

NESDIS RO Architecture Studies

IROWG-10

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Outline

- Background
- Results
- Risks, Conclusions, and Recommendations
- Questions

Background

Study Development

Deepening RO Gaps

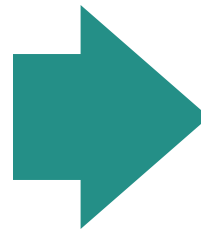
- COSMIC-2 may start losing spacecraft in ~2027
- No plans for US government RO post-COSMIC-2
- No direct replacement from any source

Kick-off

- NESDIS/SAE and UCAR developed a study looking into potential architectures for a USG RO backbone
- Following backbone study, an analysis of alternatives building from initial results was kicked off

RO Backbone Architecture Study

- Analyze architectures that could potentially provide a government backbone to meet NESIDS RO needs
- Goals:
 - Determine RO architectures to meet NESDIS requirements
 - Evaluate reference architectures for general performance
 - Evaluate ground systems capabilities for latency



RO Analysis of Alternatives Study

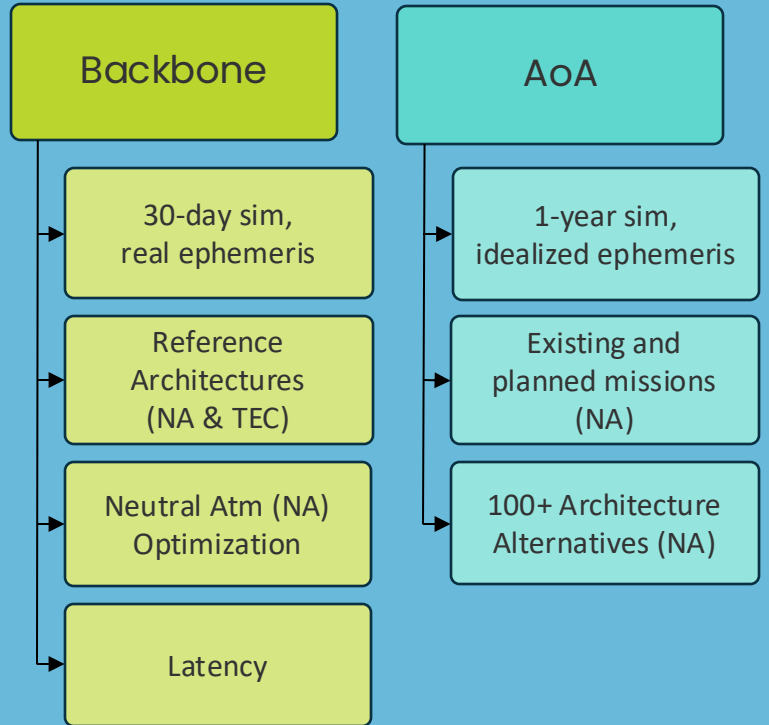
- Identify capability of current and expected RO missions and solutions to meet NESDIS needs
- Goals:
 - Identify gaps in NESDIS RO from 2024-2037 (COSMIC-2 end)
 - Evaluate potential solutions to fill gaps/meet NESIDS needs
 - Could include NOAA, international partner, or commercial missions

NESDIS RO Architecture Study Timeline

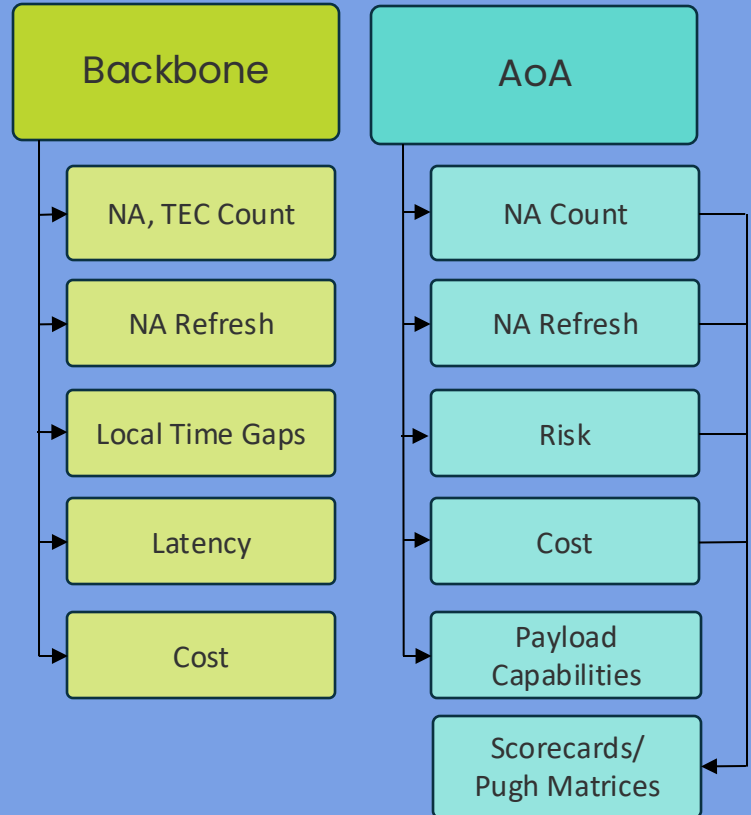


Architecture Study Framework

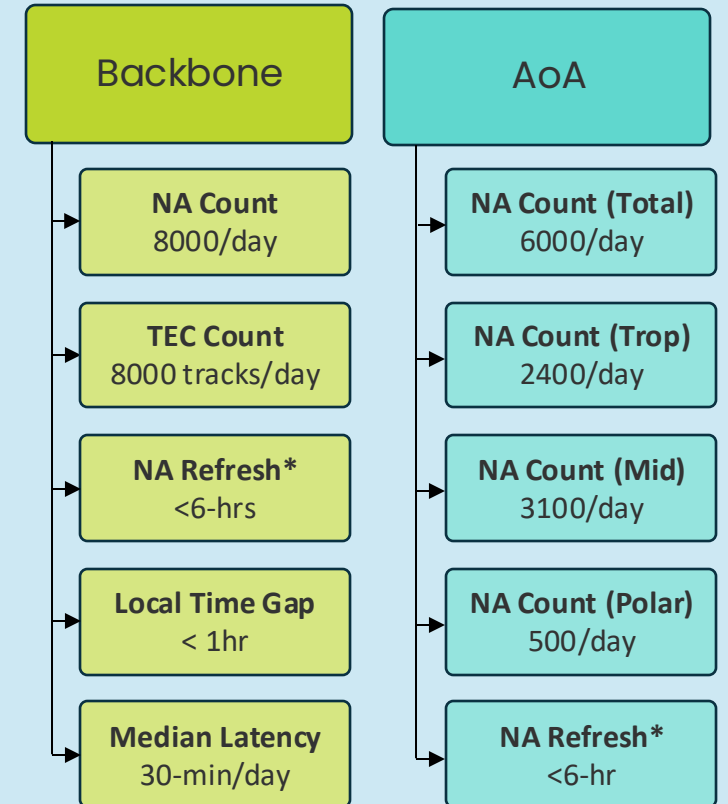
Modeling



Evaluation



Requirements

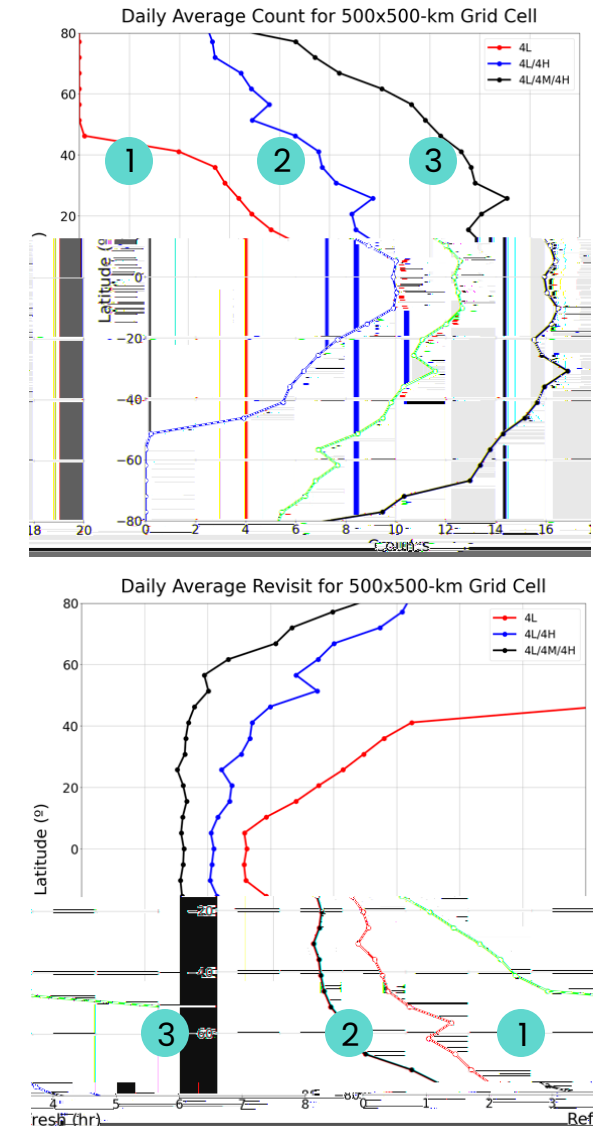
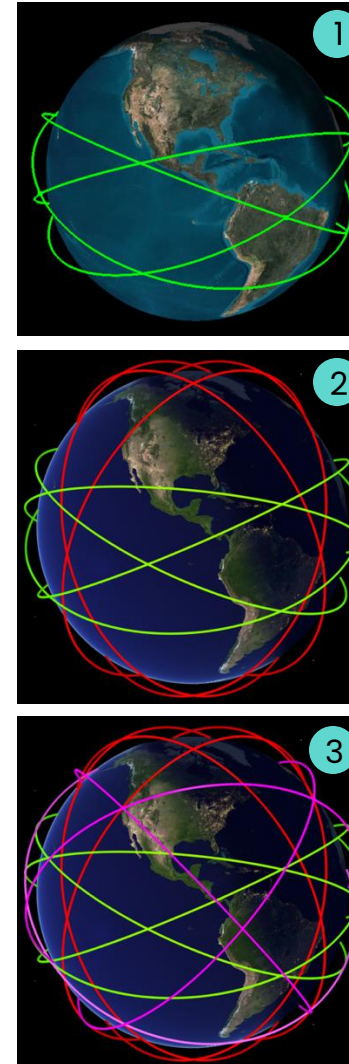


*Refresh for 500 x 500-km grid

RO Backbone Results

Reference Architectures

- Simulated three test cases with 4-12 spacecraft
 - 1 4 s/c: LEO, 24° inc
 - 2 1) + 4 s/c: LEO, 72° inc
 - 3 2) + 4 s/c: LEO, 48° inc
- Simulations performed for NA occs, TEC tracks, and observational latency
- Results:
 - Count requirement can be met with 4-s/c or more
 - Refresh requirement can be met from 30°S-30°N with 4 spacecraft
 - 8-spacecraft can meet refresh requirement globally
 - TEC counts very similar to neutral atmosphere
 - 30-min median latency easily achievable using GSaaS
- Conclusions
 - Global refresh requirement much harder to meet than counts
 - 4/8-sc solutions can meet requirements, but real-world losses would likely lead to requirements failure

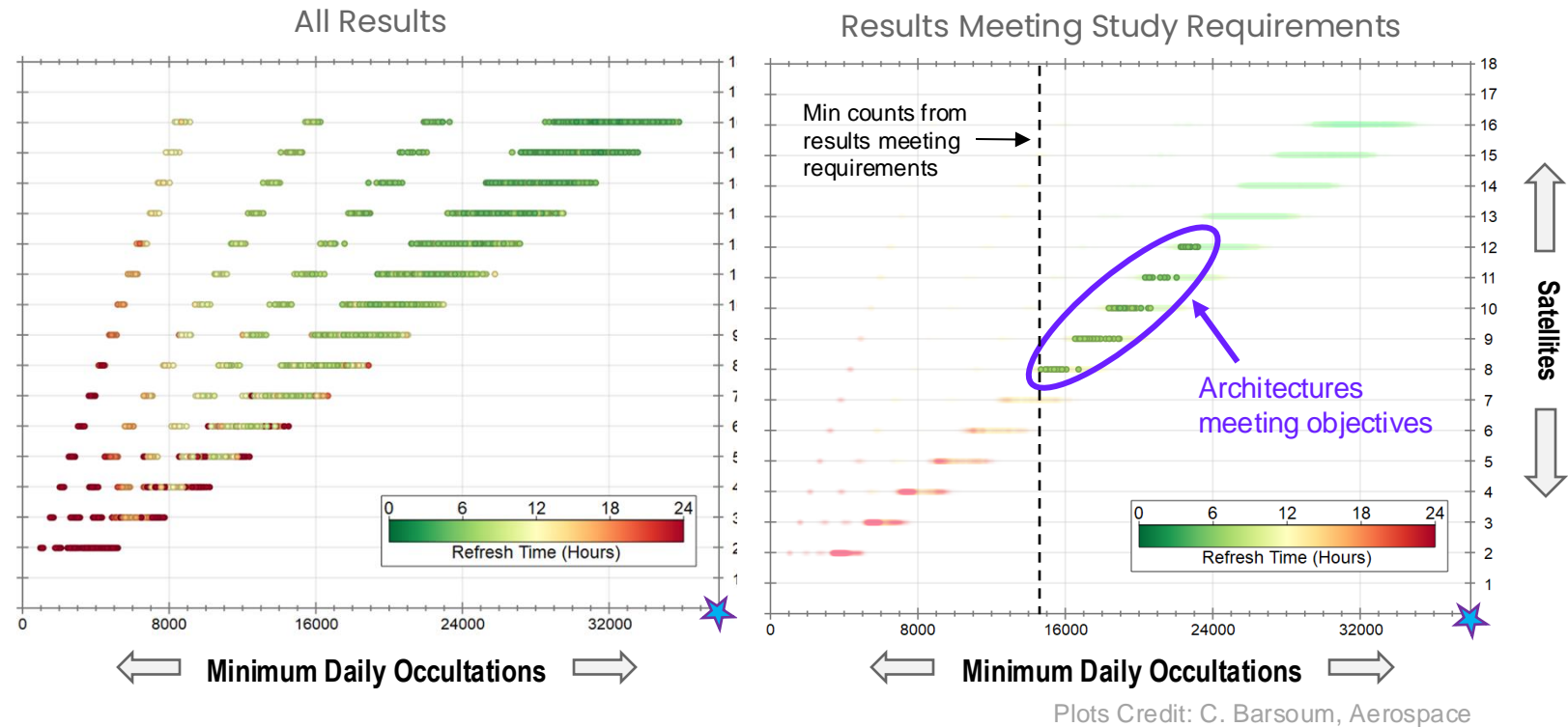


RO Architecture Optimization

Determining a minimum number of satellites

- Trade space was generated by optimizing RO architecture objectives using Aerospace genetic algorithm
- Architecture Objectives:
 - NESIDS RO requirements (count, refresh, local time)
 - 12-spacecraft max in <4 orbital planes
 - Max inc: 110°, min alt: 500-km
- Optimization Results
 - 1.2M+ architectures evaluated
 - 56,000+ optimized architectures found
 - 171 architectures met all requirements
- Conclusions
 - Solutions driven by refresh, **NOT** counts
 - A robust trade space still exists, with numerous ways to meet requirements with 8+ spacecraft

Satellites Required to Achieve Objectives

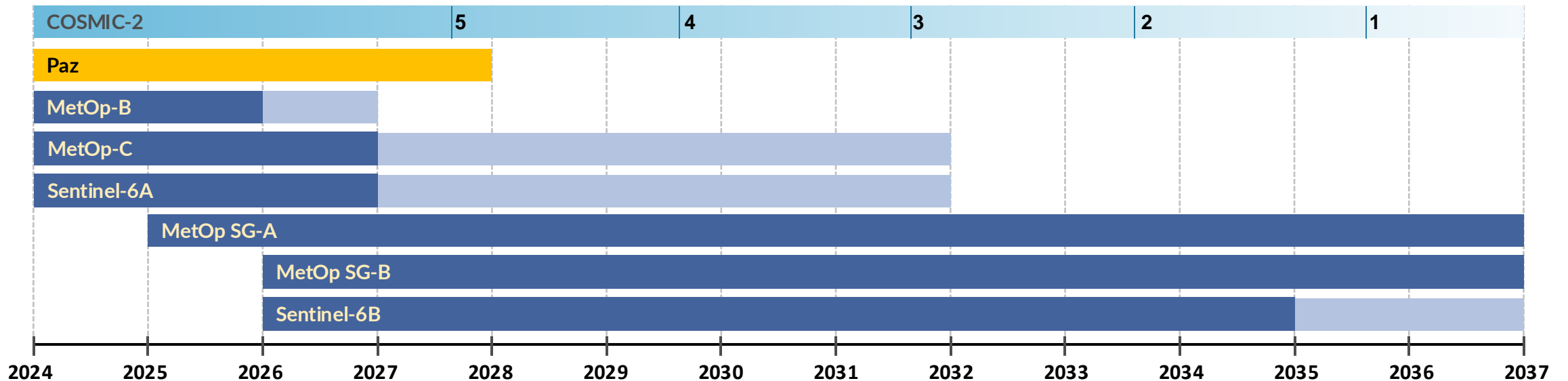


A minimum of 8 satellites are required to meet requirements globally

RO Analysis of **Alternatives**

RO Picture: 2024–2037

NOAA and International RO Partner Mission Flyout



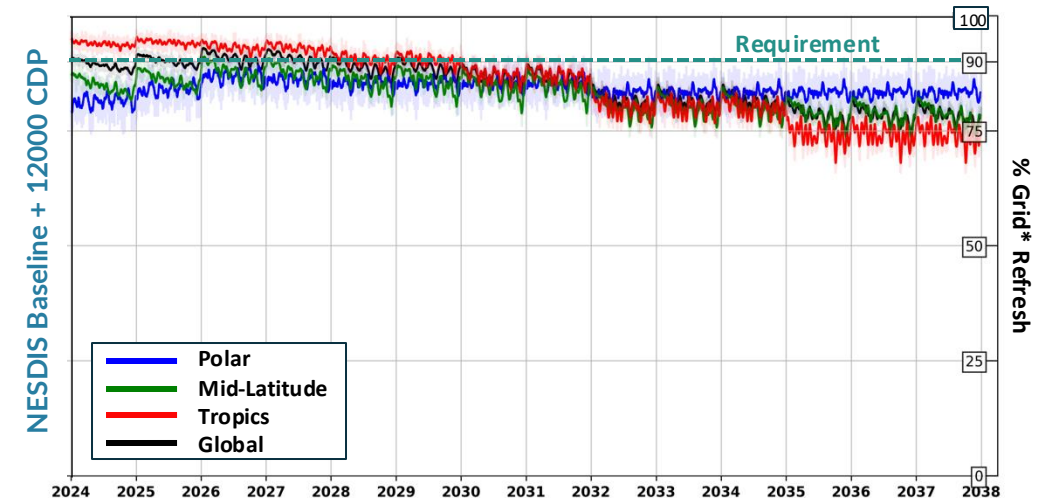
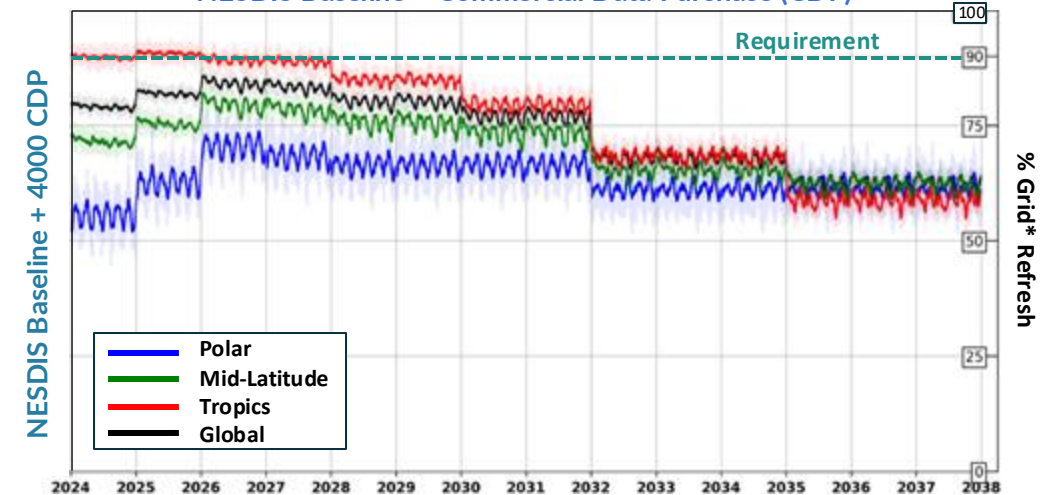
- COSMIC-2 degradation based on mid-estimate from internal program reliability study
- Partner missions based on published dates and estimates of mission extension
- Commercial provider capabilities estimated based upon previous/existing missions and orbits
- Gaps for the NESDIS RO system were assessed for count and refresh
 - Assessed globally, between 23°S-23°N, 23°-66° N/S, and 66°-85° N/S
 - NOAA and international partners considered “baseline” system

Gaps in NESDIS RO

- Count requirement can be met with partners and commercial data purchases » *no gaps exist*
- Global refresh requirement is not met currently
 - Refresh in tropics is currently met by COSMIC-2
 - Uniform distribution requirement also not met
- System is *highly sensitive* to loss of COSMIC-2
 - Cannot meet requirements with any amount of existing data following loss of **three** COSMIC-2 s/c (~2031)
 - At current levels of data, requirements failure after loss of **two** COSMIC-2 spacecraft (~2029)
 - No planned missions globally can compensate for the loss of COSMIC-2
 - Large increase in commercial data can help improve performance, but does not replace COSMIC-2 capability
- Lack of diversity in SSO- local times
 - Oversaturation of data in 9:00-11:00 and 13:00-13:30 orbits

Global Grid Refresh Over 6-hours

NESDIS Baseline + Commercial Data Purchase (CDP)

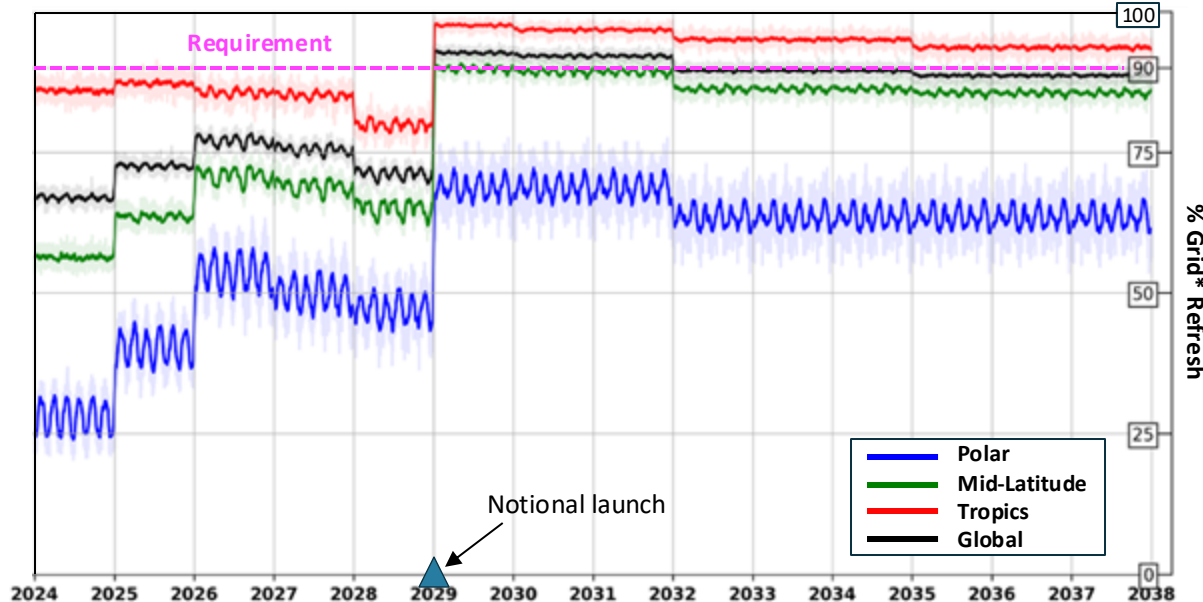


*Global grid defined as 500x500 km equal area grid between 85°S and 85°N latitude
Polar, mid-latitude, and tropic refresh are not requirements and are shown for relative contribution

Solution Alternatives

Global Grid Refresh Over 6-hours

NOAA/Partner Baseline + 6 30°inc s/c + 2 SSO s/c



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

Polar, mid-latitude, and tropic refresh are not requirements and are shown for relative contribution

- Simulated 100+ architectures to evaluate capability of existing systems and potential new missions
- Main alternatives types examined:
 - International partners
 - Commercial Data Purchases (CDP) (varying amounts)
 - Dedicated new missions (notionally NOAA-owned)
- Dedicated and coordinated missions are required to meet the refresh requirements
 - No existing or planned missions can replace COSMIC-2 capability
 - Low inclination mission with coordinated diverse orbits
 - Coordination and diversification of high-inclination orbits
- Additional alternatives being examined in next phase of the study
 - Concurrent design of RO architectures
 - Space weather products (TEC/scintillation)

Enterprise Risks

- Data Availability and Distribution
 - COSMIC-2 reliability study was limited in scope, spacecraft may fail sooner than predicted
 - Partner and commercial missions have limited orbital distribution
 - Rideshare launches have overwhelmingly focused on 09:00-11:00 and 13:00-14:00
 - Risk is assessed as **HIGH**
- Schedule/Timeline
 - COSMIC-2 loss will lead to requirements failure in 2029, with additional data purchase in 2031
 - Soonest predicted capability for a NOAA launch would be 2031
 - Risk is assessed as **Medium**

Take-Aways

- **Minimum of 8 spacecraft** are required to meet requirements outlined by the study
 - Spacecraft can be from many sources (US government, commercial, partner)
- **Total occultations per day are a non-optimal indication of RO performance**
 - Global *refresh* is main driver for architecture designs
 - Recommend that community focus on refresh when advocating for observational needs
- NESDIS distribution and refresh cannot be met by partners/commercial data alone
 - NESDIS RO enterprise is extremely sensitive to loss of COSMIC-2
- Future RO missions should coordinate on orbit diversification
 - A dedicated mission to low-inclination is necessary to meet requirements
 - Coordination and improved diversification of RO missions in both low and high inclination orbits is the most effective way to achieve requirements, and develop the most uniformly distributed system
- RO architecture studies ongoing, final recommendations to NOAA in July 2025
 - A dedicated mission to low-inclination is necessary to meet requirements

Thank You!



Backup