



**NOAA**

# GEO Overview & GEO-XO Introduction and Formulation Plans

Pam Sullivan, GOES-R & GEO-XO Program Director

September 30, 2020



# Achieving the NESDIS Vision in Geostationary Earth Orbit



## NESDIS Vision:

*A truly integrated digital understanding of our earth environment that can evolve quickly to meet changing user expectations by leveraging our own capabilities and partnerships.*

## GEO Strategic Objective:

*Advance terrestrial observational leadership in geostationary and extended orbits*

## GEO Roles:

- Maintain and extend Earth observations from geostationary and potentially Tundra orbits*
- Improve and expand our product suite*
- Collaborate with partners to collect, process, and deliver relevant data to our users*
- Interpret and provide data in manner that users can readily access and understand*





# GOES-R in Operation

- GOES-16 in service as GOES East since December 2017
  - Recently observed partial thruster degradation
  - Performance stabilized with ops mitigations
- GOES-17 in service as GOES West since February 2019
  - ABI loop heat pipe mitigations in place
- All GOES-16 & 17 data products in operational use
  - At provisional or full maturity level



*The GOES-R Series, from Africa to New Zealand*



# GOES-R in Development

- GOES-T
  - Currently In Thermal/Vacuum test
  - Launch planned on an Atlas V in December 2021
- GOES-U
  - Integration is underway, including modifications to add the Compact Coronagraph (CCOR) for detection of coronal mass ejections
  - Launch planned in 2024



*GOES-T going into TV Chamber at Lockheed*



*CCOR Concept*



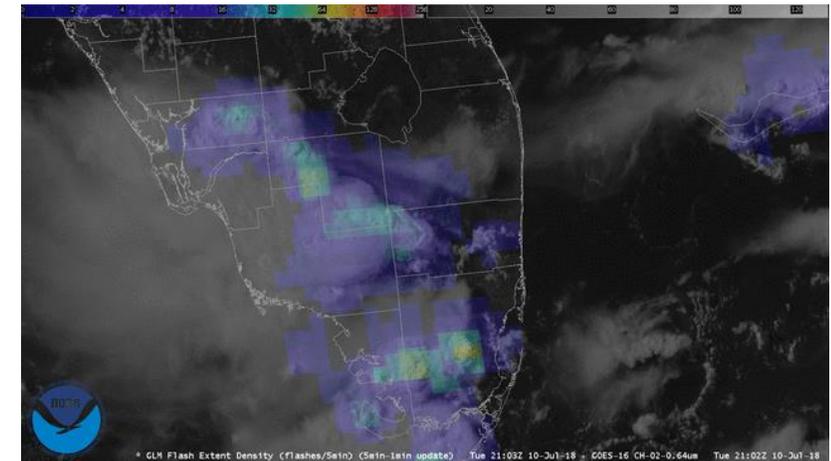
*CCOR Optical Tube Assy*



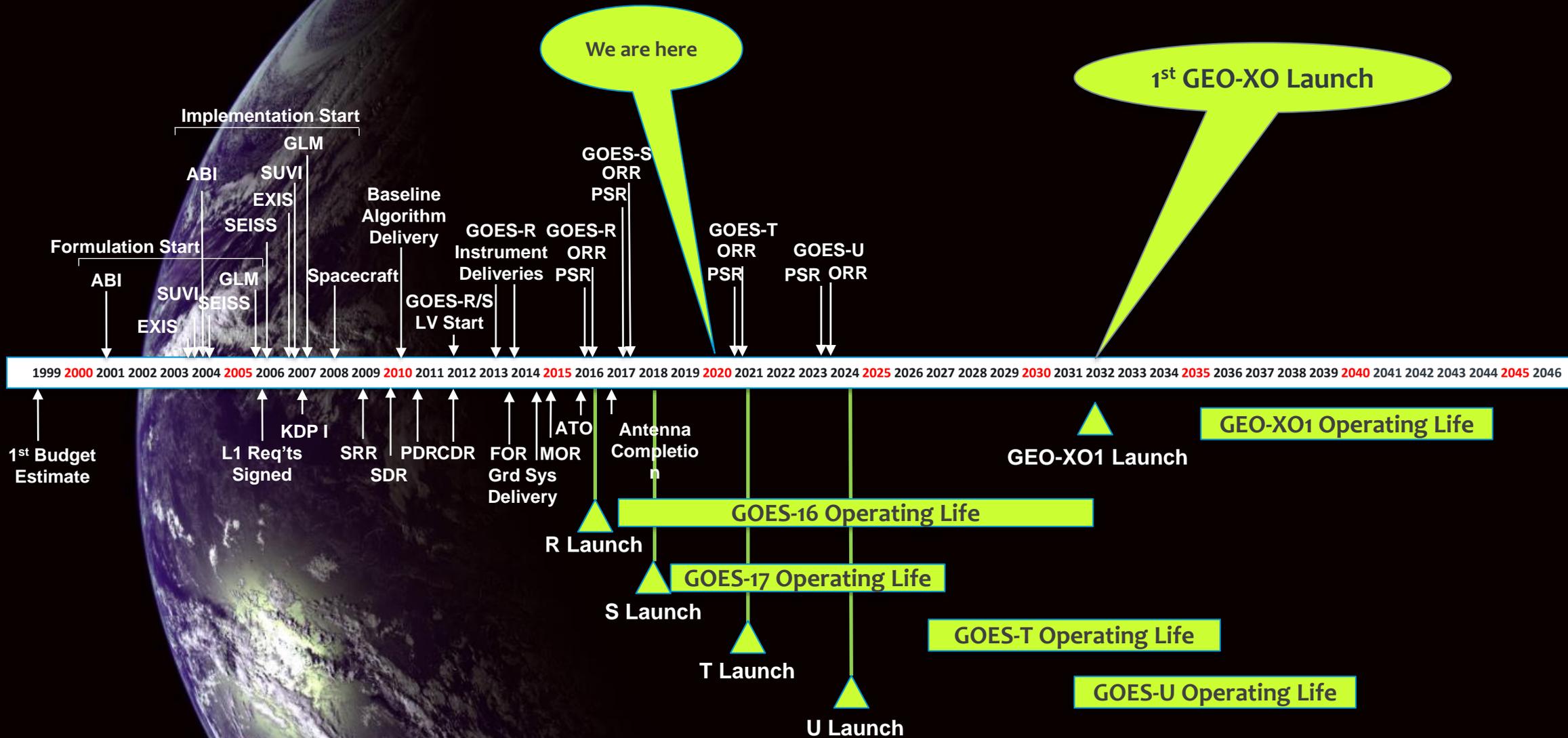
# GOES-R in Sustainment

- Continuing to evolve and expand the data product suite based on user feedback
  - Converting ABI L2 products to enterprise versions
  - Adding new products:
    - Ice Concentration & Extent, Age & Thickness, Motion
    - All Sky and Clear Sky Radiances
    - Aerosol Particle Size
    - Cloud Cover Layer
    - DMW BUFR
    - Automated Surface Observing System
    - Low Cloud / Fog
    - GLM Gridded products
  - Researching new products
    - 18 new ROSES product proposals funded in Fy20
- Ground System Server Replacement underway, after C19-related pause
- Preparing for follow-on ground sustainment contract to support 2023-2027
- Evaluating candidate functions for migration to the Cloud
  - Level Zero Storage System prototyping in process

GLM Gridded Product



# GOES-R to GEO-XO Timeline



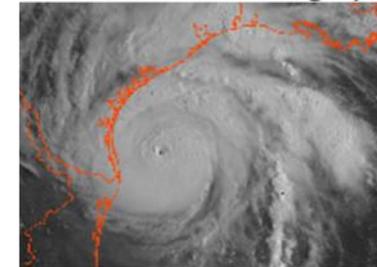


# GEO-XO Introduction

- GEO-XO = *Geostationary and Extended Orbits*
  - The mission to follow GOES-R and provide continuity for GEO observations
  - Considering expanding to include observations from “Tundra”
  - Anticipate providing space & ground services for Space Weather mission including L1 spacecraft
- GEO-XO includes all NOAA Earth-observing assets deployed above LEO:
  - Government spacecraft
  - Potential payloads hosted on commercial/partner spacecraft
  - Potential use of commercial services and observational data
- Operational in the 2030-2050 timeframe
  - Currently in pre-formulation:
    - Instrument and constellation studies underway
    - User needs assessment underway
    - Requirements definition underway
  - Approximate Program Schedule
    - Mission Concept Review, 2021
    - System Requirements Review, 2022
    - System Preliminary Design Review, 2025
    - 1st GEO Launch FY32

## Data Continuity, and Potential New Observations

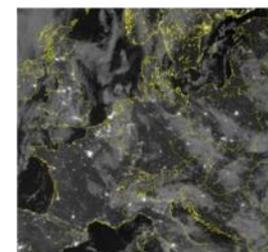
Visible & Near-IR Imagery



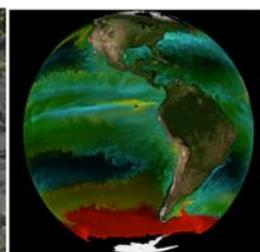
Lightning Mapping



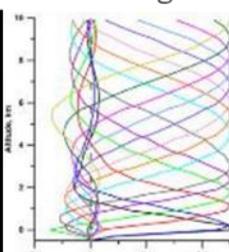
Day/Night Imagery



Ocean Color



Sounding



# ICYMI: GEO-XO Pre-Formulation thru FY20



GEO-XO Pre-Formulation Event/Activity	Timeframe	Status
NOAA Satellite Observing System Architecture Study	Pre-FY20	Complete
<b>Program Milestone Zero Review</b>	<b>Dec 2019</b>	<b>Approved</b>
GEO-XO User Requirements Working Group Established	Feb 2020	Reqs input Nov 20
User Facing Communications IPT Established	Mar 2020	Work Underway
GEO Broad Agency Announcement Study Contracts	Spring 2020	Awarded; ECD Fall/Winter 20/21
Instrument Concept Studies (w/Aerospace Corp) Initiated	April 2020	Underway; ECD Feb 21
Constellation Study Started	May 2020	Underway; ECD Dec 20
Requirement Definition Plan Briefed to NOSC	May 2020	Complete
Formulation Authorization Document	Jun 2020	Approved
NOAA-NASA Inter-Agency Agreement	Aug 2020	Approved
User Needs Workshops (on subjects of Fire, Weather, Health, Oceans, & Agriculture/Land Use)	Summer 2020	4 Complete; 5 <sup>th</sup> planned Oct 21
Program Level 1 Requirements	Sep 2020	Drafted; ECD Mar 21
Formulation Agreement	Fall 2020	Drafted; ECD Mar 21



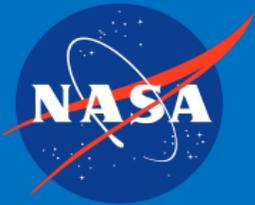


# Road to Milestone 1



- Currently completing detailed concept activities and planning for formulation phase
- Detailed Concept Design Phase activities now underway:
  - Industry and program studies of candidate instruments and architecture options
  - User needs assessments led by GEO-XO User Requirements Working Group (XORWG)
    - User needs workshops and conference listening sessions
    - OSSEs/other quantitative assessments of value for observational capabilities
    - Consulting with partner agencies on GEO-XO relevant plans
    - Generation of observational priorities and requirements
  - Data service needs assessment through User Facing Comm IPT
  - Initial L1 requirements drafted
  - Refinement of program scope, ConOps, ROM cost and schedule
- Activities in process to prepare for FY21 Formulation
  - NOAA-NASA Inter-Agency Agreement for Phase A/B complete
  - Formulation Agreements (FAD) complete
  - Program Office established and being populated
  - Program Plans needed for formulation phase are in draft
  - Contract documentation for industry Phase A studies in draft
- Planning for Mission Concept Review in March 2021 and DoC Milestone 1





# GEO-XO Pre-Formulation Studies

Alexander Krimchansky, GOES-R & GEO-XO Lead Program Systems Engineer  
NASA/GSFC

September 30, 2020





# 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
	μW 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***



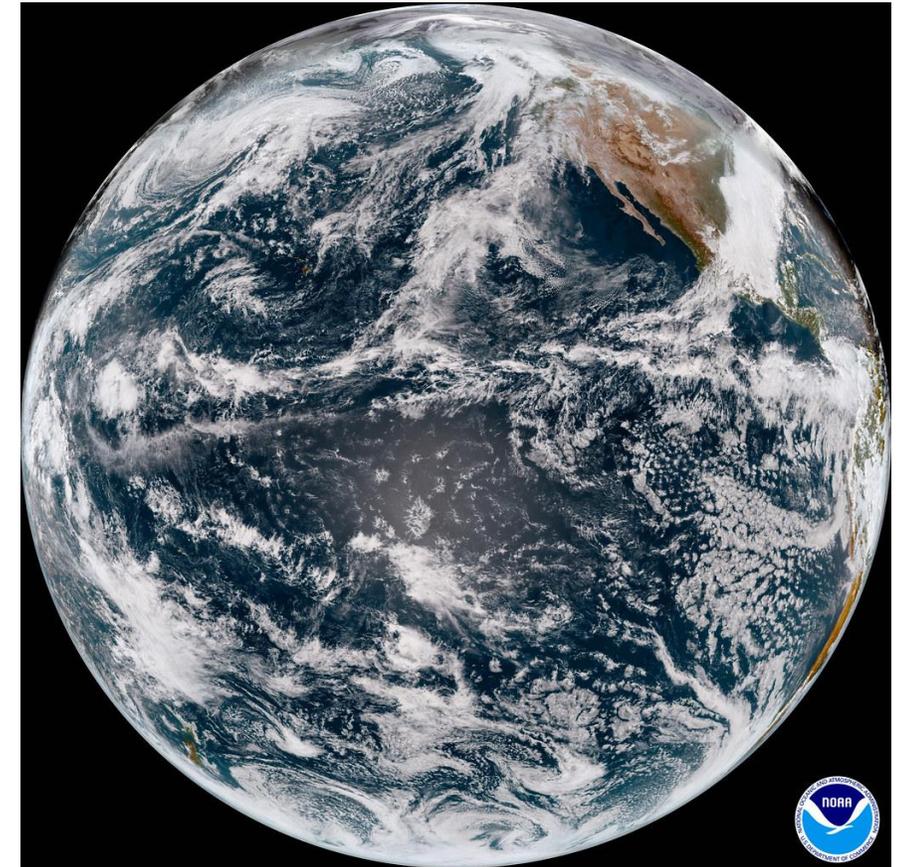
# GEO-XO Instruments under Evaluation: Imager and LM

## 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

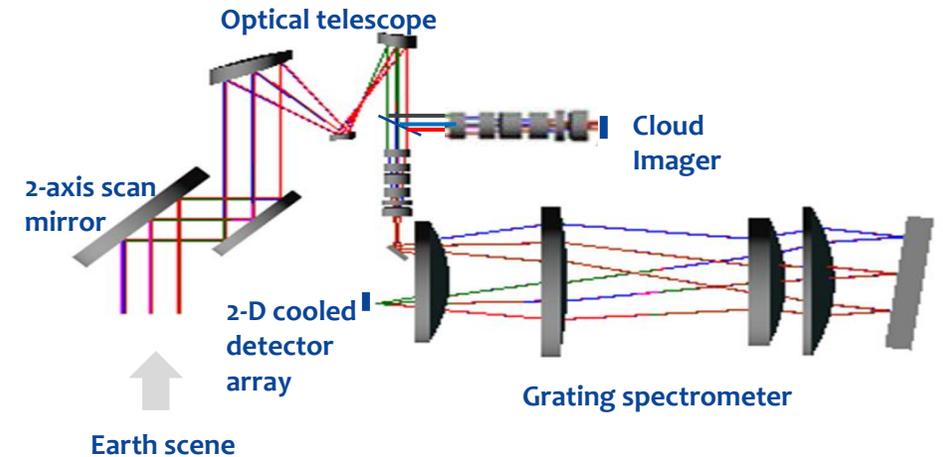




# GEO-XO Instruments under Evaluation: IR Sounder

## 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

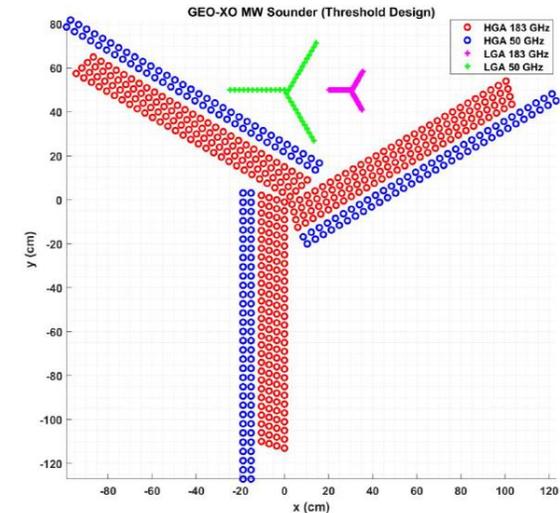
	Threshold	Objective
Spectral Bands	S/MWIR (4.08-5.92 μm)	SWIR (3.67-4.65 μm) MWIR (5.74-8.26 μm) LWIR (8.33-14.9 μm)
IGFOV	5km	4km
Accuracy	1K	0.5K



# GEO-XO Instruments under Evaluation: $\mu$ W Sounder

## 4. Microwave Sounder

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



Initial Concept from The Aerospace Corporation for Multi-Row Array\*

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

\*Tanner, T. Gaier, W. Imbriale, P. Kangaslahti, B. Lambrigtsen and B. Lim, "A Dual-Gain Design for the Geostationary Synthetic Thinned Array Radiometer," in IEEE Geoscience and Remote Sensing Letters, vol. 11, no. 8, pp. 1340-1344, Aug. 2014, doi: 10.1109/LGRS.2013.2293318; reference design

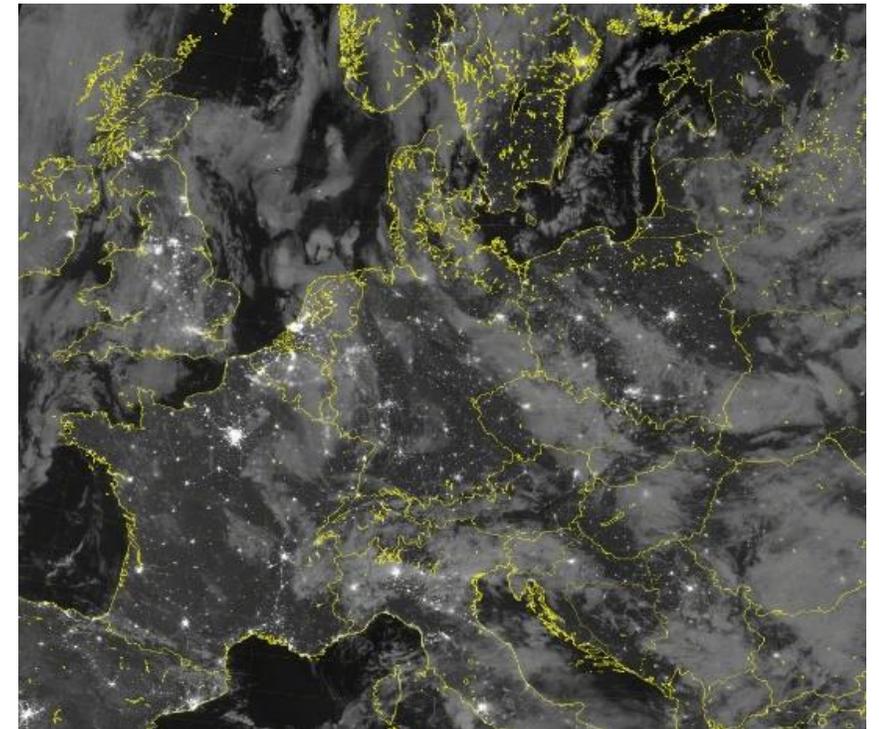
# GEO-XO Instruments under Evaluation: Day Night Band



## 5. Day Night Band

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

	Threshold	Objective
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



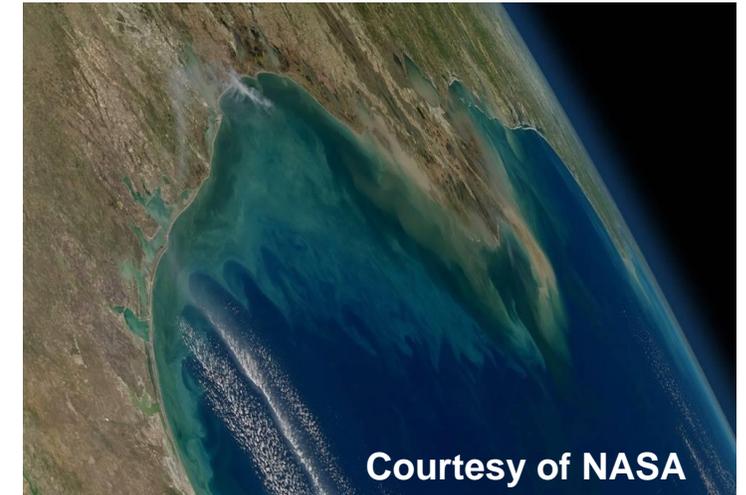


# GEO-XO Instruments under Evaluation: Ocean Color Imager and Atmospheric Composition Instrument

## 6. Ocean Color Imager

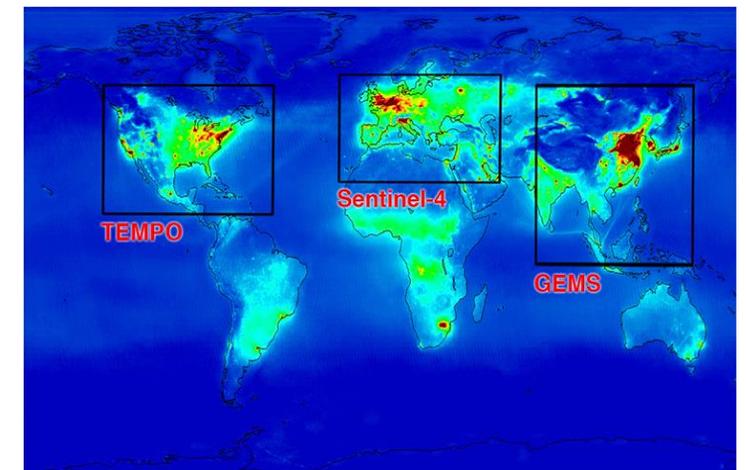
- Perhaps similar to NASA GLIMR imager
- Being studied through:
  - Aerospace study of OC variants

	Threshold	Objective
Spectral Bands	Multi-spectral-Vis SWIR with 10 bands	Hyperspectral with 2.5 $\mu\text{m}$ 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

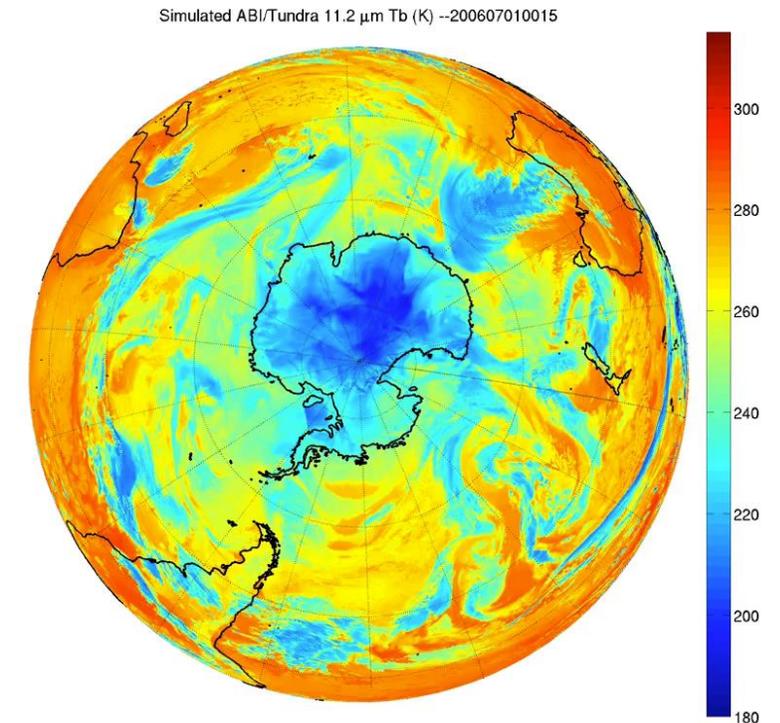


## Tundra Orbit

- 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 Li<sup>1</sup>, Jun Li<sup>1</sup>, Timothy J Schmit<sup>2\*</sup>, Fredrick W. Nagle<sup>1</sup>, Mathew Gunshor<sup>1</sup>



# 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

$\mu$ W 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

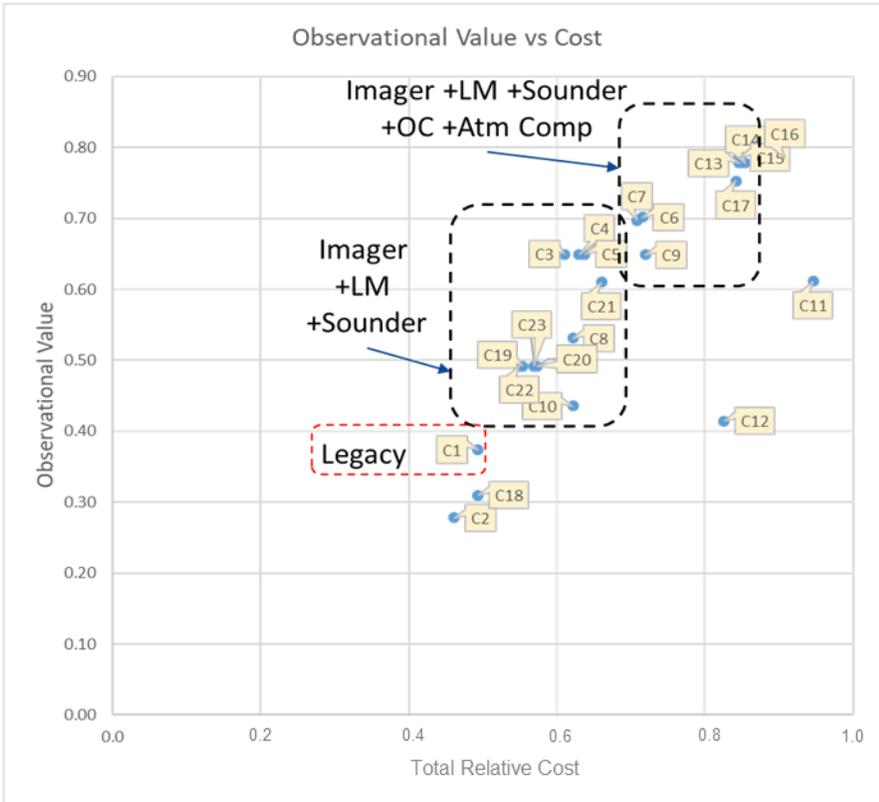
NOAA SmallSat

Hosted Payloads

Commercial Data



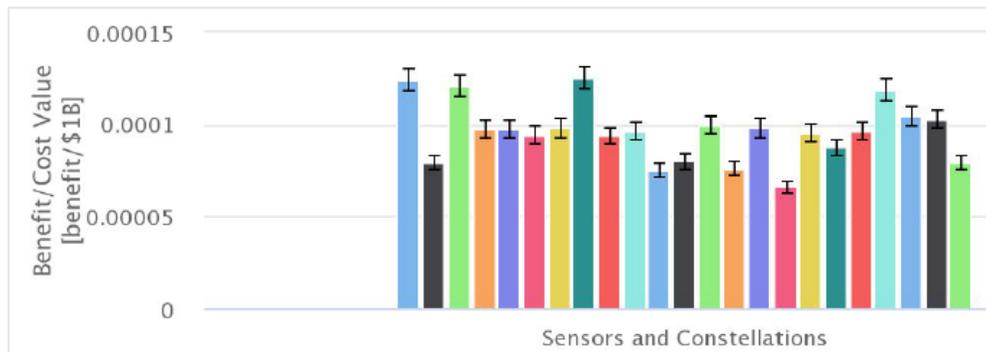
# Initial Constellation Trade Results



**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**





**NOAA**

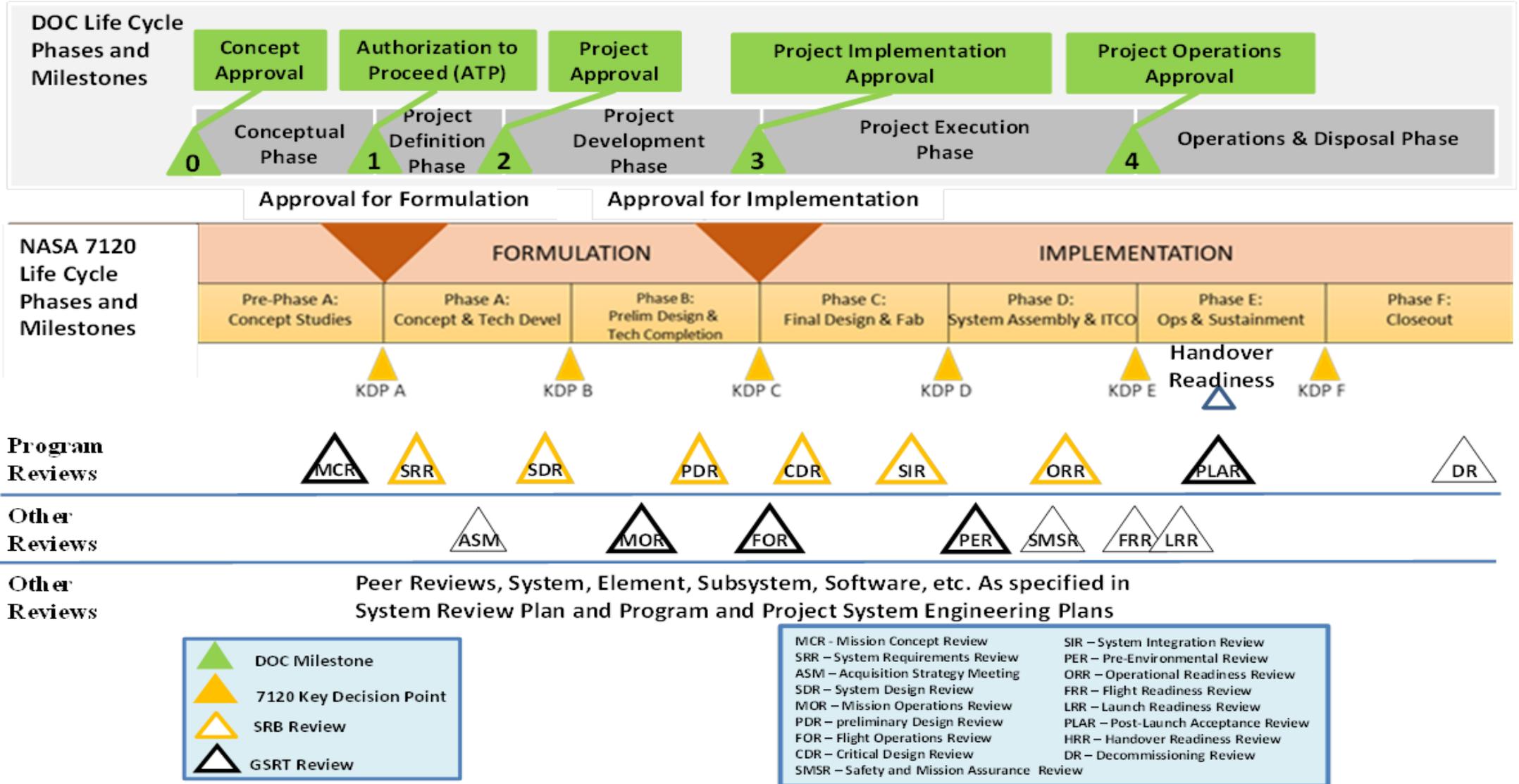
# GEO-XO Program Formulation

Pam Sullivan, GOES-R and GEO-XO Program Director

**September 30, 2020**



# Program Planned to DOC & NASA Guidance



# GEO-XO Formulation Milestones FY21-23



GEO-XO Formulation Event/Activity	Timeframe	Note
GEO BAA & Aerospace Instrument Studies Complete	Fall 2020	
User Requirements Finalized	Nov 2020	Observations Defined
Constellation Trade Study Complete	Dec 2020	Architecture Defined
Program Level 1 Requirements Approved	Mar 2021	Requirements Defined
<b>Mission Concept Review</b>	<b>Mar 2021</b>	
Program Cost Revision based on MCR Definition	Mar 2021	Align to MCR Scope
<b>DOC Milestone 1 Review</b>	<b>3QFY21</b>	<b>Program Initiation</b>
Imager Phase A Study Contracts Awarded	Mar 2021	Up to 3 Contracts
Remaining Instruments Phase A Contracts Awarded	1QFY22	Up to 3 per Instr. Type
Ground System Studies and Data Pilots Begin	1QFY22	
<b>System Requirements Review</b>	<b>3QFY22</b>	
Implementation Phase Acquisition Strategy Meeting	3QFY22	
Update Program Cost Estimate and Perform ICE	1QFY23	
<b>DOC Milestone 2 Review</b>	<b>1QFY23</b>	<b>Program Approval</b>
Spacecraft and Instrument Implementation Phase Contracts Awarded	3QFY23+	



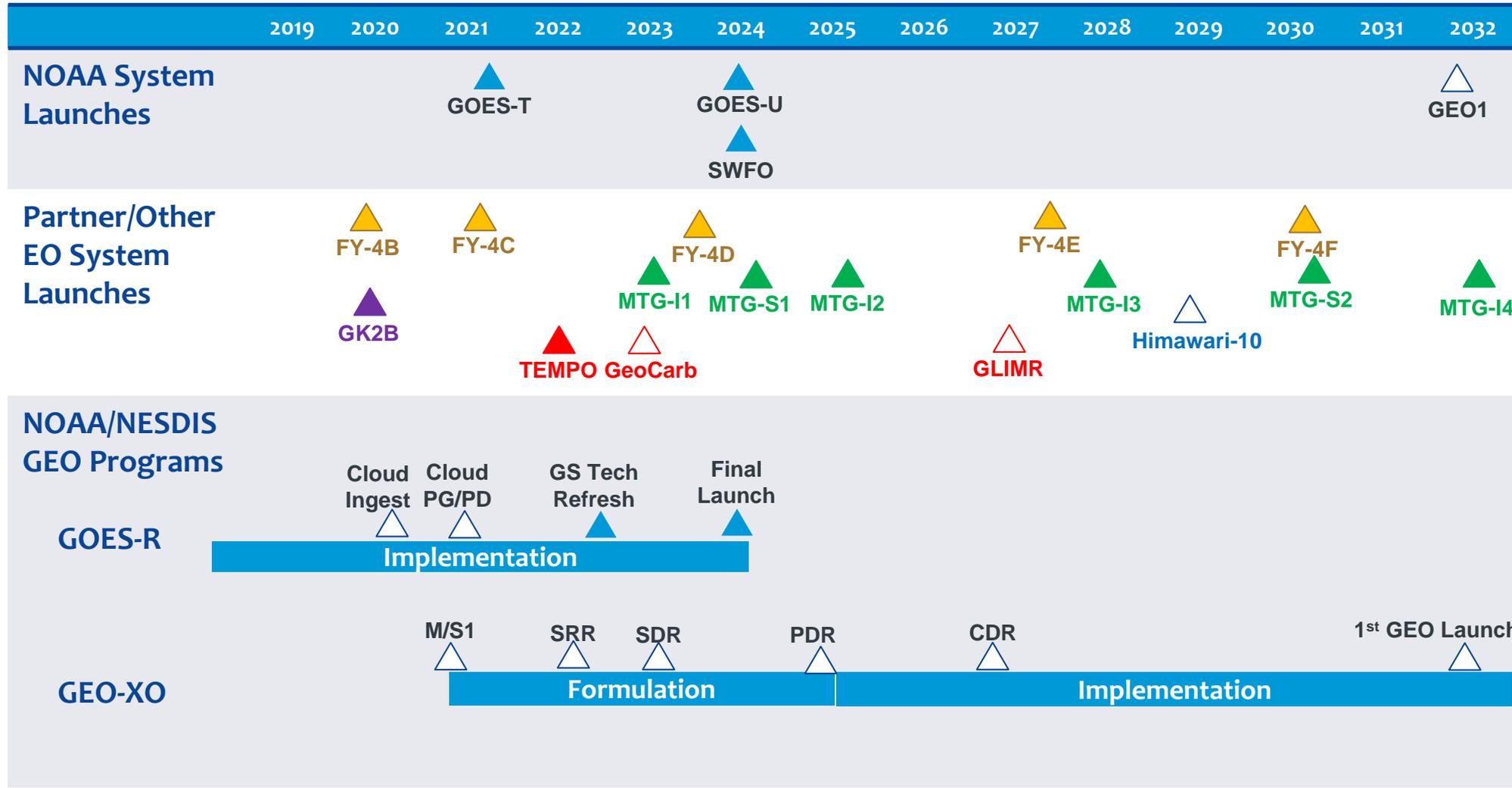
# GEO-XO Program Schedule

(Notional pending Approval/Funding)



GEO-XO Program Schedule (Notional pending Approval/Funding)																																																																
	FY20				FY21				FY22				FY23				FY24				FY25				FY26				FY27				FY28				FY29				FY30				FY31				FY32				FY33				FY34				FY35			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4								
<b>Launches</b>									▲ GOES-T												▲ GOES-U												▲ GEO1												▲ GEO2																			
<b>Milestones</b>	▲ MS0				▲ MS1				▲ MS2												▲ MS3												▲ MS4																															
<b>KDPs</b>									▲ KDP-A				▲ ASM												▲ KDP-B				▲ KDP-C												▲ KDP-D				▲ KDP-E																			
<b>Reviews</b>									▲ MCR				▲ SRR												▲ SDR				▲ PDR				▲ CDR				▲ MOR				▲ SIR				▲ FOR				▲ ORR				▲ GEO2 SIR											
<b>Imager</b>	PreF Study				Proc. Reqts				Procurement				▲ SRR				▲ PDR				▲ CDR				▲ PER				▲ FM1 Del.												▲ FM2 Del.																							
									Ph A Study				Phase B-D Development (6.5Yr)																																																			
<b>Other Instruments</b>	PreF Studies				Procur. Reqts				Procurem.				▲ PSM				▲ SRR												▲ FM1 Del.				▲ FM2 Del.																															
									Ph A Study				Phase B-D Development (6.5Yr)																																																			
<b>GEO Spacecraft</b>	Arch Studies				Reqts				Procurement				▲ PSM				▲ SRR				▲ PDR				▲ CDR				▲ Opt PER Rdy				▲ Opt Lnch Rdy																															
									Phase A-D Development												I&T/Launch				I&T/Launch																																							
<b>GEO Ground</b>									Data Delivery Prototyping/Pilots				Reqts				Procurement				▲ PSM				▲ SRR				▲ PDR				▲ CDR				Operation																											
									Ph A Study				Phase B-D Development (5Yr)																																																			

# The Next Decade of GEO Earth Observation Launches



▲ EUMETSAT  
▲ CMA  
▲ JMA  
▲ KMA  
▲ NASA  
▲ Published Date  
△ Notional Date

ALL DATES SUBJECT TO APPROVAL BY FUNDING AUTHORITIES; PARTNER DATES ARE FROM INTERNET SOURCES AND MAY NOT BE CURRENT





# Geostationary Ring of Meteorological Satellites



In Orbit

Planned

2020s

2030s



GOES-R  
Imager  
LM



GOES-R  
Imager  
LM



MSG  
Imgr



MSG  
Rapid



MSG  
Imgr



Elk-L  
Imgr



I-3DR  
Imgr  
Sndr



FY2  
Imgr



FY4  
Imgr  
Sndr  
LM



GK2A  
Imgr

GK2B  
AC  
OC



H8/9  
Imgr

MTG-I  
Imgr  
LM

MTG-I  
Rapid  
LM

MTG-S  
Sndr  
AC

I-3DS  
Imgr  
Sndr

FY4  
Imgr  
Sndr  
LM

H10/11

GEO-XO

GEO-XO



# GEO Summary

- GOES-R Series will continue to provide operational service into mid-2030s
  - Continuing to evolve data products based on user input
- Planning has started for the next generation satellite system, GEO-XO
  - Currently underway:
    - User needs assessments
    - Observational value assessments
    - Requirements development
    - Industry studies of instruments, architecture concepts, and commercial services
    - Program studies of instruments and constellation options
  - Preparing for formal program initiation following Milestone 1 decision gate in 3Q FY21
- Continuing partnership activities to inform program plans and toward vision of GEO Ring

***GOES-R and GEO-XO will maintain and advance NOAA's observational capabilities through 2050***

