



The Atmosphere Observing System (AOS) Constellation

July 11, 2022

**Presentation to NOAA Office of System Architecture
and Advanced Planning**

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Jason Hair, Project Manager

Emily Berndt, Applications Lead

Jonathan Chrono, Mission Systems Engineer



Agenda

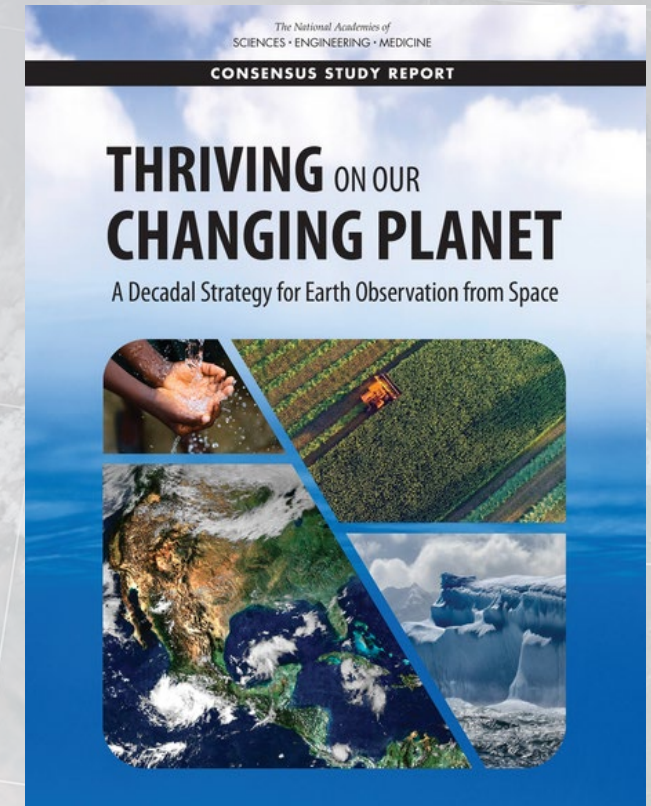
- AOS science and measurements (12 min) – Scott Braun
- Applications Considerations (5 min) – Emily Berndt
- Data latency, ground system (5 min) – Jonathan Chrone
- Plan Forward for AOS (8 min) – Jason Hair
- Questions

Decadal Survey Recommendations

Targeted Observable	Science/Applications Summary	Candidate Measurement Approach
Aerosols	<i>Aerosol properties, aerosol vertical profiles, and cloud properties to understand their effects on climate and air quality</i>	Backscatter lidar and multichannel/multiangle/polarization imaging radiometer flown together on the same platform
Clouds, Convection, and Precipitation	<i>Coupled cloud-precipitation state and dynamics for monitoring global hydrological cycle and understanding contributing processes including cloud feedback</i>	Dual-frequency radar, with multifrequency passive microwave and sub-mm radiometer

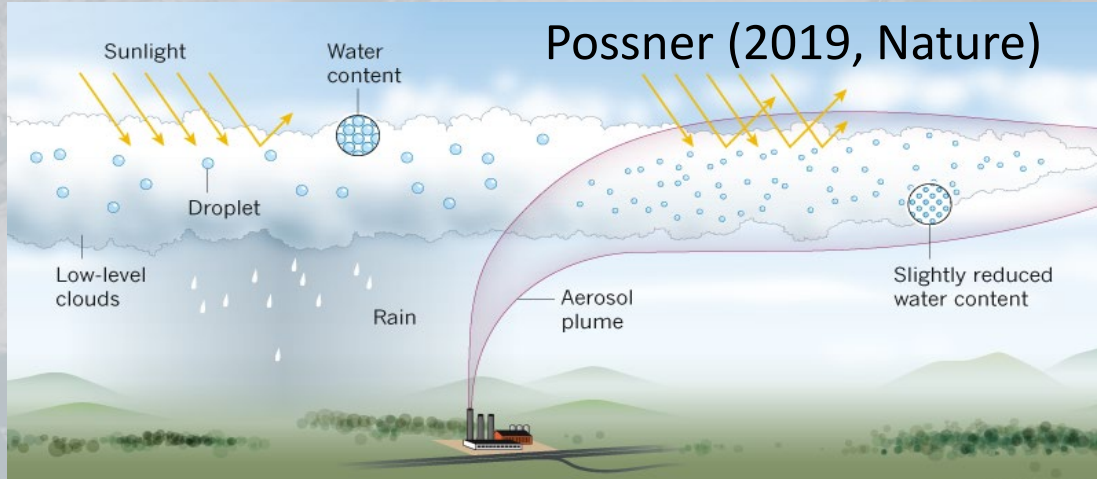
Of the 24 most important (MI) DS objectives identified by the community, AOS directly relates to 12 of them and explicitly addresses 8 of these MI's.

The 8 overarching objectives of AOS flow directly from 3 of these MI's

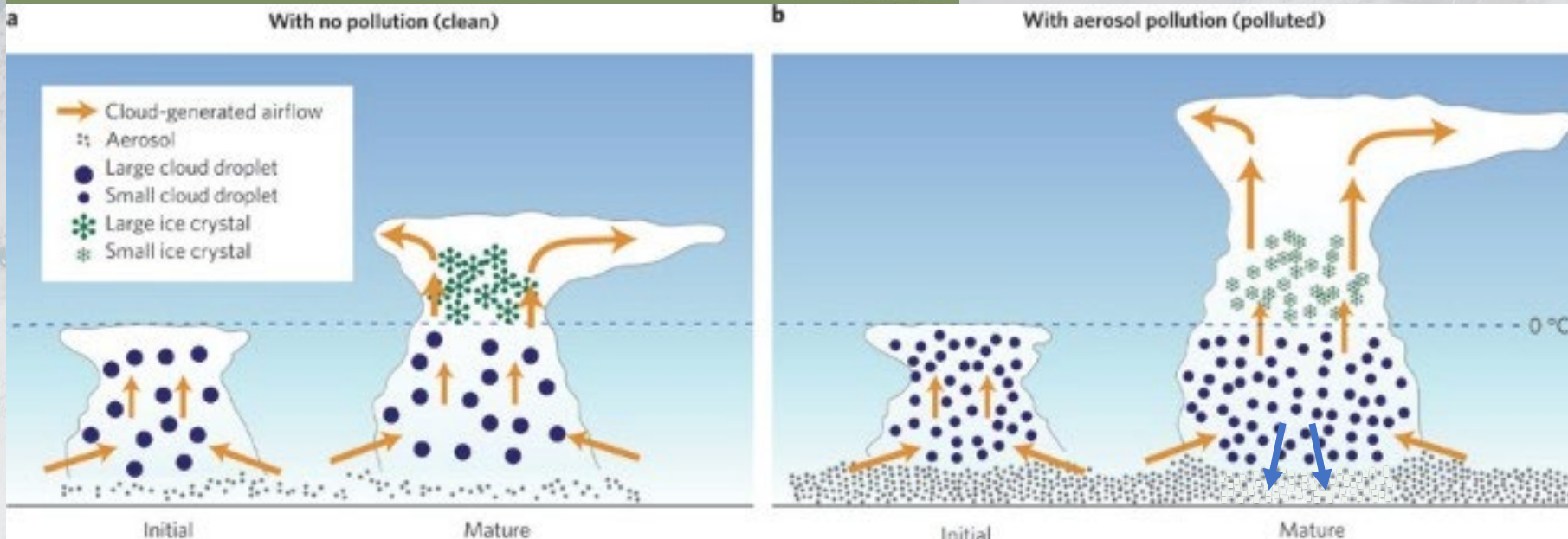


National Academies of Sciences, Engineering, and Medicine 2018

Aerosol-Cloud Interactions: Why A in Combination With CCP?



- Aerosols are critical to the formation of clouds
- Interactions are key driver of uncertainty in radiative forcing of climate
- Aerosol concentrations, properties impact cloud properties and interaction with radiation
- While still uncertain, aerosols may modify convection



Lee (2011, Nature Geo.)



ACCP Science Objectives

ACCP Goal	ACCP-P Science Objectives		Key Science Focuses
G1	O1	Low Clouds	Sensitivity of low clouds to environmental factors (thermodynamics/dynamics); solar radiative climate feedbacks
G1	O2	High Clouds	Relationship of high cloud formation/properties to deep convection, large-scale environment; infrared radiative climate feedbacks
G2	O3	Convective Storms	Relationship between storm vertical motions and microphysics
G3	O4	Cold Clouds and Precipitation	Processes that govern phase partitioning and precipitation formation in cold clouds; key drivers of climate feedbacks at high latitudes
G4	O5	Air Quality and Aerosol Attribution	Identifying major sources of aerosols and their type/species; factors that relate aerosol microphysical/optical properties to near-surface air quality
G4	O6	Aerosol Redistribution and Processing	Wet removal and processing of aerosol by clouds and precipitation; impacts of vertical and long-range transport of aerosol
G5	O7	Aerosol Direct Effects	Role of aerosols in the Earth's energy budget; impact of absorbing aerosols on climate
G5	O8	Aerosol Indirect Effects	Aerosol impacts on clouds and precipitation systems; modulation of climate forcing due to changes in cloud radiative properties

DS Questions

**C-2 (I-MI):
Climate
Feedback
and
Sensitivity**

**W-4 (MI):
Convective
Storm
Formation
Processes**

**W-5 (MI):
Air
Pollution
Processes
and
Distribution**

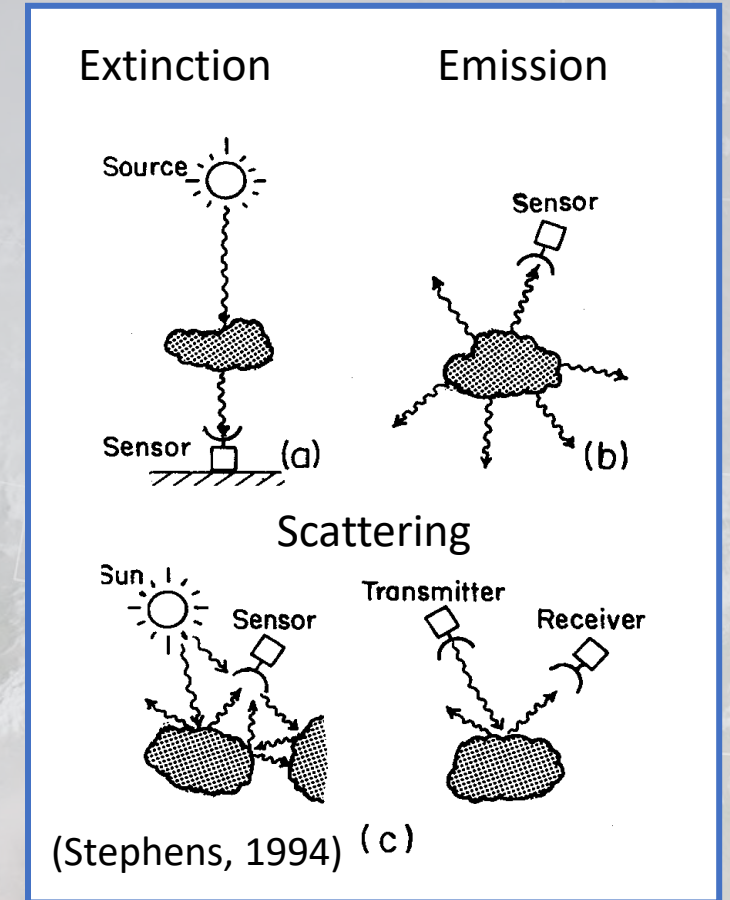
Synergy is central to the AOS observing strategy

Scientific whole > sum of scientific parts

Synergy offers:

- (i) A much more integrated view of Earth than possible with single measurement
- (ii) Tighter constraints on & better consistency of information retrieved
- (iii) The ability to fill gaps in GVs
- (iv) The possibility of extracting entirely new & refined information about 'process' from combinations of different observations

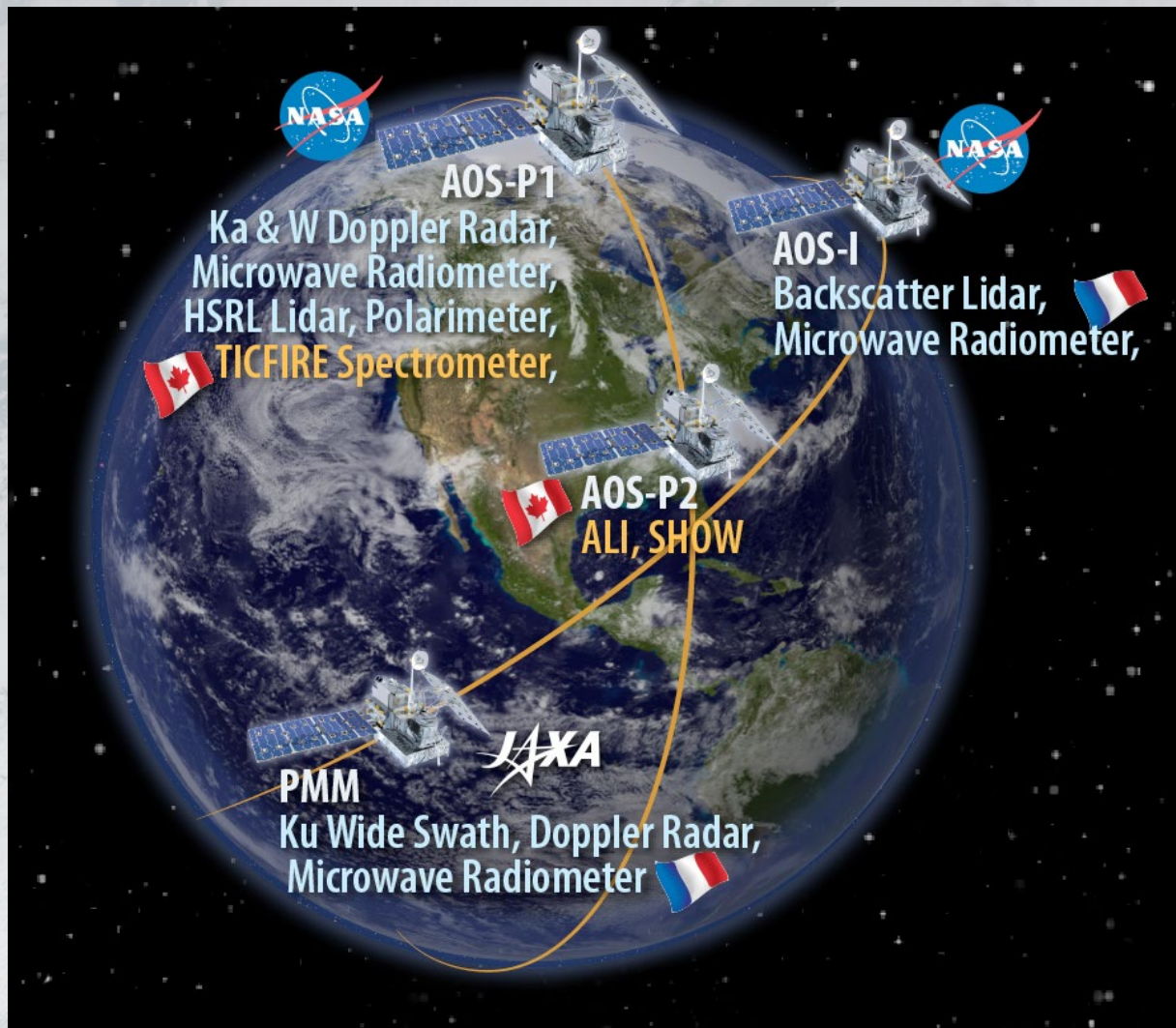
The compelling value of measurement 'synergy' has been amply demonstrated with the A-Train constellation



Different physics offer different perspectives on processes



The AOS Architecture



Inclined (55°) orbit focused on weather (sub-daily) time scales with emphasis on convection, high clouds, and aerosol/PBL evolution

Polar, sun-sync orbit focused on improved measurements for climate processes and sensor synergies

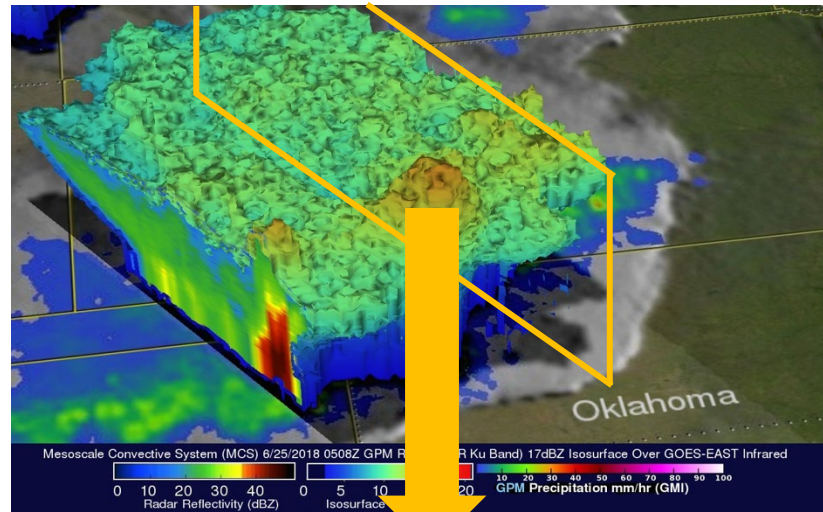
AOS will also include a sustain suborbital element



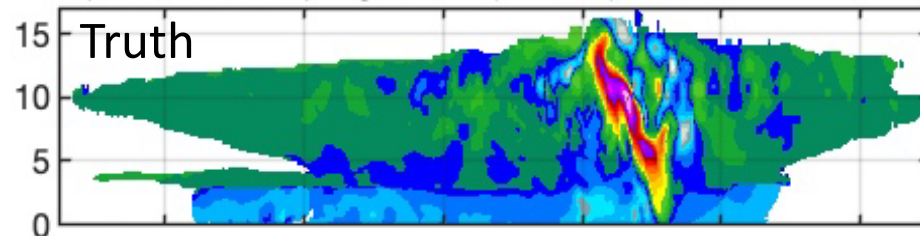
A Visual View of AOS-Inclined

Launch NET July 2028

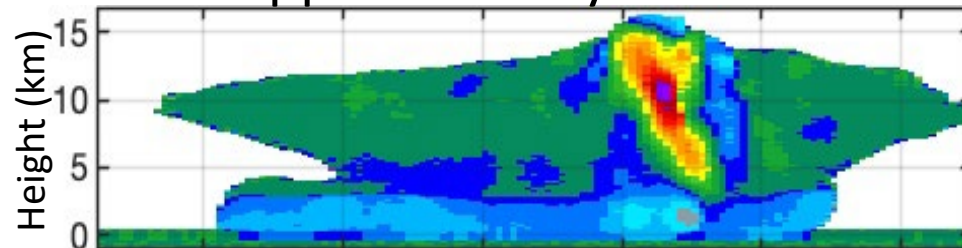
JAXA Wide Swath Ku Doppler Radar



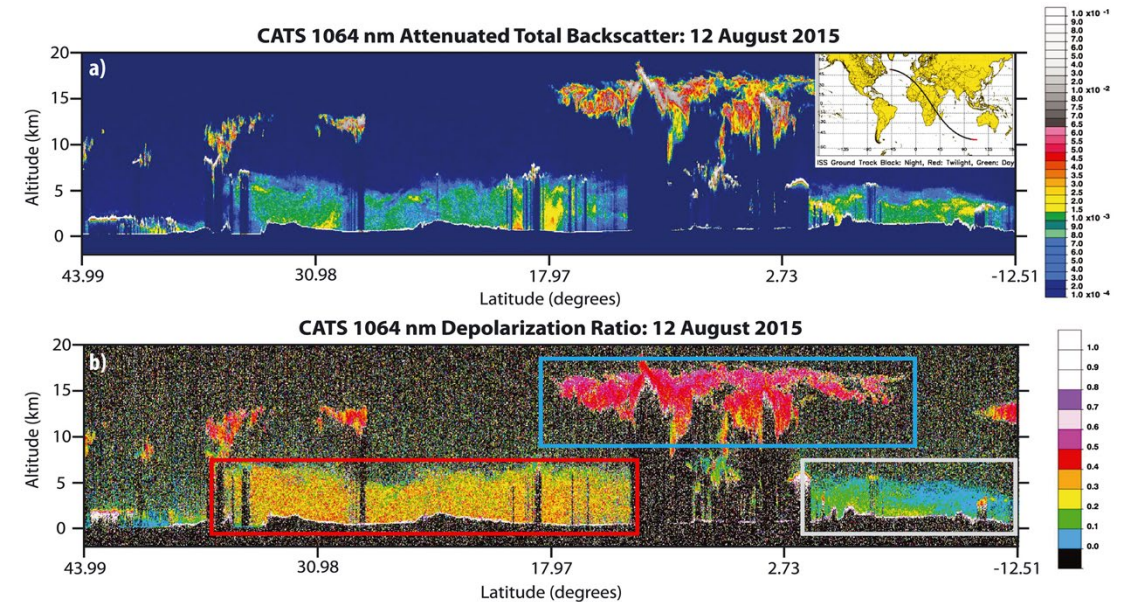
b) No radar sampling effects (13-GHz)



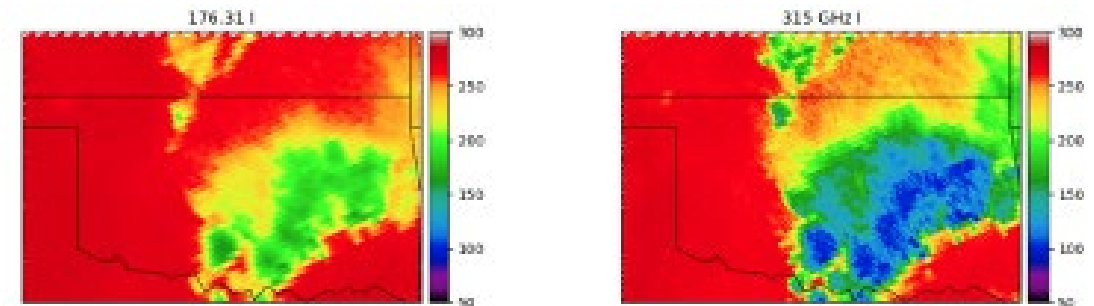
Ku Doppler Velocity



ALICAT 532-, 1064-nm Backscatter Lidar



CNES Microwave Radiometers (89, 183, 325 GHz)

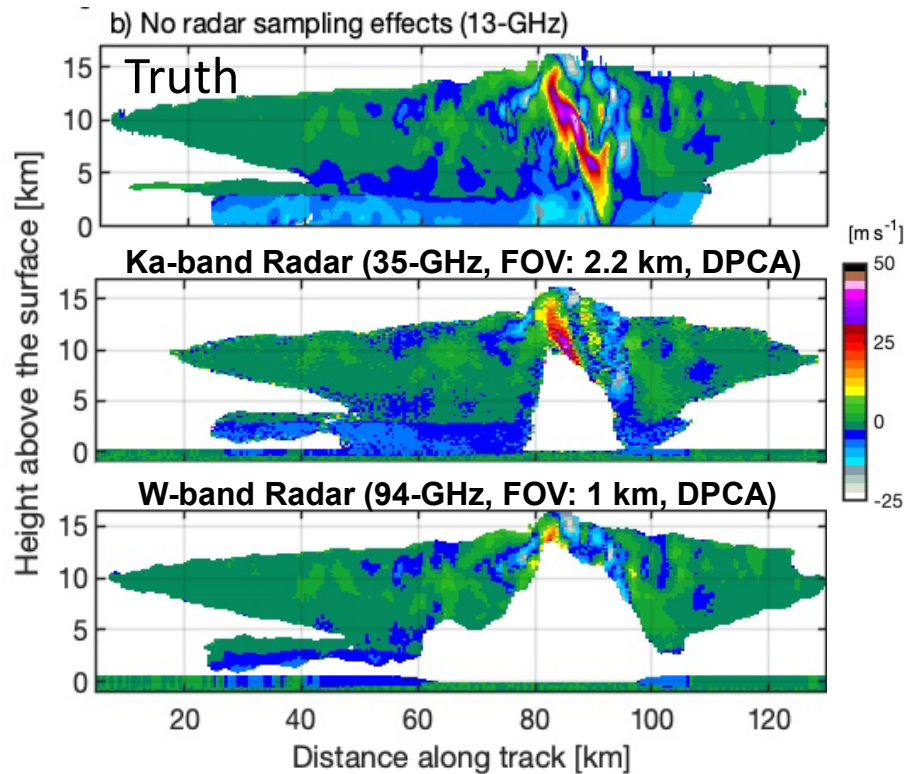


55° Inclination: Compromise between NASA, JAXA, CNES

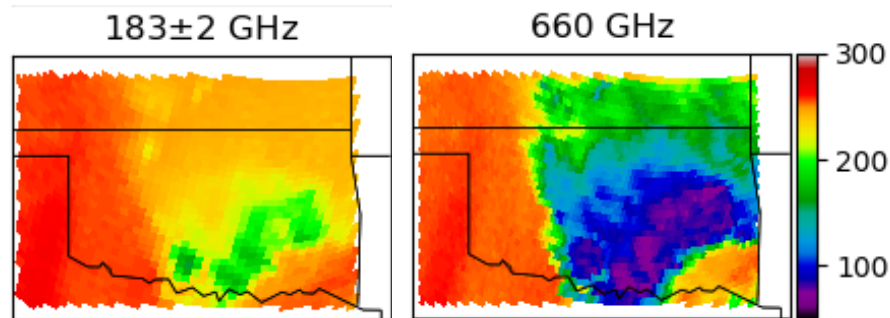
A Visual View of AOS-Polar

Launch NET December 2030

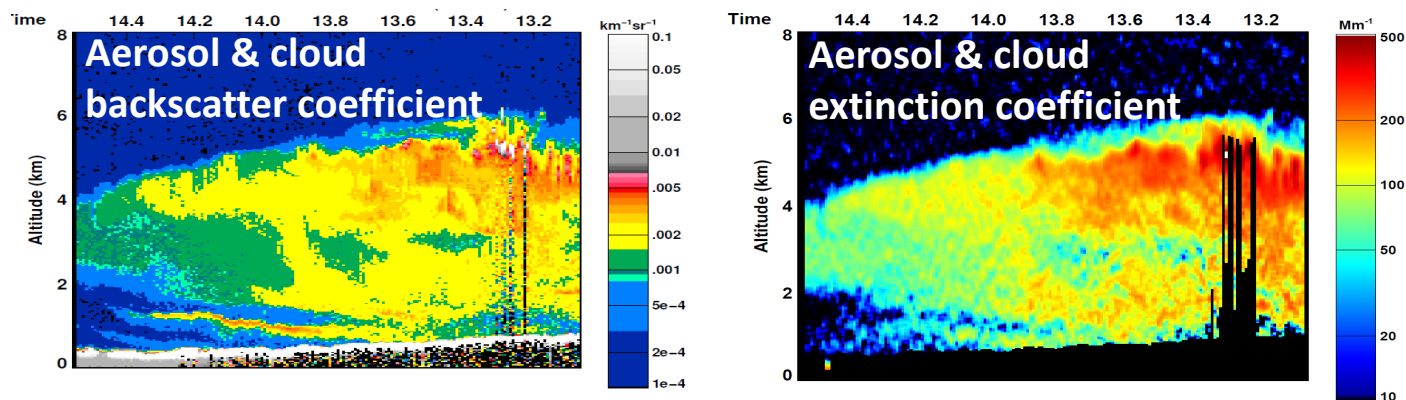
W-, Ka-band Doppler Radars



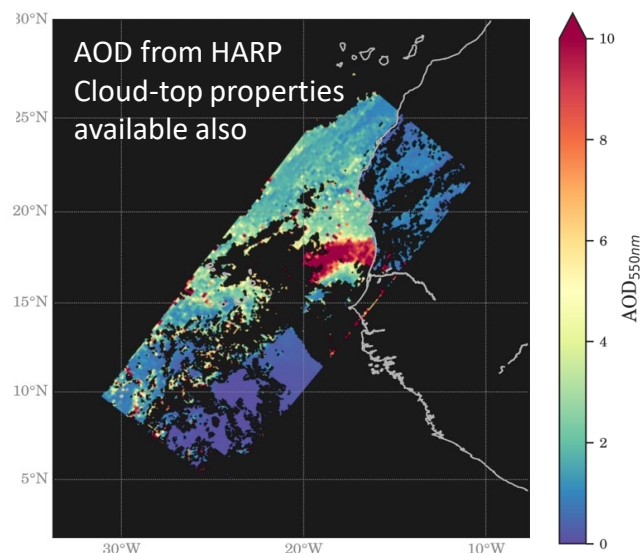
Microwave Radiometer: 89-700 GHz



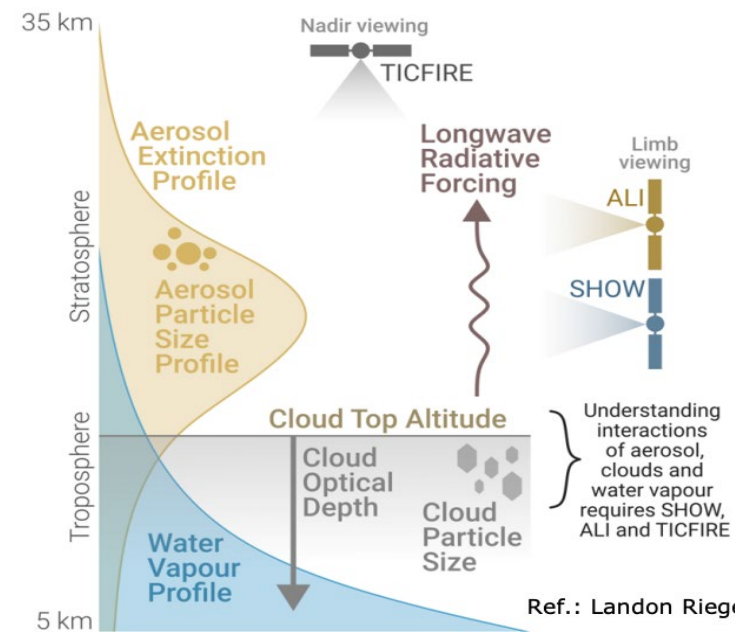
532 nm HSRL, 1064 Backscatter Lidar



UV-VIS-NIR-SWIR Multi-angle Polarimeter



CSA LWIR-FIR Spectrometer (4-73 μm) Aerosol/Moisture Limb Sounding



Airborne Campaign Concepts

Low Clouds: *Microphysics, precipitation initiation*

Convection/High Clouds: *Microphysics and dynamics, anvil cirrus lifecycle.*

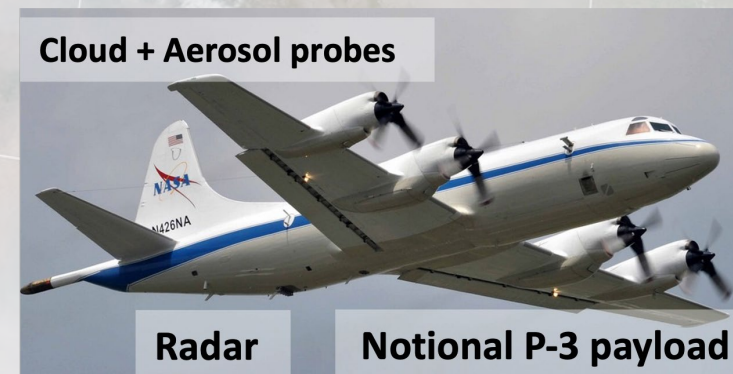
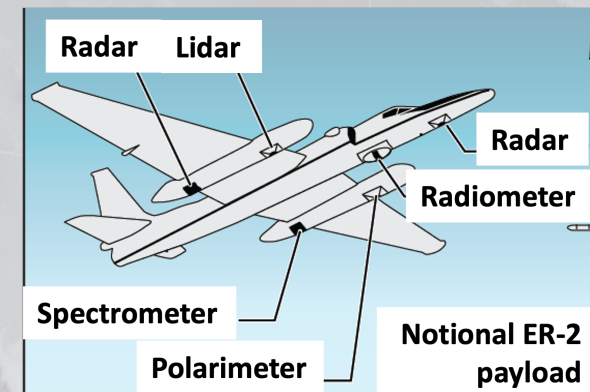
Aerosol-Cloud-Radiation Interactions:
Vertically resolved aerosol-cloud-radiation interaction processes and lifecycle.

Large airborne campaigns

- Mid-latitude continental, spring-early summer 2029
- Oceanic, early summer 2031, 2032

Campaigns after launch to enable cal-val

Payloads depicted are notional... instruments to be prioritized / deconflicted for each campaign



Potential for Future Changes

- NASA HQ organized Independent Review Board (IRB)
 - Will review all Designated Observable (DO) missions of the ESO
 - Examining scope of each mission within the context of the ESO budget
 - May recommend changes to DO missions
- IRB recommendations expected in September, KDP-A review late September or mid October

Agenda

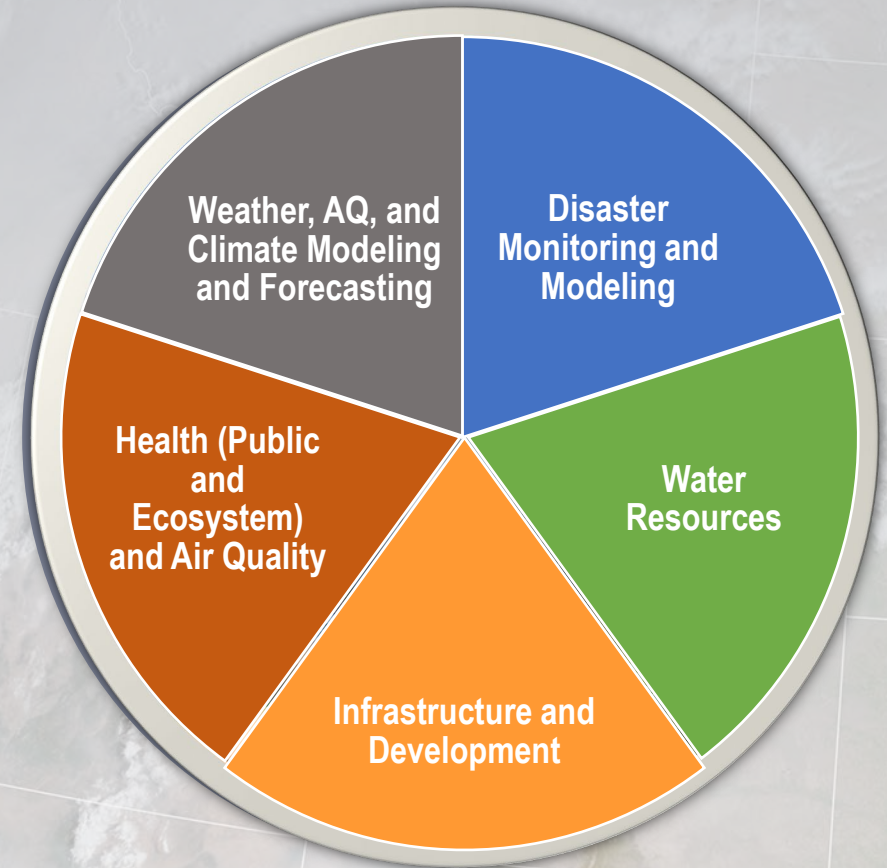
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AOS Applications

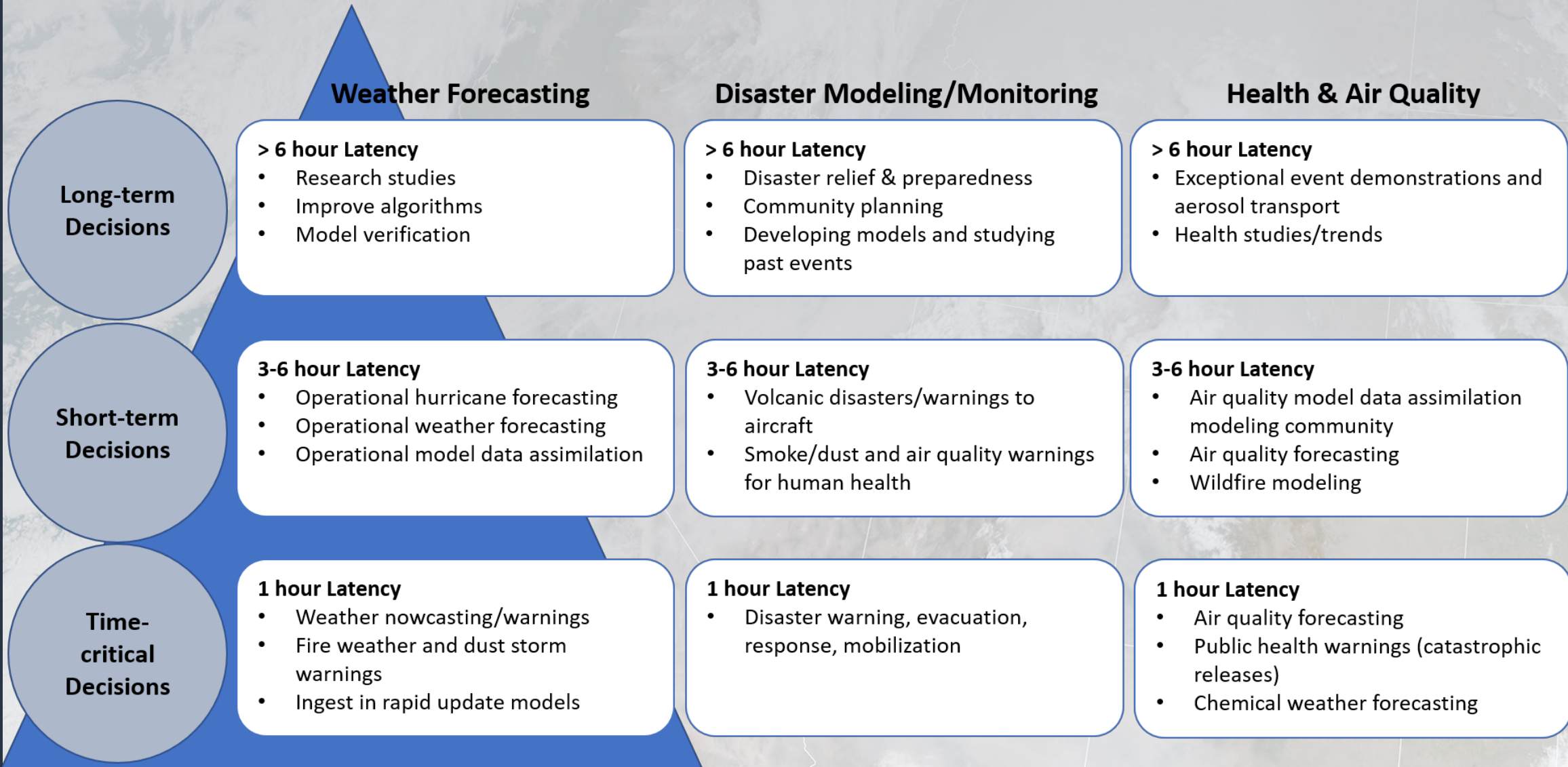
AOS will provide key information to support decision making at timescales from hours to decades, enabling improved weather and air quality forecasting today, seasonal to sub-seasonal changes in the near future, and societal challenges resulting from climate change in the decades to come.

The AOS Applications Team (AIT) is charged with ensuring that applications are considered to the greatest extent possible in mission design and implementation.

Phase-A activities focus on development of a Project Applications plan and recruitment of the earliest Early Adopters



Latency



Community Assessment Report

- Deliverable: Pre-Phase A Requirement
- CAR serves to document and synthesize information and **needs from applications communities relevant to AOS** that include communities of practice and potential
- CAR makes recommendations and provides suggested guidelines for how **components of the AOS mission may be optimized** for enhanced applications value
- CAR is a living document that will be **maintained throughout the mission life cycle** (e.g., updates will be made as changes in the architecture could impact application opportunities)

Atmosphere Observing System (AOS) Community Assessment Report (CAR)

April 2022

The objective of this Community Assessment Report (CAR) is to provide an overview of key stakeholder communities and their needs relevant to the Atmosphere Observing System (AOS) in terms of their current use and potential application of data products for decision making. This report is based solidly on input from stakeholders and serves as a reference to articulate stakeholder needs as well as provide guidelines for how to optimize the applications benefit to communities of practice and communities of potential that may use the suite of AOS products.

AOS Applications: Innovations in Science for Societal Benefit



Value of Polar Orbit for Applications

1. **Lidar/Polarimeter collocation** provides unprecedented opportunities for synergistic observations of cloud and aerosol products
2. **Novel cloud and precipitation** observations improve NWP and climate modeling and **high latitude cloud information** to support hydrometeorological applications
3. **Significant enhancement to air quality applications** in modeling, forecasting and disaster monitoring and response
4. **Novel measurements to inform policy** such as health impacts of particles

AOS Applications: Innovations in Science for Societal Benefit



Observations of volcanic plumes support aviation safety and navigation decisions

VOLCANIC ASH ADVISORY

The Met Office has been receiving reports of deposits of ash-like particles throughout the state of Grenada. Ash deposition is likely to increase with periods of



Discerning aerosol types informs air quality monitoring and health studies for identifying hazardous levels of PM



Vertical profiles of precipitation enable situational awareness of tropical cyclones



Value of Inclined Orbit for Applications

1. **Observes diurnal variability** of phenomena at all stages of storm development and aerosol emissions
2. **Provides cross-calibration/co-location with the PoR** to develop higher level (L3/L4 products) and extend the PoR for long-term data records
3. **Enables decreased time between satellite overpasses**

AOS Applications: Innovations in Science for Societal Benefit



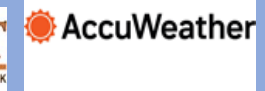
#1 Will enhance understanding of model parameterizations, thus improve weather, climate and AQ models and forecasts



#2 Provides opportunity for long-term trend analysis and characterization of extremes essential for flood and landslides nowcasts



#3 Provides information to improve monitoring, modeling, and forecasting together with PoR



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AOS Data Latency Update

- AOS science data is critical to a wide variety of applications users for weather forecasting, disaster modeling/monitoring, and air quality
 - These end-users drive latency requirements on science data
- Applications and Systems Engineering have defined a set of ‘desirements’ and requirements for latency targets
 - Used to balance applications benefit vs. Spacecraft sizing (SWaP), Cost, Risk, etc.
- A study was performed in pre-Phase A to better understand the trade space and resultant latency of existing and planned telecommunications systems
 - Trade study results will be used to better evaluate spacecraft RFP responses in Phase A
- NASA Near Space Network (NSN) is undergoing a commercialization effort, and is working directly with AOS (and other ESO missions) to help define required capabilities for the future
 - Current latency analyses are being assessed against current NSN network, which is believed to be a conservative approach since further augmentation is expected
 - AOS latency ‘desirements’ and initial requirements have been provided to NSN

Latency Targets – Required and Desired

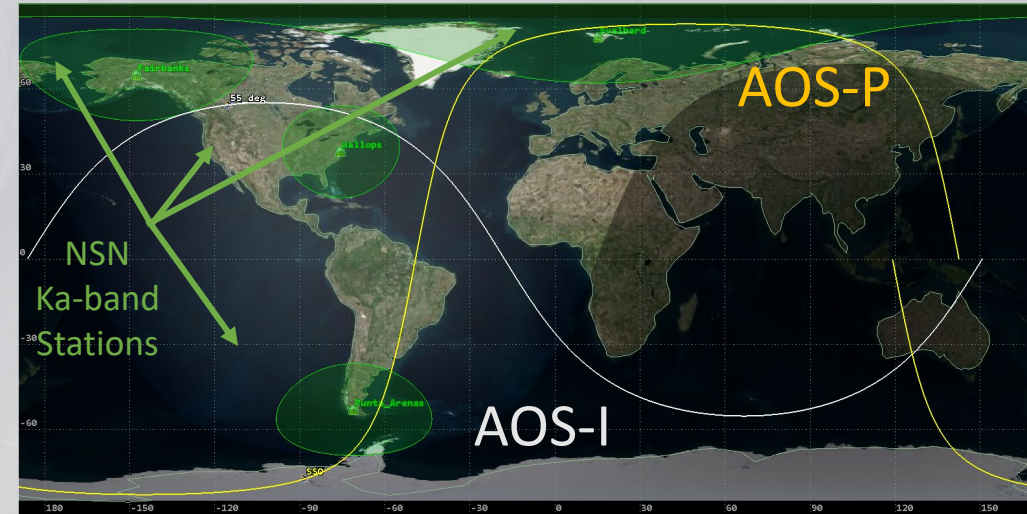
Instrument	Required Measurement Latency (Observation to Receipt at MOC)	Desired Measurement Latency (Observation to Receipt at MOC)
Radiometer	75% of data < 3hr 85% of data < 4hr 95% - 100% of data < 5-6hr	< 1 hour
Radar	75% of data < 4hr 85% of data < 5hr 95% - 100% of data < 6-7hr	1-3 hours
Lidar		1-3 hours
Polarimeter		1-3 hours
Spectrometer		< 6 hours

- Table is applicable to both AOS-I and AOS-P
 - Latency requirements are defined in the AOS Program Level Requirements Appendix (PLRA)
 - Latency ‘desirements’ are goals that the SE team will attempt to meet as a best effort

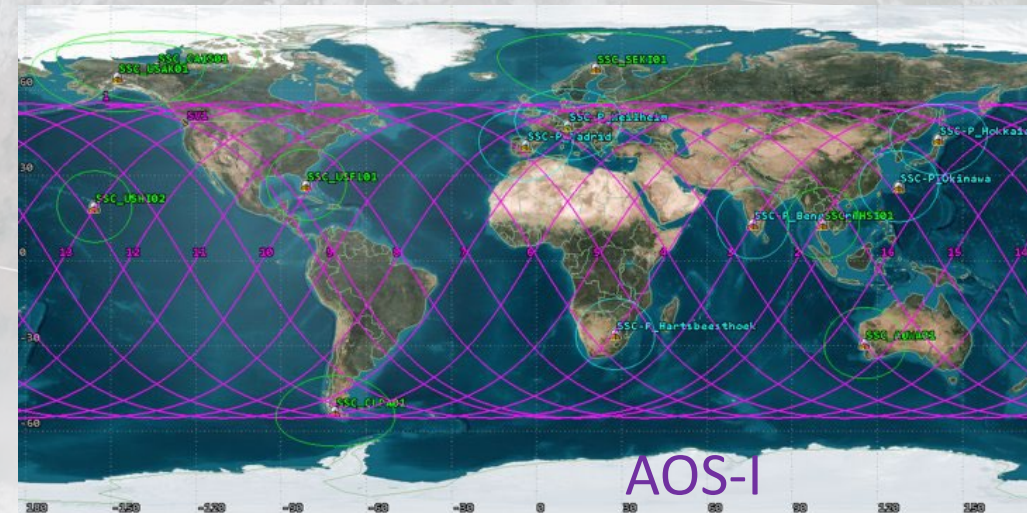
Latency Challenges

- There are limited high-rate Ka-band capable ground stations currently available via the NASA NSN
 - Ground station locations are at higher latitudes and are more favorable for polar and near polar orbits
 - AOS-P spacecraft in polar sun-synchronous orbit is likely to see Ka-band stations on each orbit
 - AOS-I spacecraft in 55 deg inclined orbit is likely to have multiple orbits each day without visibility to Ka-band ground stations
 - Orbit periods for AOS-P and AOS-I are ~1.5 hrs, so an average of more than 1 downlink per orbit is needed to achieve <1 hr latency desirment
- AOS SE team looking at alternate downlink strategies to improve latency and provide more flexibility
 - Leverage NSN and commercial X-band stations with more favorable geographic distribution for AOS-I
 - Include option to downlink the low-volume Radiometer data via the spacecraft S-band low-rate link

Ka-band



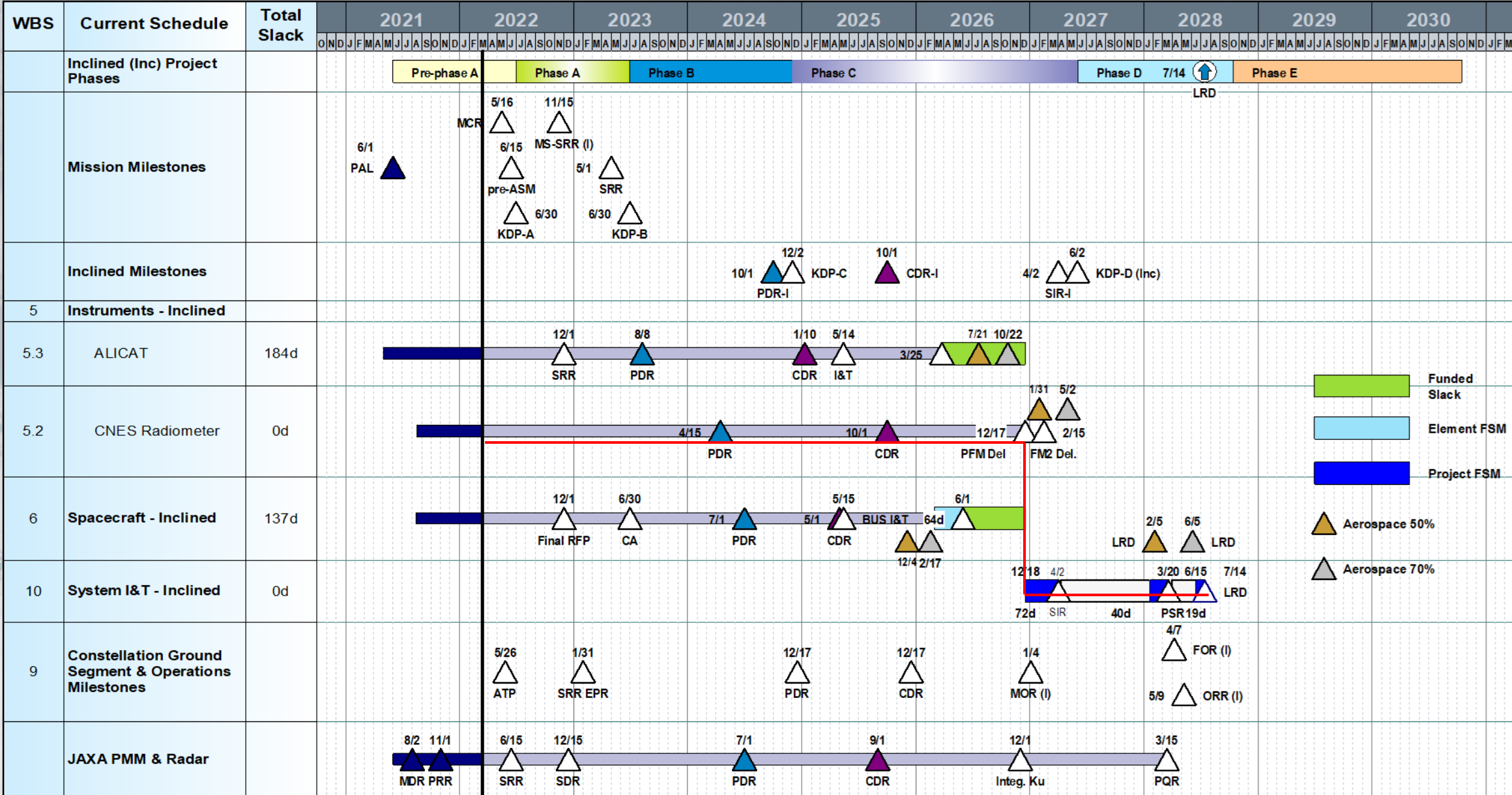
X-band



Agenda

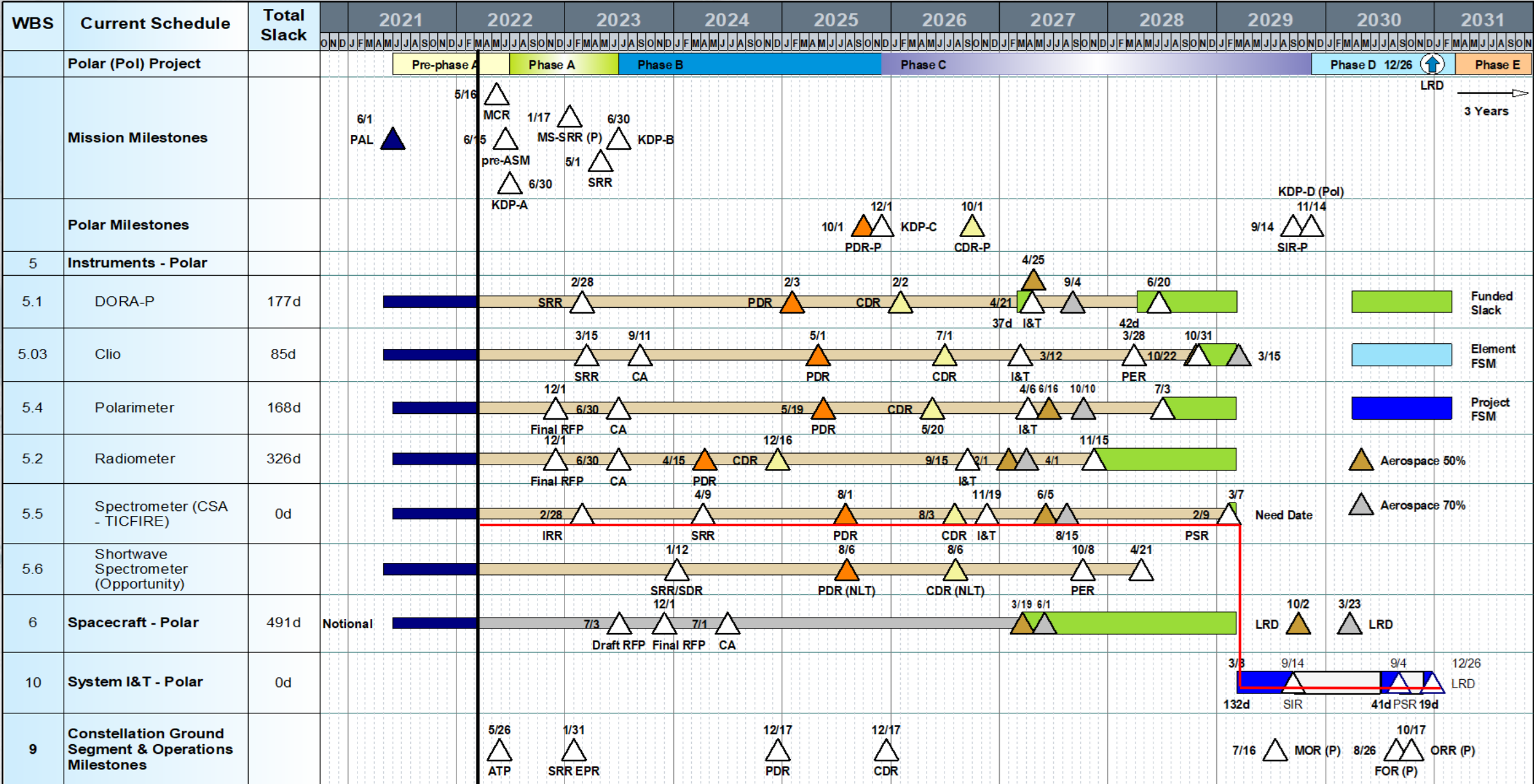
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AOS Master Schedule – Inclined (July 2028 Launch)



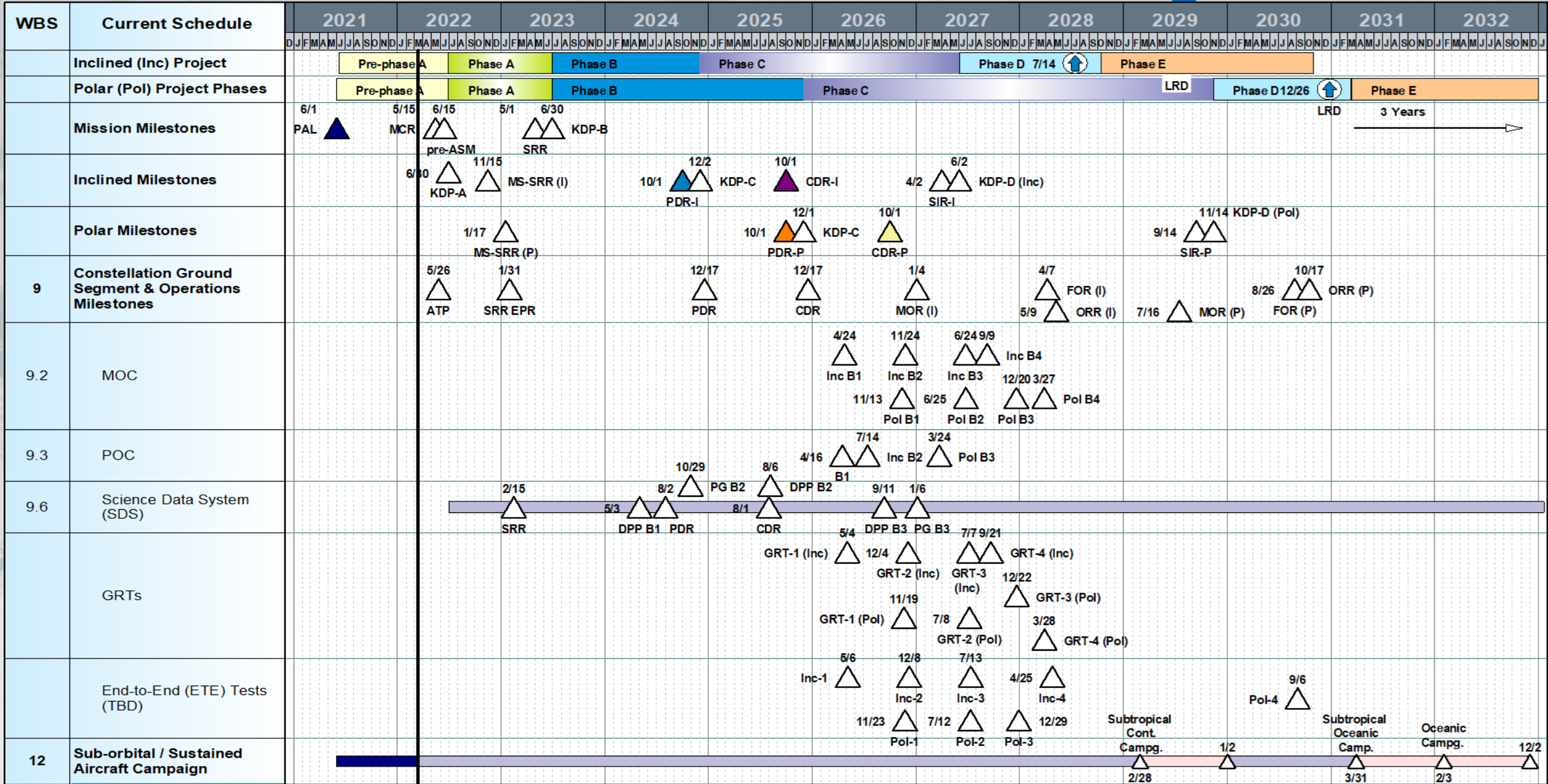
Pre-Decisional

AOS Master Schedule – Polar (December 2030 Launch)



Pre-Decisional

AOS Master Schedule – Ground Segment



Pre-Decisional

AOS Path Forward

- Information presented is pre-decisional
- Mission Concept Review and pre-Acquisition Strategy Meeting (ASM) have been held
- ASM and Key Decision Point-A are planned for October 2022
- System Requirements Review / Mission Definition Review planned for late Spring 2023
- Proceed with elements (Spacecraft and/or Instruments) approved through ASM
 - Anticipated timeframes for Request for Proposal Release are Winter 2023 through Fall 2023

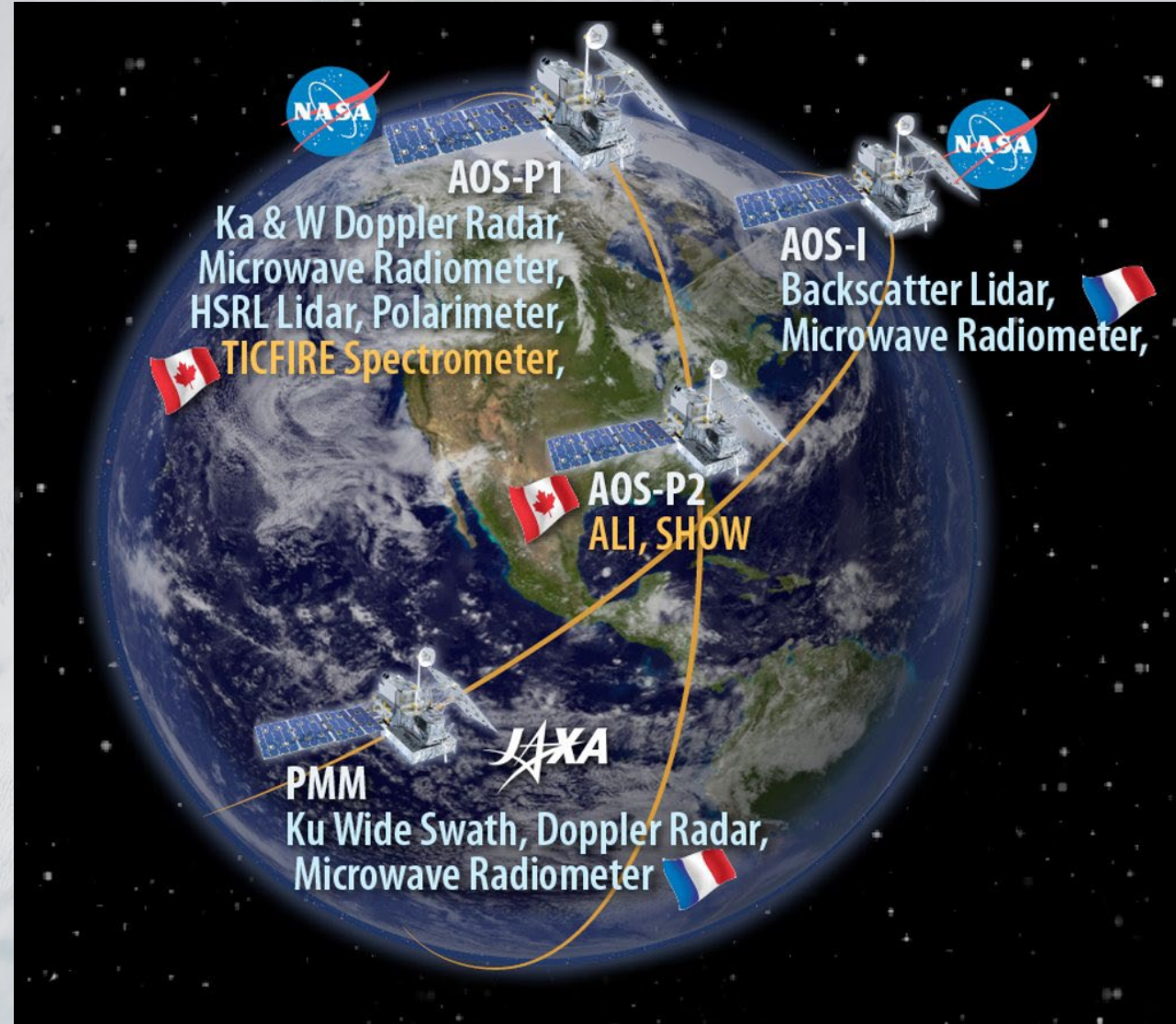
Agenda

- AOS science and measurements (18 min) – Scott Braun
- Applications Considerations (7 min) – Emily Berndt
- Data latency, ground system (5 min) – Jonathan Chrone
- Plan Forward for AOS (8 min) – Jason Hair
- Ways to Stay Informed (2 min)
- Questions

Ways to stay informed

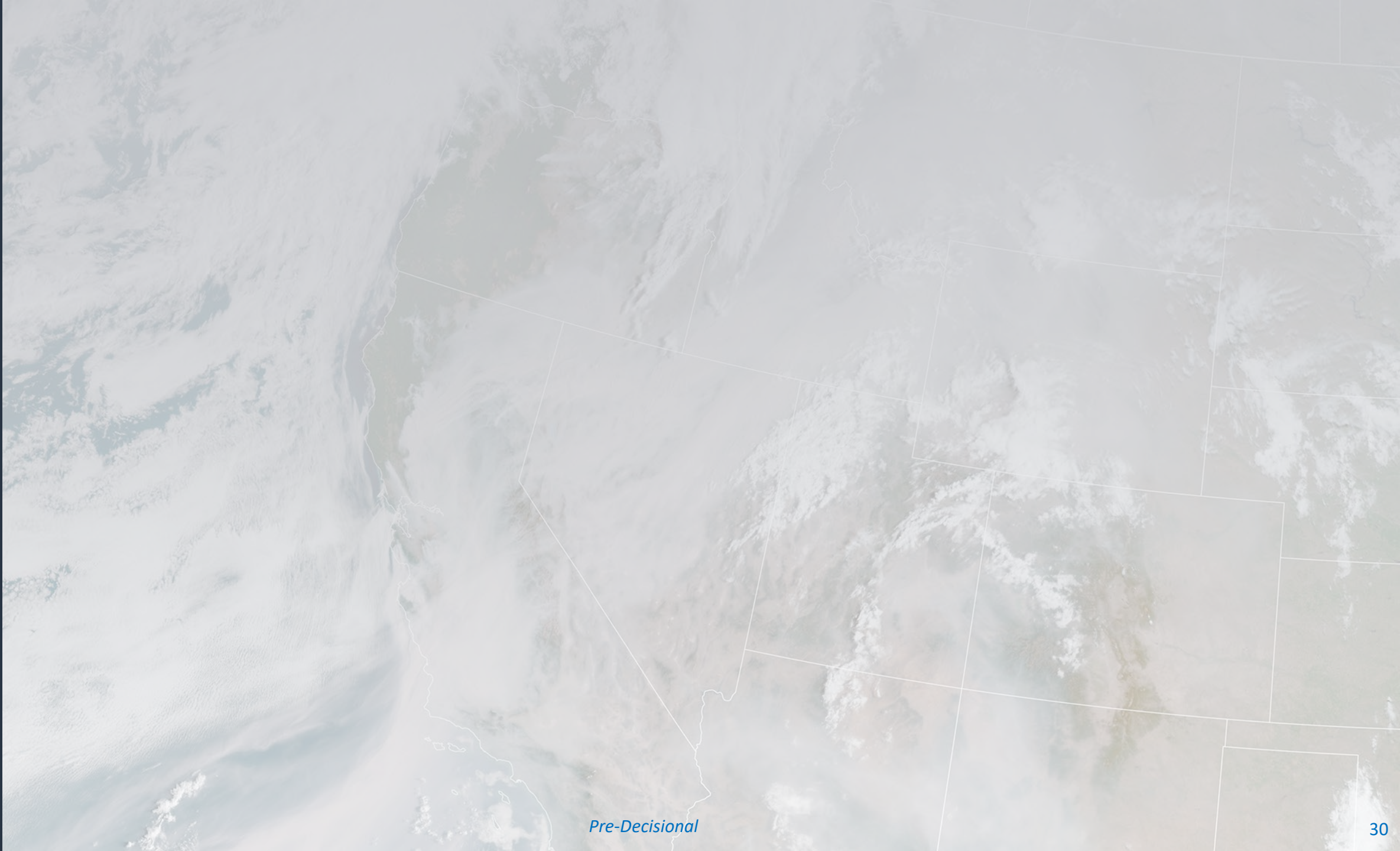
- Web-Site <https://aos.gsfc.nasa.gov>
- Contact Sheri Smith @ aos-comments@lists.nasa.gov
- Contact Project Team Personnel (POCs on web-site)
- AGU Sessions December

Questions?



ATMOSPHERE

Observing System



Instrument Details—Inclined

- JAXA radar
 - 5 km footprints, 1-km oversampling at nadir for improved resolution
 - Sensitivity: 6 dBZ at nadir, 14 dBZ off nadir
 - DPCA Doppler, 2 m/s accuracy
- CNES radiometers (tandem pair)
 - 89, 183 (3), 325 (3) GHz
 - 3-5 km resolution
- ALICAT lidar
 - 532, 1064 nm, both with depolarization
 - 30-60 m vertical resolution, 100-350 m horizontal resolution

Instrument Details—Polar

- JPL DORA radar
 - W-band, ~1.5 km horiz. resolution, 300-500 m vertical resolution
 - Sensitivity: -24 dBZ above 6 km, -20 from 2.5-6 km, -15 from 1-2.5 km, -5 below 1 km
 - Ka-band, ~2.5 km horiz. resolution, 250-500 m vertical resolution
 - Sensitivity >10-12 dBZ above 1 km, 20 below 1 km
 - Doppler accuracy, 0.5 m/s at W band, 1 m/s at Ka band
- Polar radiometers (tandem pair)
 - Required: 183 (3), 325 (3), 650-700 (H+V) GHz
 - Desired: 89, 118, 150-182, 210-240, 800-900 GHz
 - <10 km resolution baseline, <20 km threshold
- Clio lidar
 - 532 HSRL, 1064 nm, both with depolarization
 - Single-shot resolution 70/10 m horizontal/vertical

Instrument Details—Polar

- Polarimeter
 - UV (360-390 nm), VIS-NIR (410-870 nm), hyperangle (670-870 nm), SWIR (1000-1700 nm)
 - 10 angles each except 60 for cloudbow
 - 0.5 km horizontal resolution
- CSA TICFIRE

Spectral Band Centre [μm]	Bandwidth at FWHM [μm]	Maximum expected target radiance at TOA [W.m ⁻² .sr ⁻¹]	Radiometric Accuracy [W.m ⁻² .sr ⁻¹]	Noise equivalent radiance [W.m ⁻² .sr ⁻¹]	Stability
6.0 ± 0.5	4.0 ± 0.5	9.3	0.1 for all pixels	0.05 for all pixels	0.02 K drift per year in orbit
8.6 ± 0.1 ¹	0.9 ± 0.1	9.5			
10.7 ± 0.1 ¹	0.7 ± 0.1	7.7			
12.1 ± 0.1 ¹	1.0 ± 0.1	9.6			
18.3 ± 0.5	2.5 ± 0.3	9.8			
21.0 ± 0.5	3.0 ± 0.5	8.5			
28.0 ± 1.0	10.5 ± 2.0	13.5			
53.0 ± 2.0	40.0 ± 5.0	7.6			