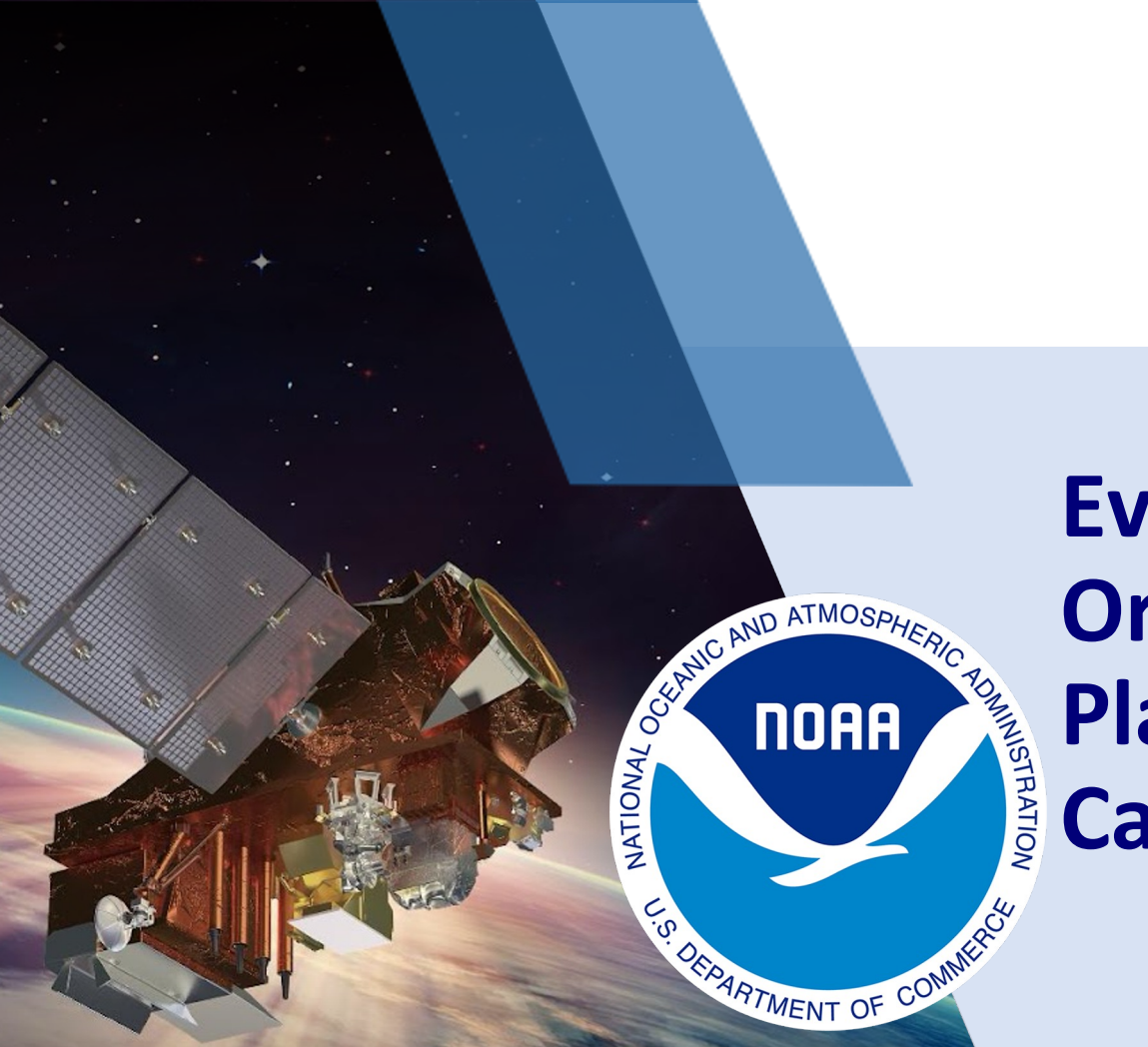


Evolution of NOAA Low Earth Orbiting Satellites Architecture and Plans for Direct Broadcast Capabilities

National Environmental Satellite, Data, and Information Service

CSPP Users Group Meeting
May 2026

Satya Kalluri, Ph.D.
Senior Scientist
Office of LEO
Satya.Kalluri@noaa.gov

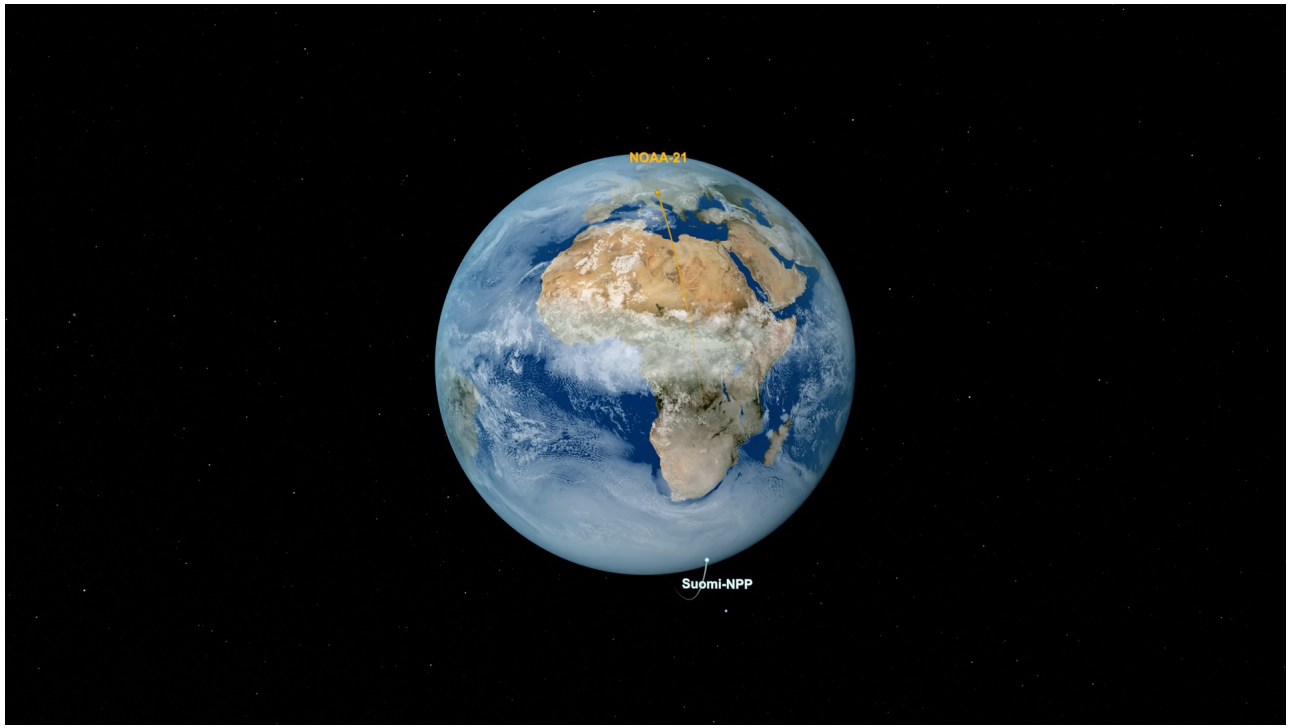
Ken Yienger
LEO Chief Architect
NASA GSFC Code 470/533
kenneth.e.yienger@nasa.gov

Outline

- Status of JPSS satellites
- Next generation Low Earth Orbit (LEO) mission planning and formulation
- Summary

JPSS

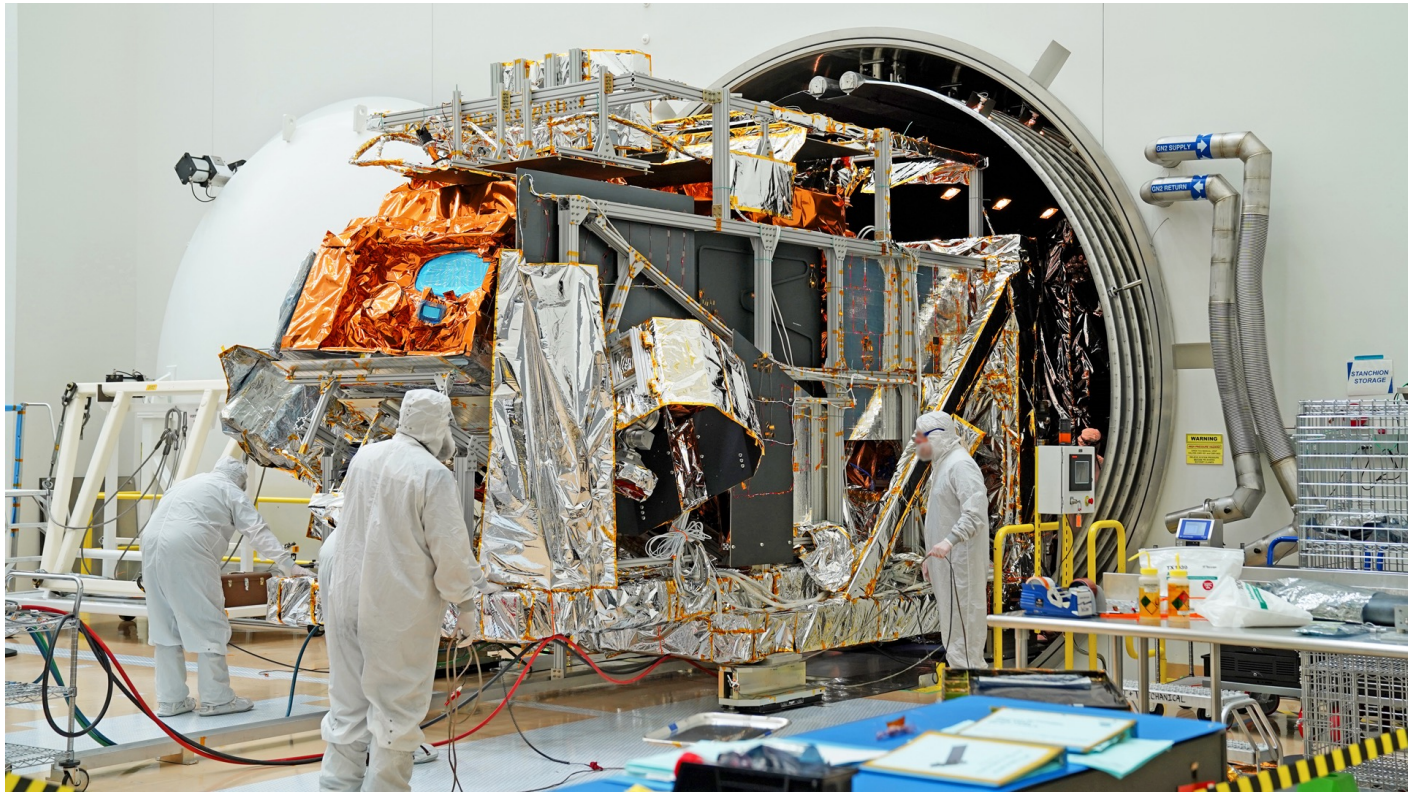
- The JPSS Program consists of:
  - Five satellites (three in orbit and two in production), each with at least four instruments
    - NOAA 21 launched on November 10, 2022 is commissioned and is the primary satellite at 1330 LTAN
    - NOAA20 launched on November 18, 2017 is the secondary satellite
    - SNPP launched in October 28, 2011 is a tertiary asset.
    - JPSS 4: Scheduled launch is Sep1, 2027.
    - JPSS 3 in storage (expected launch 2032).



JPSS 3 and 4 Finishing Up!

LEO OBSERVATIONS

JPSS3

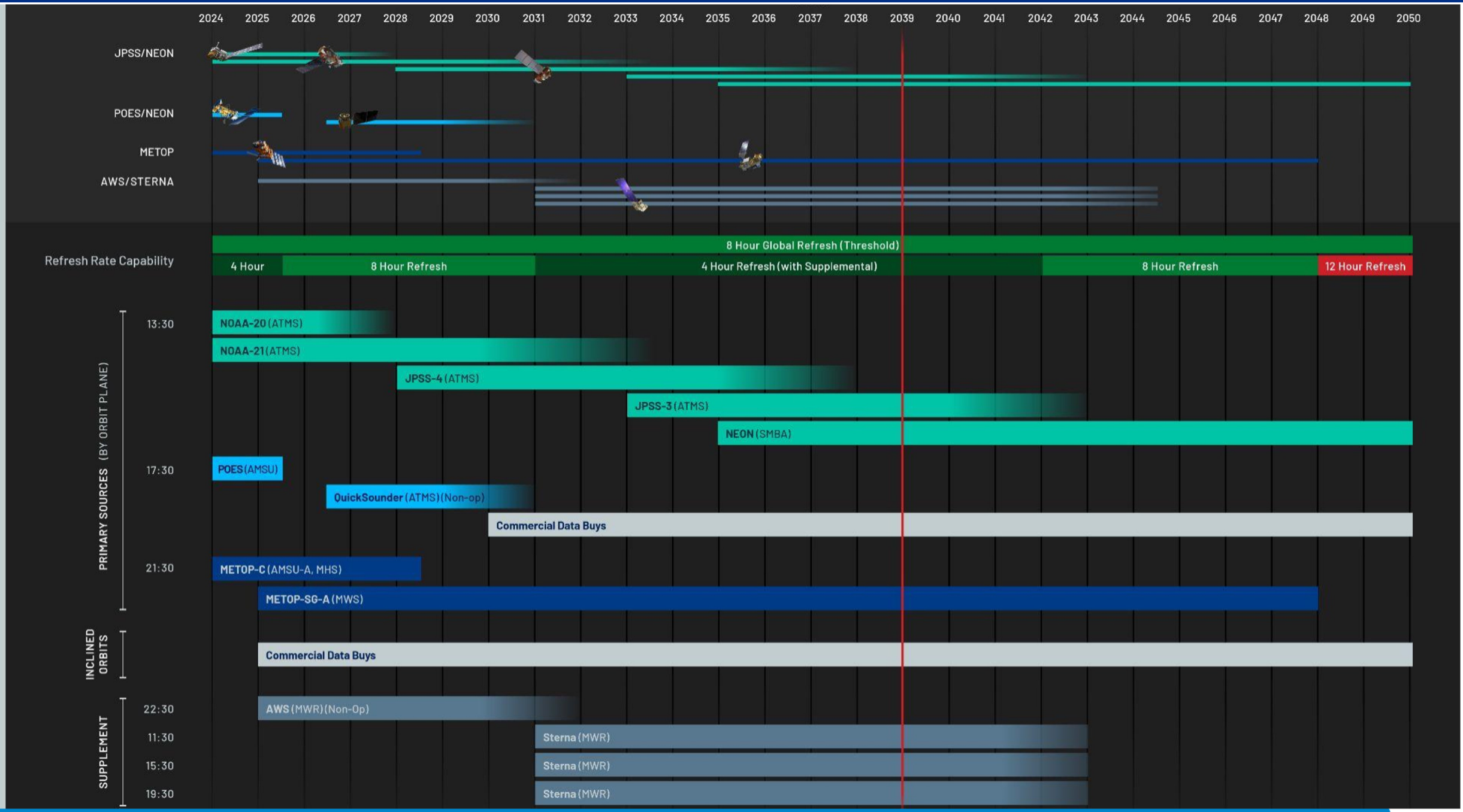


In storage

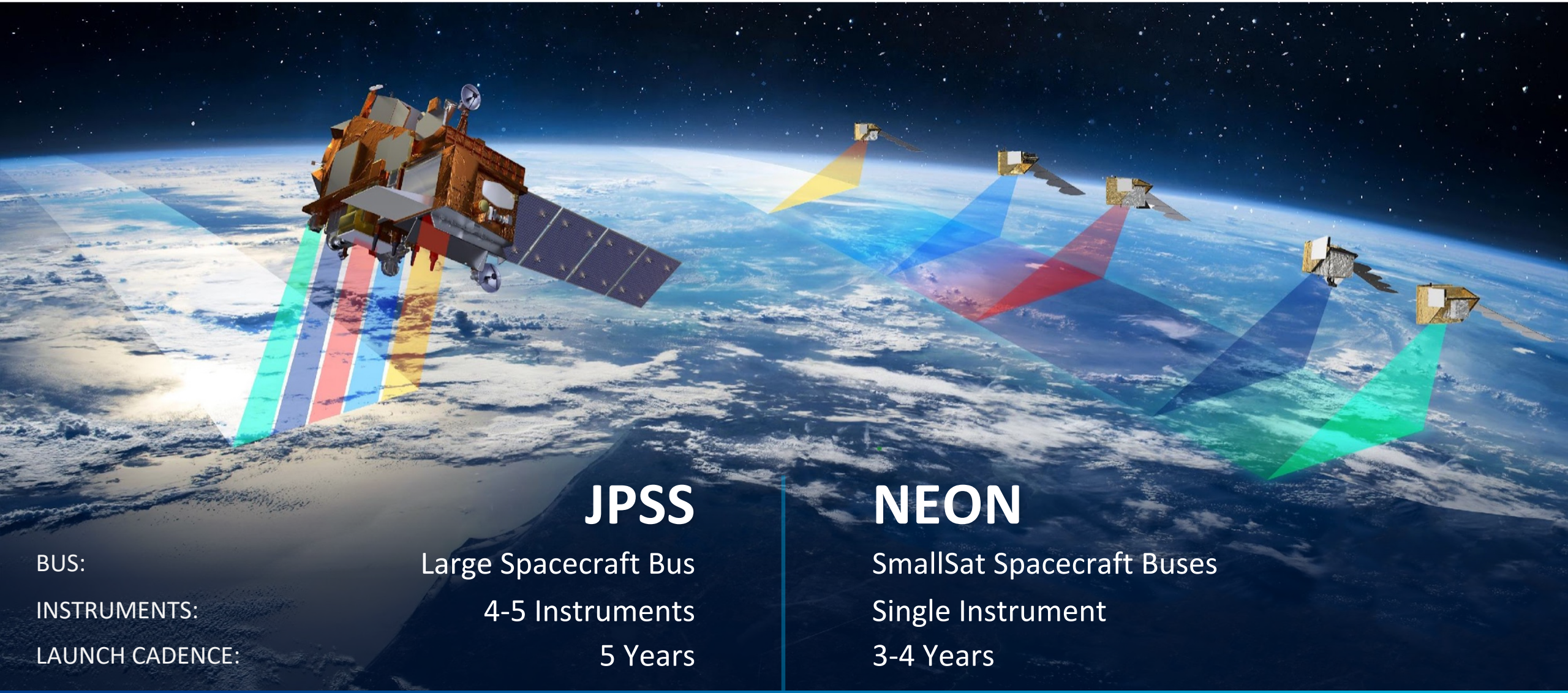
JPSS4

In test

ENVIRONMENTAL MEASUREMENTS | MICROWAVE RADIANCES



NEON is a Disaggregated Architecture



	JPSS	NEON
BUS:	Large Spacecraft Bus	SmallSat Spacecraft Buses
INSTRUMENTS:	4-5 Instruments	Single Instrument
LAUNCH CADENCE:	5 Years	3-4 Years

Architecture lends itself to flexibility, agility, resiliency

Low Earth Orbit Observations

MULTIPURPOSE IMAGERY

- Hurricane Location and Track
- Fires
- Air Quality
- Droughts and Floods
- Cloud Cover
- Land and Sea Ice
- Snow Cover
- Land Cover Changes
- Harmful Algal Blooms
- Wind Speed in High Latitudes
- Night Time Imagery
- Water Quality
- Fish Stock Assessments
- Oil Spills

UV MEASUREMENTS

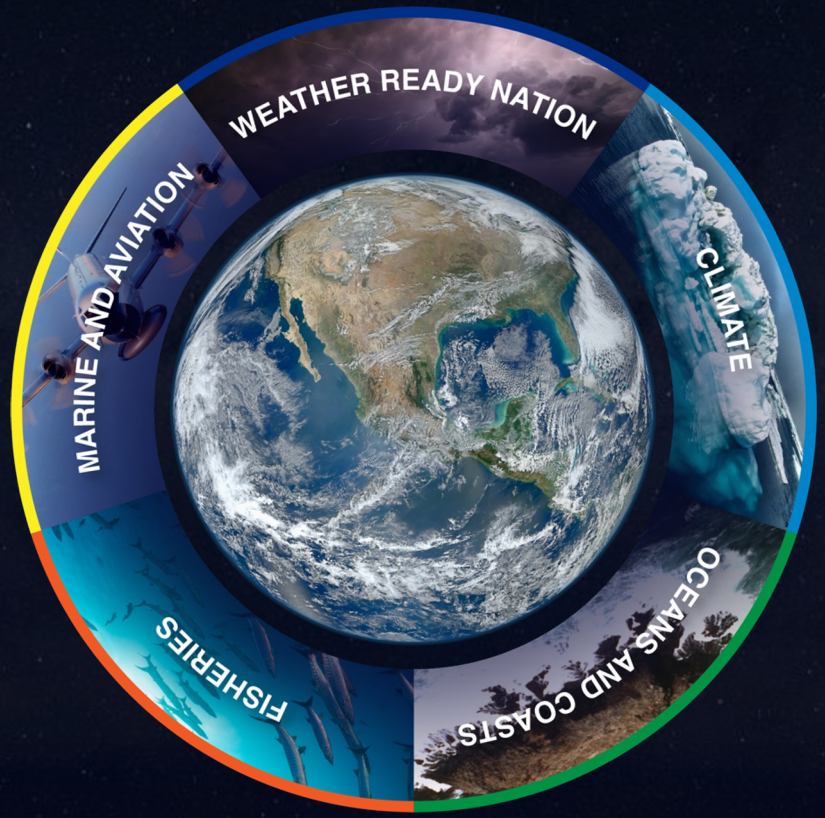
- Ozone Hole Monitoring
- Air Quality

SOUNDINGS

- Numerical Weather Prediction
- Precipitaion
- Routine Weather
- Tropical Cyclone Intensity and Track Forecasts
- Aviation Weather
- Atmospheric Rivers

ALTIMETRY

- Sea Surface Height
- Marine Weather
- Coastal Flooding



SAR

- Floods
- Oil Slicks
- Ocean Surface Winds
- Sea Ice

SCATTEROMETRY

- Ocean Surface Winds
- Marine Weather
- Tropical Cyclone Intensity

MICROWAVE IMAGERY

- Precipitation
- Land and Sea Ice
- Ocean Surface Winds
- Tropical Cyclone Location, Track and Intensity
- Marine Weather
- Soil Moisture
- Ocean Salinity

LIDAR

- Wind Speed
- Aerosols for Air Quality
- Cloud Properties for Precipitation and Climate

BUY AND PARTNER

where we can.

BUILD

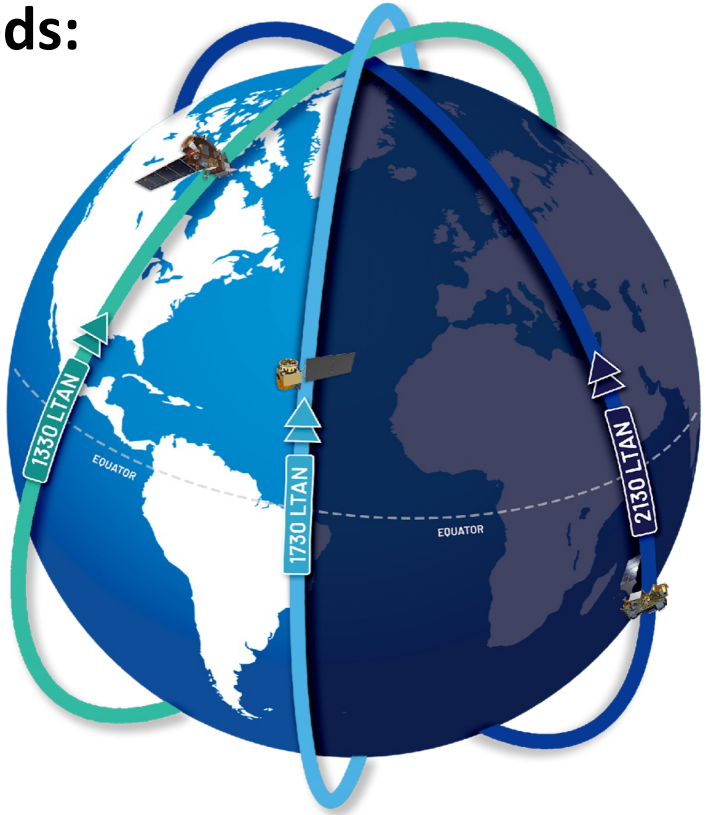
what we must.

The Office of LEO Observations uses Commercial and Government-owned assets together to provide the best value weather forecasts to the American taxpayer.

LEO Architecture Plans

Maintain a *hybrid* 3-Plane SSO Constellation—Meets User Needs:

- Local Times: 21:30 LTAN, 13:30 LTAN, 17:30 LTAN
- Global Coverage: 4-hr refresh (>90%)
- High-Latitude (Alaska): 2-hr refresh



Primary Observations (4-hr refresh):

- NOAA 13:30 LTAN: JPSS-ATMS, NEON-SMBA (2036)
- EUMETSAT 21:30 LTAN: Metop-C AMSU/MHS, Metop-SG MWS
- 17:30 LTAN: TBD Follow-on- ***Commercial?***

Additional and Demo Data (Improved refresh):

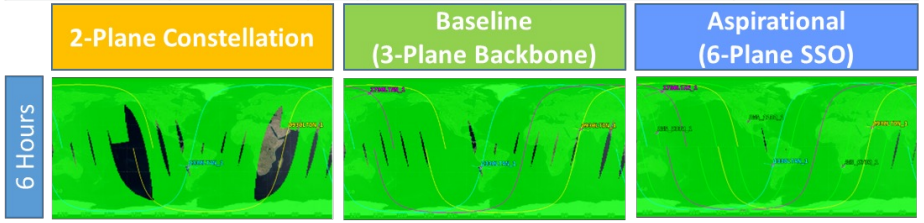
- 17:30 LTAN: QuickSounder (ATMS)
- EUMETSAT AWS (MWR): 2230 (current)
- EUMETSAT Sterna (MWR): 2-hr LTAN separation improves revisit (3 planes) 1130, 1530, 1930 (Future-2030)
- ***Inclined Orbits: Commercial orbits can improve refresh and coverage when coordinated***

Two-Plane vs. Three Planes
Impact on Global Coverage and Refresh Rates

If we do not pursue morning orbit, what is result on constellation coverage and refresh rates ?

- Current two-plane (METOP/METOP-SG in 0930 LTDN, JPSS/NEON in 1330 LTAN)
  - Achieves 80% Global Coverage in 6 hours (90% in 8 hours)
  - Achieves 4-Hour Refresh to Polar Regions (Alaska POR)
- Adding Third Plane (NEON in 1730 LTAN)
  - Achieves 90% Global Coverage in 4 hours
  - Achieves 2-Hour Refresh to Polar Regions (Alaska POR)
- Adding Sterna Partnership (0330/0730/1130 LTDN)
  - Achieves 80% Global Coverage in 2 hours
  - Achieves 1-Hour Refresh to Polar Regions (Alaska POR)

Capability Level	Global Refresh Rates	LEO Reference Architecture Options			
		#	Local Time (LT) of Orbit Planes		
2-Plane	6 Hours	2	1 x 1330 LTAN	1 x 0930 LTDN	
Baseline	4 Hours	3	1 x 1330 LTAN	1 x 0930 LTDN	1 x 1730 LTAN
Aspirational	2 Hours	6	1 x 1330 LTAN	1 x 0930 LTDN	1 x 1730 LTAN
			1 x 0330 LTDN	1 x 0730 LTDN	1 x 1130 LTDN



Time (hr)	2-Plane Constellation	3-Plane Backbone	Aspirational (6-Plane)
0.5	10.91%	16.84%	30.35%
1	20.64%	31.53%	53.75%
2	39.87%	55.94%	**81.60%**
3	52.69%	74.78%	94.43%
4	64.73%	**90.06%**	98.75%
6	**81.92%**	97.02%	99.63%
8	94.03%	98.59%	99.84%
12	99.22%	99.64%	100%
24	100%		

Microwave Radiance Measurements

Table 7 and Tables 12/13 summarize Microwave Radiance Requirements [LEO-OO-146-153, 174, 178, 182-188]

Table 7: MW Sensor Data Observational Parameters (Reference Only)

Performance Level	Threshold	Objective
Nadir Resolution	32 km for Temperature 16 km for Moisture	8 km for Temperature 5 km for Moisture
Latency	60 min	15 min
Refresh	6 hr	1 hr
Coverage	Global in 24 hr	Global in 6 hr

Table 12: AVTP Observational Parameters (Reference Only)

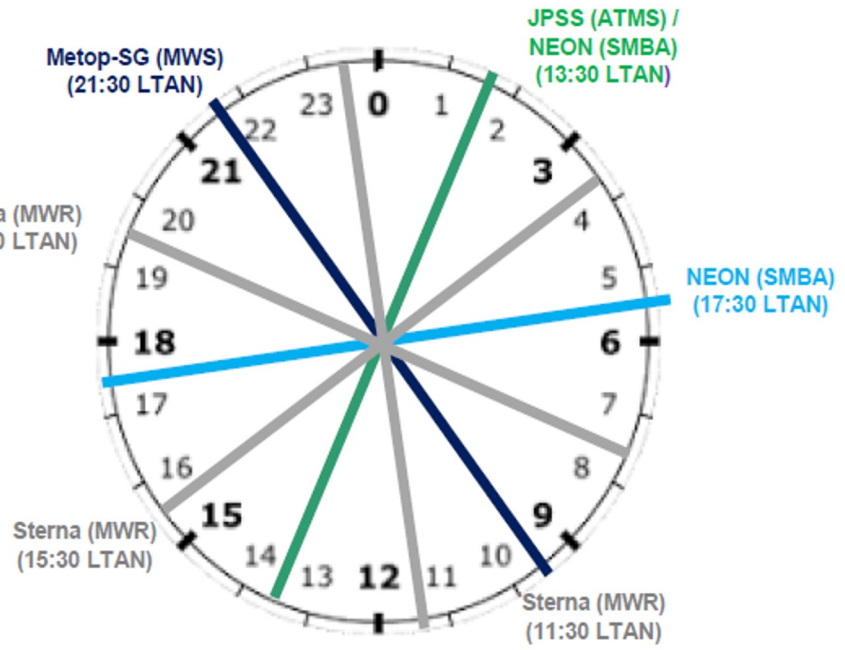
System Capability	Threshold	Objective
Horizontal Cell Size (IR Contribution)	15 km	1 km
Horizontal Cell Size (MW Contribution)	50 km	5 km
Vertical Reporting Interval (IR Contribution)	2 km	1 km
Vertical Reporting Interval (MW contribution)	4 km	2 km
Mapping Accuracy	5 km	0.5 km
Measurement Uncertainty	TABLE 3-11 (MW, IR)	N/A
Latency	60 min	15 min
Refresh	6 hr	2 hr
Coverage	Global within 24 hr	Global Within 6 hr

Table 13: AVTP Observational Parameters – Precision Tables (Reference Only)

Parameter	Threshold (MW Contribution)	Threshold (IR Contribution)	Objective
Surface to 850 mb over ocean	2.5 K per 1 km Layer	1.6 K per 1 km Layer	0.75 K per 1 km Layer
850 to 300 mb over ocean	1.5 K per 1 km Layer	1.6 K per 1 km Layer	0.75 K per 1 km Layer
300 mb to 30 mb	1.5 K per 3 km Layer	1.5 K per 3 km Layer	0.75 K per 3 km Layer
30 mb to 1 mb	1.5 K per 5 km Layer	1.5 K per 5 km Layer	0.75 K per 5 km Layer
1 mb to 0.5 mb	3.5 K per 5 km Layer	3.5 K per 5 km Layer	0.75 K per 5 km Layer

**Temperature Measurement Precision Expressed as an error in layer average temperature.*

Proposed MW Constellation (Targets 2 hr Global Refresh)



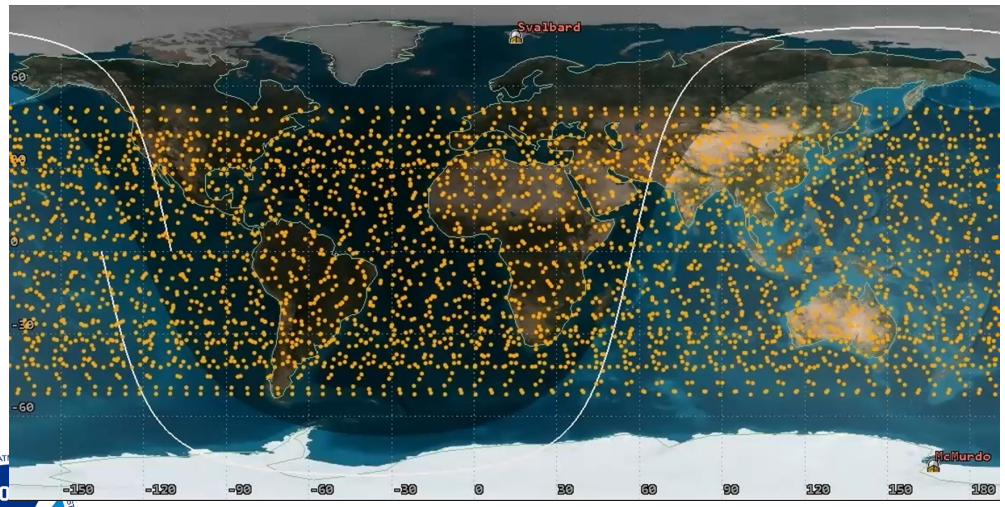
Next Generation Satellite Communications

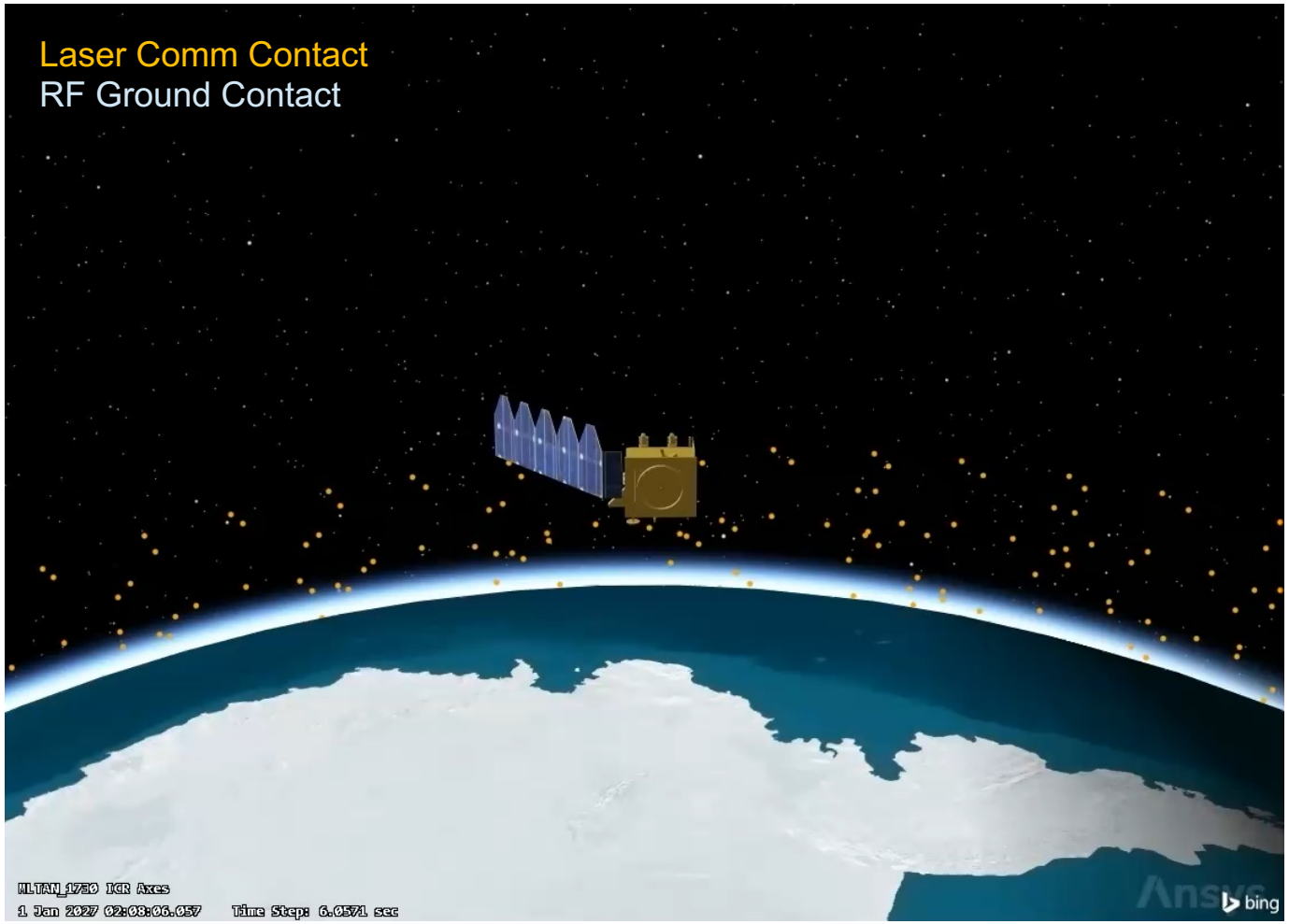
LEO OBSERVATIONS

Concept of Operations: 3 Layers of Science Data relay

1. Laser Communications via Commercial Internet Relay Service Providers
   - Starlink or Amazon LEO Illustrated
2. Traditional RF Contacts Over Poles (X-band)
   - Svalbard (KSAT) and McMurdo(NOAA)
3. Direct broadcast: X-band

- Lowers Latency to < 15 Minutes





MWS Innovations and Objectives

Targeted improvements for a future MWS sensor include:

- Hyperspectral Microwave Sounder capabilities- greater precision
- RFI Detection
- Inter-Calibration Approach
- V (50 GHz) and F (118 GHz) Bands for Temperature in the same instrument
- Commercial should plan for a 3-5 year lifespan for data continuity

Constellation approach:

- Provide higher temporal resolution globally
- Combine NOAA-owned, NOAA-partnerships, and commercial data to improve refresh rates and coverage

SMBA Instrument

Band (freq)	JPSS ATMS (22 ch)	Metop-SG A MWS (24 ch)	NEON SMBA (30+ ch)		Uses
			Hyperspectral Capability	RFI Detection Capability	
K (23.8 GHz)	Analog	Analog	Required	Required	Column Integrated Observations & Quality Control
Ka (31.4 GHz)	Analog	Analog	Required	Required	Window
V (50-60 GHz)	Analog	Analog	Required	Required	Temperature (T) – primary
W (88.2 GHz)	Analog	Analog	Not Required	Required	Window
F (114.5-118.58 GHz)	Not Included	Not Included	Required	Not Required	Temperature (T) – secondary
D (165 GHz)	Analog	Analog	Not Required	Not Required	Window
G (183.31 GHz)	Analog	Analog	Required	Not Required	Humidity (q)
J (229 GHz)	Not Included	Analog	Not Required	Not Required	Window & Ice Cloud Detection

SMBA frequency channels addressed in Pre-Phase A Vendor Studies

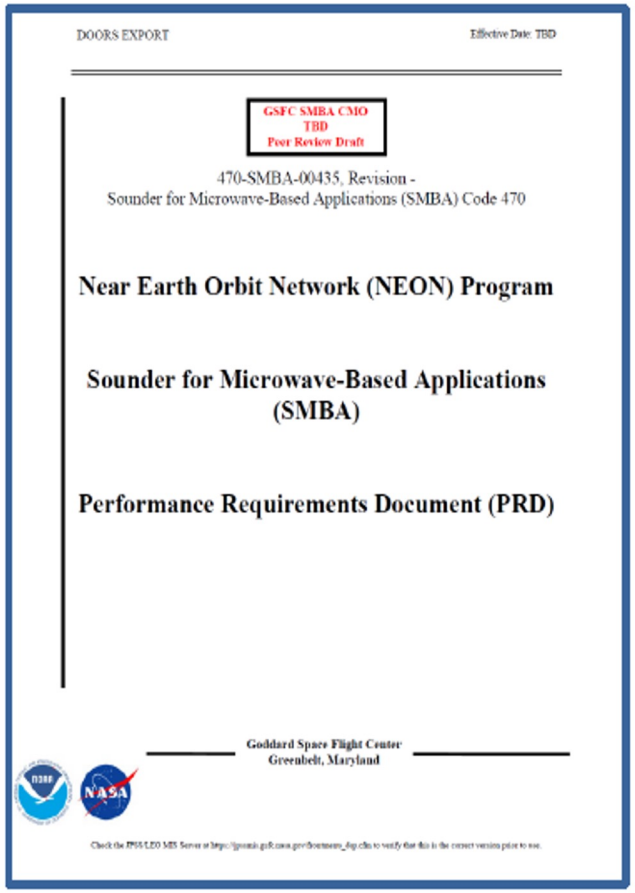
* Not part of ATMS EDRs but measurable with multiple platforms

MW Instruments	Environmental Data Products														Others
	AVTP	AVMP	CLW	Imagery	LSE	MP	RR	LST	SIC	TPW	SWE	TP	SC	3D Winds*	
JPSS – ATMS (K, Ka, V, W, G)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	Ice Water Path, Cloud Detection
METOP-SG A – MWS (K, Ka, V, W, G, 229)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	Ice Water Path, Could Detection, Ice Cloud
NEON – SMBA (K, Ka, V, W, F, G, 229)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	Ice Water Path, Cloud Detection Ice Cloud, RFI detection (if digital)
AWS/Sterna – MWR (V, W, G, 325)	X	X				X						X		X	Ice Water Path, Cloud Detection

AVTP/AVMP: Atmospheric Vertical Temperature/Moisture Profile
CLW: Cloud Liquid Water
LSE: Land Surface Emissivity
MP: Moisture Profile
RR: Rainfall Rate
LST: Land Surface Temperature
SIC: Sea Ice Concentration
TPW: Total Precipitable Water
SWE: Snow Water Equivalent
TP: Temperature Profile
SC: Snow Cover

SMBA Performance Requirements Document (SMBA PRD)

SMBA Science Performance Requirements and Prioritization Trace Directly to NEON Observational Objectives (NESDIS-REQ-4400) [Section 4.4]



DOORS EXPORT

Effective Date: TBD

GSFC SMBA CMO
TBD
Peer Review Draft

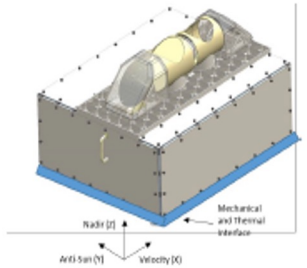
470-SMBA-00435, Revision -
Sounder for Microwave-Based Applications (SMBA) Code 470

Near Earth Orbit Network (NEON) Program

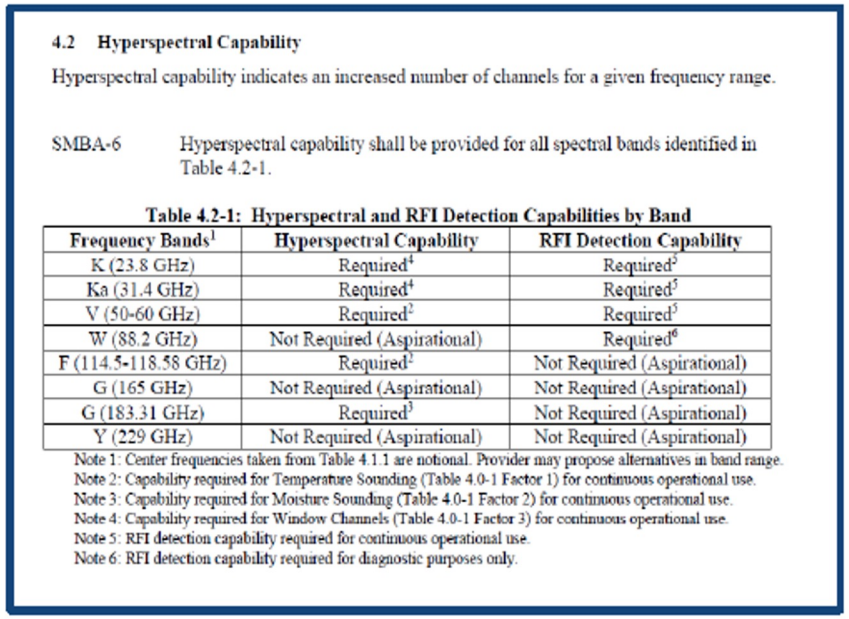
Sounder for Microwave-Based Applications (SMBA)

Performance Requirements Document (PRD)

Goddard Space Flight Center
Greenbelt, Maryland



High-Performance Microwave Sounder Concept



4.2 Hyperspectral Capability

Hyperspectral capability indicates an increased number of channels for a given frequency range.

SMBA-6 Hyperspectral capability shall be provided for all spectral bands identified in Table 4.2-1.

Table 4.2-1: Hyperspectral and RFI Detection Capabilities by Band

Frequency Bands[1]	Hyperspectral Capability	RFI Detection Capability
K (23.8 GHz)	Required[4]	Required[2]
Ka (31.4 GHz)	Required[4]	Required[5]
V (50-60 GHz)	Required[2]	Required[5]
W (88.2 GHz)	Not Required (Aspirational)	Required[6]
F (114.5-118.58 GHz)	Required[2]	Not Required (Aspirational)
G (165 GHz)	Not Required (Aspirational)	Not Required (Aspirational)
G (183.31 GHz)	Required[3]	Not Required (Aspirational)
Y (229 GHz)	Not Required (Aspirational)	Not Required (Aspirational)

Note 1: Center frequencies taken from Table 4.1.1 are notional. Provider may propose alternatives in band range.
Note 2: Capability required for Temperature Sounding (Table 4.0-1 Factor 1) for continuous operational use.
Note 3: Capability required for Moisture Sounding (Table 4.0-1 Factor 2) for continuous operational use.
Note 4: Capability required for Window Channels (Table 4.0-1 Factor 3) for continuous operational use.
Note 5: RFI detection capability required for continuous operational use.
Note 6: RFI detection capability required for diagnostic purposes only.

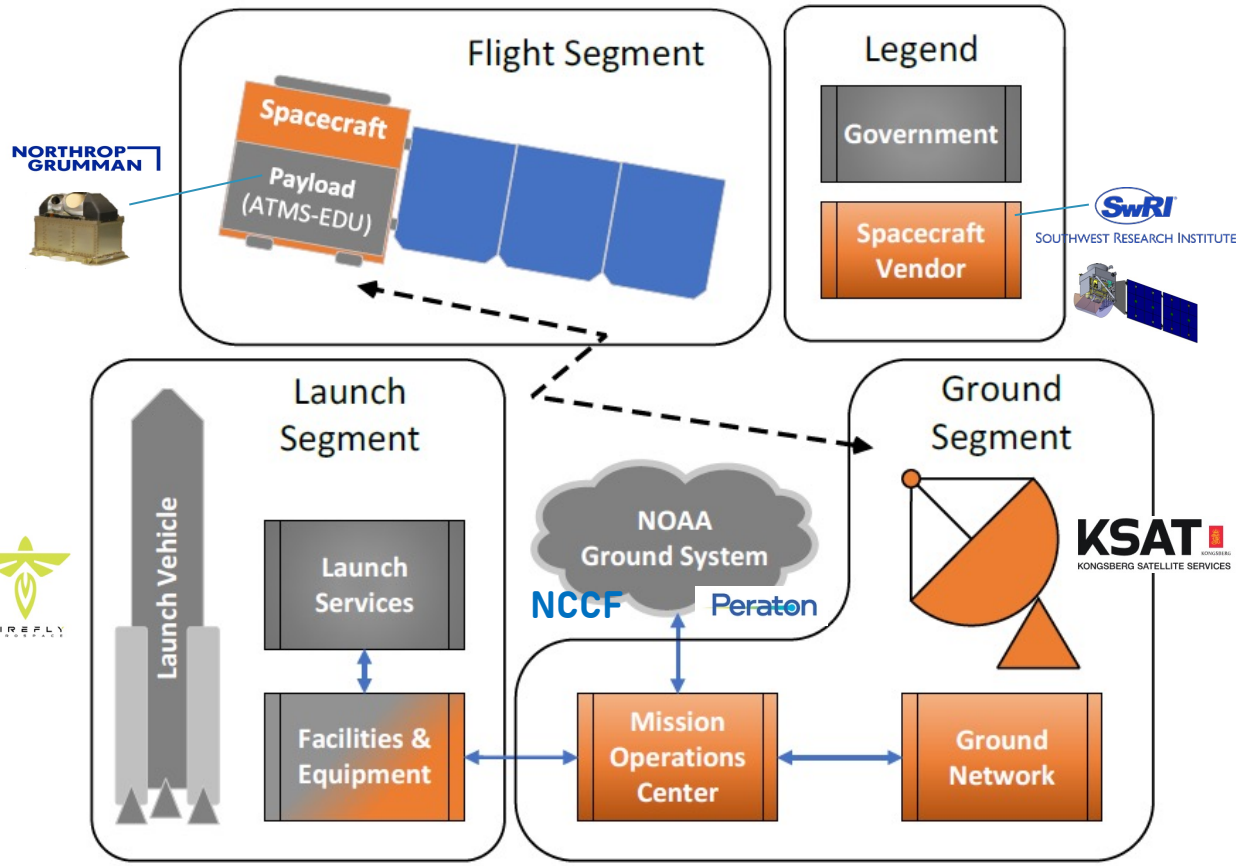
SMBA Hyperspectral Capability

- Theoretical studies have shown benefits to Numerical Weather Prediction, Planetary Boundary Layer & other applications
  - Limited real-world demonstrations to date, although several attempts in progress
- Real-world demonstrations in progress

Ongoing Trade Topics :

- Digital backend technology is available to do the signal processing
  - Determining which bands, number of channels, and band width
- Processing
  - FPGAs require significant power and generate significant heat, re-programmable on orbit
  - ASICS use less power/less heat, but are not re-programmable
- Intermediate data volume is large

QuickSounder Mission Architecture



Spacecraft & Mission Operations Vendor

- Southwest Research Institute (SwRI) awarded QuickSounder Spacecraft and Mission Operations (QS-SMOS) contract
- Responsible for:
  - Commercial Satellite
  - Mission Data Transport (Ground Network) using KSATlite Commercial Services
  - Mission Operations (Center @Boulder, CO)

Government

Payload (ATMS-EDU)

- Refurbished ATMS EDU (NG Azuza)
- Cross-track microwave sounder that provides temperature and moisture observations (22 Channels, 23.8 GHz – 183.3 GHz)

NOAA Ground System

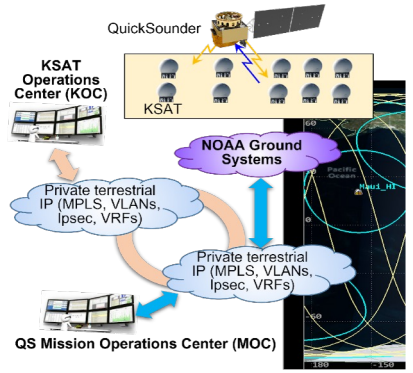
- Mission Data Processing and Dissemination based on legacy NOAA systems that are part of the NESDIS enterprise (IDPS & NCCF)

Launch Vehicle

- Firefly Alpha @Vandenburg SFB, Dedicated
- Backup: SpaceX (USSF-178) Rideshare

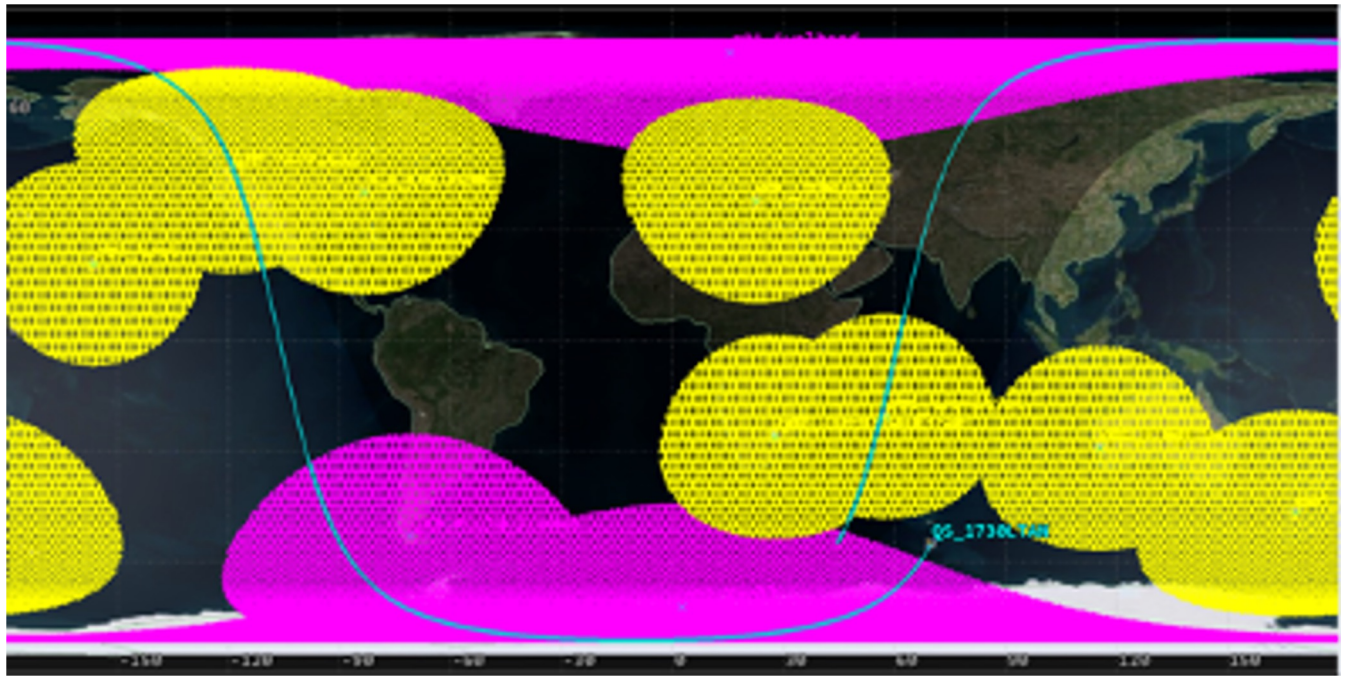
QuickSounder KSAT Scope

- Utilize 11 Ground Stations for Downlink
- Utilize 3 Ground Stations (Polar/Near Polar) for Uplinks
- Average of ~40 contacts per day (Avg 3 Downlinks/Orbit)



SwRI is working to add 5 KSAT Lite Ground Stations to reduce the number of violation per day not meeting the 50-minute latency (see Backup)

#	Location	Lat (N)	Long (E)	T/R
q01	Svalbard, Norway	78.2315	15.4111	Uplink & Downlink
q02	Troll, Antarctica	-72.0027	2.5253	Uplink & Downlink
q03	Punta Arenas, Chile	-52.9364	-70.8701	Uplink & Downlink
q04	Mingenew, Australia	-29.0100	115.3417	Downlink
q05	Awarua, New Zealand	-46.5288	168.3799	Downlink
q06	Mauritius	-20.5014	57.4506	Downlink
q07	Athens, Greece	37.8451	22.6233	Downlink
q08	Hartebeesthoek, South Africa	-25.8860	27.7056	Downlink
q09	Hawaii, US	20.8173	-156.4548	Downlink
q10	Portland, Oregon	45.8500	-119.6300	Downlink
q11	Columbus, Ohio	40.1000	-83.1900	Downlink



EPS-Sterna

Satellites and instruments

The initial EPS-Sterna constellation is composed of six satellites in sun-synchronous polar orbits. In only five hours or less, the microwave sounders on these satellites will make observations covering 90% of the globe.

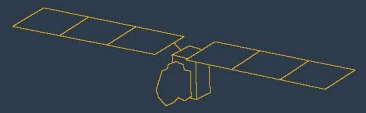
Satellite designs

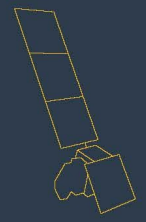
Payload

- Passive Microwave Radiometer (19 channels)

Number of satellites

- 6 satellites in constellation on 3 planes
- 20 satellites in total (18 plus 2 spares)



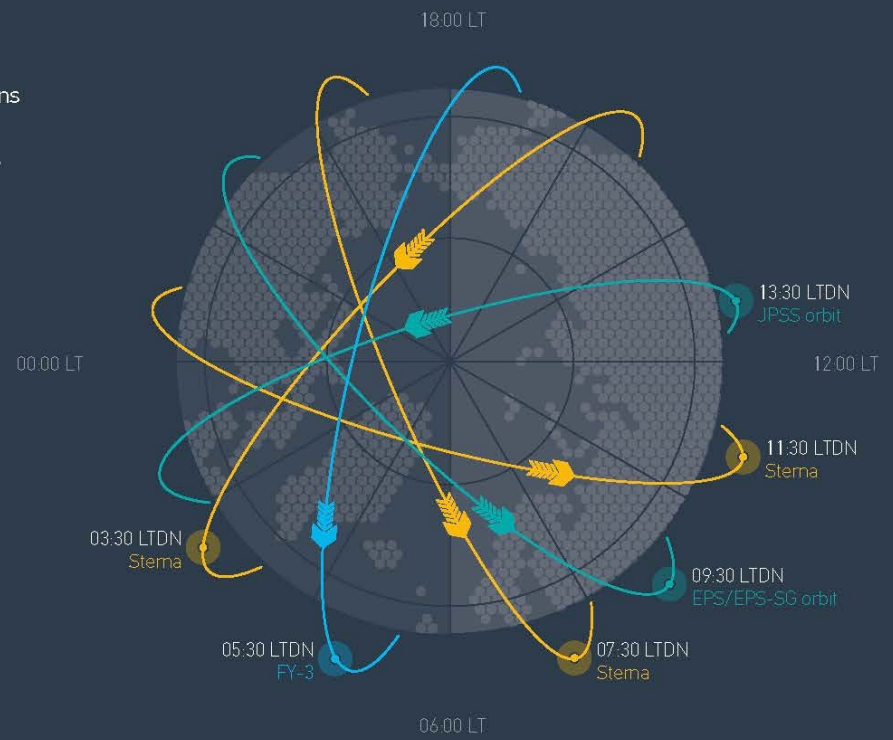


EPS-Sterna utilises one satellite design which, thanks to at least two different configurations, can fly in different orbits with various orbital illumination conditions.

Altitude	Mass in orbit	Payload mass	Design lifetime	Mission duration	Expected launch date of first satellite
595 km	135kg	30kg	5 years	13 years	2029

Orbital planes

Sterna will complement the observations from satellites in the EUMETSAT Polar System – Second Generation (EPS-SG), the National Oceanic and Atmospheric Administration's Joint Polar Satellite System (JPSS), and the Chinese FengYun-3 (FY-3) system.

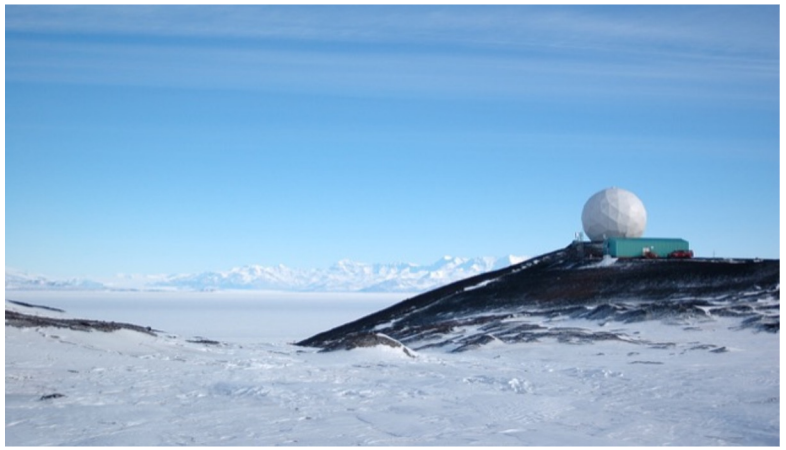


From: Towards EPS-Sterna (EUMETSAT)

PENGUIN

Polar EUMETSAT/NEON Ground station upgrade Integrated Network

- Common Joint pipeline compatible, delivering data from multiple partners
  - 5 data acquisition stations reduce product latency
  - Placed strategically at McMurdo to maximize polar downlinks and complement other Arctic downlink sites
  - Provides resilience and geographic diversity



Summary

- NESDIS is on a path to a hybrid Microwave Sounder system through:
  - ***Commercial Data***
  - ***International Partnership data***
  - ***Government Systems***
- All components are necessary to meet NOAA requirements, but could be in *coordinated and diverse orbits*.
- Commercial MWS data could be used to improve our global refresh rate to complement government provided backbone orbits.
- Future NOAA LEO NEON satellites are envisioned to have several layers of science data transmission capabilities including direct broadcast for near real time data, as well as optical and RF for stored mission data for low latency data access.