orbit: Mission Needs Served

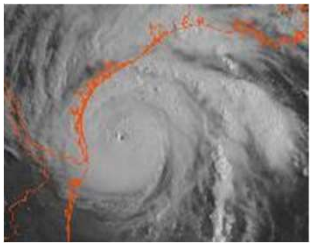
Ongoing Needs: Users require continuity of existing observations with improved performance

- **Data for short-range forecasting, severe weather watches and warnings, and monitoring hazardous environmental conditions** including tropical storms, severe storms with lightning and damaging winds, snow, ice, flooding, fog, fires, smoke, and volcanic ash. These are currently provided by Imagers and Lightning Mappers.

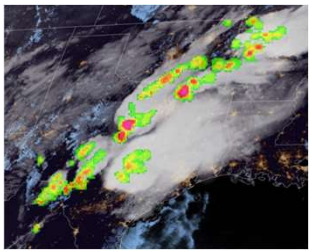
Growing Needs: Users expect NOAA to meet new requirements with new observations

- **Improved numerical weather prediction and local nowcasting,** delivered by Hyperspectral IR Sounder
- **Monitoring dynamic coastal/ocean features, ecosystem change, water quality, and hazards**, delivered by Ocean Color Instrument
- **Monitoring air quality and linkages with weather and climate,** delivered by Atmospheric Composition Instrument

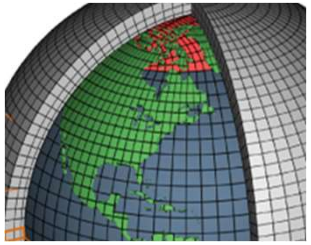
Vis/Near-IR Imagery [Supporting NWS]



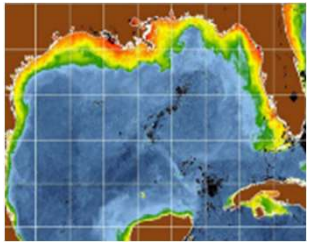
Lightning Mapping [NWS]



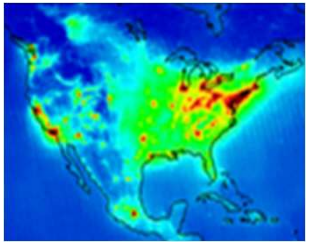
IR Sounding [NWS]



Ocean Color [NOS, NMFS]



Atmo. Composition [OAR]



More than a **20X** return on investment for GEO weather observations: Weather forecasting yields a **$162 Billion/year**[1] benefit to the global economy, with U.S. geostationary satellites providing an estimated ~**14%** of the benefit

1: "The Value of Surface-based Meteorological Observation Data" WMO/WorldBank 2021.

Real Life Examples: GOES Impacts

Hurricane Monitoring: GOES-R Series satellites' Advanced Baseline Imager (ABI) can monitor hurricanes in near real-time, identifying cloud features and patterns, and providing crucial estimates of central pressure and maximum sustained winds.

Sept 27, 2024: Top Story from cnn.com

Severe Storm Tracking: Along with the ABI, the GOES-R lightning mapper allows for better detection and short range forecasts of heavy rainfall and flash flooding and monitor severe storms.

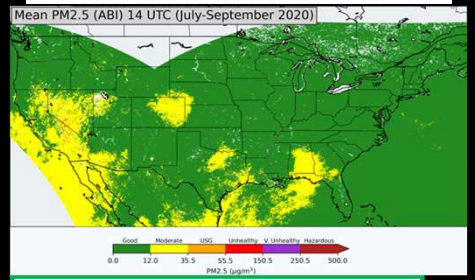
June 14, 2023: Severe Storms Across SE U.S.

Wildfire Detection: GOES-R Series satellites frequently detect fires before they are spotted on the ground – often before emergency notifications to 911. The satellites are also used to pinpoint the exact location of a fire after reports of smoke.

July 25, 2024: Park Fire in northern California

GeoXO's Multi-Instrument Synergy for Atmospheric Composition Observations

PM2.5 derived from GOES ABI AOD



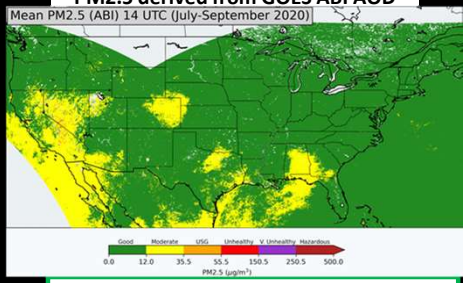
GeoXO Constellation

GEO-West
- Visible/Infrared Imager
- Lightning Mapper
- Ocean Color

GEO-Central
- Hyperspectral Infrared Sounder
- Atmospheric Composition
- Partner Payload

GEO-East
- Visible/Infrared Imager
- Lightning Mapper
- Ocean Color

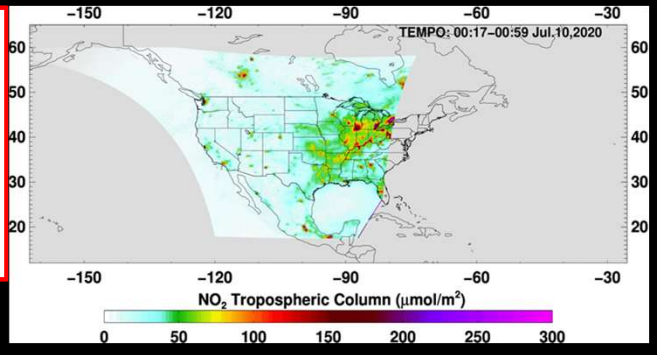
PM2.5 derived from GOES ABI AOD

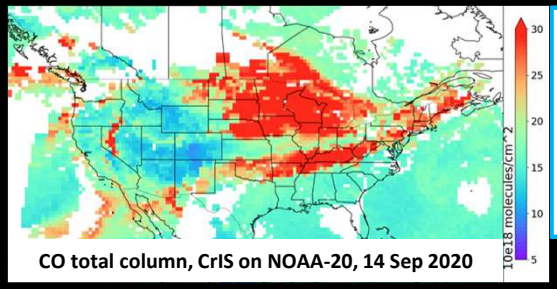


Vis/IR Imager (GXI)
- Fire detection
- Fire radiative power
- Aerosol type
- Aerosol optical depth
- Aerosol concentration

Vis/IR Imager (GXI)
- Fire detection
- Fire radiative power
- Aerosol type
- Aerosol optical depth
- Aerosol concentration

UV/Vis Spectrometer (ACX)
- Ozone
- Nitrogen dioxide
- Sulfur dioxide
- Formaldehyde
- Aerosol layer height





CO total column, CrIS on NOAA-20, 14 Sep 2020

IR Sounder (GXS)
- Ozone
- Carbon monoxide
- Carbon dioxide
- Ammonia

Low Earth Orbit: Mission Needs Served

Ongoing Needs: Users require continuity of existing observations:

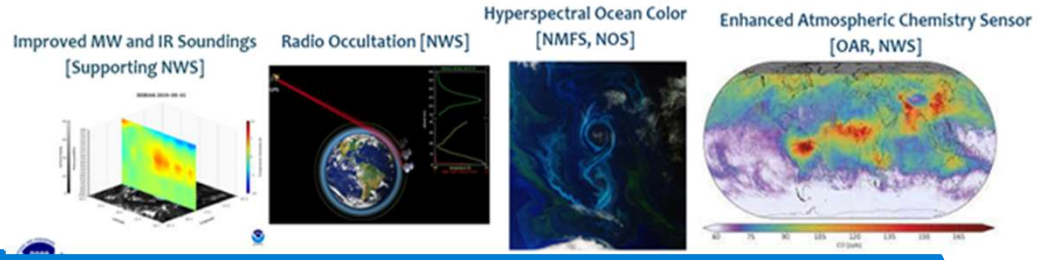
- **Numerical Weather Prediction (NWP) models demand measurements from Microwave, Infrared and RO Sounders on polar orbiting satellites for accurate forecasts.** NOAA's polar satellites are the backbone of global NWP models.
- **Detection and monitoring of hazards such as fires, droughts, floods, poor air quality, and coral bleaching need data from Imaging radiometers from polar orbiting satellites such as JPSS.** Visible and Infrared Imaging Radiometer Suite (VIIRS) on JPSS also provides critical data for measuring upper atmosphere wind speed for NWP models, sea surface temperature and ocean color for fisheries and the ocean service.
- **NOAA meets Clean Air Act mandates, requiring Ozone Monitor measurements to** track the health of the ozone layer and corresponding atmospheric chemistry.

Weather forecasting provides **a $162B/year benefit** to the global economy, with **U.S. Low Earth Orbiting satellites providing 80% of data** that are used in numerical weather prediction models*

**Global observing system experiments in the ECMWF assimilation system, Using satellite soundings at ECMWF and future plans, & The Value of Surface-based Meteorological Observation Data" WMO/WorldBank 2021.*

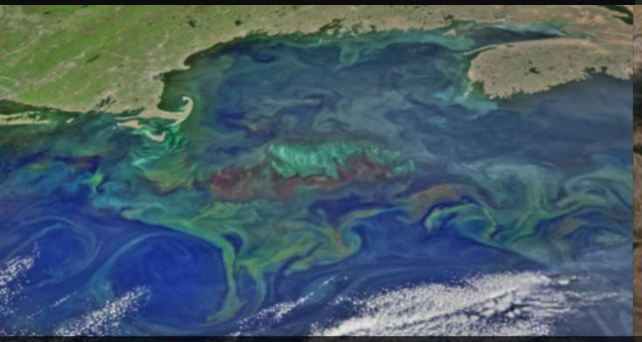
Growing Needs: Users expect NOAA provide improved observations and forecasts:

- **Higher resolution forecasts for short term and long term weather prediction** demand Improved microwave, infrared and RO soundings - more frequent observations with improved spatial and vertical resolution to measure the atmosphere closer to Earth's surface
- **The Blue Economy and coastal communities requires improved information on phytoplankton and harmful algal blooms.** Hyperspectral ocean color imagery at improved spatial resolution will meet this need.
- **Timely and accurate forecasts of air quality hazards require enhanced atmospheric chemistry sensors** for monitoring gases such as sulphur dioxide that cause smog. Improved measurements of ozone and trace gasses such as nitrogen dioxide, methane and formaldehyde are need to assess climate change.



Real Life Examples: LEO Impacts

Ocean Health



May 26, 2015: VIIRS on Suomi NPP captured swirls of phytoplankton and algae in the Gulf of Maine.

"It would take a research ship moving 10 knots for **more than five years** to collect the same amount of data captured in this single image."

— Dr. Amy K. Huff, Senior Research Scientist, NOAA/NESDIS Center for Satellite Applications and Research (STAR)

Fire, Smoke, and Dust Detection

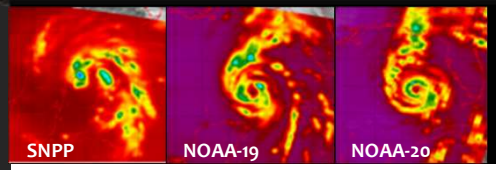
October 8, 2024: NOAA-20 satellite imagery reveals extensive smoke coverage from wildfires across Idaho

"A lot of our end users are operational air quality forecasters. They use aerosol and trace gas satellite data to help prepare operational forecasts of ozone and particulate matter for the public, while health researchers use the data to study the effects of air pollution on public health."

— Dr. Kimberly Hyde, a biological oceanographer with the NOAA Northeast Fisheries Science Center

Hurricane Observation

September 26, 2024:
JPSS VIIRS and ATMS imagery of Hurricane Helene

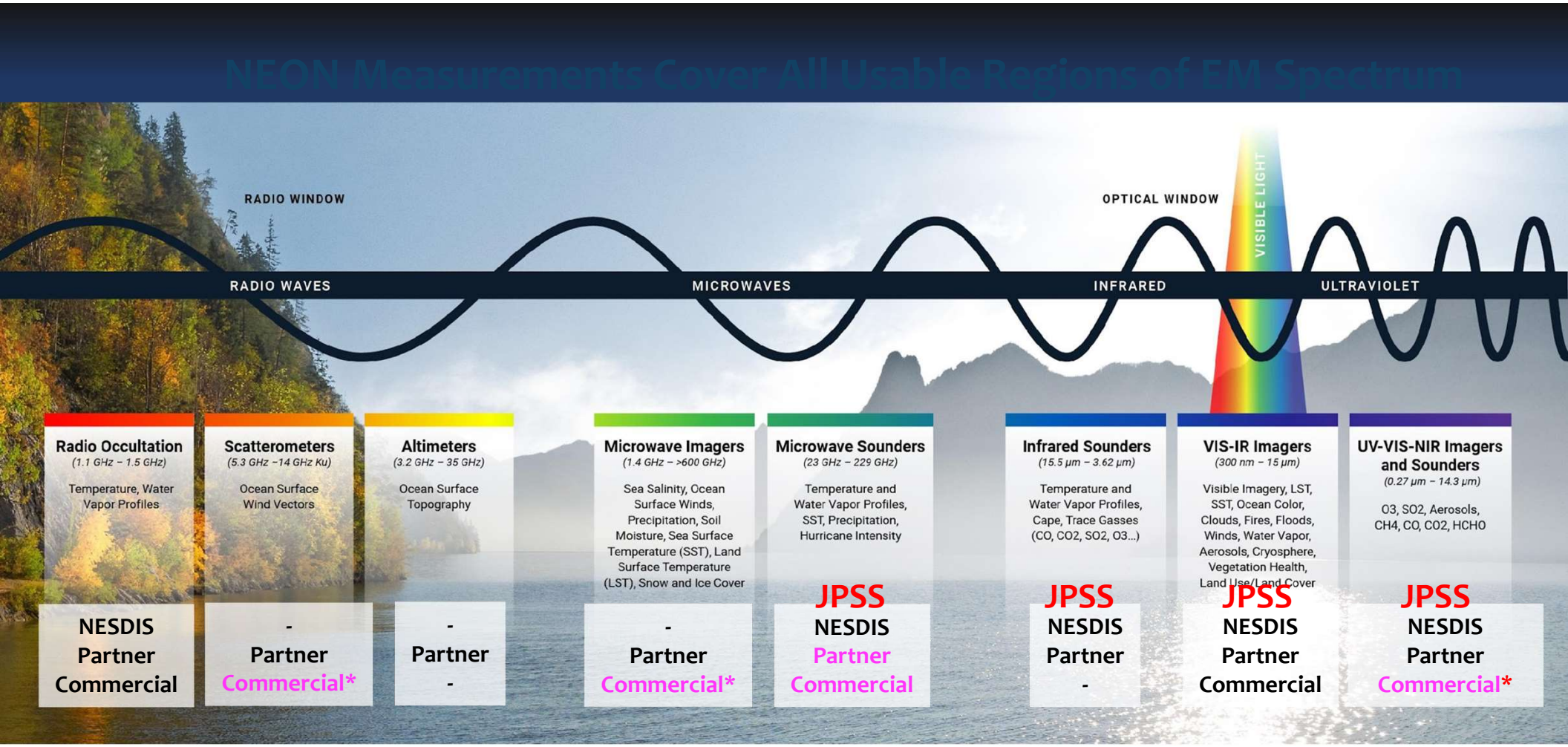


Multiple LEO orbits provide frequent updates on hurricane status.

"The greater accuracy of hurricane forecasts in 2020 relative to 2007 **saved about $5 billion**, on average, in emergency funds and damages."

— National Bureau of Economic Research Report

NEON Measurements Cover All Usable Regions of EM Spectrum



Current Systems **Potential Future Systems** *** indicates current studies**

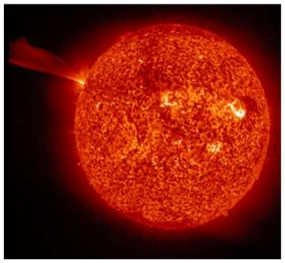
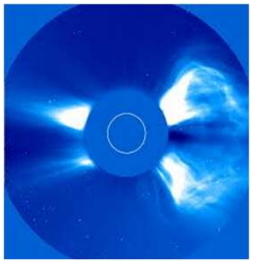
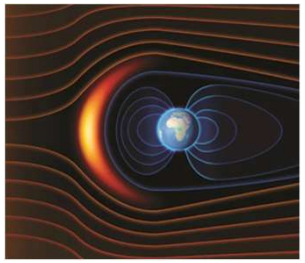
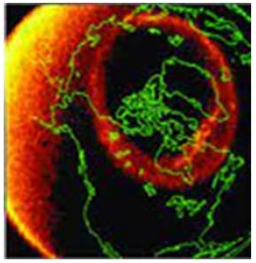
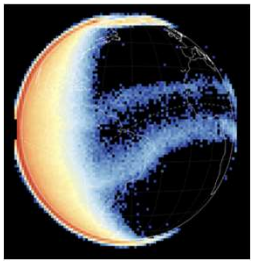
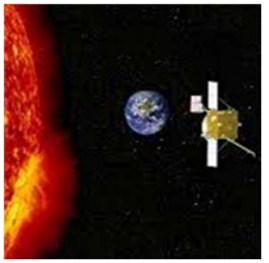
Space Weather: Mission Needs Served

Ongoing Needs: Users require continuity of existing observation for protecting **critical power grid infrastructure, civil aviation,** and provide **space situational awareness (SSA)**:

- **Power grid, aviation,** and **SSA** require solar wind in situ data, coronal and solar imagery for early warning of damaging space weather events to protect critical national infrastructures.
- **Aviation, space commerce, navigation,** and **communications** need ionospheric and magnetospheric observations and forecasts for disturbances resulting from solar and geomagnetic activity**.**

Growing Needs: Users expect NOAA to meet new requirements with new observations:

- **Longer-lead time** and **more accurate solar storm warnings** require operational off-Sun-Earth-axis (L5) observations.
- **Aviation, energy,** and **defense** require forecast the location of the auroral oval and probability.
- **Aviation, space commerce, energy, defense** would use thermosphere imagery and in situ observations for upper atmospheric weather and satellite drag forecasting**.**

Real Life Examples: SWX Impacts

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

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

Communications
- Use backup capabilities
- Alternative frequencies

Rocket Lab launches 2 satellites, returns booster to Earth after delay from surprise solar storm

By Mike Wall | Contributions from Tereza Pultarova last updated 4 days ago

The company's Electron rocket carried two commercial Earth-imaging satellites into orbit Friday (March 24), then splashed down in the ocean.

March 24, 2023

The Washington Post
Democracy Dies in Darkness

CAPITAL WEATHER GANG

How a rather mundane space storm knocked out 40 SpaceX satellites

As the sun enters a more active phase, even minor geomagnetic activity could pose problems for smaller SpaceX satellites.

By Kasha Patel
February 12, 2022 at 9:00 a.m. EST

February 12, 2022

Solar storm bombarding Earth now may reach 'extreme' levels, sparking auroras down to Alabama and straining hurricane-weakened power grids

News By Tariq Malik published October 10, 2024

Supercharged northern lights displays may be visible as far south as California or even Alabama.

October 10, 2024

The New York Times

Solar Storm Crashes GPS Systems Used by Some Farmers, Stalling Planting

The storm interfered with navigational systems used in tractors and other farming equipment, leaving some farmers temporarily unable to plant their crops.

Listen to this article · 3:45 min Learn more

Share full article

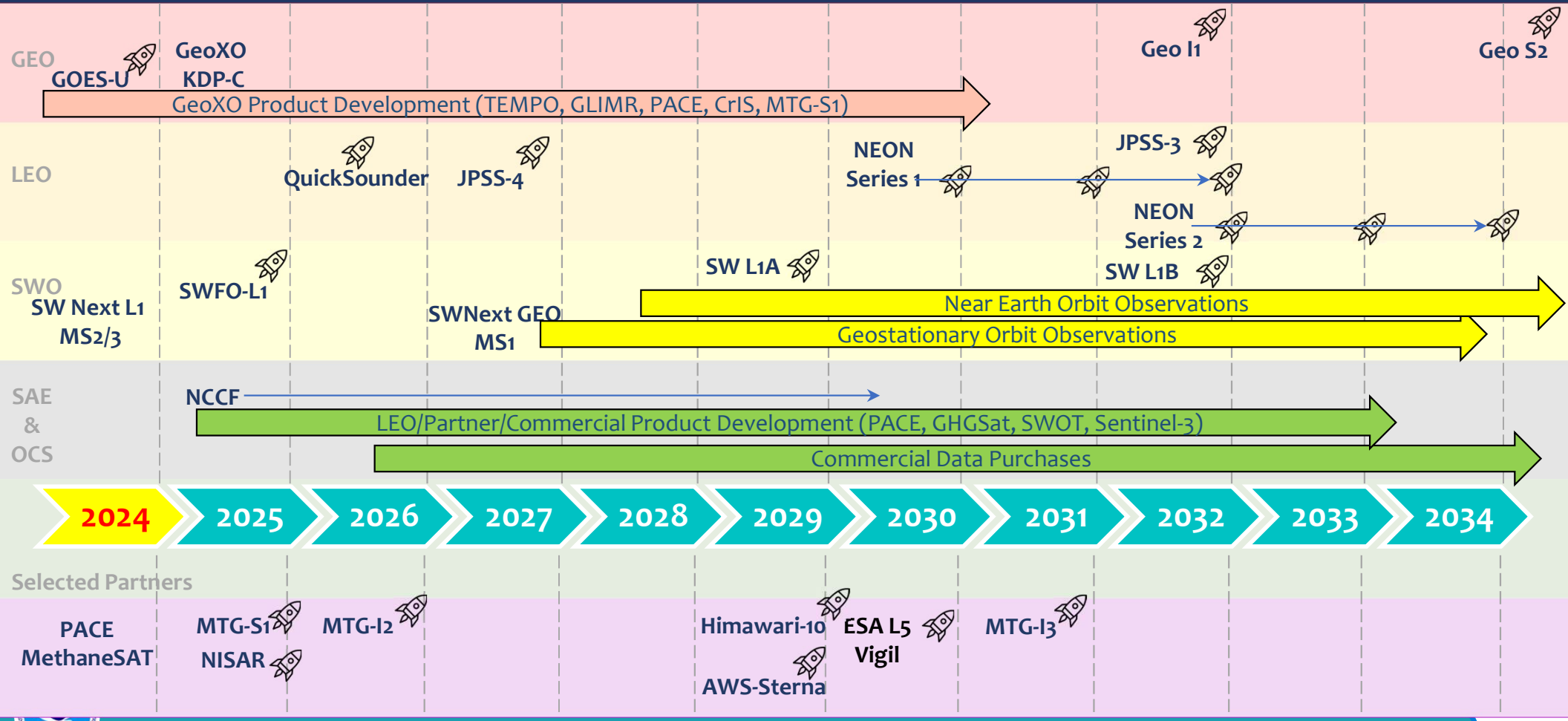
A tractor at O'Connor Family Farms near Blooming Prairie, Minn. Tiffany Graham

May 13, 2024

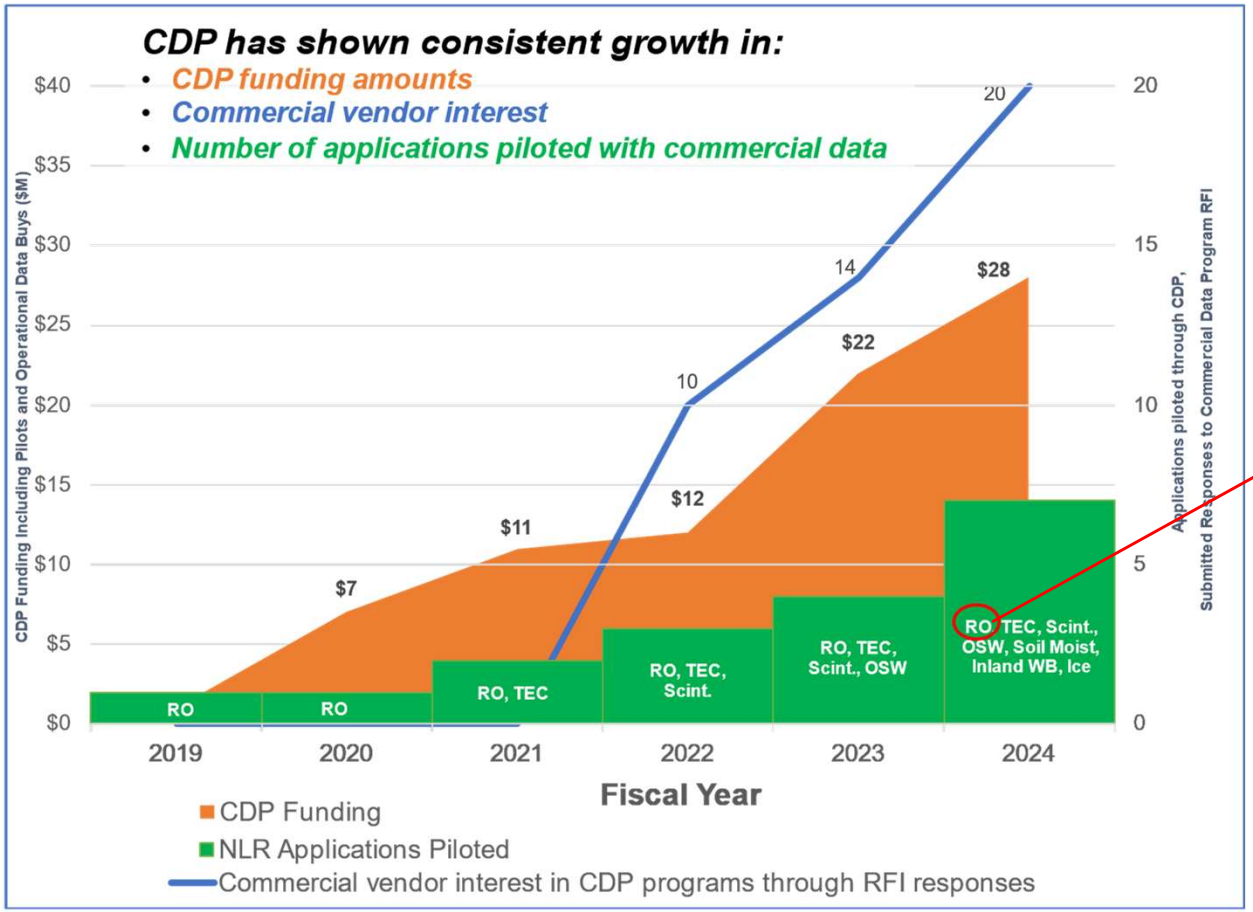
SWO-related **economic losses could be "even more than a trillion dollars" just for the power grid,** without accurate forecasts. FEMA: **Space weather sits alongside pandemic** as the only two natural hazards with the potential for **nationwide and global impacts.**

Source: Congressional Budget Office (CBO), 2020: Enhancing the Security of the North American Electric Grid & Federal Emergency Management Agency (FEMA), 2019: 2019 National Threat and Hazard Identification and Risk Assessment

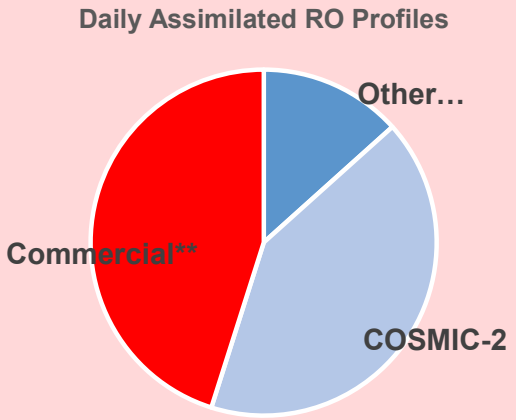
The Next 10 Years for NESDIS: 2024-2034



NESDIS Engaging Commercial Space for Operations



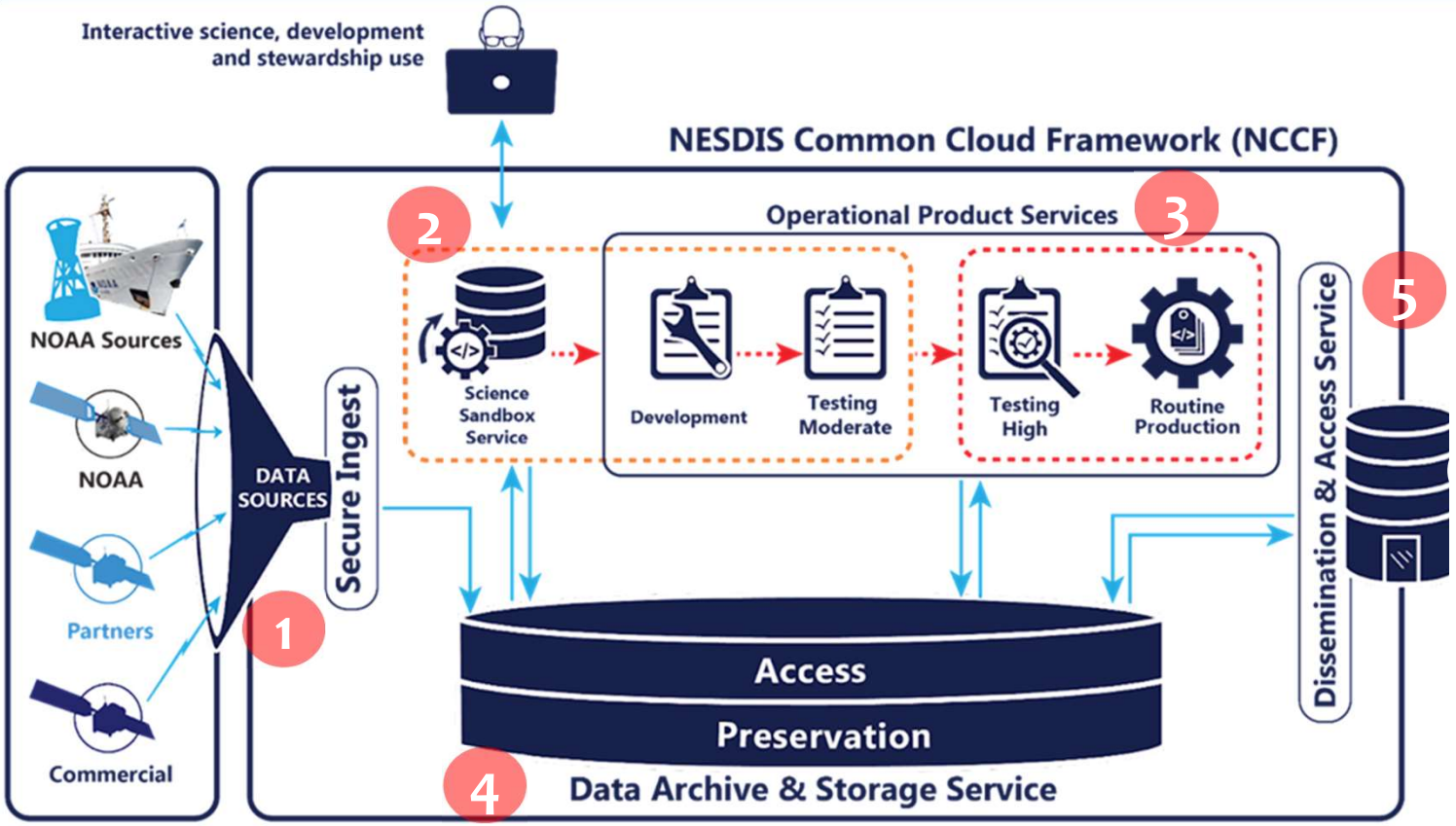
Commercial data from NOAA and EUMETSAT purchases now makes up **nearly half** of all NOAA assimilated GNSS-RO data:



Source: NESDIS CDP, UCAR COSMIC 2023.
***Commercial data consists of coordinated NOAA (CDP) and EUMETSAT purchases*

CDP Funding: NESDIS/CDP Enacted Appropriation ($M)
Applications include RO=radio occultation, TEC=space weather total electron content, Scint.=space weather scintillation, OSW=GNSS-reflectometry ocean surface winds, Soil=GNSS-reflectometry soil moisture, Inland WB=GNSS-Reflectometry inland water body properties, Ice=GNSS-Reflectometry ice properties

Cloud-Based Ground Enterprise Strategy

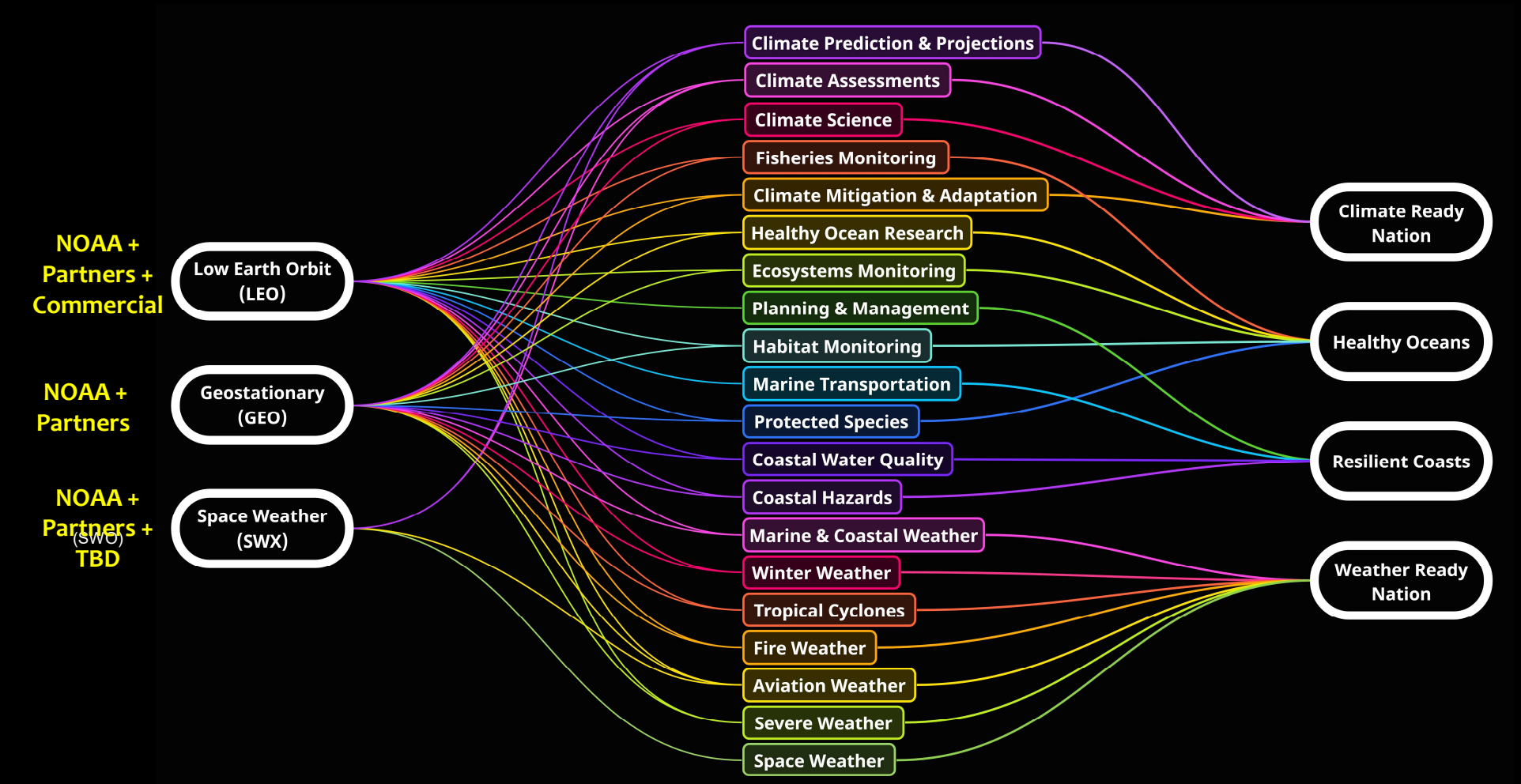


Five Basic Services:

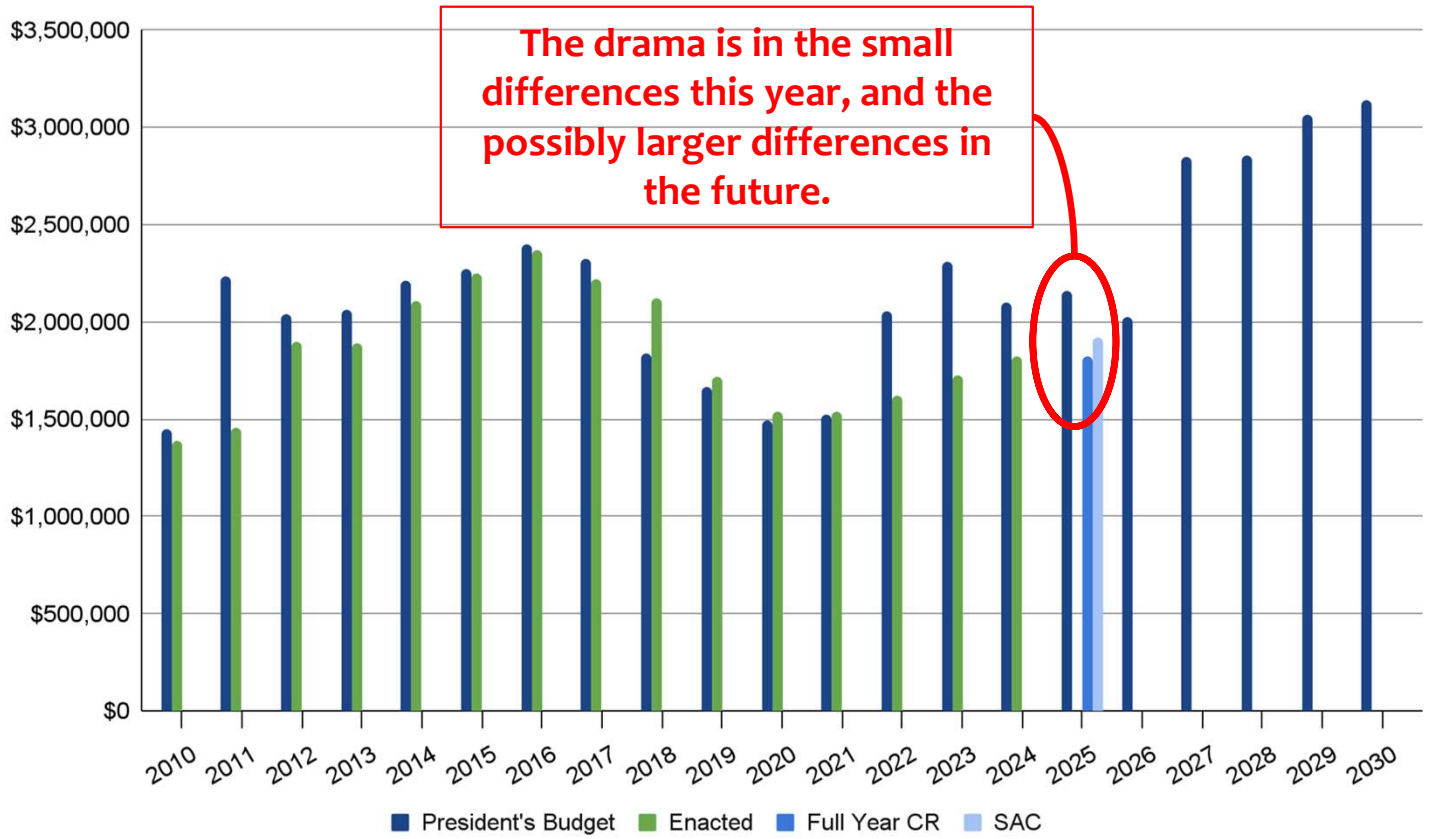
1. Secure Ingest
2. Science Sandbox
3. Operational product processing
4. Data archive & Storage
5. Dissemination & Access

Data Ingest from Sources | Data Flow | Automated Code Deployment | Moderate FISMA | High FISMA

NESDIS Missions Enable the Full Spectrum of Climate Resilience, Ecosystem Awareness, and Adaptation



NESDIS Budget Enacted/Planned: 2010-2030



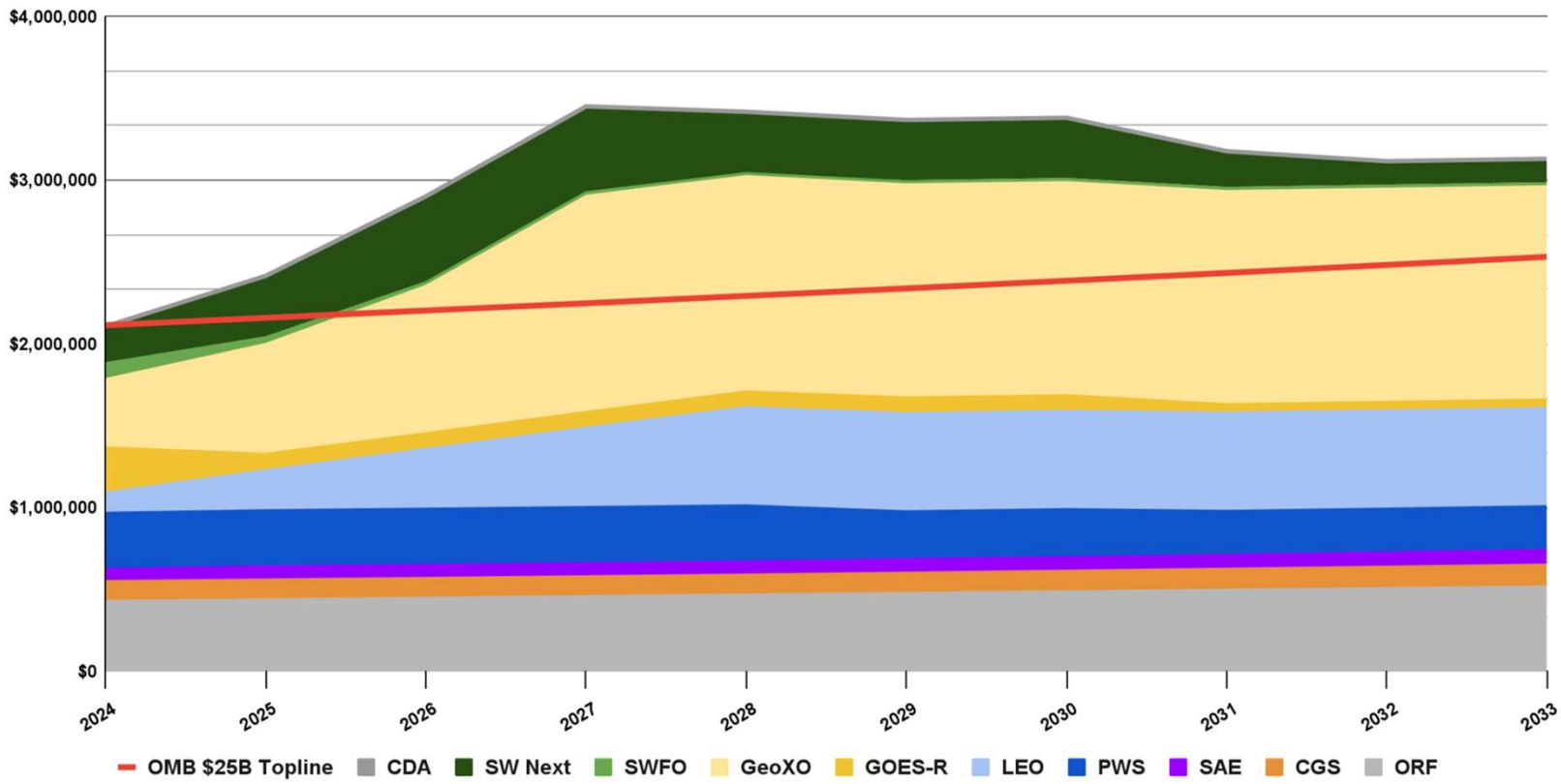
Operations, Research and Facilities (ORF)

Operations, Research and Facilities (ORF) Program, Project or Activity	FY 2024 Enacted ($M)	FY 2025 President's Budget ($M)
Environmental Satellite Observing Systems	310.8	324.2
Office of Satellite and Product Operations (OSPO)	250.2	262.5
Product Development, Readiness & Application (PDR&A)	59.9	60.7
U.S. Group on Earth Observations (USGEO)	0.8	1.0
National Centers for Environmental Information (NCEI)	70.0	73.3
NOAA Community Project Funding/NOAA Special Project	TBD	0.0
TOTAL, NESDIS - ORF	380.8	397.5

Procurement, Acquisition and Construction (PAC)

Procurement, Acquisition and Construction (PAC) Program, Project or Activity	FY 2024 Enacted ($M)	FY 2025 President's Budget ($M)
Systems Acquisition	**1,413.7**	**1,738.3**
Geostationary Systems - R Series (GOES-R Series)	**276.0**	**83.5**
Geostationary Earth Orbit (GEO)	**285.0**	**798.4**
Polar Weather Satellites (PWS)	**342.4**	**342.4**
- Joint Polar Satellite System (JPSS)	84.8	0.0
- Polar Follow On (PFO)	257.6	342.4
Low Earth Orbit (LEO)	**78.5**	**68.4**
- Near Earth Orbit Network (NEON)	78.5	68.4
Space Weather Follow On (SWFO)	**97.2**	**39.7**
Space Weather Next (SW Next)	**151.6**	**236.8**
Common Ground Services (CGS)	**114.0**	**120.5**
Systems/Services Architecture & Engineering (SAE)	**69.0**	**48.5**
NESDIS Construction - Command and Data Acquisition (CDA) Facilities	**2.5**	**2.5**
TOTAL, NESDIS - PAC	**1,416.2**	**1,740.7**
GRAND TOTAL, NESDIS	**1,796.9**	**2,138.2**

NESDIS Budget Profile (FY24-FY33) to Meet Mission Needs



What does the FY25 PB and FY26 DOC Submission Support?

LEO

- Continuity observations including KPP soundings are met with a disaggregated constellation
- Increased risk for failure for infrared soundings (no longer 2 failures to a gap)
- QuickSounder Mission
- **Limited partner data exploitation**
- **Commercial RO data buys only**
- **No increase in capability for emerging mission critical needs**

GEO

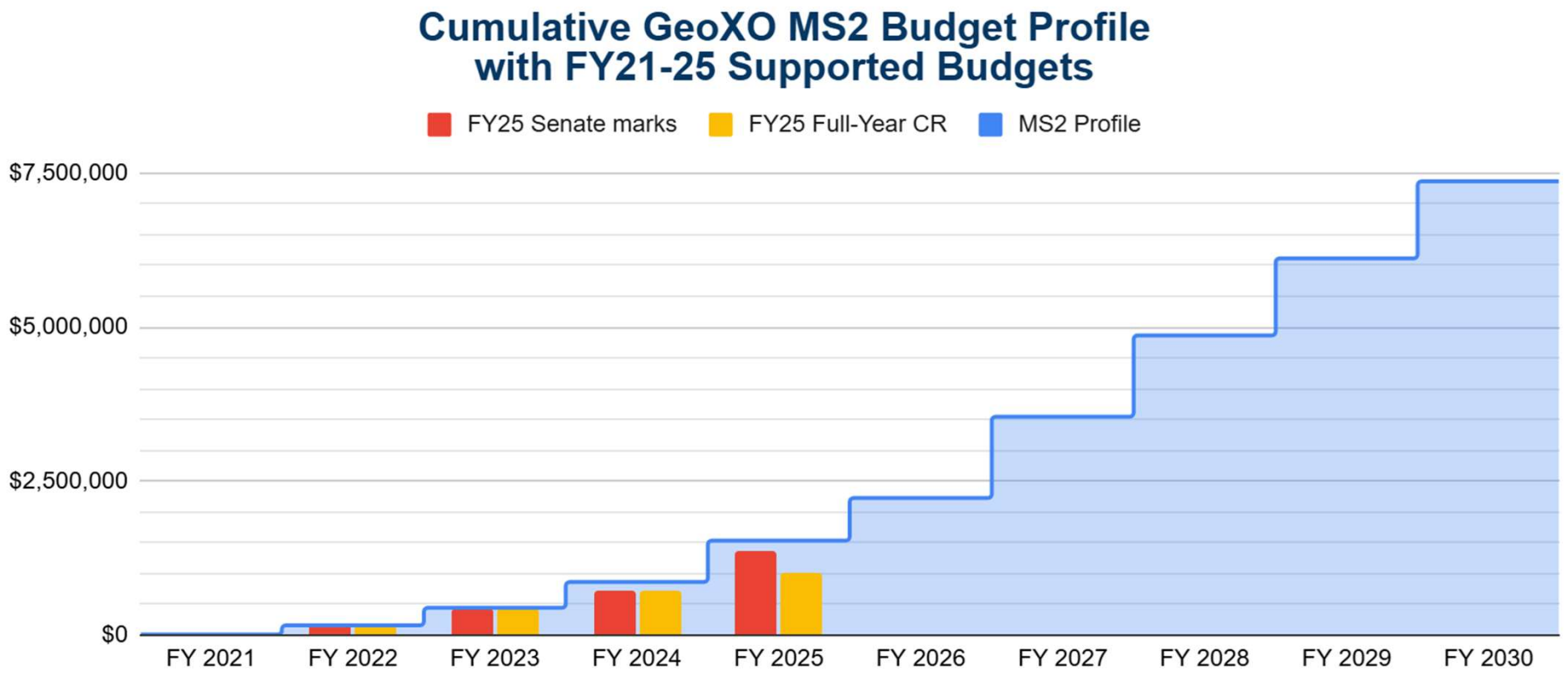
- Imagery KPP is met
- New mission critical needs for improved forecasts and watches, oceans/coasts and air quality measurements are met
- US contribution to GEO Ring is met

SWO

- Continuity (single- string) met for observation of KPP CME and solar wind at L1
- GEO measurements extended beyond GOES-R with single mission*
- Emerging needs for longer lead time for solar warnings (L5) are met

We made these choices in our NOAA budget submittals, prioritizing investments based on mission constellation needs
(on orbit reliability into the 2030s, redundancy posture, etc.)

GeoXO Deficit



Current Enacted Levels are Insufficient for Even Continuity

LEO

- Continuity observations including KPP soundings are met with a disaggregated constellation
- ***No increase in capability for emerging mission critical needs***

GEO

- Imagery KPP is met
- Lightning observations are continued
- ***New mission critical needs*** for oceans/coasts and air quality measurements ***are not met***
- Emerging GEO Sounding need is ***not met***, impacting US contribution to GEO Ring

SW

- Continuity (single- string) met for observation of KPP CME and solar wind at L1
- Partner mission at L5
- GEO SW measurements extended beyond GOES-R with single mission
- ***No increase in capability for emerging mission critical needs***

<u>TO MEET OBSERVATIONAL CONTINUITY ONLY</u>, NESDIS will need an <u>additional $2.5B in PAC</u> above current Enacted levels through FY26-30. (Approx. $1.97B/year + inflation)

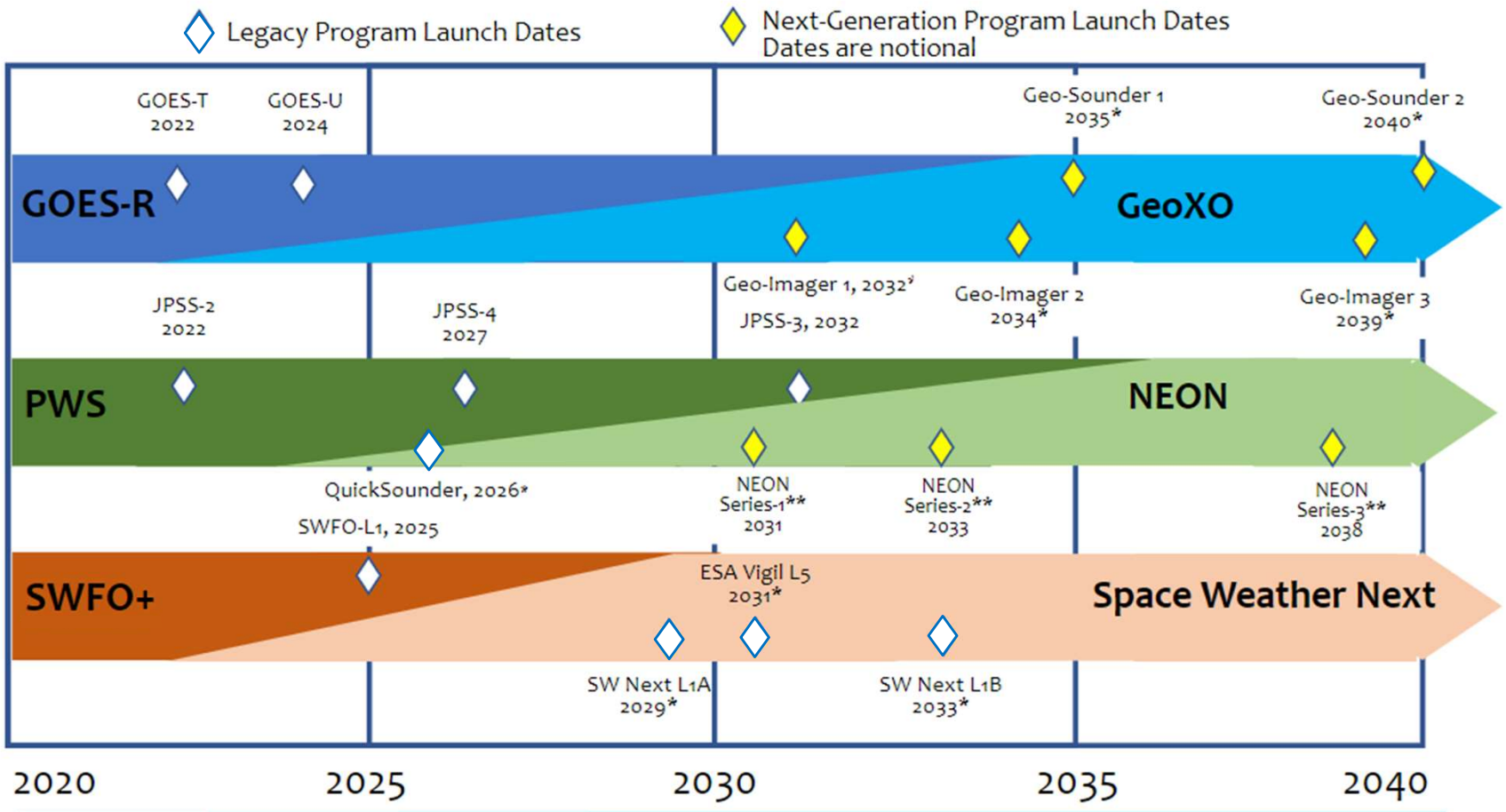
Key Takeaways

- Stakeholders have generally concurred with the mission we present, even the expanded mission
- Funding has been supplied at just the cost level for those years, without funding for requested long lead items (for GeoXO) and without funding for risk reduction investments (for LEO and SWO), but …
- Enacted budgets have not aligned with the President's Budget for next generation satellite programs since 2022
- Some funding has been supplied for IT infrastructure innovation
- NESDIS has developed numerous budget options to address prioritization tradeoffs, but at the cost of established mission needs

FY25 is a "make or break year" for GeoXO. First checkpoint is December 21, 2024 (post current CR) to understand FY25 enacted budget numbers.

BACKUP SLIDES

Notional Flyout for NOAA's Next-Gen Satellite Constellation



* In NOAA baseline plan

** The NEON mission sequencing after QuickSounder are subject to change based on the assessment of periodic mission impact assessments.