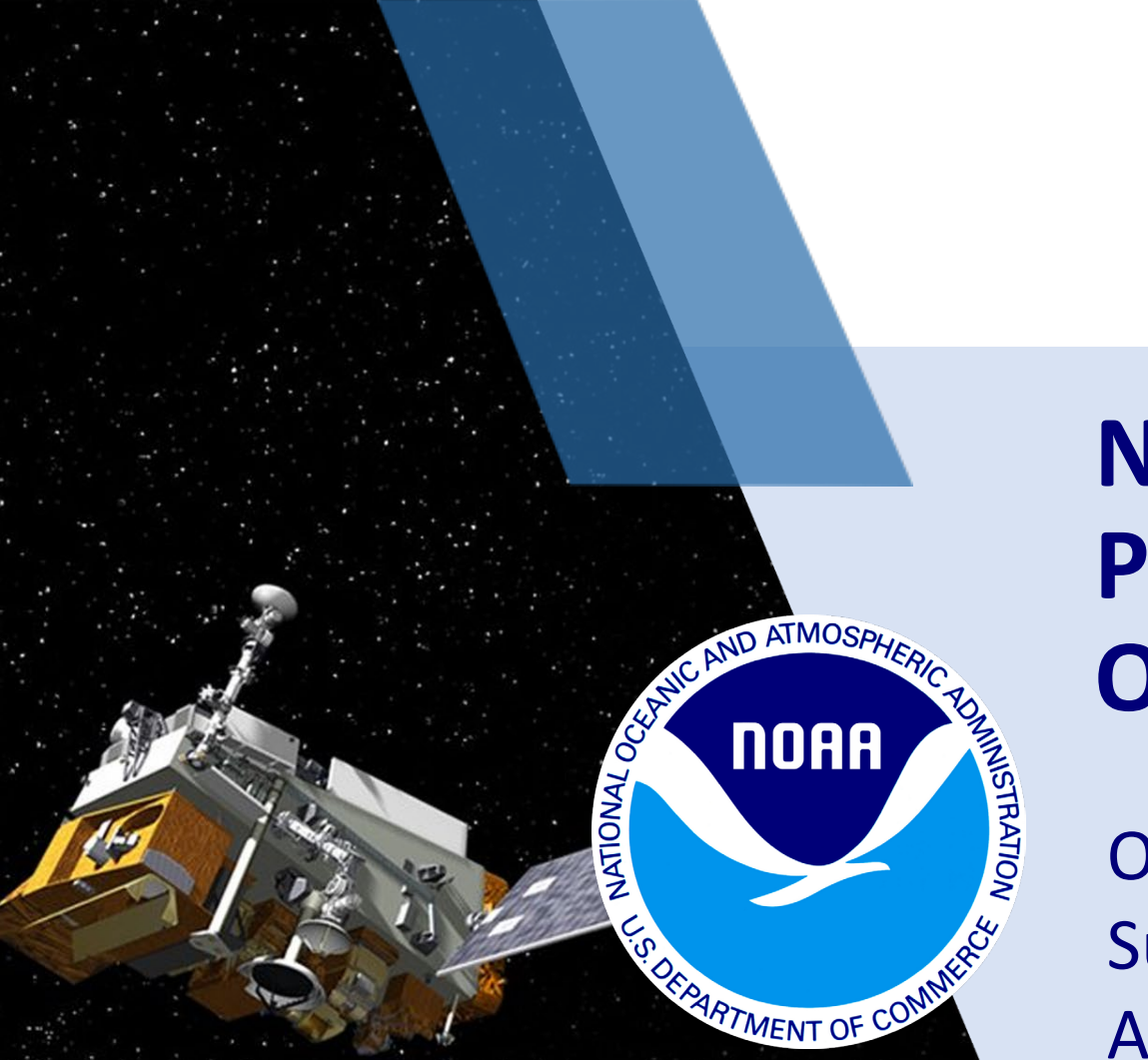


NOAA/NESDIS Commercial Data Program (CDP) and Radio Occultation (RO)

Overview of the Commercial Strategy and Summary of the Phase 1 RO Analysis of Alternative (AoA)

National Environmental Satellite, Data, and Information Service

Sept. 13, 2024

Office of Systems Architecture and Engineering
Products Mapping and Piloting Branch
Natalie Laudier, Branch Chief

NESDIS Approach to Radio Occultation (RO)

- NOAA/NESDIS goal for Radio Occultation is a Hybrid Architecture
  - Commercial Data
  - International Partnership
  - Investigating a NOAA-owned constellation and what it would look like

- NOAA/NESDIS Commercial Data Program currently purchases commercial RO data
  - New “Guidance for NOAA Commercial Data Buys” (Draft)- Provides a framework for NOAA Programs and Offices conducting Commercial Data Buys

- Conducting a RO Analysis of Alternatives Study
  - Identify the hybrid capabilities that will fulfill NOAA requirements as COSMIC-2 degrades.
  - Identify the needs for a NOAA-owned RO constellation and if required

NESDIS Commercial Data Program Overview

Purpose: Acquire and assess value-added commercial *space-based environmental* observation data to support NOAA's mission.

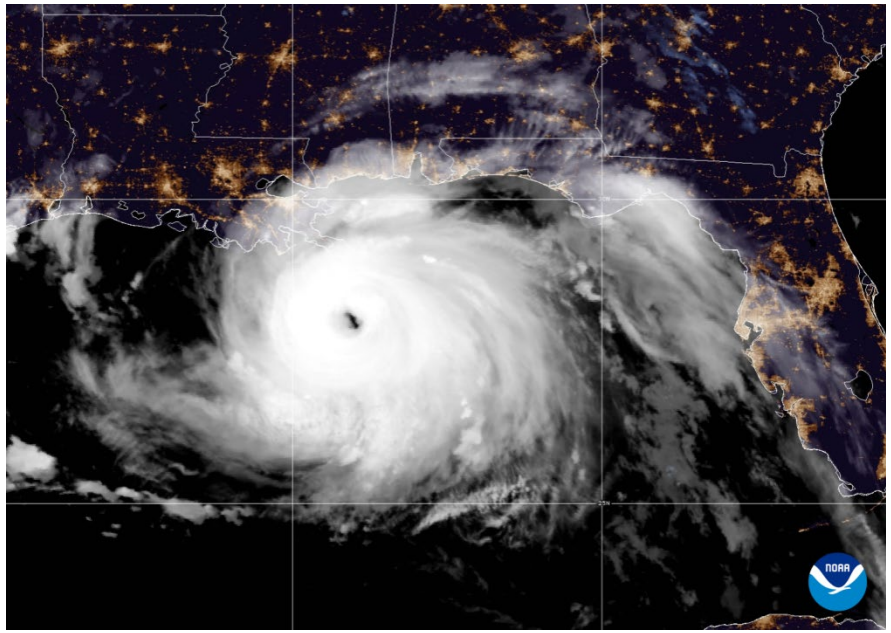
The NESDIS Commercial Data Program (CDP) contains two lines of effort:

Commercial Weather Data Pilots:

Demonstrates the quality and impact of commercial data on weather, climate and space environment applications

Commercial Data Purchases:

Supports operational weather forecast applications



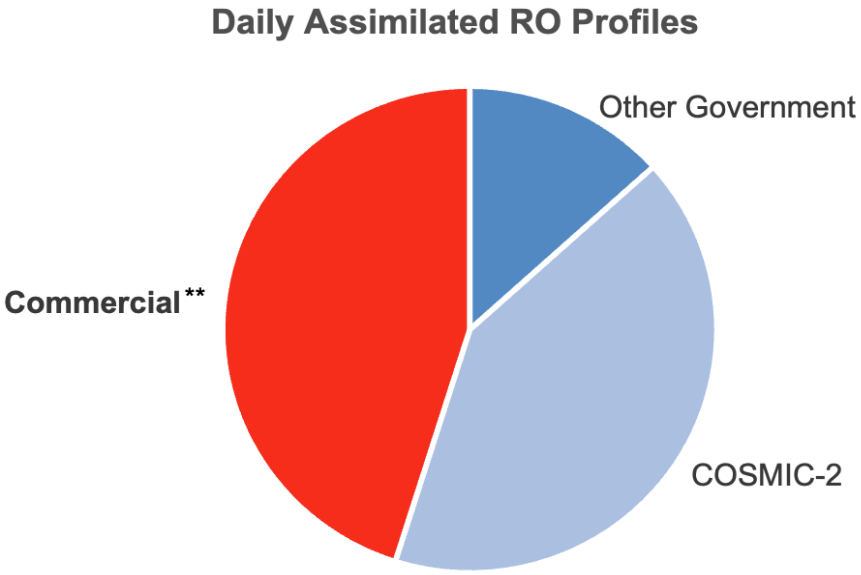
Hurricane Ida making landfall

NESDIS Commercial Data Program Information:

https://www.space.commerce.gov/business-with-noaa/commercial-weather-data-pilot-cwdp/

NESDIS CDP Operational RO Data Buys (RODB)

- NESDIS CDP successfully purchases and integrates commercial GNSS-RO data, which is a highly valuable input for operational weather modeling.
- Used in Operational NWP Neutral Atmosphere and Space Weather models



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

Commercial GNSS-RO data from NESDIS CDP and EUMETSAT purchases now make up nearly half of all RO data assimilated into weather models.

Radio Occultation Data Buy (RODB)-2 IDIQ Delivery Orders:

Delivery Order	Vendor	RO Profiles per day	Period of Performance	Length	Data Sharing License
DO-1T	PlanetiQ Spire	500 500	6 Apr 2023 – 4 May 2023	1 month	Unrestricted
DO-2	PlanetiQ	3100	18 Jul 2023 – 18 Jan 2024	6 months	Unrestricted
DO-3	Spire	3000	18 Jan 2024 – 18 Sep 2024	8 months	Unrestricted
DO-4	**PlanetIQ Spire**	**2200 800**	**18 Sep 2024 – 18 Sep 2025**	**12 months**	**Unrestricted**

GNSS-RO Data Operationally Assimilated by NOAA

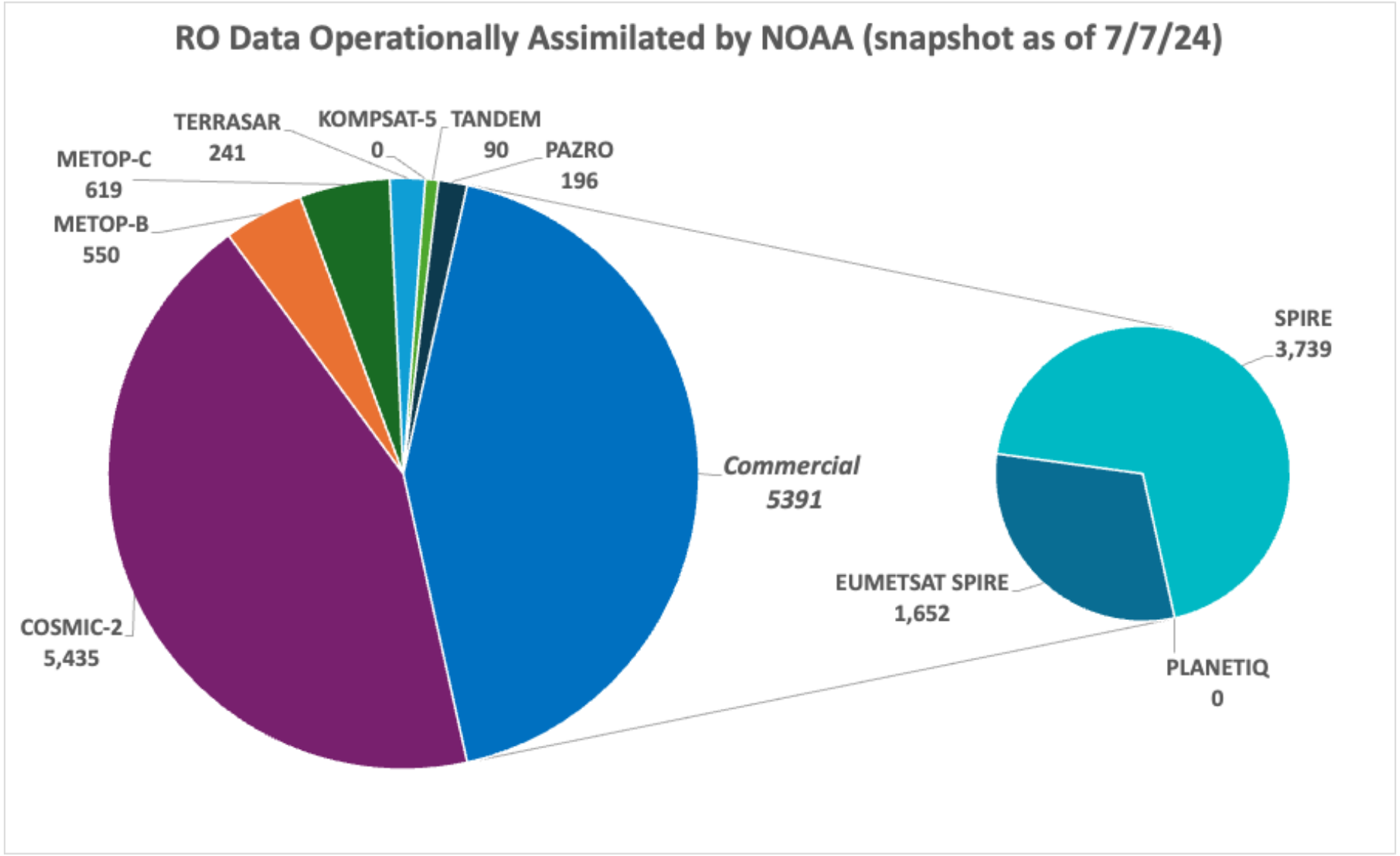
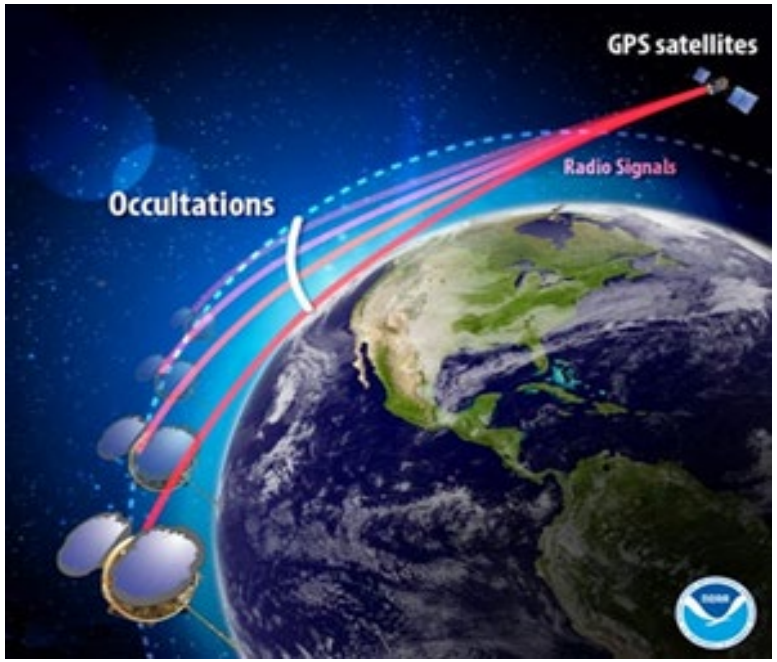


Chart illustrates total RO data assimilated by NOAA as of 7/7/2024.

NESDIS Commercial Data Purchase Impacts

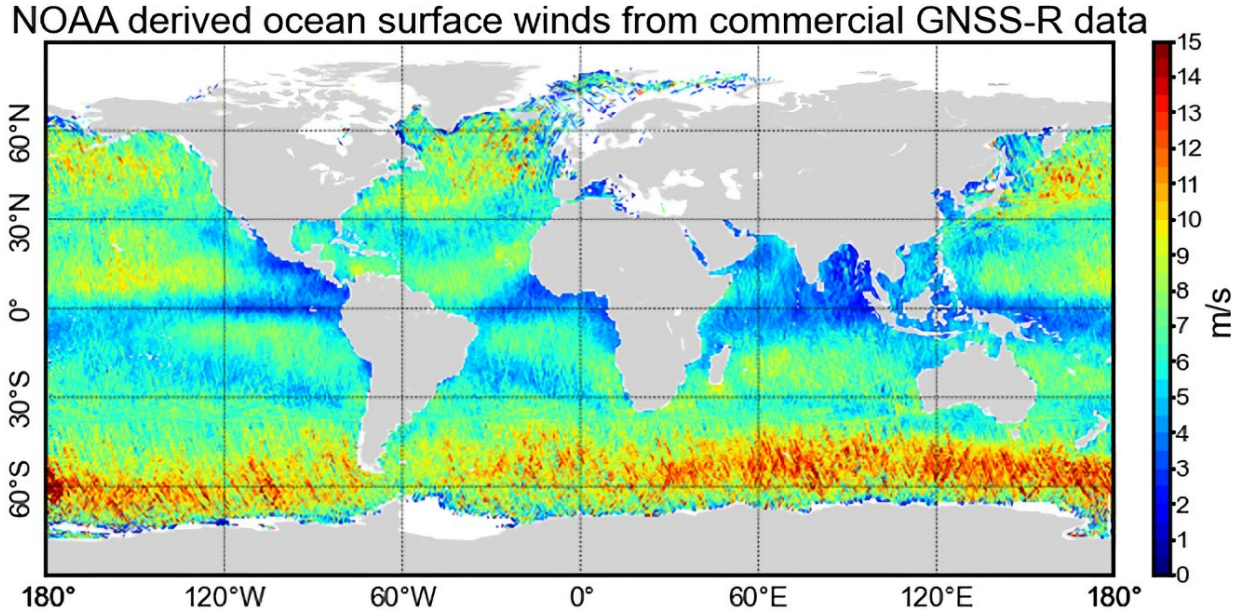
- Benefits of GNSS-RO observations for weather applications:
  - Cost-effective
  - Global coverage
  - Continuous monitoring under all weather conditions
  - Broad applications for space weather and climate prediction
- Enhancements of assimilating GNSS-RO into Numerical Weather Prediction models:
  - 10% forecast error reduction
  - 10-20% tropical cyclone forecast skill improvements
  - Accuracy improvements extend across all forecast lead times



GNSS-RO receivers observe distortion of GNSS signals as they transit the atmosphere. NOAA produces quasi-vertical RO soundings based on bending angles from satellite-based RO open-loop measurements made during a GNSS occultation event.

2023-2024 NESDIS Commercial Weather Data Pilots

- **Space Weather Pilot (ended in 2024):** NESDIS CDP conducted a successful pilot study of exploiting commercial GNSS-RO data for space weather parameters. ***The final report is now available.***
- **GNSS Ocean Surface Winds (OSW) GNSS Reflectometry Pilot (ongoing):** NESDIS CDP is executing a pilot study to use commercial reflectometry data to derive ***ocean surface wind speeds*** and additional environmental measurements.



Through a Commercial Weather Data Pilot, NOAA is developing methods for determining ocean surface wind speeds globally using commercial GNSS-R (reflectometry) satellite data.

NOAA Data Sharing License Options

Operational Data Purchases	Option 1	Unlimited distribution rights
Data Pilots	Option 2	Distribution to U.S. Government agencies, National Meteorological Centers (NMC), WMO Met Centers, CGMS members, non profit organizations, Academic entities for non-commercial use with no further distribution
	Option 2a	Option 2 plus unlimited distribution after 24 hours

NESDIS CDP prefers less restricted data sharing options

Commercial Weather Data Pilots and Projects

Pilots:

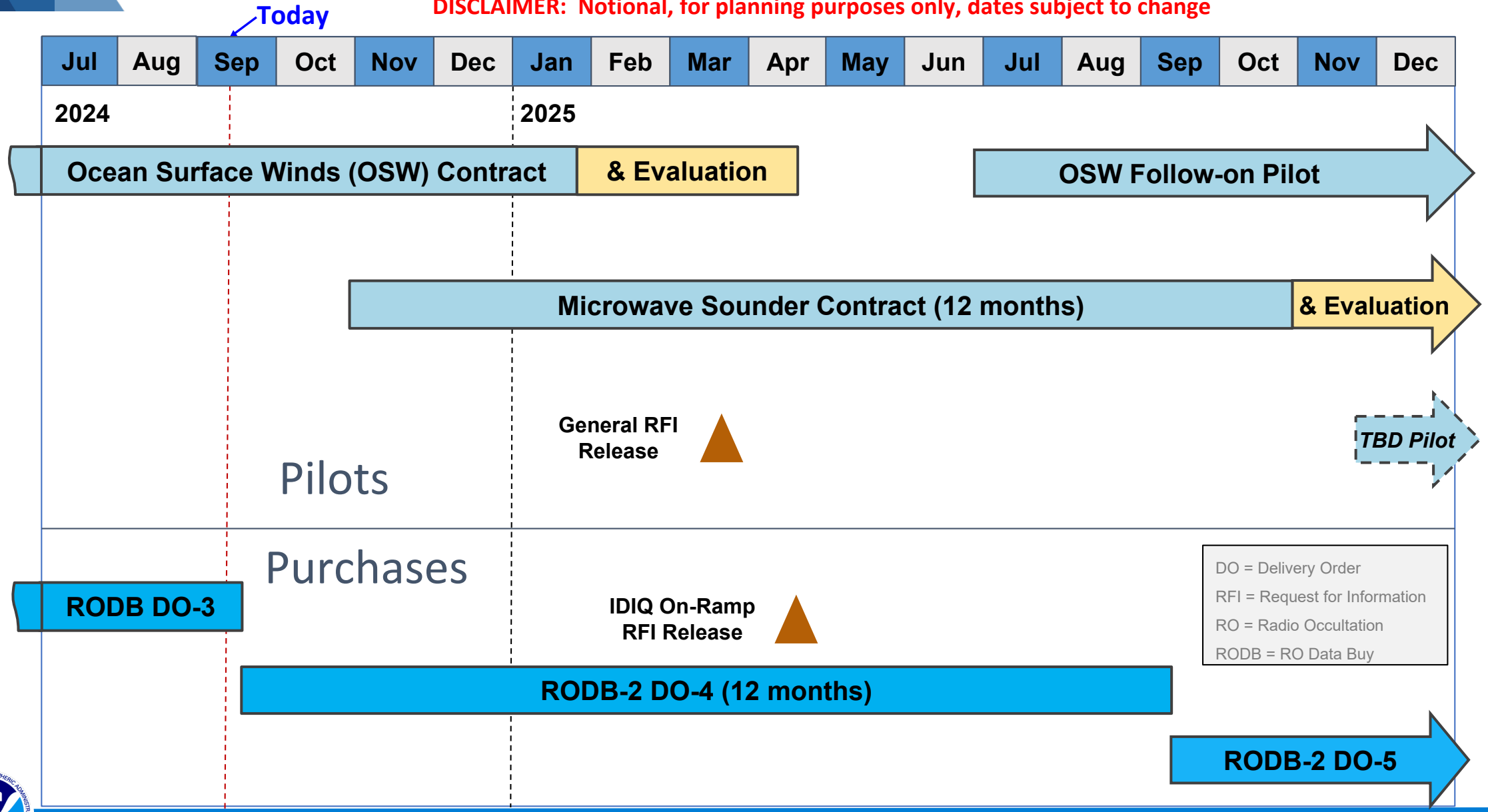
- **Microwave Sounder Pilot:** Awarding a pilot (to begin in Nov/Dec 2024) to
  - Investigate the utility
  - Assess the quality and impact, primarily for the evaluation of atmospheric vertical temperature and moisture profiles measurements.
  - Leverage past microwave research from NASA's TROPICS mission.

Projects:

- **HyperSpectral Microwave:** Investigate utility of novel Hyperspectral Microwave technology
  - Leveraging efforts from SAE's own Joint Venture programm – results will inform future CDP piloting efforts
- **Polarimetric RO:** Beginning to investigate the utility of PRO profiles to estimate precipitation rates and types
- **Space Weather:** Continued coordination on advancing TEC and Scintillation capabilities

2024-2025 NESDIS CDP Planning

DISCLAIMER: Notional, for planning purposes only, dates subject to change



NOAA Commercial Data Program Community Day

September 26, 2024

1-230pm (EDT)

Focus: General-Request for Information (G-RFI)

Virtual Event - Register Now

Radio Occultation Analysis of Alternatives (AoA) Phase 1 Overview

Study objectives:

- Identify the gaps in Radio Occultation (RO) coverage as COSMIC-2 degrades, and assess alternatives to meet NOAA's neutral atmosphere (NA) RO requirements through 2036.

Methodology:

- Assessed hybrid architectures composed of:
  - Partner missions
  - Commercial data
  - NOAA constellation
- Assessed performance over time, estimated costs, and risks.
  - Based on Coverage, refresh, and latency requirements.

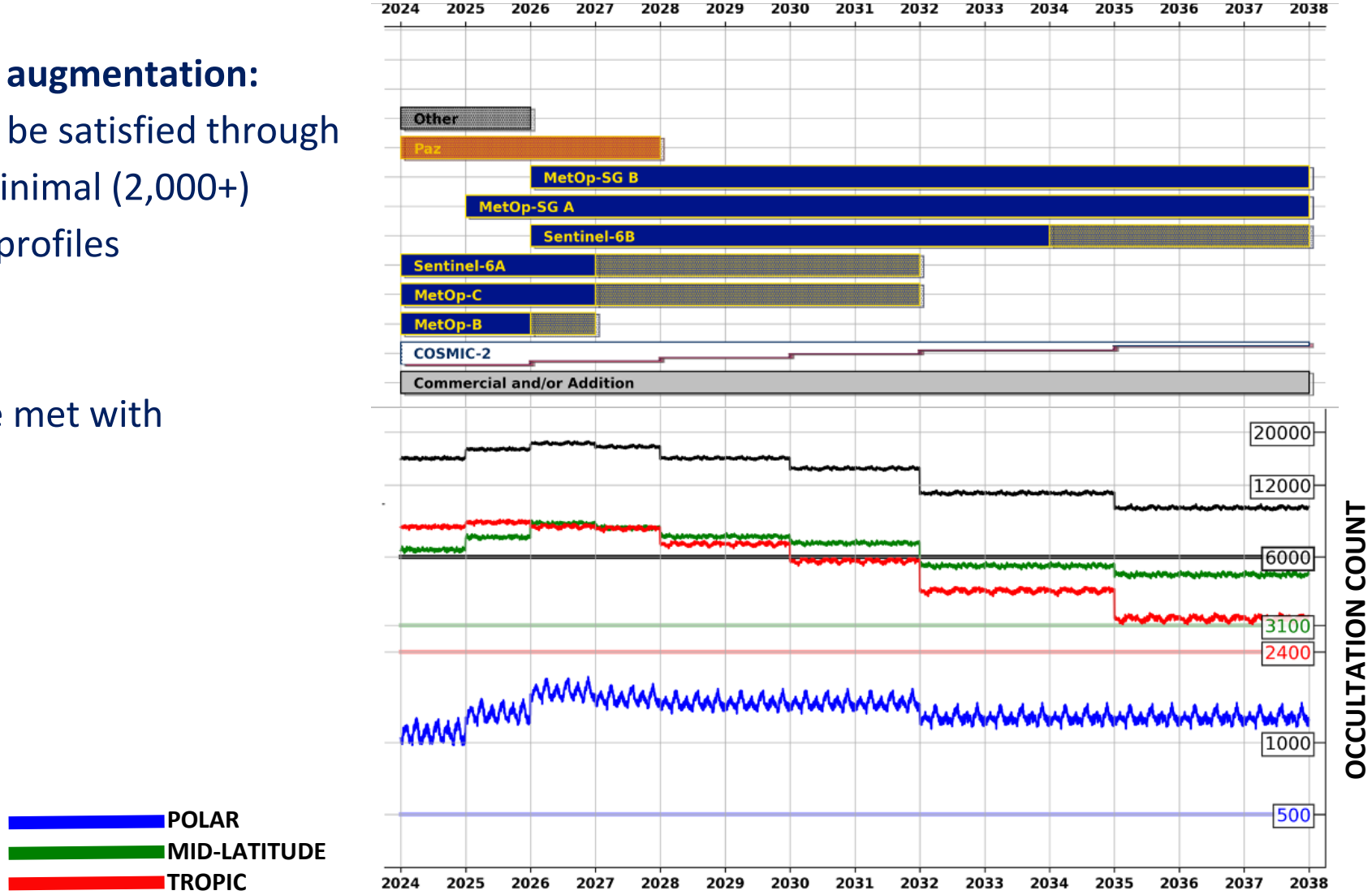
Performance Analysis: Counts Conclusions

Baseline <u>with</u> 4000 commercial augmentation:

- **All** count requirements will be satisfied through the assessed period with minimal (2,000+) commercially provided RO profiles

Takeaway:

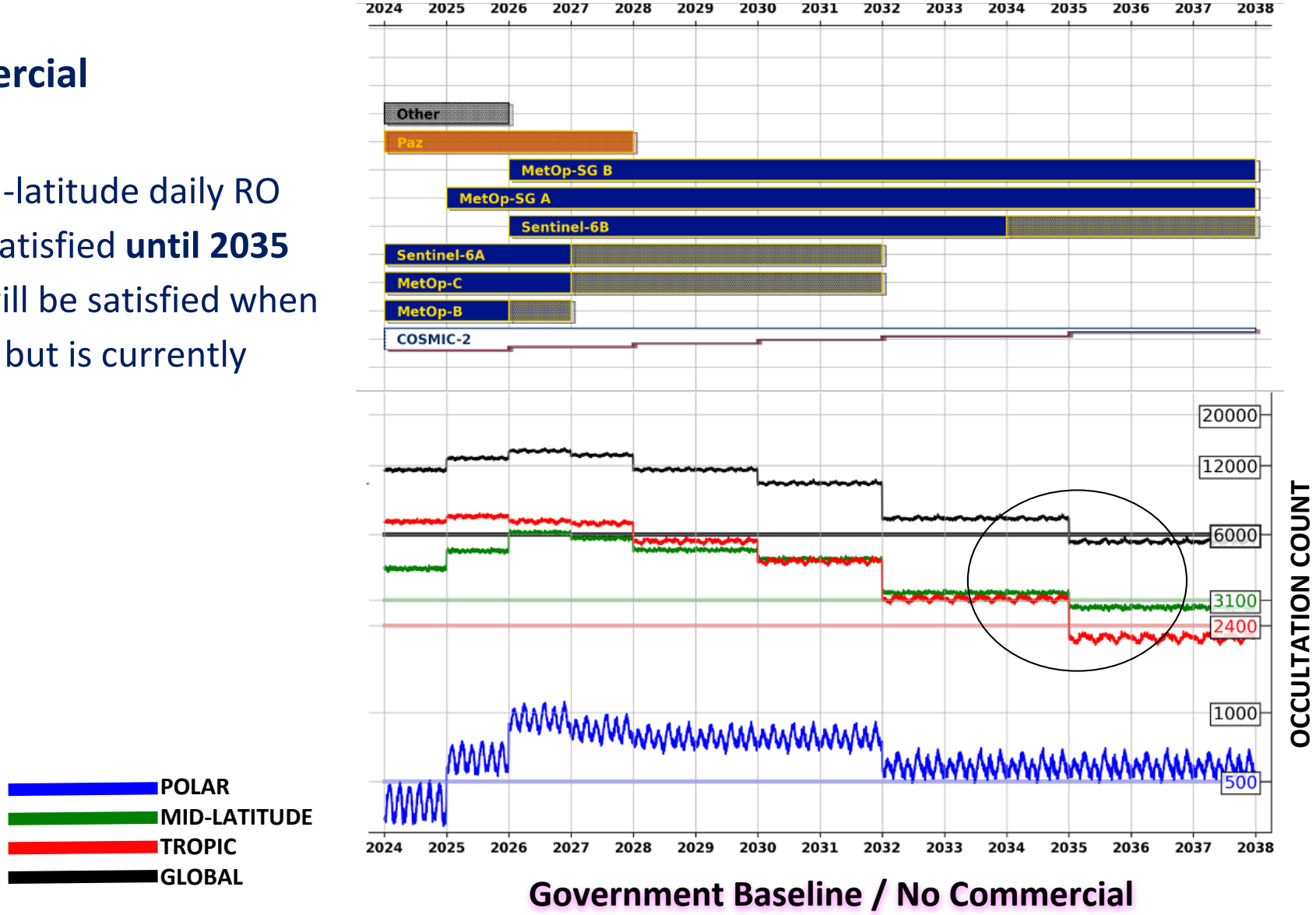
- RO Count requirements are met with commercial augmentation.



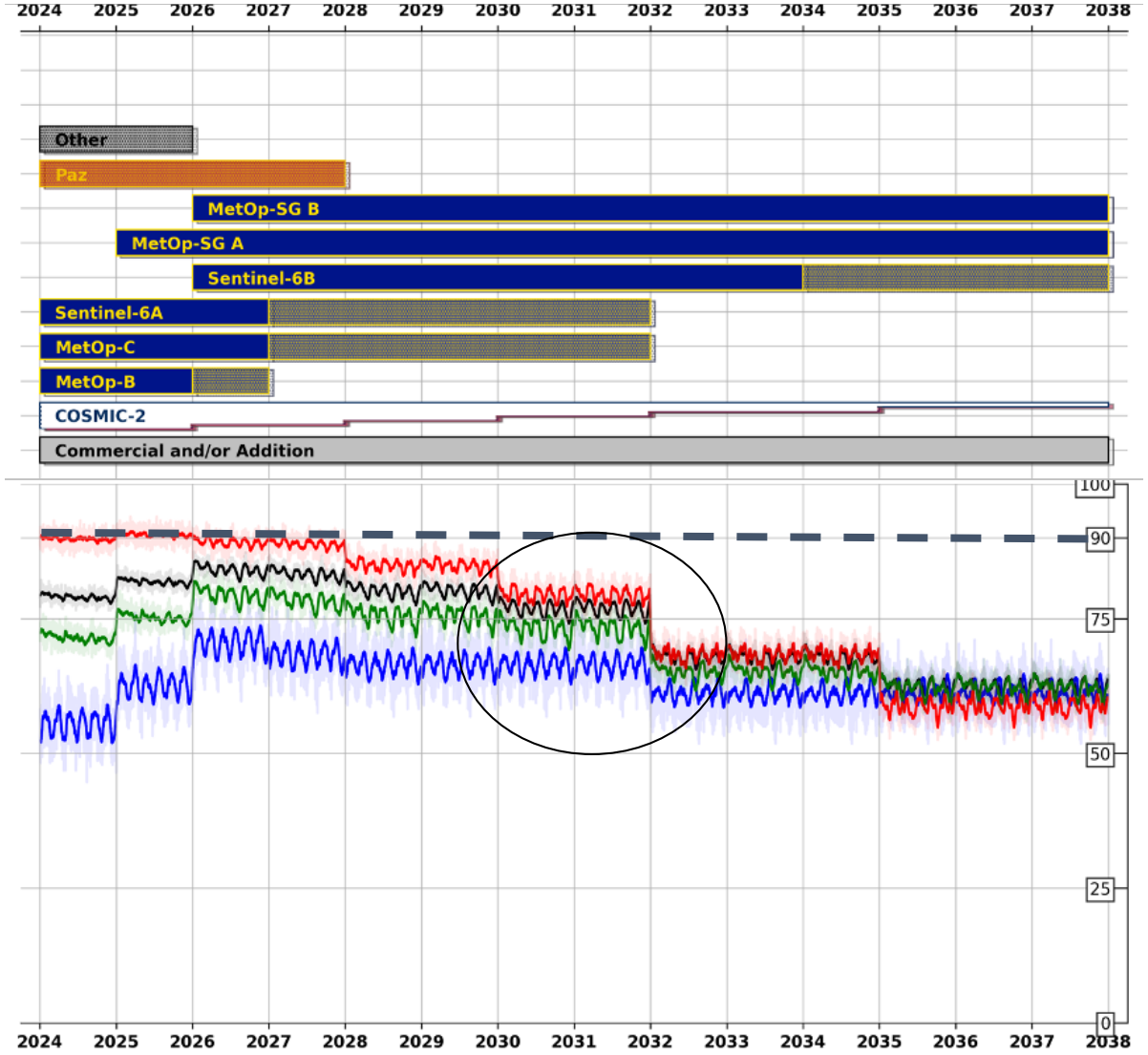
Commercially Augmented Baseline (4,000/day)

Performance Analysis: Counts Conclusions

- **Baseline <u>without</u> commercial augmentation:**
  - Global, tropic, and mid-latitude daily RO count requirement is satisfied **until 2035**
  - **Polar** daily RO count will be satisfied when MetOp-SG is launched but is currently failing



Performance Analysis: Refresh Conclusions



Commercially Augmented Baseline (4,000/day)

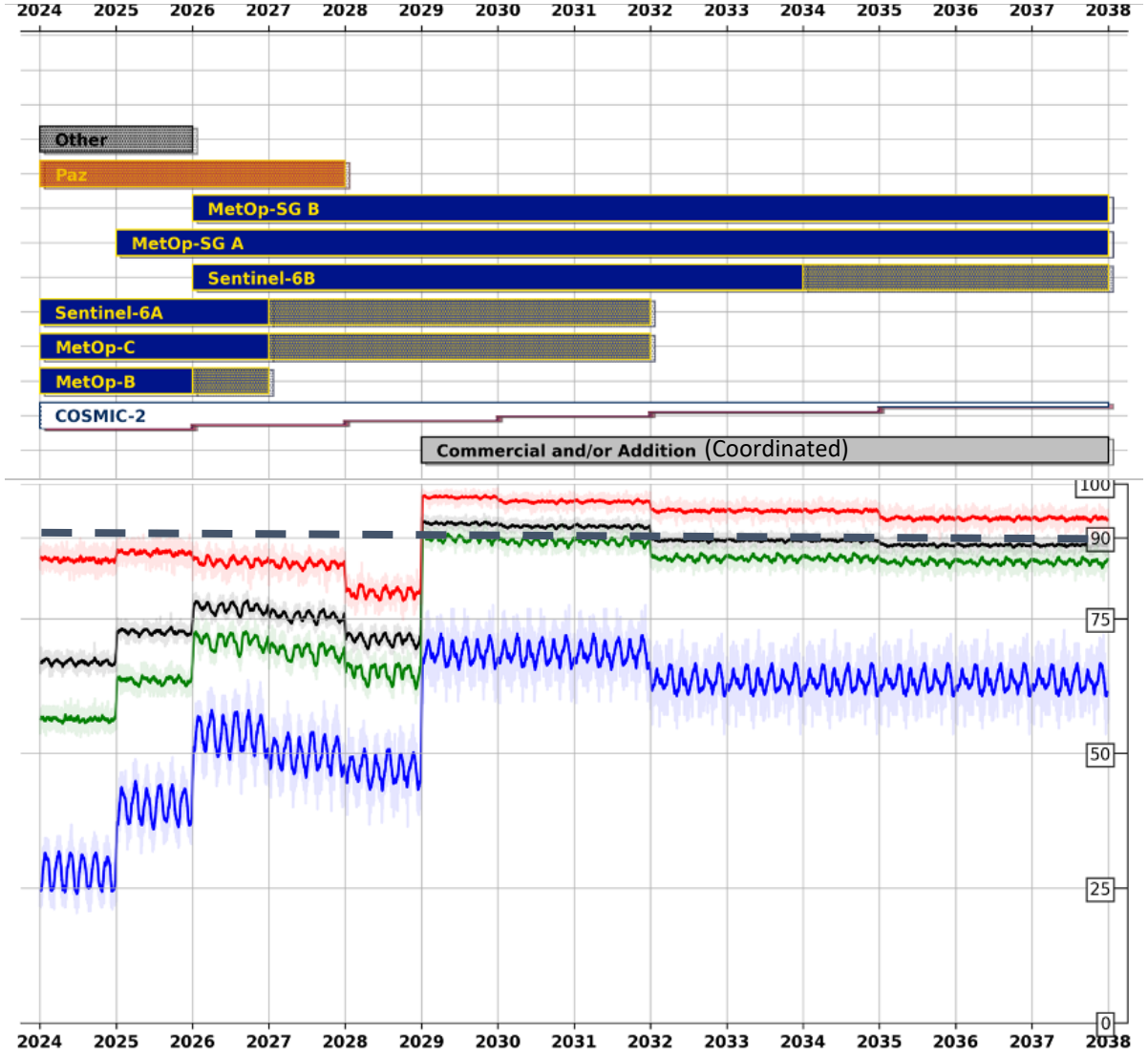
- **Refresh for Baseline and 4000 Commercial**
  - Currently the global refresh and uniform distribution requirement in not being met
  - COSMIC-2 carries a similar requirement in the **tropics**, so this meets ~90% performance
- **Refresh is highly sensitive to COSMIC-2** loss/degradation, hence the step-function shown

POLAR
MID-LATITUDE
TROPIC
GLOBAL

*__Global__ grid defined as 500x500 km equal area grid between 85°S and 85°N latitude

*__Polar__, __mid-latitude__, and __tropic__ refresh are not provided requirements and are only shown for relative contribution

Performance Analysis: Refresh Conclusions



Dedicated 6x30° + 2x~98° (SSO)

- **Added dedicated 6 Satellites at low-latitude orbit and 2 Additional Coordinated high-latitude orbit satellites.**
  - **Could be commercial contribution, LEO planned, NOAA-owned.**
- ***Coordinated & diverse orbits*** are the most effective way to achieve refresh requirements
  - 2029 Launch was for modeling only
- The requirement can be achieved by:
  - (1) Maintain continuity from *coordinated & diverse* **low-latitude orbits**
  - (2) Increase observations made from *coordinated & diverse* **high-latitude orbits**

POLAR
MID-LATITUDE
TROPIC
GLOBAL

*__Global__ grid defined as 500x500 km equal area grid between 85°S and 85°N latitude

*__Polar__, __mid-latitude__, and __tropic__ refresh are not provided requirements and are only shown for relative contribution

Key results

Key results:

- RO observing system is sensitive to the loss of COSMIC-2 in tropics and mid-latitudes
- Counts per day requirement is much easier to meet than refresh requirement
  - Count requirements can be met by partners and commercial
- Uniform distribution requirements and refresh cannot be met by partners and commercial
- **NOAA-owned constellation in *low-inclination orbit* in addition to a coordinated and diverse constellation in *high-inclination* orbit would meet requirements by 2028-2031.**

- **Will continue this AoA analysis with a Phase 2 in FY25.**

Phase 2 Next Steps

- Better understand the impact of NWP forecasts from deviations in RO capabilities
  - OSSE's, model sensitivities
  - Leverage ROMEX Results
- Expand partnerships
- Expand scope of study to include all of the products produced from an RO constellation, including
  - Ionospheric TEC
- Optimize the modeled constellations

Questions?

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Gerry Peltzer, NESDIS CDP Support: gerard.peltzer@noaa.gov

NESDIS Commercial Data Program Information:

https://www.space.commerce.gov/business-with-noaa/commercial-weather-data-pilot-cwdp/

Bullpen Slides

NOAA/NESDIS Commercial Data Program Background

- In 2016, NOAA began the NESDIS Commercial Data Program with a Radio Occultation Data Pilot.
- In 2020, awarded 1st Commercial Data Buy (RODB-1)
- Today, NOAA uses commercially available Radio Occultation (RO) data to respond to the demand for environmental information and satisfy observational requirements.
- Derive Neutral Atmosphere and Ionospheric products from Global Navigation Satellite System RO (GNSS-RO)
- Exploring non RO-based commercial space-based environmental monitoring data sources

Methodology of Study

Performance Analysis

One-year propagation **simulation of 101 use cases** executed
Sensors modeled based upon capabilities demonstrated in operations (or advertised for future missions)

Payload Analysis

Detailed investigation into **published performance parameters** and SWAP values

Cost Analysis

Standard cost models
Historical/actual costs
Estimates from partners
Open source data

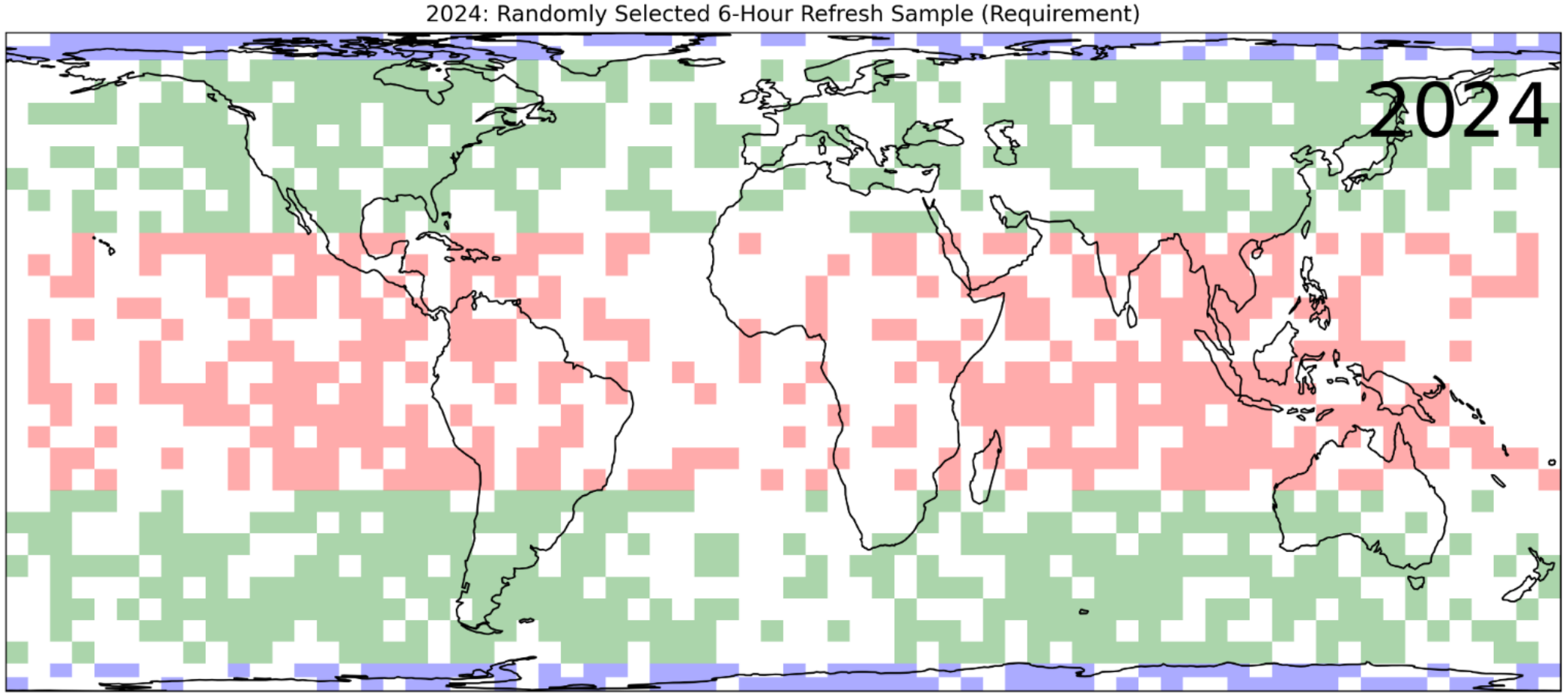
Risk Analysis

Risk ratings determined through **NASA Risk Management Handbook criticality methodology**

Evaluation Matrix

Takes into account all factors analyzed, provides a rating scale to compare alternatives

Partners + 4k Commercial, No COSMIC-2



Note: If something seems visually off about these cells "not moving" over the course of years, it's because of the approach taken to model them; for expedience, only one year worth of data was modeled for every satellite on an arbitrary date. Various configurations by year were then combined based upon flyouts. This presents a small modeling error in that the ascending node of the GNSS satellites should be moving ~1-2 degrees per year. This is only meaningful over the course of one year if an observing satellite has very slow precession, which only occurs at pure polar orbits (~90 degrees).