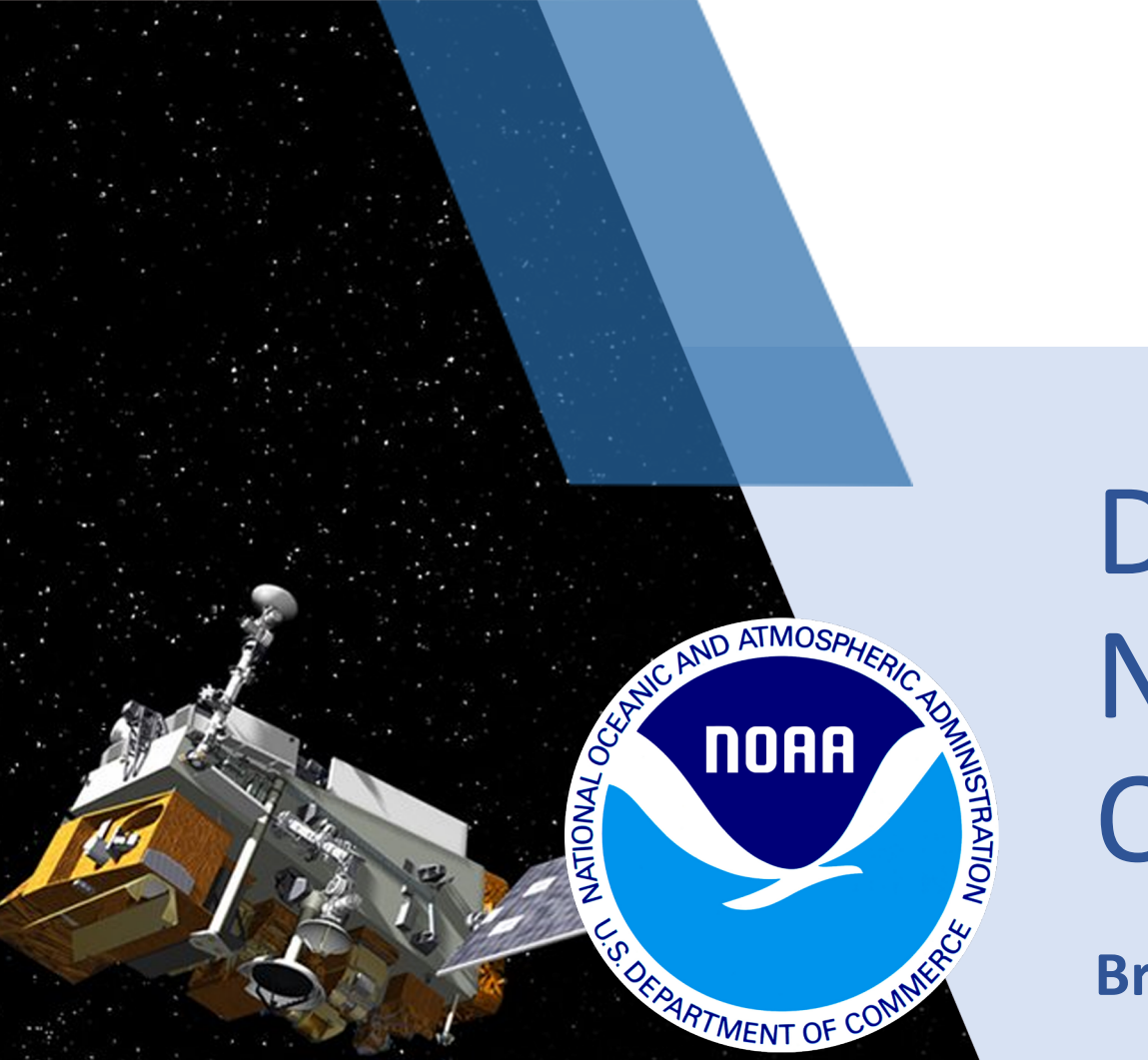


National Environmental Satellite, Data, and Information Service

June 16, 2021

Developing NOAA's Next-Gen Earth Observation Capability

Briefing to ITWG – Advanced Sounders

Mitch Goldberg, NESDIS Chief Scientist

Vanessa Griffin, Office of Systems Architecture and Advanced Planning (OSAAP)

Next generation sensors and data

Action ITSC22-AS-5 to Karen St Germain to provide information on the new NOAA trade study mission
Action ITSC22-AS-6 to ASWG Co-chairs to organize ASWG members and provide feedback to NOAA on all aspects of the proposed mission(s)

Recommendation ITSC22-AS-4 to space agencies to keep IR and MW sounders together on the same platform**.**

Recommendation ITSC22-AS-5 to space agencies to study whether to have or not the imager on the same platform

Recommendation ITSC22-AS-6 to space agencies to keep inter-satellite good calibration and consistency for both IR and MW**.**

Action ITSC22-AS-7 to ITWG Co-chairs:

Bring these recommendations to the attention of Space Agencies at CGMS.

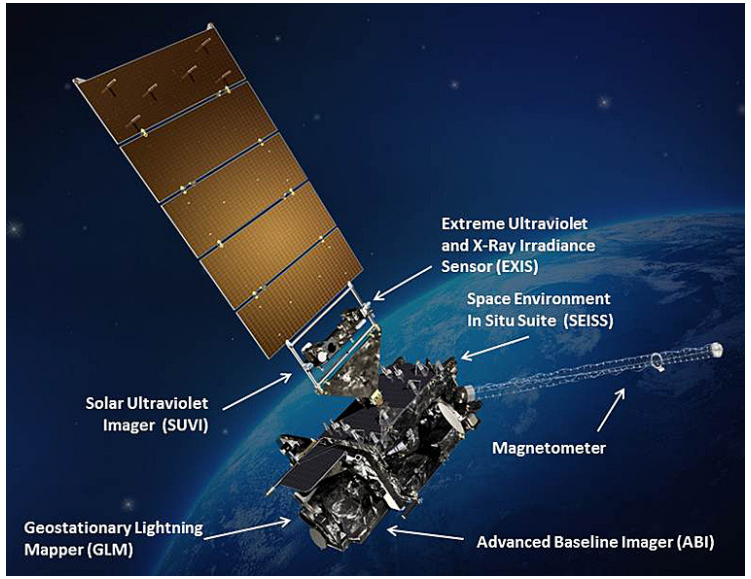
Today's Space Architecture

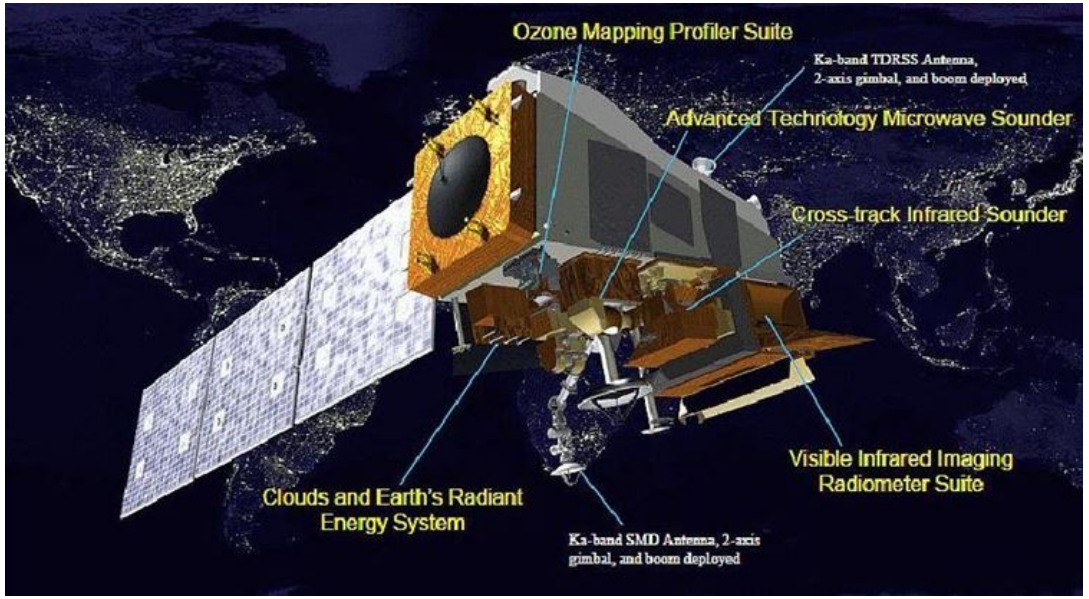
Today's space-based observation architecture is highly capable – but not adaptable.

Large, capable satellites require:
- Very low risk for each satellite
- 10+ years in development

Very low risk requires:
- Locked up funds
- High cost for top end of assurance scale

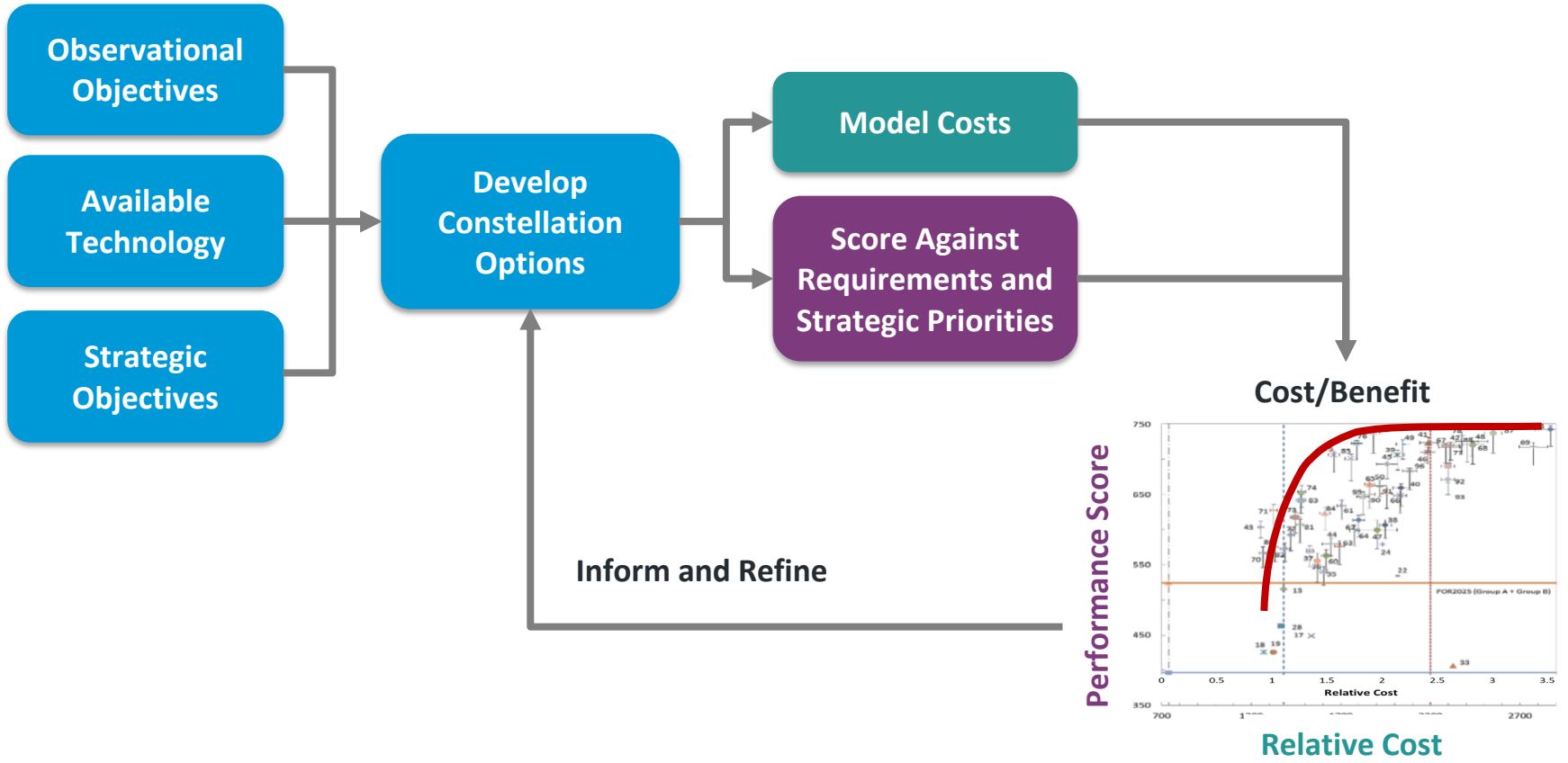
Long development requires:
- Inability to exploit tech advances





2018 Architecture Study Informs Our Next-Gen Decisions

NSOSA identified the most cost effective space segment architectures for performing the NOAA mission beyond the POR to 2050.



High-Value Frontier Attributes

Mix of higher-impact observations

- Small & medium platforms
- Enhanced imagery & high-altitude coverage

More agility

- Disaggregated
- Onramps to new technology

New business models

- Data purchases, ride shares, & hosted payloads

Four Pillars Support Next-Gen Earth Observations

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

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.

GEO-XO

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 & 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.

Joint Venture – Leveraging Partnerships

Current

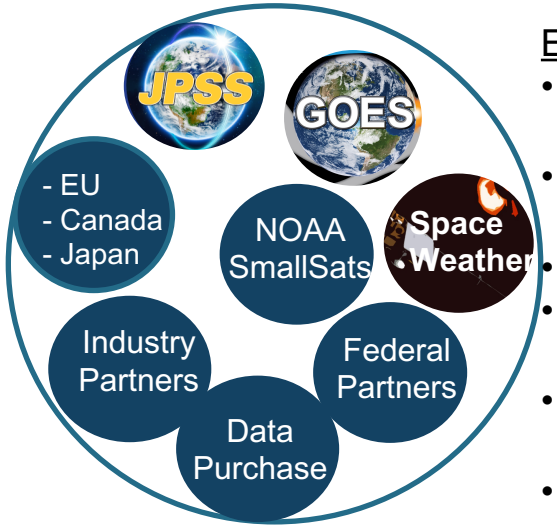
NOAA launched Low Orbit

NOAA launched Geostationary

Partner Satellites

- EU
- Canada
- Japan

2030-2050



Enterprise Architecture

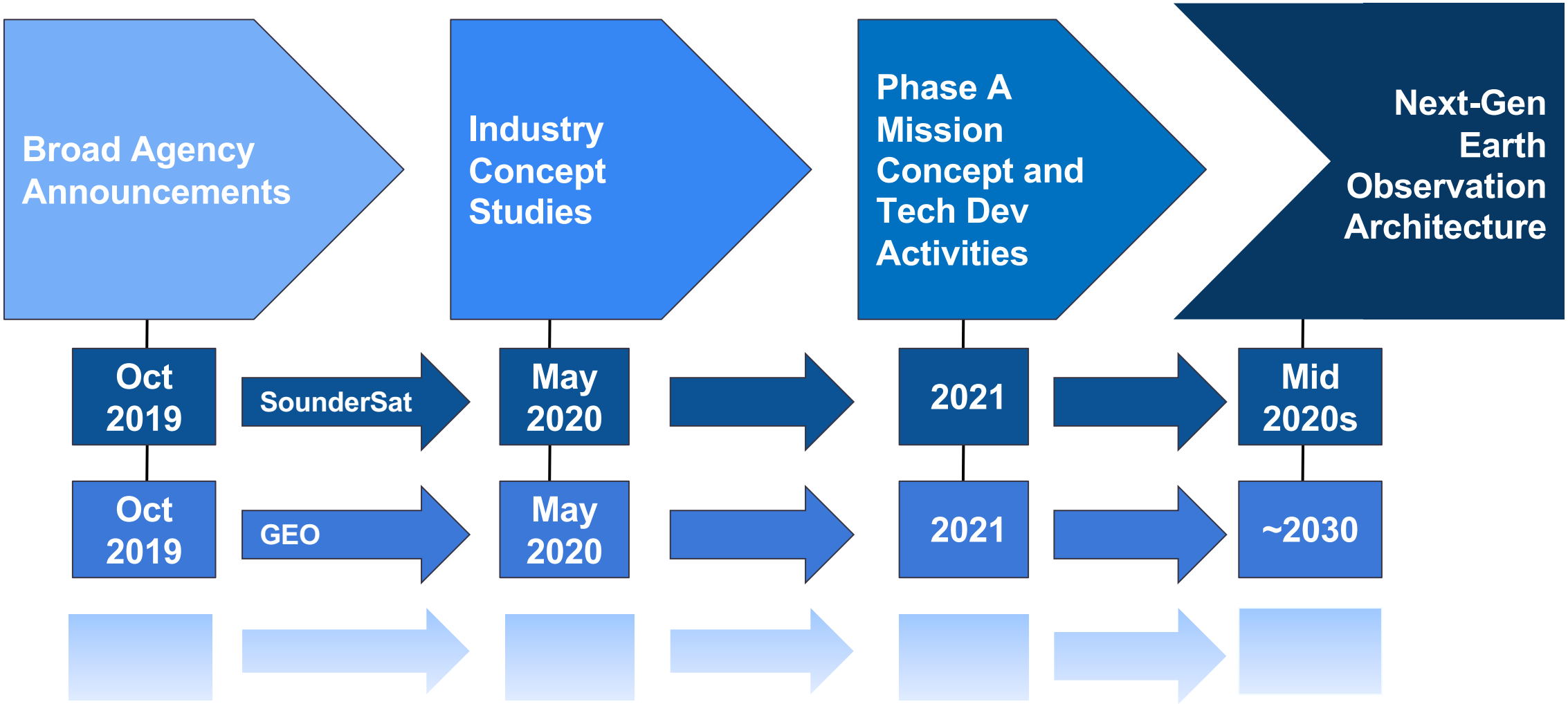
- Partially disaggregated Low Orbit
- Mixed US government Geostationary
- Partner Satellites
- Mixed resolution, update rates
- NOAA launched, rideshare, and payload
- Data buys

Joint Venture

Leverage capabilities being developed by other federal partners & industry - to provide high return on funds

- Exploit partner data
- Exploit partner technologies
- Partner to supplement other agencies' initiatives to meet NOAA needs
- Initial Concept Development to operationalize new data & technology

Partnering with Industry: Ongoing Cycles to Leverage Industry Concepts, Ideas & Innovation



GEO-XO Industry Concept Analyses

FY20 funds being used to partner with industry for options to **replenish GOES-R Series data by 2030**:

Instruments

- Regional, real-time weather imagery
- Space weather data
- High latitude observations – highly elliptical orbits (Tundra) for Arctic observations
- Hyperspectral sounding

Implementation solutions

- Standard satellite bus
- Small satellites for space weather instruments
- Hosting services
- Commercial data

2020: Completed Pre-Phase A Studies
2021: Starting Phase A

SounderSat Industry Concept Analyses

Priorities in LEO:

- SounderSats providing critical sounding data
- Small to medium instruments observing 3D winds, ocean surface vector winds, precipitation data, and low light imagery

Industry awards to explore design and capability options:

- Sounding instruments (microwave, infrared, radio occultation)
- New acquisition and observing system concepts:
  - Commercial services
  - Multi-orbit coverage
  - Common satellite bus for flexibility in instruments flown
  - Rapid launch cadence
  - Demonstration missions
  - Risk tolerance and observing system risk management

2020: Initial pre-Phase A studies completed

2021: Complete pre-Phase A and begin focused industry designs and collaborations

Mid-2020s: Demonstration Flights

BAA Concept Studies awarded to date: GEO-XO

Instruments

- **Raytheon:** Real Time Imager (RTI)
- **Lockheed Martin:** Flexible Hosted Imager (FHI)
- **L3Harris:** Advancing Today's ABI Foundation into the Next-Gen GEO Imaging Solution
- **L3Harris:** Hyperspectral GEO Sounder Study
- **Leidos:** GEO Earth Multispectral Mapper (GEMM) for Terrestrial Weather Imaging
- **JPL:** GEO IR Sounder
- **JPL:** GeoSTAR: A Geostationary Microwave Sounder for NOAA
- **Ball Aerospace:** Ball Operational Weather Instrument Evolution - (BOWIE) Geostationary IR Sounder Study for Compact Hyperspectral IR Observations (CHIRO)
- **Northrup Grumman:** Photonic Imaging Spectrometer Instrument Concept Exploration
- **Northrup Grumman:** Geostationary Microwave Sounding Unit (GEMSU)
- **Ball Aerospace:** Dedicated Auroral Imager for a Tundra Satellite

LEO constellations/Commercial data and services

- **BAE Systems:** Infrared Sounding Instrument Constellation Study
- **ASTRA:** GEO Utilzation of Common LEO Architecture for Weather (G-CLAW)
- **GeoMetWatch:** Global HyperSpectral Atmospheric Sounding Capability: Commercial Fee-for-Service Option
- **Maxar SSL:** Commercial Hosting Service for Sustained GEO Weather Missions
- **Xplore:** PANORAMA - Commercial Earth-Sun L1, L4, L5 Missions

BAA Concept Studies awarded to date: LEO Soundings

Instruments

- **L3Harris:** Infrared LEO Sounder Instrument Study
- **Northrup Grumman:** Alternative Leo Small Microwave Sounder (ASMiS)
- **Ball Aerospace:** Ball Operational Weather Instrument Evolution -Microwave (BOWIE-M) Sounder Study
- **Ball Aerospace:** Ball Operational Weather Instrument Evolution (BOWIE) IR Sounder Study
- **Raytheon:** LEO Sounding Satellite (SounderSat) Concept Exploration (HIRIS)
- **Colorado State University:** TEMPEST-based CubeSat Microwave Sounder for Temperature and Moisture Profiling
- **JPL:** Developing Microwave Sounders for NOAA Users in 2030

Missions

- **York Space Systems:** Gaea – LEO SounderSat Mission Concept Study
- **Brandywine Photonics:** MetNet Small Weather Satellite Network Mission Concept
- **L3Harris:** Joint LEO Sounding Mission Study
- **Northrup Grumman:** Next-Gen MW/IR/RO Sounder Sat Evaluation
- **GeoOptics:** CICERO-X: An Alternative Mission Concept For Global Atmospheric Sounding
- **Northrup Grumman:** Microwave Reference Radiometer (MIRER) Constellation Architecture

Constellations

- **Northrup Grumman:** Small Satellite Constellation
- **MAXAR SSL:** Common Bus for Sustained Hosting of LEO Weather Missions

Evolution from GOES-R to GeoXO – 1
Growing needs require new observations

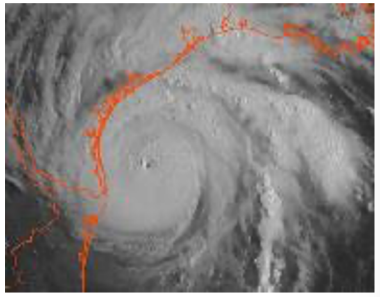
GOES-R provides Visible/Infrared Imagery and **Lightning** data:

- Essential for short-range forecasting, issuing severe weather watches and warnings, and monitoring hazardous environmental conditions including tropical storms, severe storms, damaging winds, snow, ice, flooding, fog, fires, smoke, and volcanic ash

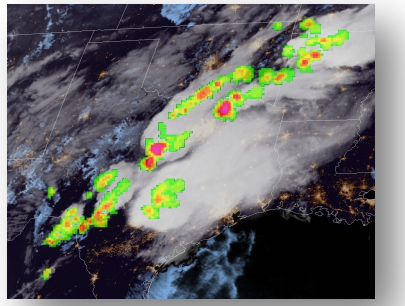
GeoXO will continue and improve Imagery and Lightning data and add new observations:

- **Hyperspectral IR Sounder** for numerical weather prediction and local nowcasting
- **Ocean Color Instrument** for monitoring dynamic coast/ocean features, ecosystem change, water quality, and hazards
- **Atmospheric Composition Instrument** for monitoring air quality and the linkage between air quality, weather, and climate

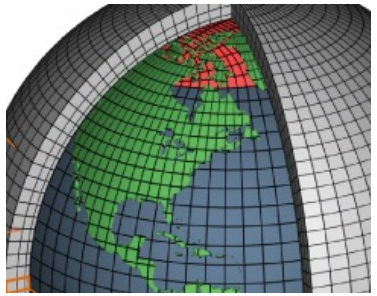
Vis/Near-IR Imagery



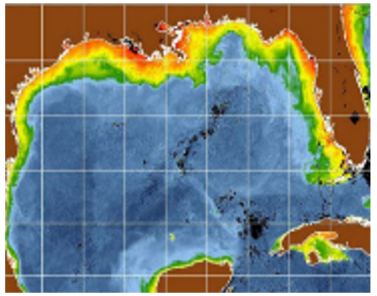
Lightning Mapping



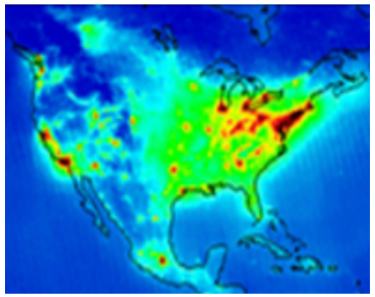
IR Sounding



Ocean Color



Atmo. Composition



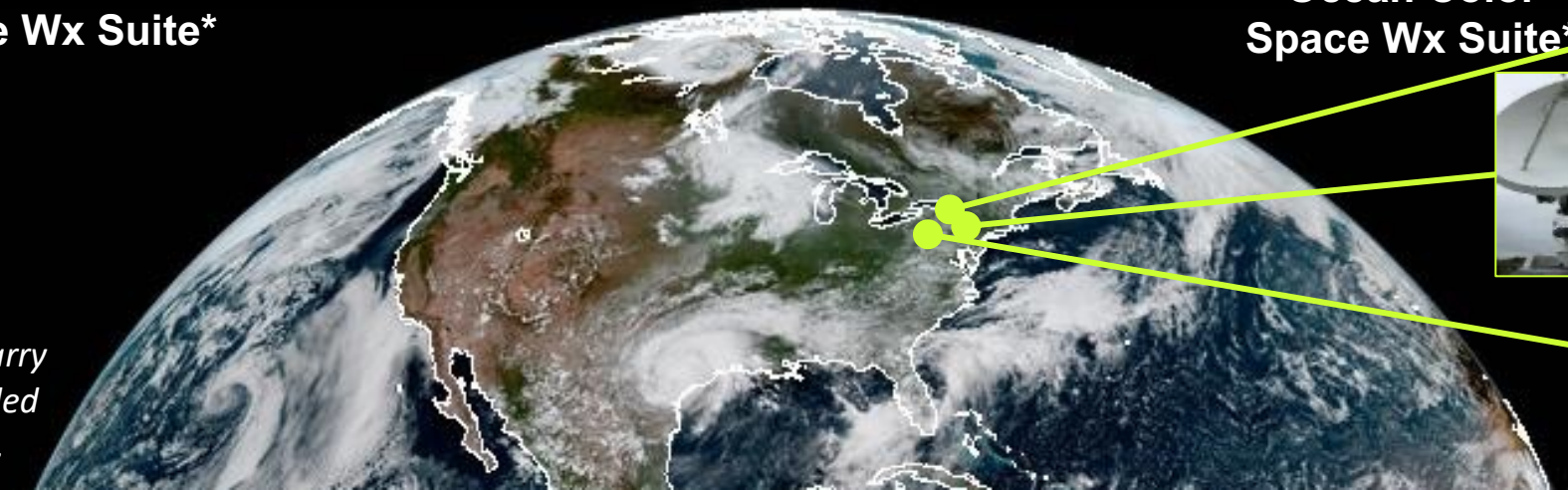
Recommended GEO-XO Architecture

(Preliminary, pending program approval)

GEO-West
Vis/IR Imager
Lightning Mapper
Ocean Color
Space Wx Suite*

GEO-Central
Hyperspectral IR Sounder
Atmospheric Composition
Partner Payload

GEO-East
Vis/IR Imager
Lightning Mapper
Ocean Color
Space Wx Suite*



NOAA Satellite Operations Facility, Suitland MD

Command and Data Acq. Station Wallops VA

Consolidated Backup Unit, Fairmont WV

**GEO-East and West will also carry Space Weather Program-provided Solar and In Situ instruments.*

What is 'LEO' from NESDIS' perspective?

- LEO Definition
  - LEO provides global measurements
    - Vice GEO definition of persistent regional measurements
  - LEO is not bound by a specific orbit geometry or altitude
- LEO Requirements
  - The LEO Program will provide measurements to support NOAA Line Office needs as captured in the NESDIS-Level Requirements (NLR)
    - Continuity of the product baseline, generated from:
      - Measurements currently provided by JPSS
      - Current non-JPSS partner measurements from LEO (e.g. altimetry, scatterometry, microwave imagery)
    - Evolving to support changes to NLR:
      - Measurement needed for new products (e.g. 3-D Winds)
      - Enhanced performance measurements (e.g. improved temporal or spatial resolution)

LEO Observations

NESDIS Level Requirements – Geophysical Products

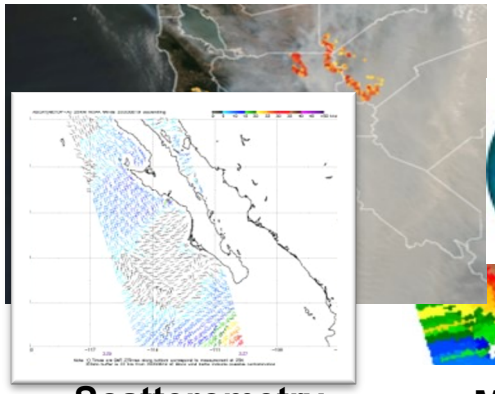
Atmosphere	Cryosphere	Land	Ocean, Fresh Water & Coasts

Analytical

Climate | Weather | Ocean, Fresh Water & Coasts

Foundational Products: Satellite Radiances and Satellite Imagery

Multipurpose VIS/NIR/IR

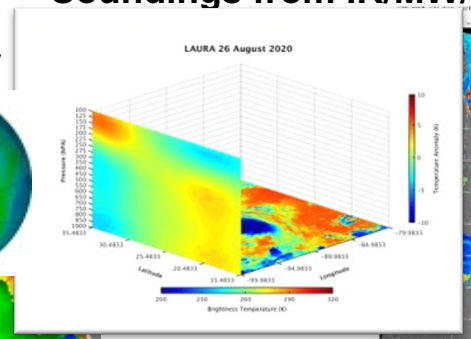


Scatterometry

UV Imagery

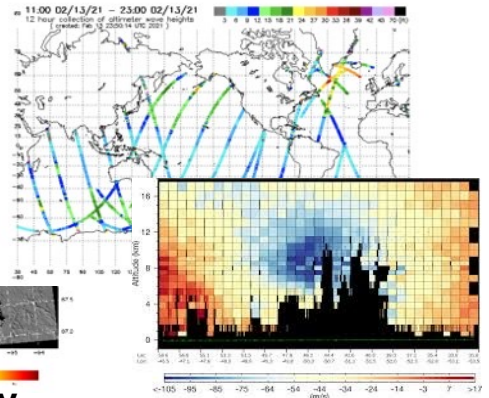
MW Imagery

Soundings from IR/MW/RO



RADAR Imagery

Altimetry



LIDAR

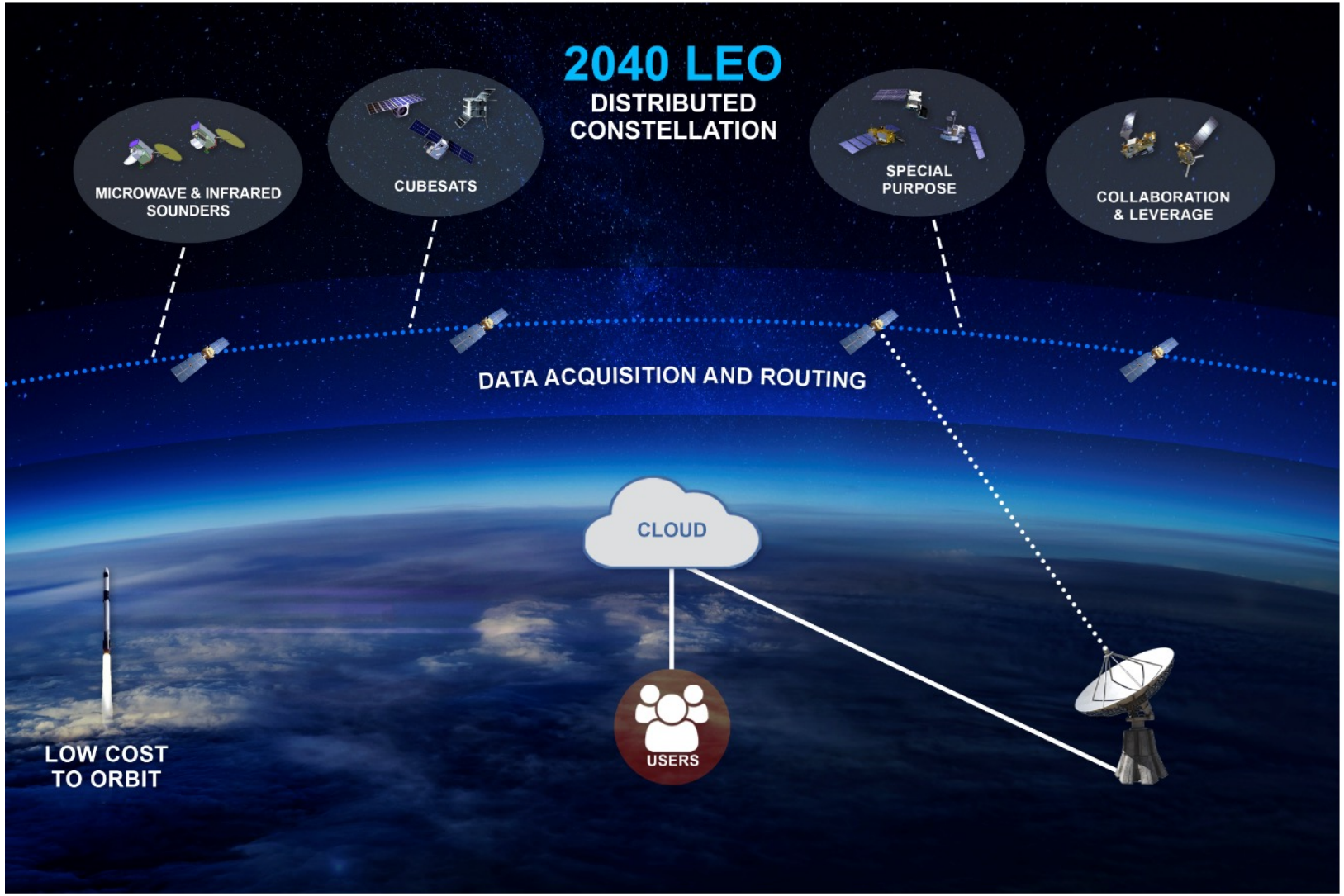
Nearly <u>every product category and subcategory</u> across the thematic areas described in the NESDIS Level Requirements relies on observational measurements from LEO

Mission Summary – Current: 2021 – 2038

- Primary - Secondary

	Managed	Collaborated	Leveraged
Multipurpose Imagery VIS/NIR	JPSS, POES	MetOp, MetOP-SG	Terra, Aqua, GCOM-C, Sentinel 3A, 3B, 3C, 3D
Passive MW Imagery		GCOM-W, MetOP-SG, GOSAT-GW	DMSP, SMAP, SMOS, GPM, CMIR
Special purpose imagers (UV; Ocean Color; Atm Chem)	JPSS, POES	MetOp, MetOP-SG	TROPOMI, OCO-2
MW/IR Sounding	JPSS, POES	MetOp, MetOP-SG	Aqua
RO		COSMIC-2, MetOp, MetOp-SG	GRAS, KOMPSAT-5 Sentinel-6, PAZ, TerraSAR-X, TanDEM-X. CWD
Scatterometry		MetOp MetOp-SG	ScatSat1, OceanSat 1,2,3
Altimetry		Jason-3, Sentinel-6	CryoSat-2, AltiKa/SARAL, Sentinel-3
RADAR			Sentinel 1A, 1B, 1C, 1D, RCM, RADARSAT, GPM, NISAR, EarthCARE
LIDAR			Aeolus, CALIPSO

2040 LEO Vision



Ideally

- We continue the backbone observations in the 13:30 orbit. (MW, IR, Imagery, Ozone)
- The backbone is critical for both weather and climate applications, and for intercalibration (GSICS)
- We look at driving applications for higher temporal coverage.

Applications drive NOAA services, and Observations drive Applications

- Hence, better to define the applications needs prior to defining the observational needs
- Applications will drive:
  - The type of observations and their attributes
  - Accuracy/Precision, Spatial, Temporal.
- For example –
  - Microwave imagery/soundings support tropical storm monitoring in all weather conditions
  - AMSR2 and SSMIS supports that need, but is the room to run?

Tropical Storm Monitoring. - notional

Driving Applications	Jobs to be done	Current use of satellite information	How LEO is used	LEO Primary shortfalls
Tropical Storm Monitoring		LEO/GEO	Microwave detection of tropical cyclone centers are especially important when the center cannot be detected by visible or infrared because of clouds. Microwave penetrates clouds for thermal profiling of the tropical cyclone's warm core to assess intensity. Microwave sounders/imagers are also used to estimate rain intensity.	Spatial and temporal resolution. Finer spatial resolution provides more detail information on rainbands and center location. Currently AMSR2 provides the best spatial resolution, followed by SSMIS - but the temporal resolution is coarse ~ 8 hours. An analysis is needed to determine the knee in the curve with respect to temporal resolution. A TBD initial estimate is hourly

NWP

Driving Applications	Jobs to be done	Current use of satellite information	How LEO is used	LEO Primary shortfalls
NWP temperature and water vapor information		GEO/LEO	The observation types having the largest impact in NWP are currently microwave and infrared sounders because they provide vertical information of the temperature and water vapor needed by forecast models. Impacts from RO are increasing with better coverage. Microwave can penetrate clouds and providing more global coverage and the expense of lower vertical resolution, while infrared provides higher vertical resolution at the expense of poorer global coverage because of clouds. Therefore, both microwave and infrared sounders are deployed on LEO operational weather satellites. NWP needs global coverage.	Pending major shortfall because of upcoming gap in early morning orbit. For NWP with a 6-hour time window, global coverage during that time window is provided when there are at least 3 LEO orbits with ECT separated by 4 hours (eg. 1:30 5:30, 9:30, 13:30, 17:30, 21:30 GMT). Hourly regional models require higher temporal refresh, so maximum effectiveness may call for hourly temporal refresh. However hourly models initial state comes from the global model, so a temporal refresh of every 2 hours may be a reasonable goal. A higher temporal refresh can be used to derive 3D winds

Fires

Driving Applications	Jobs to be done	Current use of satellite information	How LEO is used	LEO Primary shortfalls
Fire detection and smoke forecasting		LEO/GEO	Fire perimeter lines need to be resolved at 500 meters or better. Fire radiative power needed for locating intense fires and used as input to smoke forecasts which depends on FRP	Pending major shortfall because of upcoming gap in early morning orbit. For higher latitudes at least 3 orbit planes are needed with ECT separated by 4 hours (eg. 1:30 5:30, 9:30, 13:30, 17:30, 21:30 GMT). However, assumes larger 3000 km swaths. -- Need to determine correct number of satellites to provide hourly coverage of vis/IR imagery. . For monitoring fire perimeters - 500 meter resolution or better highly desirable, but need to study trade space

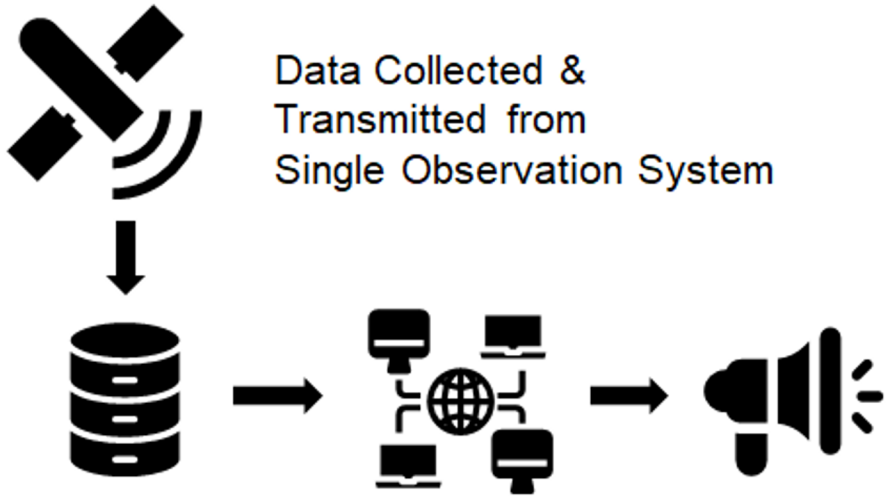
Aviation – ash and clouds/turbulence

Driving Applications	Jobs to be done	Current use of satellite information	How LEO is used	LEO Primary shortfalls
Aviation needs/applications		LEO/GEO	Retrievals from LEO are used to more precisely estimate volcanic ash details, such as concentration and loading. Parallax issues tend to be extreme over the Bering and northern Alaska. LEO makes it much easier to more precisely geo-locate ash. 00 – 04Z is the mean convective peak over mainland Alaska which corresponds to early morning LEO coverage. Analyzing details of clouds especially over western Alaska and higher latitudes, also to some detail in the southern Mainland of Alaska. Data from LEO is the primary source the Alaskan Aviation Weather Unit (AAWU)uses to define cloud coverage details.	Pending major shortfall because of upcoming gap in early morning orbit. For higher latitudes at least 3 orbit planes are needed with ECT separated by 4 hours (e.g., 1:30 5:30, 9:30, 13:30, 17:30, 21:30 GMT). However, assumes larger 3000 km swaths. -- Need to determine correct number of satellites to provide hourly coverage of vis/IR imagery. Spatial resolution of 1 km or better highly desirable, but there is trade space.

A New Paradigm in Data Science and Information Services

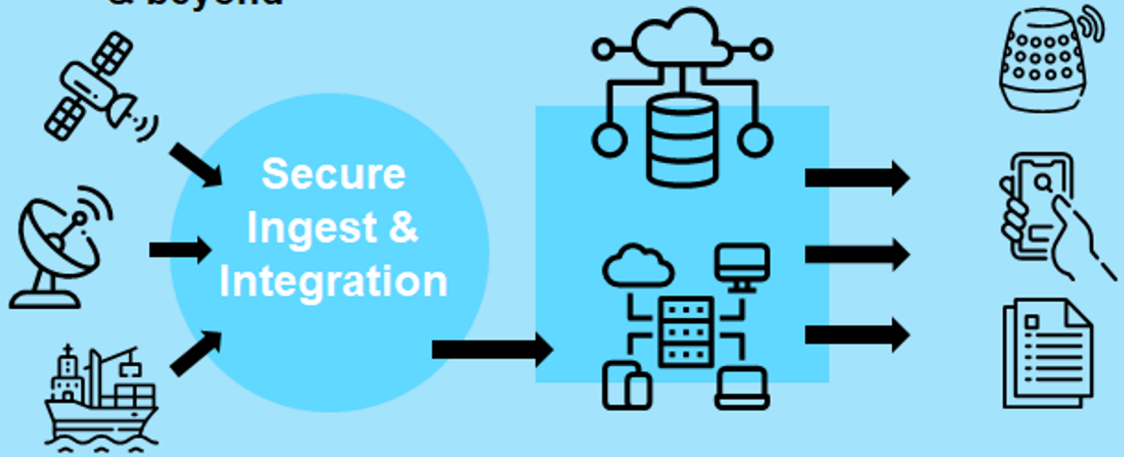
TODAY'S GROUND SERVICE

- Single system data services
- Limited computing power



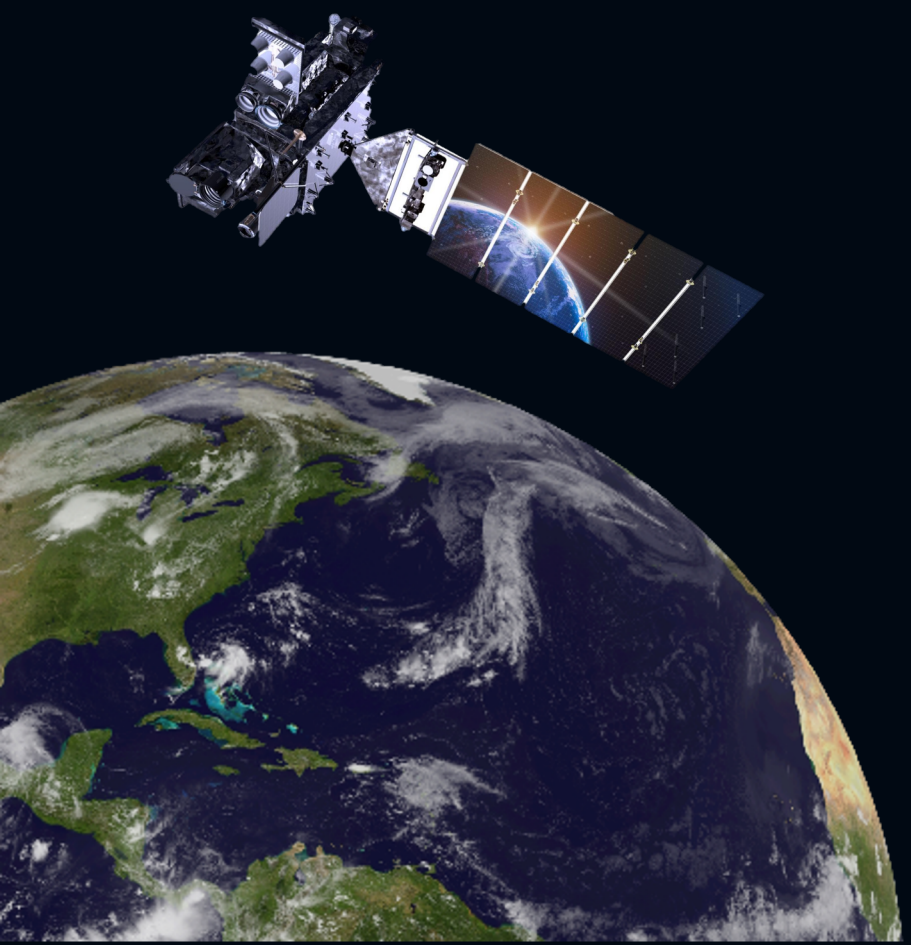
TOMORROW'S GROUND SERVICE

- Secure ingest for all data types
- Powered by AI, data science
- Super-computing capability through cloud transition & beyond



Next Steps in Next Gen: Taking Initiative

NESDIS is expanding partnerships to explore and initiate new space and ground capabilities:



- **GEO-XO:** Phase A studies of instruments. Mission Concept Review in 2021
- **LEO Program and Sounder Mission:** Milestone-0 review completed March 10, 2021. Mission Concept Review in 2022

  Collaboration with NASA, DOD, and Industry on Technology & Data Exploitation
- **Commercial RO Data Purchase:** Operational use in NCEP Models in 2021
- **Ground Study:** Developing our next-gen ground system. Design Cycle 1 completed in 2021