NOAA Agency Report

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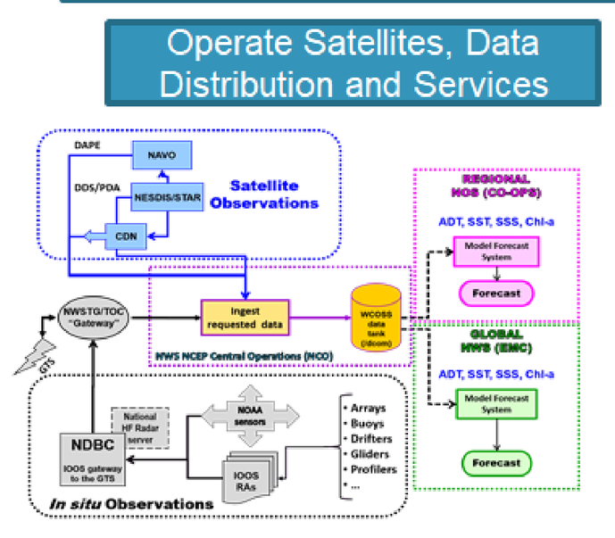
National Environmental Satellite Data and Information Service
DEPARTMENT OF COMMERCE

NESDIS

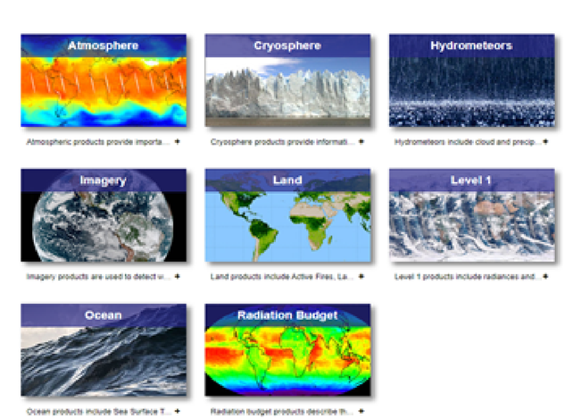
Provide secure and timely access to global environmental data and information from satellite and other sources to promote and protect the Nation's security, environment, economy, and quality of life.

Operate Satellites, Data Distribution and Services



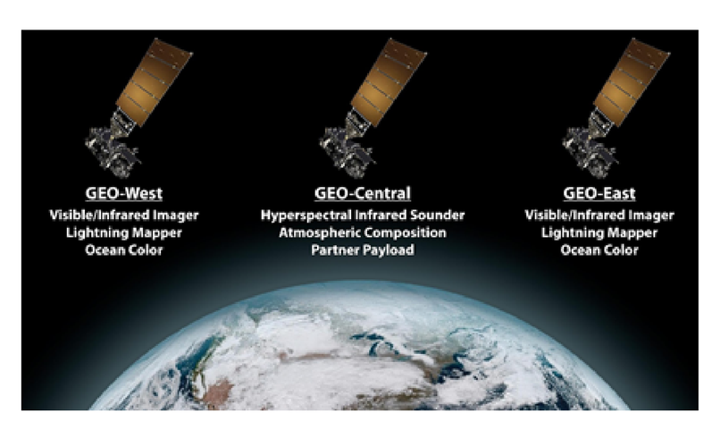
- Operational processing and dissemination
- Data stewardship and archive
- Assessments (State of the Climate)
- Quality Assurance/Control (QA/QC)
- NRT monitoring (CoastWatch/OceanWatch)

Develop Science Algorithms



- Satellite instrument cal/val
- Level 1-4 product development and R2O
- Data assimilation/observation operators, radiative transfer

Planning



- Outreach and user-engagement
- Requirements definition
- Architecture studies (value assessments, OSSEs, OSEs)

NOAA's Next-Gen Earth Observation Strategy

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

LEO

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

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.

Space Weather

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.

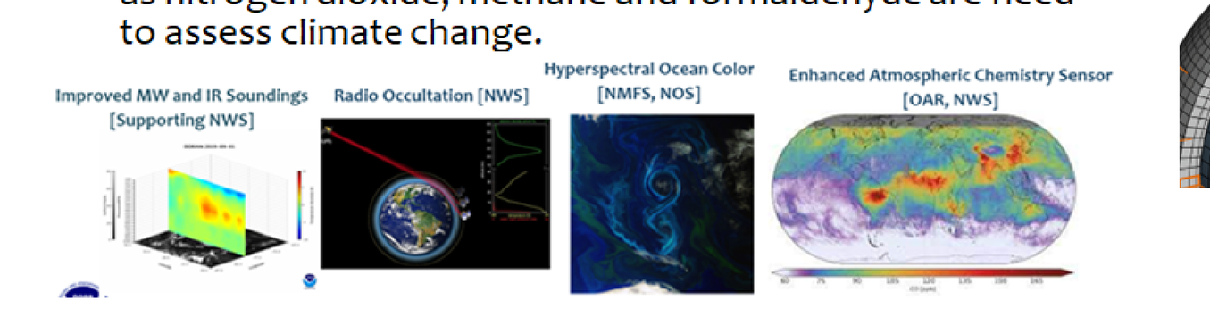
Common Ground Services

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 new and better products and services.

Growing User Needs

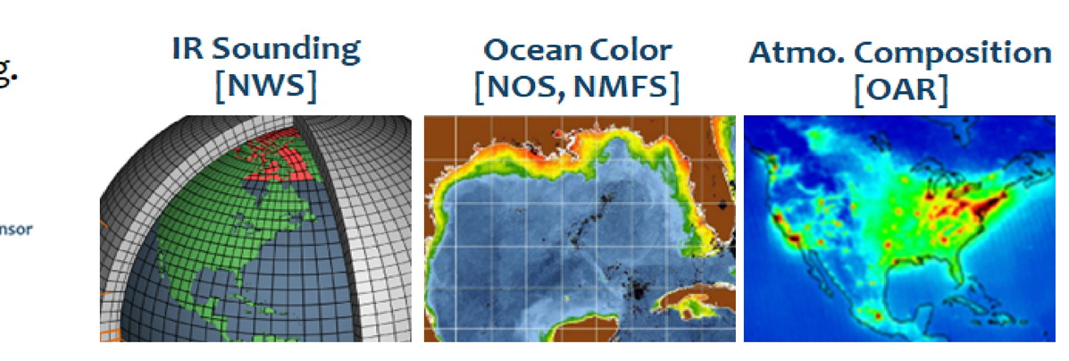
LEO: Users expect NOAA provide improved observations and forecasts (from NOAA, International, Commercial):

- **Higher resolution forecasts for short term and long term weather prediction** - improved microwave, infrared and RO soundings, ocean surface vector winds. 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
- **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.

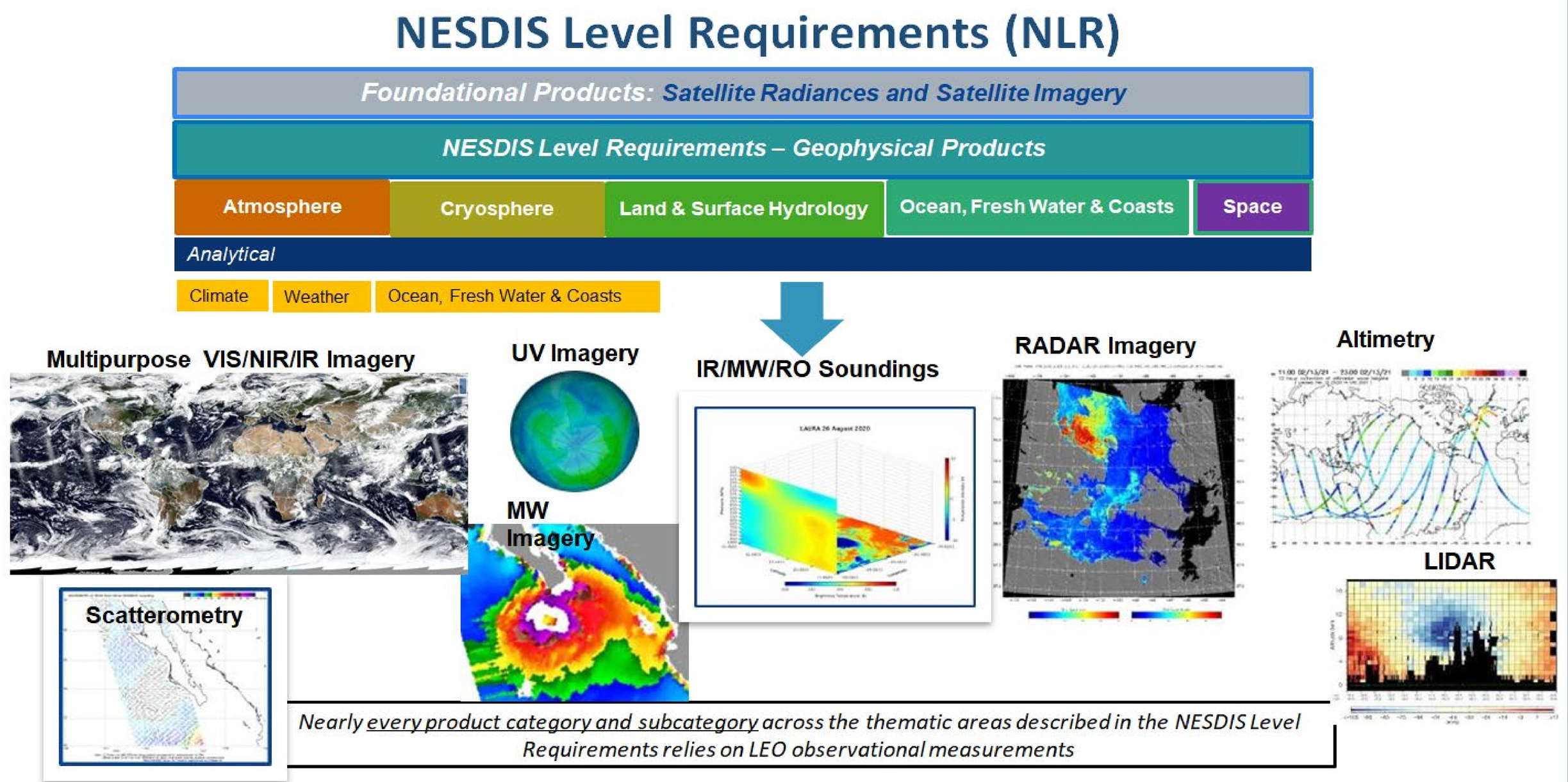


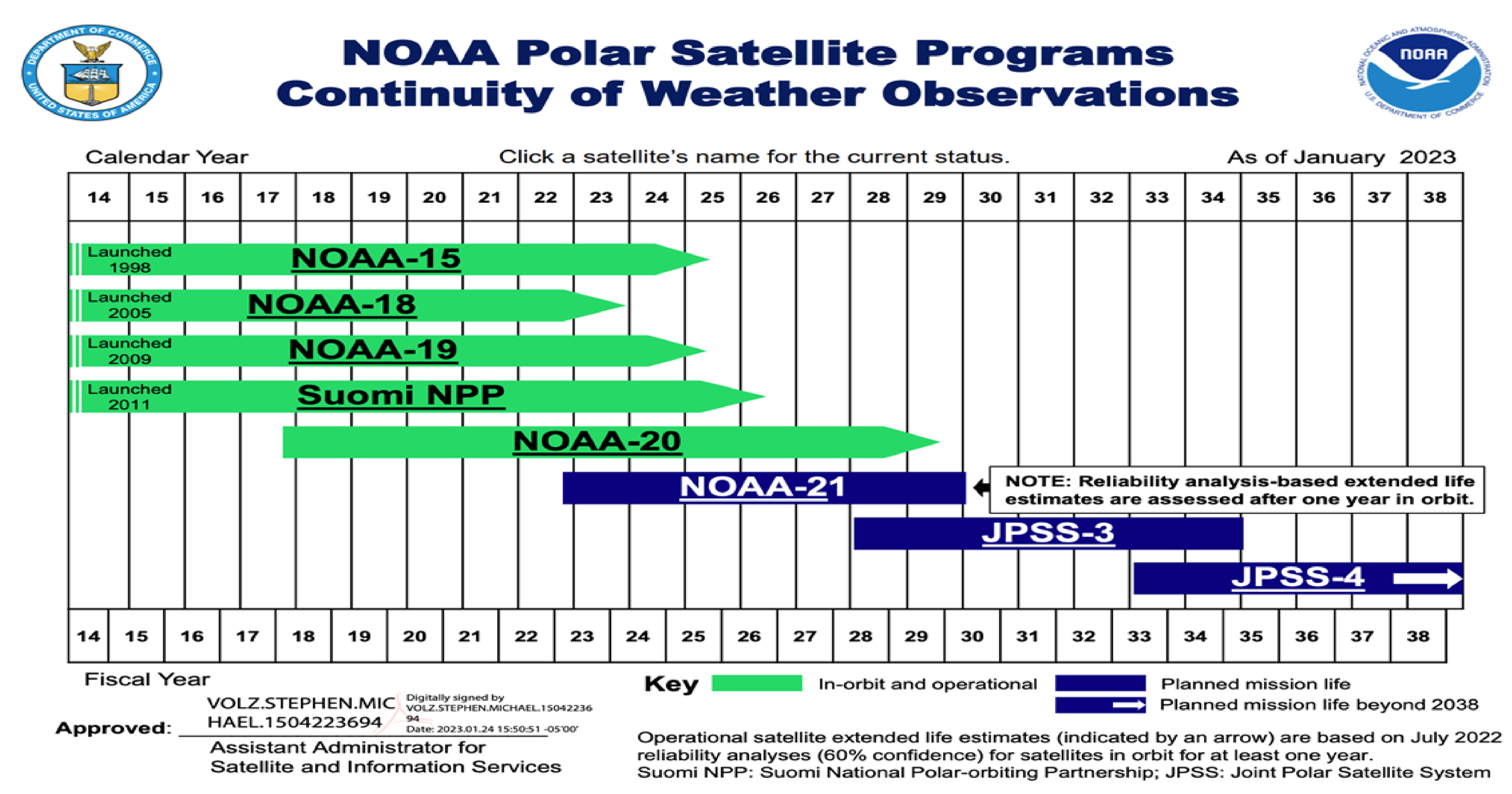
GEO: Users expect NOAA to meet new requirements with new observations

- **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



NESDIS Level Requirements (NLR)





NESDIS Five-Year Product Plan

Product Baseline

NESDIS Five-Year Product Plan documents the implementation-specific elements related to the Product Baseline, and will be annually reviewed and updated

- Description of Algorithms
- User-Impact Driven Priorities
- Fly out Charts
- R2O Transitions and Planned Improvements
- Algorithm Innovation
- Data Exploitation
- Planned Retirements

- Meet or exceed the Product Baseline requirements

Sets the basis for the product portfolio implementation and planning

- Algorithm & Data Source plans
- International & Partner agreements
- Commercial acquisitions
- Infrastructure requirements
- Cloud Services
- Operations impacts
- Mission Mgt resources
- Archive plans
- Budget planning
- User Readiness
- Science Team coordination
- Program coordination

LEO Measurements Activities NOAA

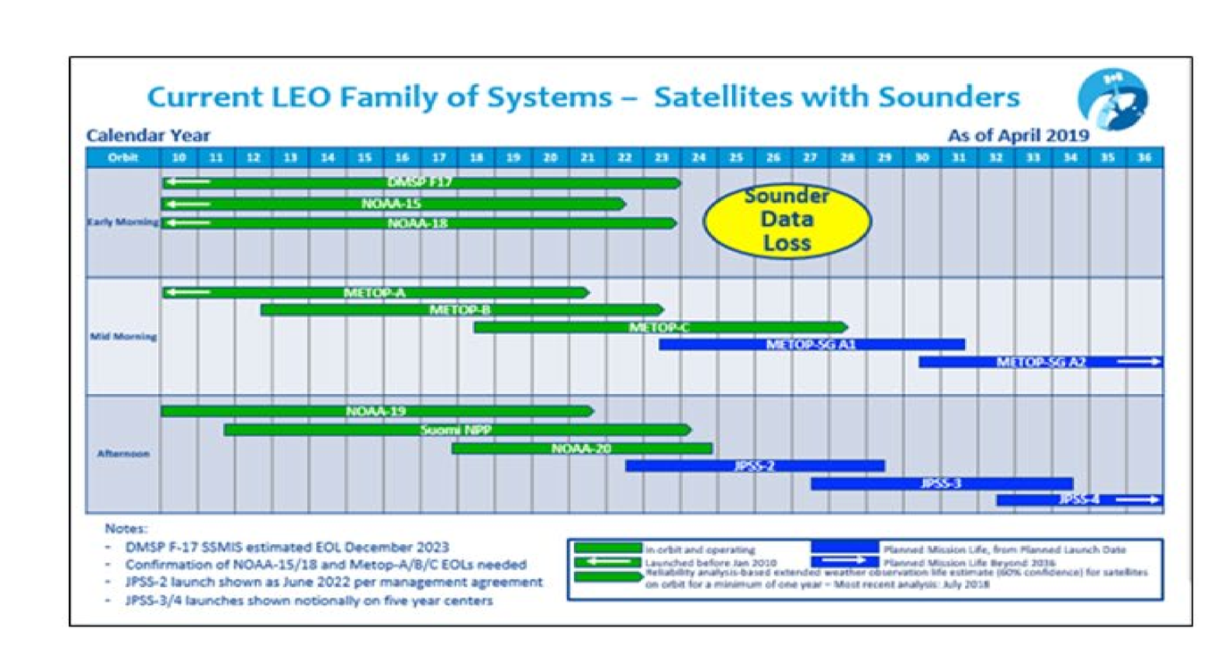
- NOAA relies on a family of LEO missions that we Manage (e.g. JPSS), Contribute under partnerships (e.g. Met Op) and Leverage (e.g. ESA/Sentinel missions)
- The Joint Polar Satellite System is the backbone of NOAA's polar-orbiting operational environmental satellite system and is the Program of Record (POR).
- NOAA relies on partner missions to supplement JPSS observations
  - Met Op (EUMETSAT)
  - GCOM-W (JAXA)
  - DMSP (DOD)
- LEO provides global measurements
  - Vice GEO definition of persistent regional measurements
- LEO is not bound by a specific orbit geometry or altitude
- It is expected that a disaggregated architecture would offer greater flexibility and agility to launch a variety of sensors on a constellation of satellites (compared to a single large spacecraft with multiple payloads).

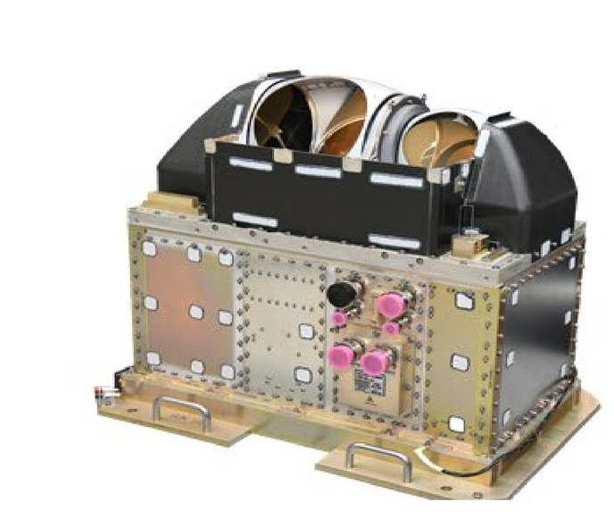
LEO Program

- **The LEO Program seeks to leverage recent innovations by the commercial aerospace industry in small satellite technology, access to space, communications and ground services (aka "New Space") in order to**
  - Improve the agility and resiliency of the architecture
  - Shift from using large, multi-instrument satellites flown on a set cadence, toward smaller satellites to place specific observational capabilities in the desired locations when needed
  - Allow for rapid and efficient replenishment of on-orbit assets and response to changes in observational needs
- **Strategic investments in the ten-year funding profile aimed at achieving the evolving requirements for LEO observations through continuous innovation by**
  - Initiating phased acquisition of the next generation instruments to extend measurements from LEO based on need
  - Exploring new acquisition and collaboration approaches
- **Development schedule is phased in anticipation of when capabilities are needed, beginning with the microwave sounding in the early-morning orbit**
  - Implementing the QuickSounder mission to understand how best to exploit "New Space"

QUICKSOUNDER PROGRAM STATUS

- ***Pathfinder mission to determine the viability of commercial space for future NOAA LEO satellite programs***
  - *Early morning orbit (17:30 LTAN) 824 km*
  - *Launch Readiness Date (LRD) December 31, 2025 with a goal of Sept 01, 2025*





Address the user needs of Early morning coverage

NEXT GEN MICROWAVE SOUNDER STATUS

- ***The Sounder for Microwave-Based Applications (SMBA) is the first instrument development effort for the next gen LEO platforms***
- ***SMBA will serve as the backbone microwave sounder for the new program. The team plans to include:***
  - *All ATMS channels plus 118GHz and 229GHz channels*
  - *Radio Frequency Interference (RFI) detection and hyperspectral capabilities*
  - *Intercalibration performance*
- ***Multiple vendors will be selected for Phase A studies to provide feedback and develop technology for SMBA over the course of 1 year***
  - *Industry Day held on December 7*
  - *Request for Proposals release planned for March 2023*

Virtual MW and IR Sounding Workshops

- ***Held two virtual workshop with the NWP community***
  - *July 28, 2021 Microwave sounding workshop*
    - *https://www.jpss.noaa.gov/science_events/20210728-noaa-microwave-sounder-workshop/*
  - *December 6, 2021 IR sounding workshop*
    - *https://www.jpss.noaa.gov/science_events/20211206-noaa-virtual-infrared-sounder-workshop/*
  - *Presentations from NWS, IPWG, ECMWF, Met Office, STAR, JPL, JMA, ITOVS, BOM, SSEC, JTWC, OAR, LATMOS, GMAO*
  - *Over 125 people attended from NOAA, CIs and industry*
  - *Covered all applications that soundings contribute to: NWP DA, Precipitation, Tropical Cyclone intensity, Atmospheric Chemistry*

Questions Addressed by the Presenters

- *What applications rely on soundings?*
- *What is the importance of soundings to your applications?*
- *Which channels/frequencies are most important to your application?*
- *What is the information content provided by different wavelengths to your application?*
- *What improvements are recommended for future sounders?*
  - *Spatial resolution, different/more wavelengths, noise, temporal refresh, latency etc*

Summary from MW Sounding Workshop (1)

- *MW soundings have the highest impact on NWP among various satellite data that are used in data assimilation.*
- *NWP centers rely on a 3 orbit backbone constellation with sensors providing data in the 23 GHz to 183 GHz frequencies, and this capability should be maintained and continued in future.*
- *New sensors should aim to achieve lower noise and striping than current sensors.*
- *Frequencies in the 50-60 GHz frequencies have more information content than the 118 GHz channels for temperature sounding, and 118 GHz channels should not be considered as a replacement for lower frequency channels.*

Summary from MW Sounding Workshop (2)

- *The 183 GHz channels are important for humidity soundings.*
- *Measurements in frequencies at 23, 31, 50, 51, and 89 GHz are also used for surface sensing in clear conditions, QA/QC and Cloud clearing in DA, and precipitation.*
- *MW sounders on older satellites that are operating beyond their mission life still provide impactful measurements and should be continued as long as technically possible. (Legacy POES)*
- *More studies are needed to define supplemental missions to the backbone (frequencies, orbits etc)*

Summary from MW Sounding Workshop (3)

- *It takes 1-2 years to full test and implement new measurements in to NWP DA. Longer mission life is therefore recommended.*
- *Both future backbone and supplemental MW sounder missions should incorporate technology to address radio frequency interference (RFI).*
- *A constellation architecture that combines diverse backbone and supplemental missions with differing launch dates and mission lifetimes needs a robust calibration strategy that recognizes inter-calibration, absolute calibration, and traceable calibration as intertwined.*

Summary from IR Sounding Workshop (1)

- *IR soundings have the second largest impact on NWP.*
- *Maintaining the backbone with highly capable sensors like CrIS and IASI is critical*
- *Only cloud free radiances (fully clear scenes) or completely overcast pixels are assimilated. Heterogenous scenes are ignored. (IR cannot see through clouds).*
- *Successfully handling clouds is absolutely critical for IR exploitation (cannot use the same techniques as MW because the physics is different).*

Summary from IR Sounding Workshop (2)

- *LW+MW have the highest information content and these channels only used in NWP Data Assimilation (DA). SW channels are not assimilated yet because on non-local thermodynamic equilibrium. Early results of assimilating SW show mixed results.*
- *Future sounders should have higher spatial resolution since the models are moving to 1-2 km spatial resolution. Also, higher spatial resolution enables better cloud clearing or looking in between clouds.*
- *Much of the DA is adaptive and autonomous, but new sensors require significant human resources. Problematic sensors will be ignored. (users will rely on sensors that are stable and well understood). Calibration stability is very important.*

Summary from IR Sounding Workshop (3)

- *While low noise is necessary, it should not come at the cost of other factors such as spectral and spatial resolution. NEdT and spectral resolution should be considered together. (we cannot use our microwave brains for IR sounders)*
- *Onboard processing like IASI for data reduction is acceptable. (CrIS does not do onboard processing because a) JPSS spacecraft can support the band width for high data b) NOAA+NASA users want all the raw data for recalibration and reprocessing etc.)*

Summary from IR Sounding Workshop (4)

- *Colocation with MW sounders is desirable but not essential. Same with an imager as well (__nice to have an imager next to a IR sounder but it is not critical__)*
- *At NOAA, the NUCAPS systems uses IR+MW together to do retrievals that go to AWIPS (But that is because of long history of colocating IR+MW sensors on the same platform, and the algorithms are designed to use the data together)*
- *Frequent IR measurements of water vapor enable tracking of winds (e.g. hourly coverage). Examples include winds from AIRS at the poles.*

Summary from IR Sounding Workshop (5)

- ***Low latency (DBNet) is valuable since it allows observations to be used in rapid refresh models that have short cut-off forecast runs.***
- *Hyperspectral IR sounders provide valuable supplemental information for atmospheric chemistry - SWIR (CO, CO2), MWIR (CH4) and LWIR (O3). All are critical for supporting global air quality and climate services. IR sounders provide good augmentation to other type of sensors since they sample most of the troposphere which is otherwise relatively under sampled. They complement nicely other solar SWIR missions dedicated to atmospheric chemistry such as MOPITT, OMPS, SCIAMACHY, GOSAT, OCO-2, TROPOMI, GeoCarb etc.*

Summary from IR Sounding Workshop (6)

- *The SW range of the IR sounders in future should be extended to (1.5-2.5 micrometers) since it is required to retrieve the entire total tropospheric column of CO, CO2, and CH4. Spectral range and resolution matter - the higher the resolution, the closer we can measure the air we breathe.*
- *Morning and afternoon orbits better capture photochemical processes*
- *West coast fires had a dramatic impact on air quality with significant emissions of CO, O3, PAN and NH3. (The 2020 fires caused damage of ~$16B which is 4X NOAA budget). IR sounders tracked these emissions quite well.*
- *Atmospheric chemistry from IR sounders is used in several systems (JPL's TROPESS, ESA's CAMS and C3S, NOAA's GFS and RAQMS, NASA's GMAO, CLIMCAPS)*