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

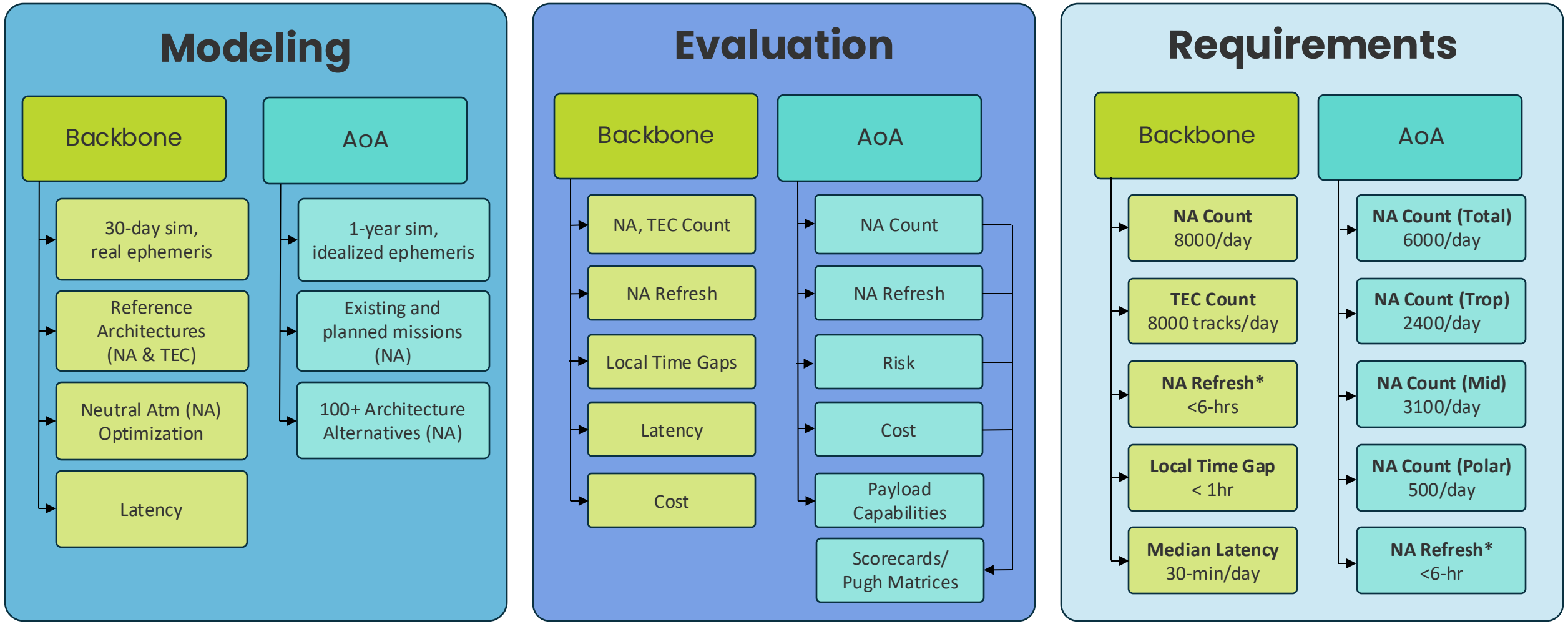
- Analyze architectures that could potentially provide a government backbone to meet NESIDS RO needs
- Goals:
  - Determine RO architectures to meet NESDIS requirements
  - Evaluate reference architectures for general performance
  - Evaluate ground systems capabilities for latency

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



*Refresh for 500 x 500-km grid

RO Backbone Results

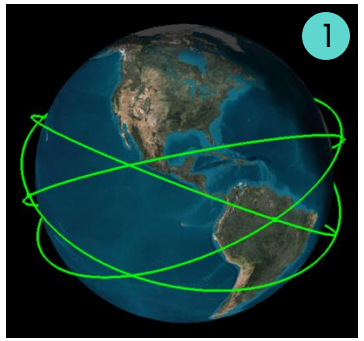
Reference Architectures

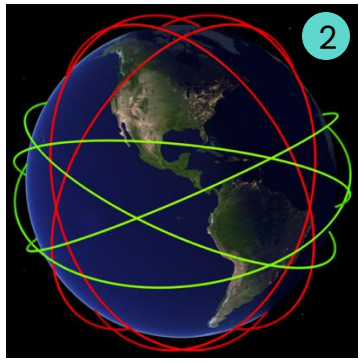
- Simulated three test cases with 4-12 spacecraft
  1. 4 s/c: LEO, 24º inc
  2. 1) + 4 s/c: LEO, 72º inc
  3. 2) + 4 s/c: LEO, 48º inc

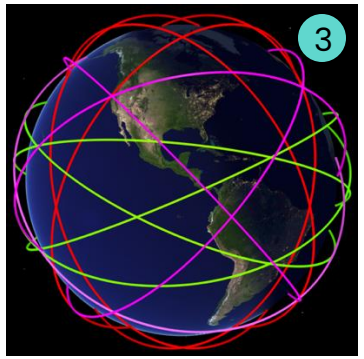
- Simulations performed for NA occs, TEC tracks, and observational latency

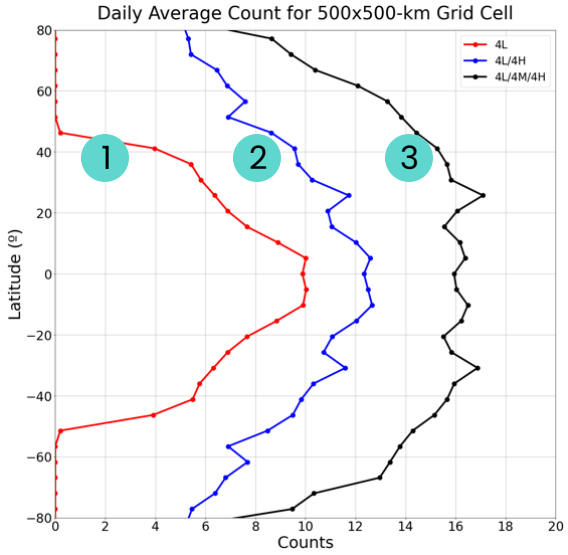
- Results:
  - Count requirement can be met with 4-s/c or more
  - Refresh requirement can be met from 30ºS-30ºN with 4 spacecraft
  - 8-spacecraft can meet refresh requirement globally
  - TEC counts very similar to neutral atmosphere
  - 30-min median latency easily achievable using GSaaS

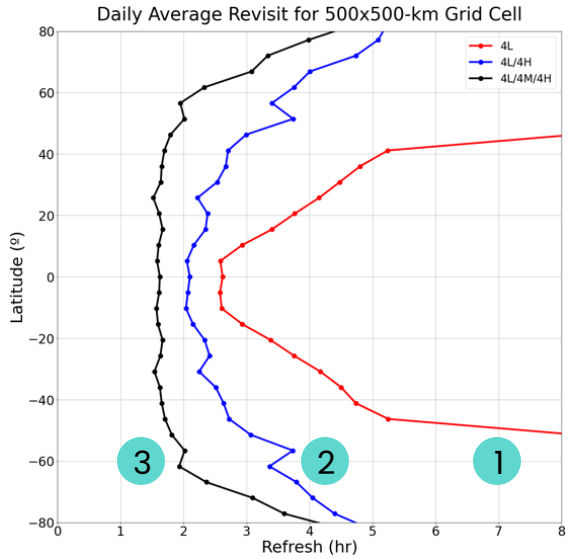
- Conclusions
  - Global refresh requirement much harder to meet than counts
  - 4/8-sc solutions can meet requirements, but real-world losses would likely lead to requirements failure











RO Architecture Optimization

Determining a minimum number of satellites

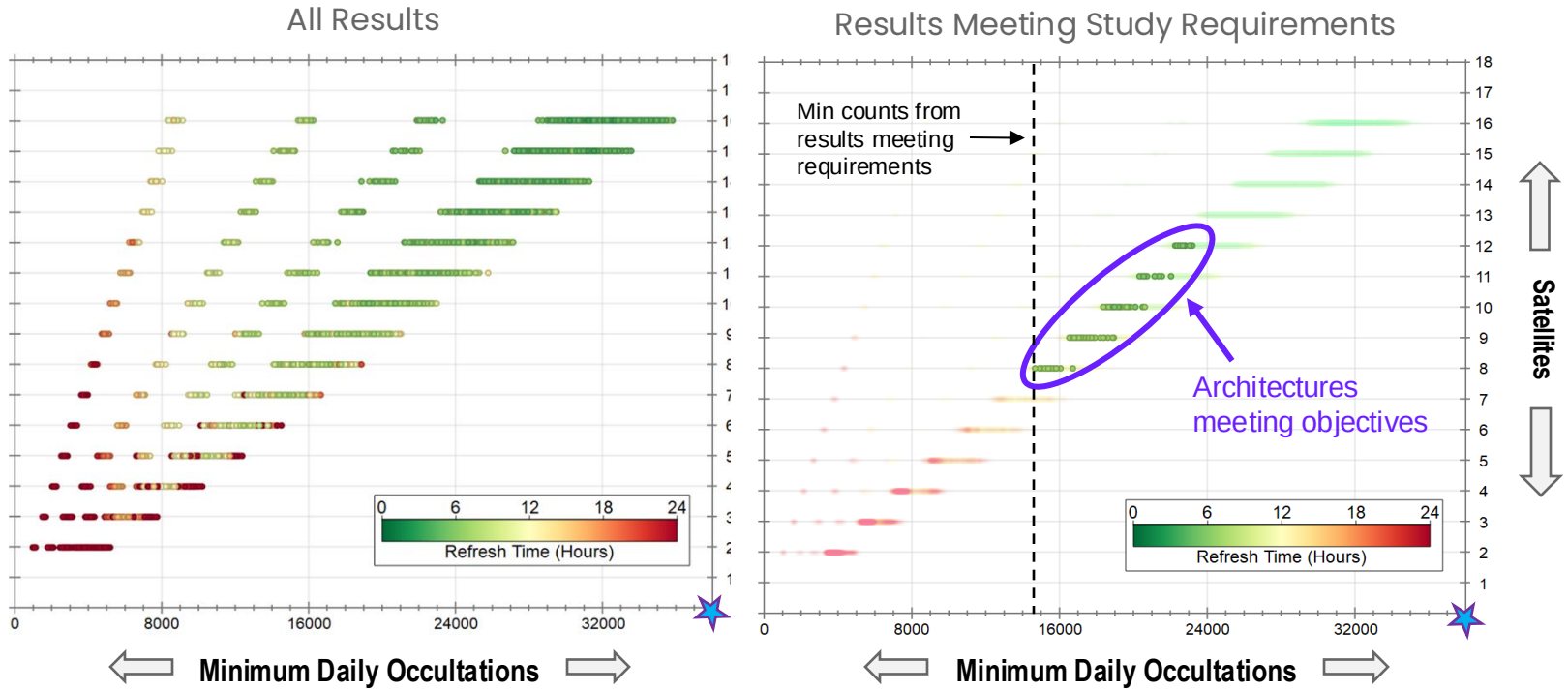
- Trade space was generated by optimizing RO architecture objectives using Aerospace genetic algorithm

- Architecture Objectives:
  - NESIDS RO requirements (count, refresh, local time)
  - 12-spacecraft max in <4 orbital planes
  - Max inc: 110º, 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

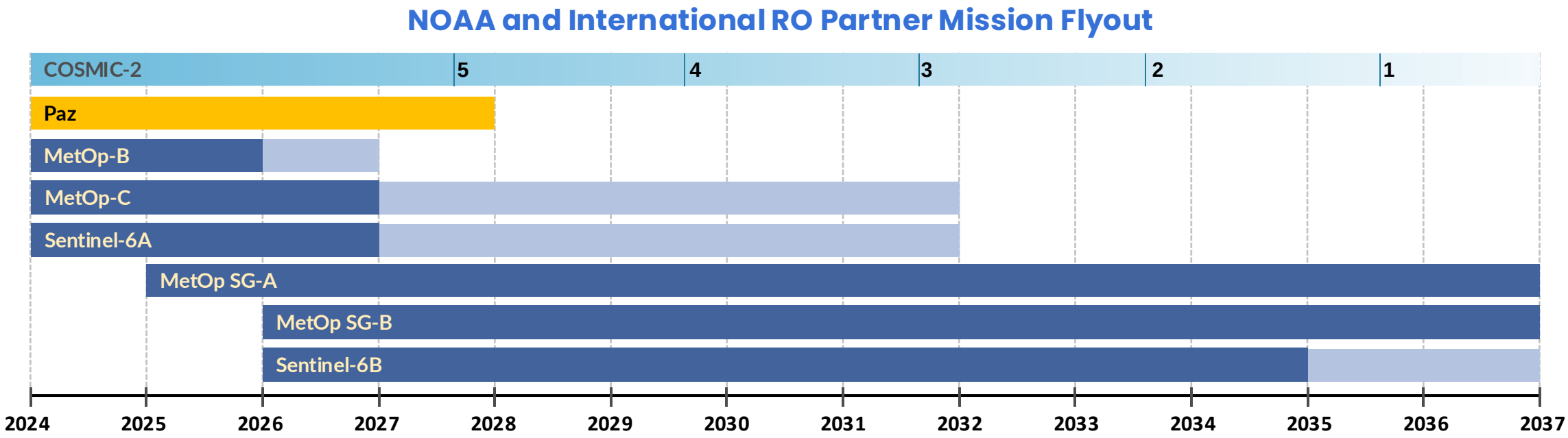


Plots Credit: C. Barsoum, Aerospace

A minimum of 8 satellites are required to meet requirements globally

RO Analysis of Alternatives

RO Picture: 2024–2037



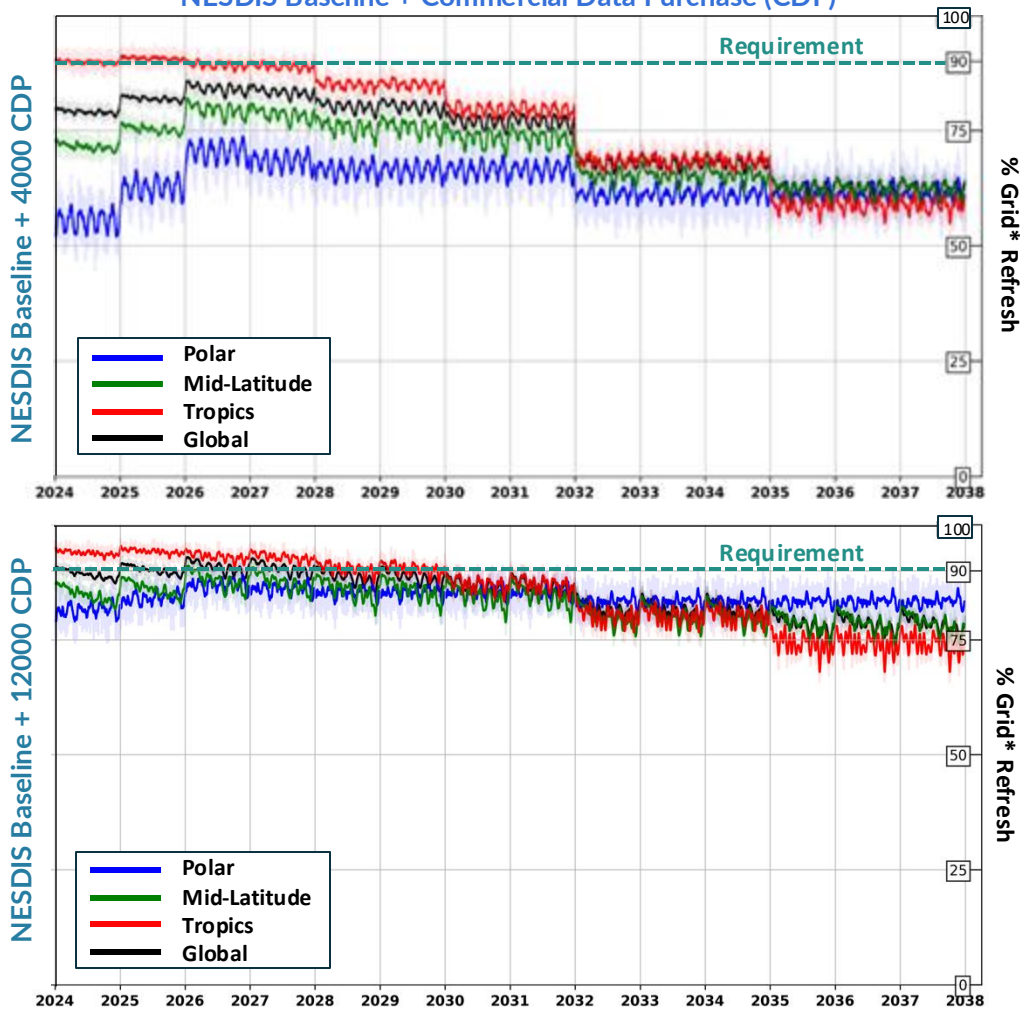
- COSMIC-2 degradation based on mid-estimate from internal program reliability study
- Partner missions based on published dates and estimates of mission extension
- Commercial provider capabilities estimated based upon previous/existing missions and orbits
- Gaps for the NESDIS RO system were assessed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

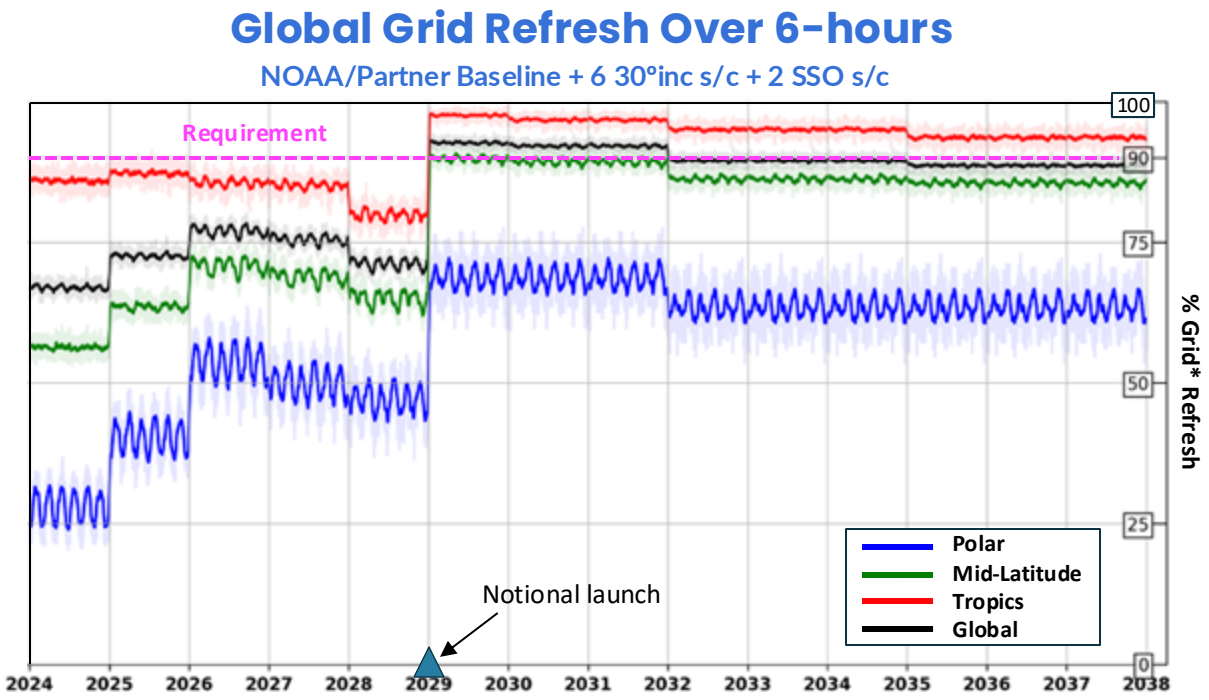
NESDIS Baseline + Commercial Data Purchase (CDP)



*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



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- 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!


NOAA
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Backup