



GEO-XO Pre-Formulation Studies

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GEO-XO Pre-Formulation Studies Topics



- NSOSA and Inputs to GEO-XO
- Industry Studies
- Program Studies
- Instrument Studies
- Constellation Study
- User Facing Communications & Cloud Studies
- Summary





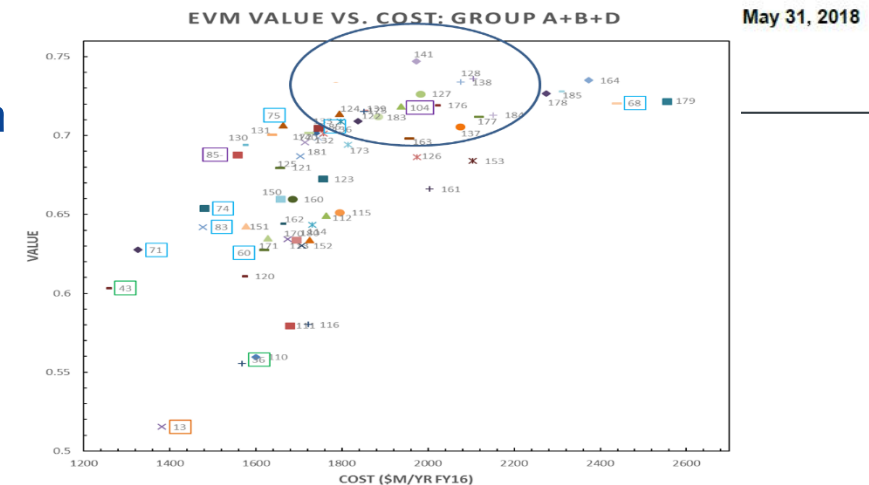
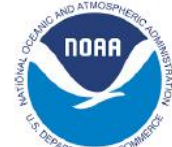
NSOSA Served as GEO-XO Analysis of Alternatives



- NSOSA study conducted over 2014-2018
 - Assessed alternative space segment architectures for post Program-of-Record period for all NOAA Earth and Space Weather missions
- NSOSA study process included:
 - NOAA management defined mission objectives, constraints, assumptions, and value assessments
 - SPRWG user group assigned observational study performance ranges and priorities
 - Effectiveness analysis and cost estimate for each constellation option
 - “Efficient Frontier” comparison of Value vs Cost for all options

The National Oceanic and Atmospheric Administration
(NOAA) Satellite Observing System Architecture Study

Building a Plan for NOAA's 21st Century Satellite
Observing System





NSOSA Conclusions for GEO-XO



- GEO-XO should consider trades for how to platform terrestrial and solar observation instruments:
 - Comprehensive GEO-only system
 - GEO/Tundra agile system with both terrestrial and solar observation capabilities
 - Disaggregated terrestrial and SpWx system with option for using hosted payload services
 - GEO/Tundra agile system focused on terrestrial weather observation
 - Dedicated solar observer primarily for GEO, but that could also be flown in L5
 - Govt hosted or commercially hosted imager or other instrument
 - Hosted solar and in-situ instruments study joint with NESIDS Space Weather Program (SWP)
- Study recommended that current GOES-R communications functions (GRB, HRIT, SAR, EMWIN) be transitioned to alternative services

Due to stand up of NESDIS SWP, recommended trades are now being performed across GEO-XO and SWP programs



Broad Agency Announcement Industry Studies



Category	Company	Title
Imagers	L3Harris	Advancing Today's ABI Foundation in to the Next-Gen GEO Imaging Solution
	Leidos	GEO Earth Multispectral Mapper (GEMM) Terrestrial Weather Imaging
	Raytheon	Real Time Imager (RTI)
	Lockheed Martin	Flexible Hosted Imager (FHI)
	Northrop Grumman	Photonic Imaging Spectrometer Instrument
Sounders	Ball Aerospace	Ball Operational Weather Instrument Evolution (BOWIE) – Geostationary IR Sounder Study for Compact Hyperspectral IR Observations (CHIRO)
	L3 Harris	Hyperspectral GEO Sounder
	Northrop Grumman	Geostationary Microwave Sounding Unit (GEMSU) Instrument Concept
	JPL	GEO IR Sounder
	JPL	GeoSTAR: A Geostationary Microwave Sounder for NOAA
LEO Sounders for GEO Requirements	BAE Systems	Infrared Sounding Instrument Constellation Study
	ASTRA	GEO-Utilization of Common LEO Architecture for Weather (G-CLAW)
Commercial Hosting	Space Systems/Loral	Commercial Hosting Service for Sustained GEO Weather Missions
Commercial Data	GeoMetWatch	Global HyperSpectral Atmospheric Sounding Capability: Commercial Fee-for-Service Option
Space Weather	Ball Aerospace	Dedicated Auroral Imager for a Tundra Satellite
	Xplore	PANORAMA – Commercial Solar Observatory Earth-Sun L1 Mission

NSOSA informed BAA studies will feed into architecture decisions and program critical path



Government Pre-Formulation Studies Supporting GEO-XO



Category	Subject	Outcome	Lead
Instruments	IR Sounder	Design concept, SWAP & cost estimate	GEO-XO / Aerospace Corp
	μ W Sounder	Design concept, SWAP & cost estimate	GEO-XO / Aerospace Corp
	Ocean Color Imager	Design concept, SWAP & cost estimate	GEO-XO / Aerospace Corp
	Day Night Band Imager	Design concept, SWAP & cost estimate	GEO-XO / Aerospace Corp
	Lightning Mapper	Focal plane tech dev plan	GEO-XO
Space Architecture	GOES Disaggregation	Design concept for disagg Earth & SWx	GOES-R / GSFC MDL
	SpWx SmallSat	Design concept, SWAP & cost estimate	GOES-R / GSFC MDL
	GEO-XO Constellation	Constellation selection based on observational & programmatic priorities	GEO-XO
Data Distribution & Ground System	User Facing Comm IPT	AoA for DCS, GRB, EMWIN/HRIT services	GEO-XO & OSAAP
	Cloud Delivery Analysis	Availability and latency statistics	GEO-XO / MIT/LL
	Data Rate/Antenna Size	Sizing for Primary/Rebroadcast Systems	GEO-XO
	Cloud LZSSc & H8	Pilot for cloud data storage and distro	GOES-R & OSGS
	Next Gen Enterprise GS	AoA for NESDIS enterprise ground ~2034	OSAAP

GEO-XO Program Office and OSAAP studies will augment decision process



GEO-XO Instruments under Evaluation: Imager and LM



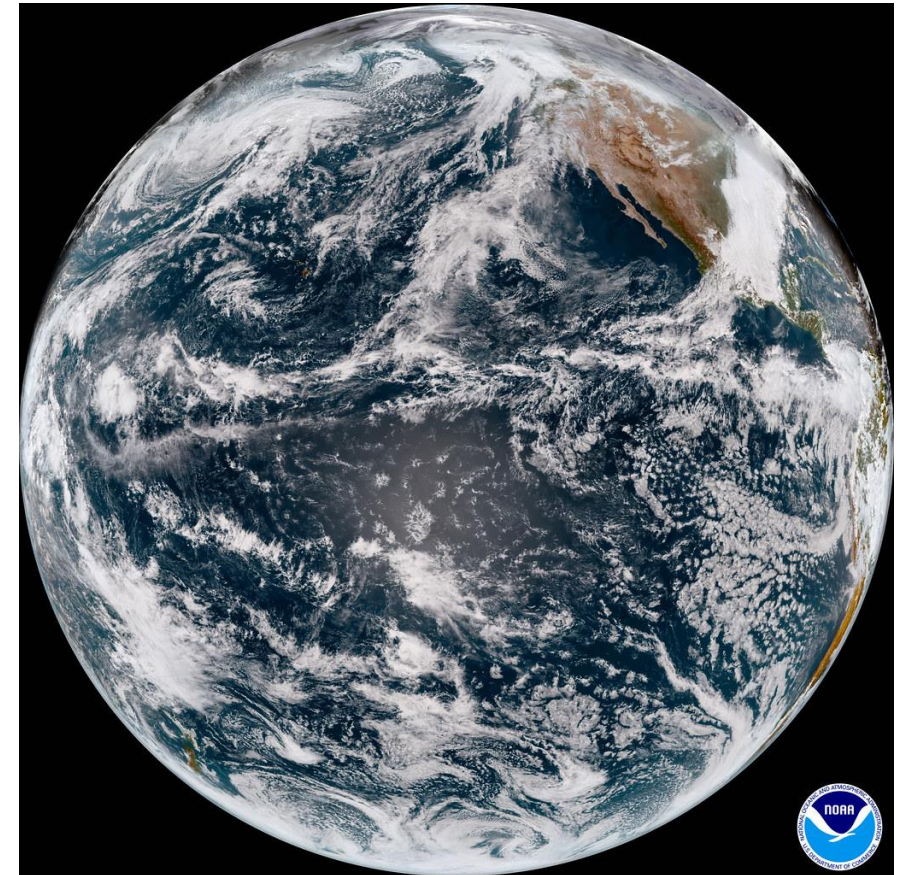
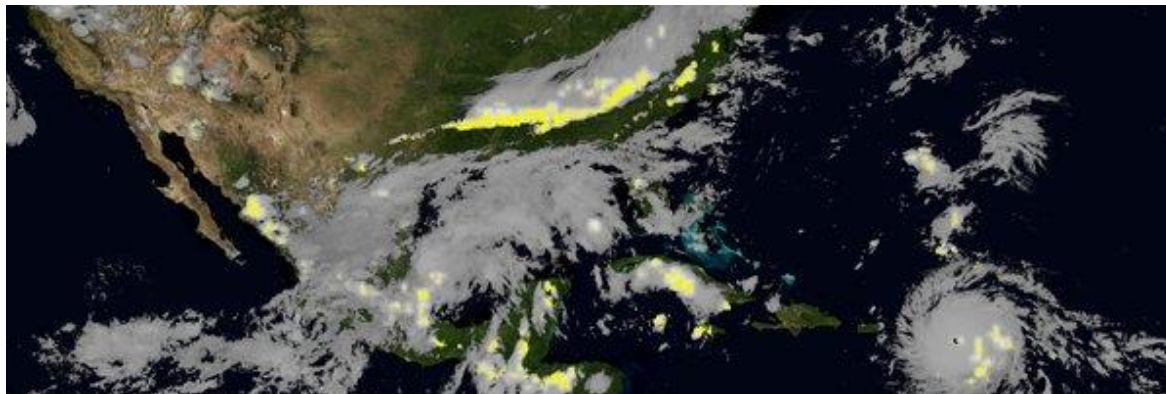
1. Imager

- ABI-like quality with potential upgrades being studied
- Being studied through 5 BAA industry studies
 - Leidos, Lockheed, L3Harris, Northrop, Raytheon



2. Lightning Mapper

- GLM-like or upgraded with higher spatial resolution
- Being assessed with program evaluation of:
 - GLM vs MTG LI designs
 - Focal plane technology

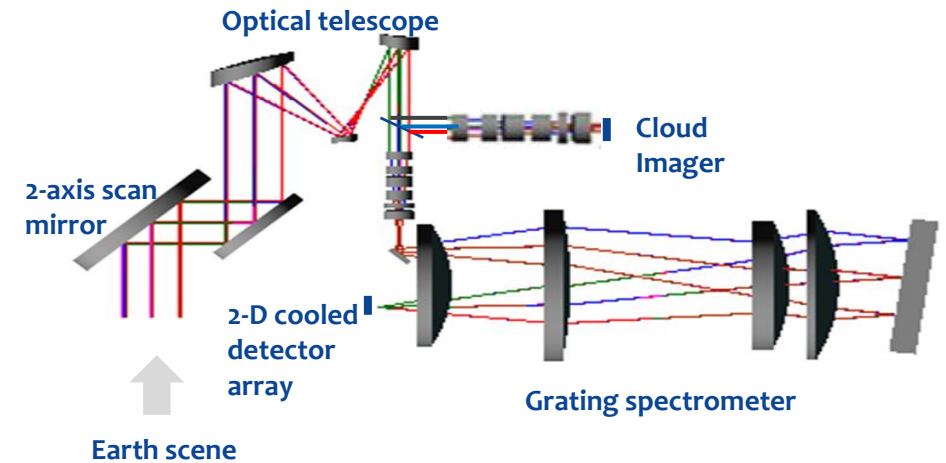




GEO-XO Instruments under Evaluation: IR Sounder

3. Hyperspectral IR Sounder

- Hundreds to thousands of channels
- Variations on sounder designs (spectral and temporal coverage) being studied
- Being assessed through:
 - OSSEs to estimate benefit to NWP
 - Discussed in Joel McCorkel presentation
 - 4 BAA industry studies of GEO sounders
 - Ball Aerospace, GeoMetWatch, JPL, L3Harris
 - 2 BAA industry studies of LEO swarm of sounders
 - ASTRA, BAE
- Aerospace Corp study of 4 IR Sounder variants
 - Threshold Performance Variants based on demonstrated designs & technologies
 - Objective Performance Variants with greater spectral coverage, resolution and NEDT performance
 - Mass Ranges– 150kg to 300kg
- Evaluating inclusion of co-located DNB capability



Initial Concept from The Aerospace Corporation

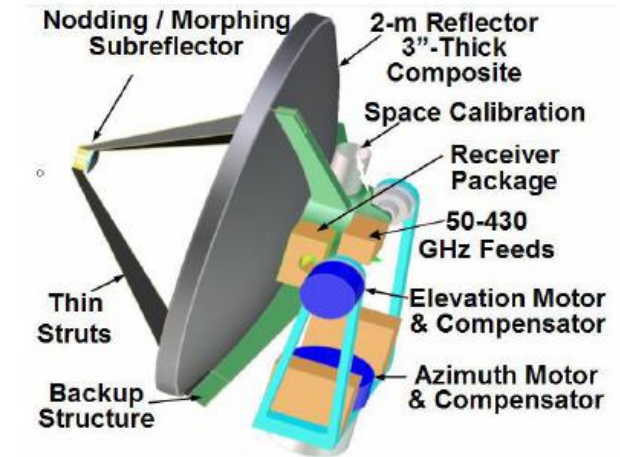
	Threshold	Objective (Goals)
Spectral Bands	S/MWIR (4.08-5.92 μm)	SWIR (3.67-4.65 μm) MWIR (5.74-8.26 μm) LWIR (8.33-14.9 μm)
IGFOV	5km	4km
Accuracy	1K	0.5K

GEO-XO Instruments under Evaluation: μ W Sounder



4. Microwave Sounder

- Both solid aperture and sparse aperture interferometric options being studied
- Being studied through:
 - OSSE to estimate benefit to NWP
 - 2 BAA industry studies
 - JPL, Northrop Grumman
- Aerospace study of 2 μ W Sounder variants
 - Threshold Variant
 - Multi-row array
 - Objective Variant(s)
 - Real aperture design(s)
 - Mass Ranges– 320kg to 400kg



Bajpai, S. et al., "Latest developments of geostationary microwave sounder technologies for NOAA's mission" Proc. of SPIE Vol. 6410 64100F-9

	Threshold	Objective (Goals)
Spectral Bands	~50GHz ~183GHz	~89GHz ~118GHz ~165GHz ~183GHz
IGFOV	30km-100km	13km-20km
Accuracy	1K	0.5K



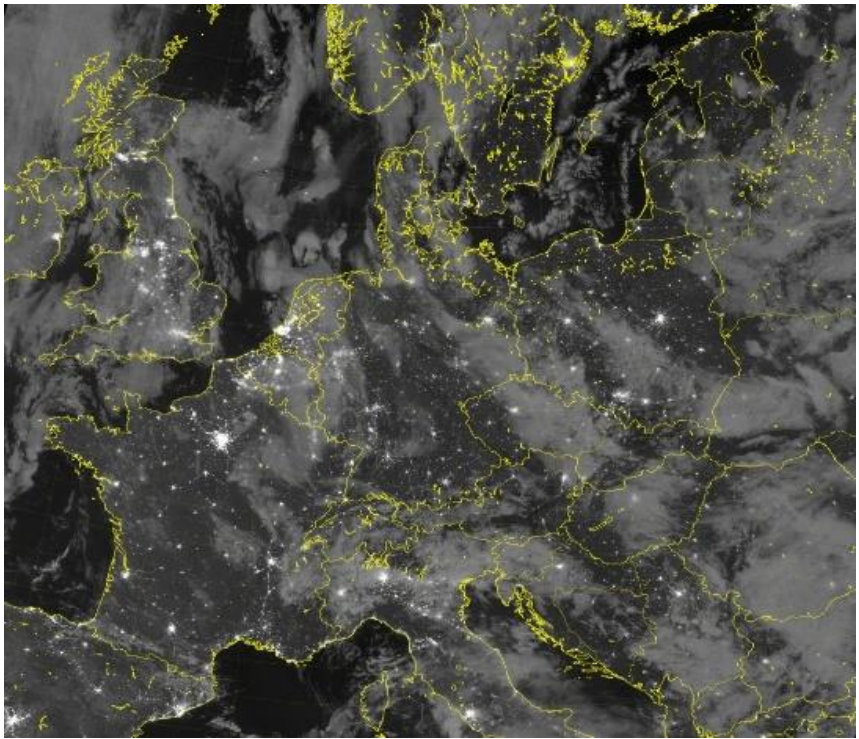
GEO-XO Instruments under Evaluation: Day Night Band



5. Day Night Band

- Similar to the VIIRS DNB, except with GEO latency and refresh capability
- Evaluating options for standalone DNB or as addition to Imager or Sounder
 - Being studied through:
 - BAA industry studies
 - Aerospace study

	Threshold	Objective (Goals)
Spectral Bands	1 VNIR broadband nighttime band	2 bands, including a VNIR broadband nighttime band
IGFOV	1km	0.25km
Noise (night) under half-moon illumination conditions	VNIR SNR: 20:1 (TBR) under ½ moon illumination conditions	VNIR SNR: 50:1 (TBR) under ½ moon illumination conditions



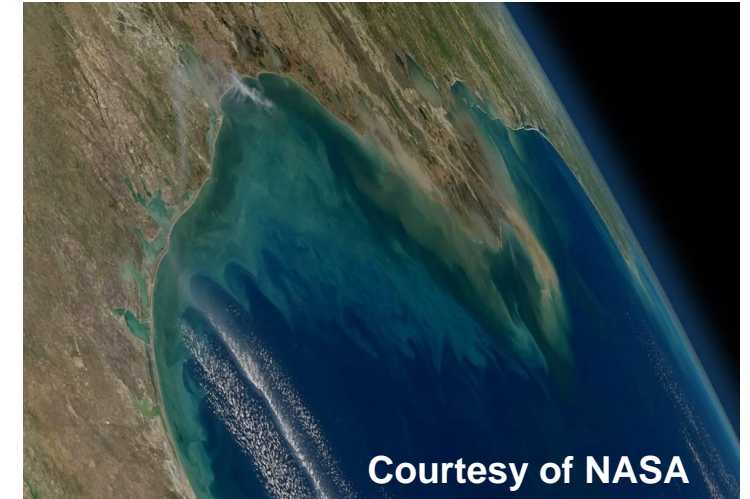


GEO-XO Instruments under Evaluation: Ocean Color Imager and Atmospheric Composition Instrument

6. Ocean Color Imager

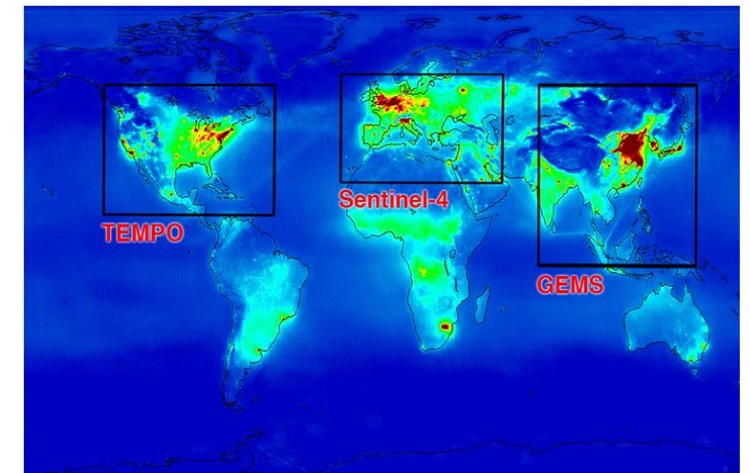
- Perhaps similar to NASA GLIMR imager
- Being studied through:
 - Aerospace study of OC variants

	Threshold	Objective (Goals)
Spectral Bands	Multi-spectral-Vis SWIR with 10 bands	Hyperspectral with 2.5 μm bands in the vis-SWIR
Coverage	Coastal	Coastal
Resolution	500m	250m



7. Atmospheric Composition

- Perhaps similar to NASA TEMPO UV/VIS spectrometer
- Being assessed with program evaluation of:
 - TEMPO and Sentinel 4 design
 - Ability to meet some measurements with other instruments (Imager, Sounder, or OC)





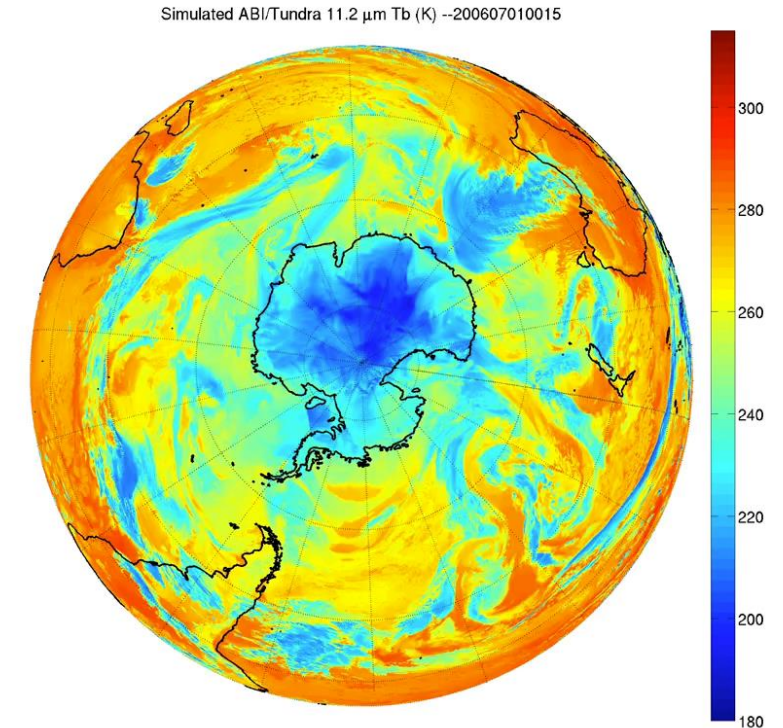
GEO-XO Extended Orbits under Evaluation

Tundra Orbit

- Imager
 - With 2 spacecraft, orbit provides persistent view of Arctic region
- Atmospheric Composition
- Evaluating polar vs critically-inclined orbits
- Being assessed through:
 - Program review of prior DoD study
 - BAA white papers
 - Tundra observational study by STAR, under OPPA Tech Maturation Program (2019-2020)

L1 Orbit

- SWP leading study efforts
- Solar & In-situ measurements
- Being assessed through
 - BAA studies



Courtesy of Zhenglong Li¹, Jun Li¹, Timothy J Schmit^{2*}, Fredrick W. Nagle¹, Mathew Gunshor¹



GEO-XO Constellation Trade



- Constellation Variations
 - Number of spacecraft
 - Orbital locations of spacecraft
 - Payloads per spacecraft
- Observations are those under consideration by the XORWG
- SpWx program defining the SpWx instruments to be accommodated
 - GEO-XO providing technical feasibility and cost estimates
- 23 Constellations defined for initial consideration, including legacy and non-legacy variants
- Evaluation using NSOSA-derived methodology and ASPEN
- Schedule
 - Initial Evaluation & down select mid-August
 - Final Selection mid-December



Observations Under XORWG Evaluation
Imager
IR Sounder
μW Sounder
Lightning Mapper
Day Night Band Imager
Atmospheric Composition
Ocean Color Imager
Tundra Imager
Tundra Atmospheric Composition

Sample of Constellations under Study



Key:

NOAA Satellite

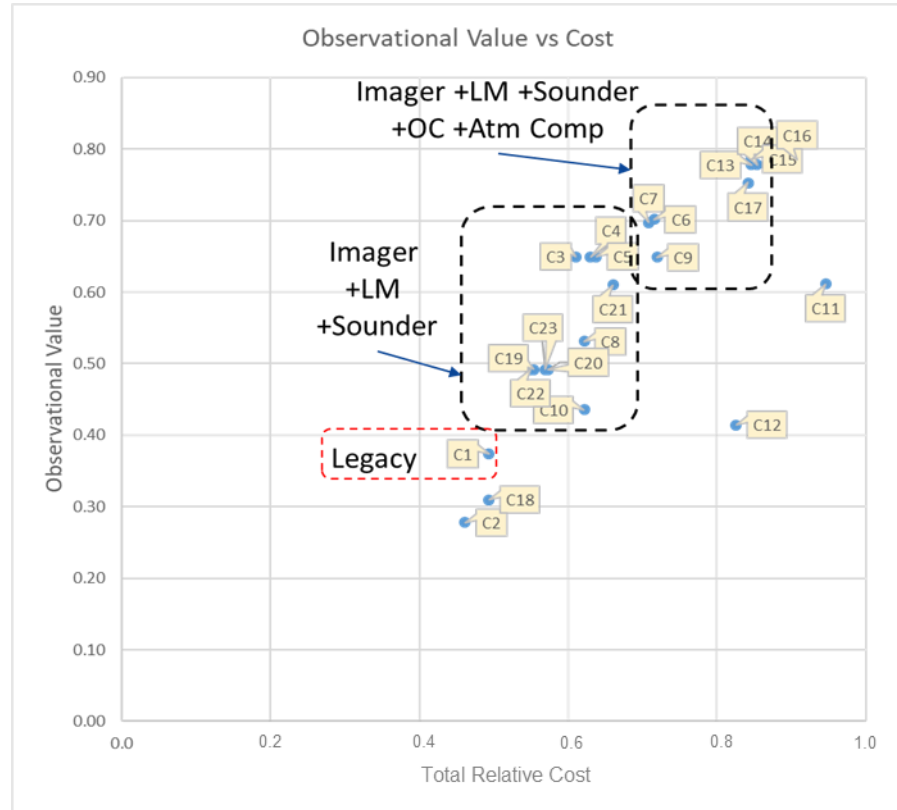
NOAA SmallSat

Hosted Payloads

Commercial Data



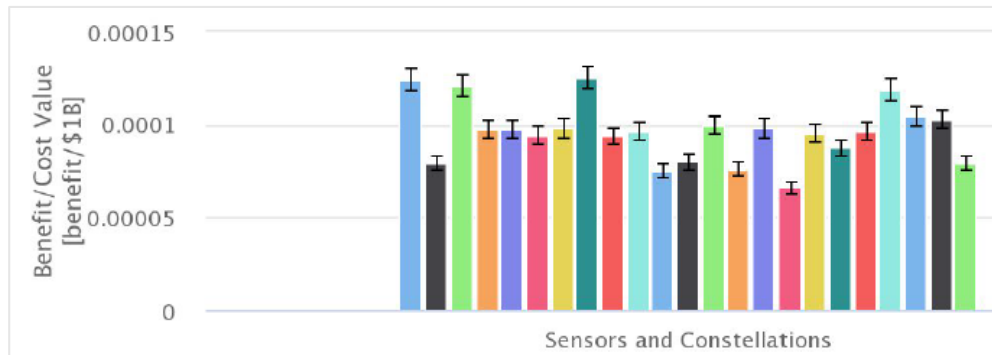
Initial Constellation Trade Results



NSOSA-Derived Method Result

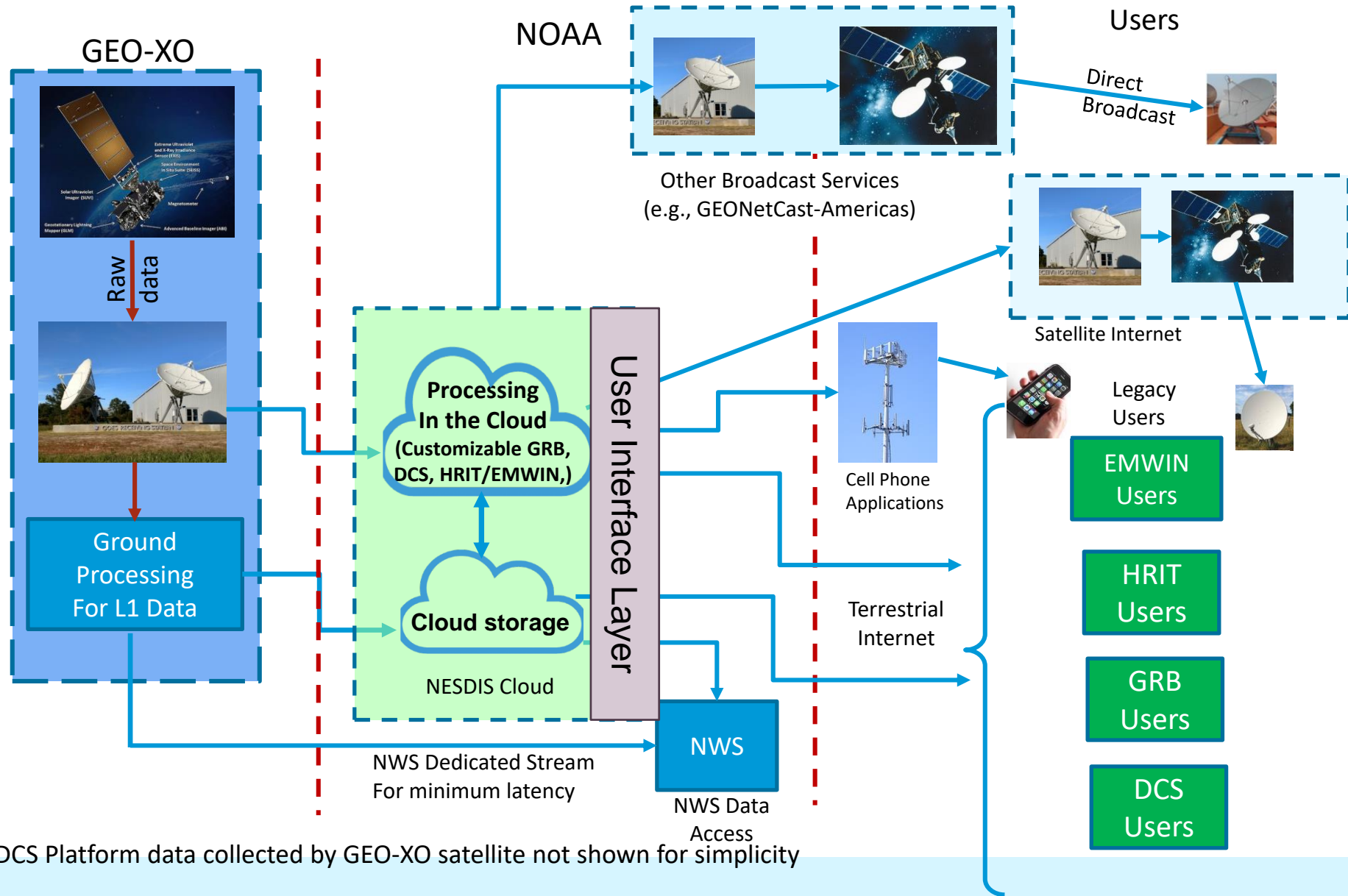
- Observational priorities for meet NOAA Mission Service Areas (MSAs) have been identified:
 - Weather: Imager, Sounders, Lightning
 - Oceans & Coasts: Ocean Color
 - Climate: Atmospheric Composition
- Constellations were scored based on how they support observational priorities
- Initial cost estimates generated
- Remaining work:
 - Refine observational priorities, folding in user input and BAA study data
 - Refine cost, folding in data from BAA study data on hosting, swarm, and commercial data
 - Define schedule and cost phasing
 - Risk assessment
 - Selection of final constellation

ASPEN Result





Anticipated GEO-XO Data Flows



*DCS Platform data collected by GEO-XO satellite not shown for simplicity



GOES-R/GEO-XO Cloud Efforts

GOES-R Ground Segment Project Prototyping

- Functional
 - Accessible S3 bucket for partner access
 - User Management
 - Resource Management
- Programmatic
 - Demonstrate data flow from operational system to GOES-R Cloud Prototyping VPC
 - Supports objectives of the NESDIS Cloud Phase 2 IPT

Cloud Distribution Pilot

- Functional
 - Distribute from GOES-R Cloud Prototype VPC authoritative GRB data to 3rd party user
 - Develop unique front end user interface and test distribution model
- Programmatic
 - Demonstrate and test latency, availability, and quality of GRB stream
 - Incorporate user needs in front end development



Estimated Data Rate for a Single Location

	Raw Data Rate (Mbps)	Compressed Raw Data Rate (Mbps)	L1B Data Rate (Mbps)	Compressed L1B (Mbps)
Imager	360	150	250	156
IR Sounder	445	200	250	156
Lightning Mapper	40	40	40	25
Ocean Color (OC)*	55	32.4	45	28
Atmospheric Composition (AC)*	70	43.8	55	34
		466	640	400

- Final Payloads not yet determined, instruments may not reside on the same spacecraft

**Daytime Operation*



GEO-XO Pre-Formulation Studies Summary



- The NSOSA study examined a wide range of architecture options for next generation Earth and Space Weather satellite programs in LEO, GEO, Lagrange and Tundra orbits
- NSOSA results informed program-specific pre-formulation studies in 2019-2020
- Ongoing pre-formulation studies are evaluating key observational and architecture questions needed to define the GEO-XO instrument complement and constellation
- GEO-XO pre-formulation studies are on track to inform program requirements and architecture definition for Mission Concept Review in March 2021 and subsequent formulation activities
- GEO-XO is coordinating with OSAAP on the NESDIS Ground Enterprise Study (NGES)





BACKUP



Acronyms

ABI – Advanced Baseline Imager
AC – Atmospheric Composition
AoA – Analysis of Alternatives
ASPEN – Advanced Systems Performance Evaluation Tool for NESDIS
BAA – Broad Agency Announcement
BOWIE-CHIRO – Ball Operational Weather Instrument Evolution – Geostationary IR Sounder Study for Compact Hyperspectral IR Observations
DCS – Data Collection System
DNB – Day Night Band
DoD – Department of Defense
EMWIN – Emergency Managers Weather Information Network
FHI – Flexible Hosted Imager
G-CLAW – GEO-Utilization of Common LEO Architecture for Weather
GEMM – GEO Earth Multispectral Mapper
GEMSU – Geostationary Microwave Sounding Unit
GeoSTAR – Geostationary Synthetic Thinned Aperture Radiometer
GEO-XO – Geostationary and Extended Orbits
GLIMR – Geosynchronous Littoral Imaging and Monitoring Radiometer
GLM – GOES Lightning Mapper
GOES-R – Geostationary Operational Environmental Satellite – R Series
GRB – GOES Rebroadcast
GSFC – Goddard Space Flight Center
HRIT – High Rate Information Transmission
IGFOV – Instantaneous Ground Field of View
IR – Infrared
LZSSc – Level Zero Storage Space Cloud
MDL – Mission Design Lab
μW – Microwave
MIT/LL – MIT Lincoln Labs
MSA – Mission Service Area

MTG LI – MeteoSat Third Generation Lightning Imager
NASA – National Aeronautics and Space Administration
NEDT – Noise Equivalent Differential Temperature
NESDIS – National Environmental Satellite, Data, and Information Service
NOAA – National Oceanic and Atmospheric Administration
NSOSA – NOAA Satellite Observing Systems Architecture
NWP – Numerical Weather Prediction
NWS – National Weather Service
OC – Ocean Color
OPPA – Office of Projects, Planning, and Analysis
OSAAP – Office of Systems Architecture and Advanced Planning
OSSE – Observing System Simulation Experiment
RTI – Real Time Imager
SAR – Search and Rescue
SNR – Signal to Noise Ratio
SPRWG – Space Platform Requirements Working Group
SpWx – Space Weather
STAR – Center for Satellite Applications and Research
SWIR – Short Wave Infrared
TEMPO – Tropospheric Emissions: Monitoring Pollution
UV/VIS – Ultraviolet-Visible
VIIRS – Visible Infrared Imaging Radiometer Suite
VNIR – Visible and Near-Infrared
VPC – Virtual Private Cloud
XORWG – GEO-XO User Requirements Working Group