ACCP Aerosols, Clouds, Convection, and Precipitation Study

ACCP Designated Observable Multi-Center Architecture Study

ACCP Quarterly Community Forum

June 22, 2020

Agenda

- Study Status & Overview (15min)
- ACCP Science (15min)
- ACCP Architectures (15min)
- Scientific Assessment of Architectures (15min)
- Independent Science Community Committee (SCC) remarks (15min)
- Plan Forward & Community Engagement Opportunities (15min)
  - Sub-Orbital Working Group
  - Modeling Working Group
- Questions & Comments (30min)
  - Due to large number of people on the call, please mute your microphones and send Sheri Smith your questions or comments at Sheri.L.Smith@nasa.gov
  - We'll go through these at the end

ACCP Study Team

Study Management Team (SMT)

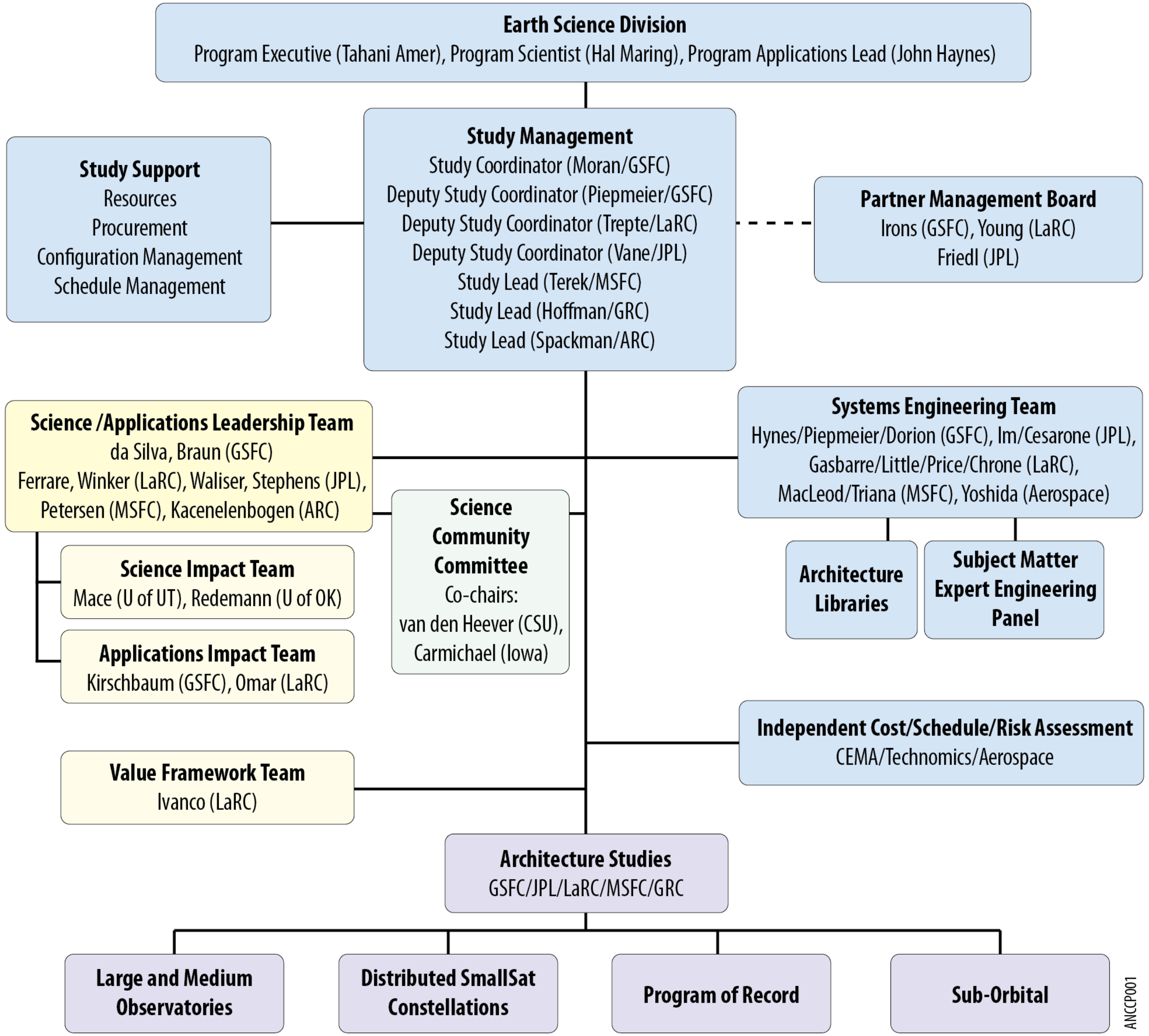
- Overall Leadership and Management of Study and Delivery of Study Report
- Community Engagement
- Assessment of Architectures
  - Cost Estimation & Validation
  - Programmatic Risk
  - Other Programmatic Factors

Science/Applications Leadership Team (SALT)

- Definition of Science & Applications Traceability Matrices
- Assessment of the Utility of the Geophysical Variables in Meeting Each Objective

Science & Applications Impact Teams (SIT and AIT)

- Assessing the Science & Applications Value of Architectures (Science Quality of Each Architecture wrt Meeting Geophysical Variables)



Science Community Committee

- Independent Assessment of SATM
- Independent Assessment of Science & Applications Benefit by Community of Users

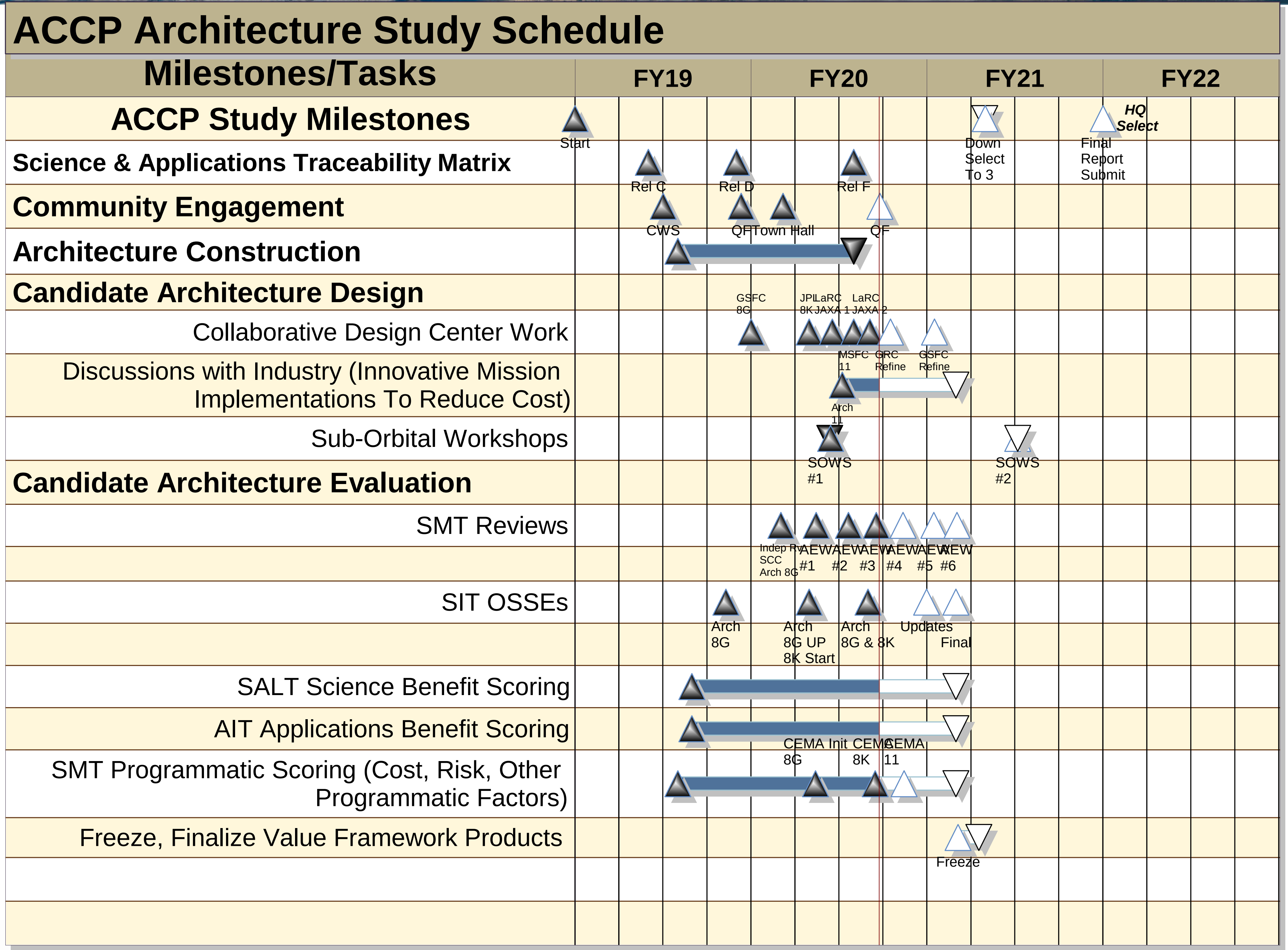
Systems Engineering Team (SET)

- Definition of Architectures
- Assessment of Architectures
  - Technology Readiness
  - Technical Risk

Value Framework Team

- Development of Standard and Systematic Approach to Science, Applications, and Programmatic Evaluations of Architectures to facilitate Down-Select Decisions

ACCP Study Status/Progress & Plan FY21



Architecture Construction is Completed (Final Freeze in Aug)

Architecture Designs (Space Segment) Nearly Completed (Final Tweeks in Oct)

- ***Large/Medium Spacecraft*** *in Oct. 2019 at GSFC (Architecture 8G)*
- ***ESPA Grande Spacecraft*** *in Jan. 2020 at JPL (Architecture 8K)*
- ***JAXA Large Spacecraft*** *in Mar. 2020 at LaRC (Architecture 8G-1)*
- ***ESPA Spacecraft*** *in April 2020 at MSFC (Architecture 11s)*
- ***JAXA Medium Spacecraft*** *in May 2020 at LaRC*

Sub-Orbital and Ground Segment Still In Work

Architecture Evaluation In Process

- ***OSSEs*** *are challenging but making good progress*
- *Architectures are challenging to get in* ***Cost Box*** *(doing Independent Costing with CEMA and Aerospace)*
- ***Instrument Technical Readiness Assessment challenging; TRA*** *panels completed preliminary assessments for Radars, Lidars, Radiometers, Polarimeters*
- *Starting to work with* ***Industry on Innovative*** *options to reduce Launch, SC, Gnd cost*

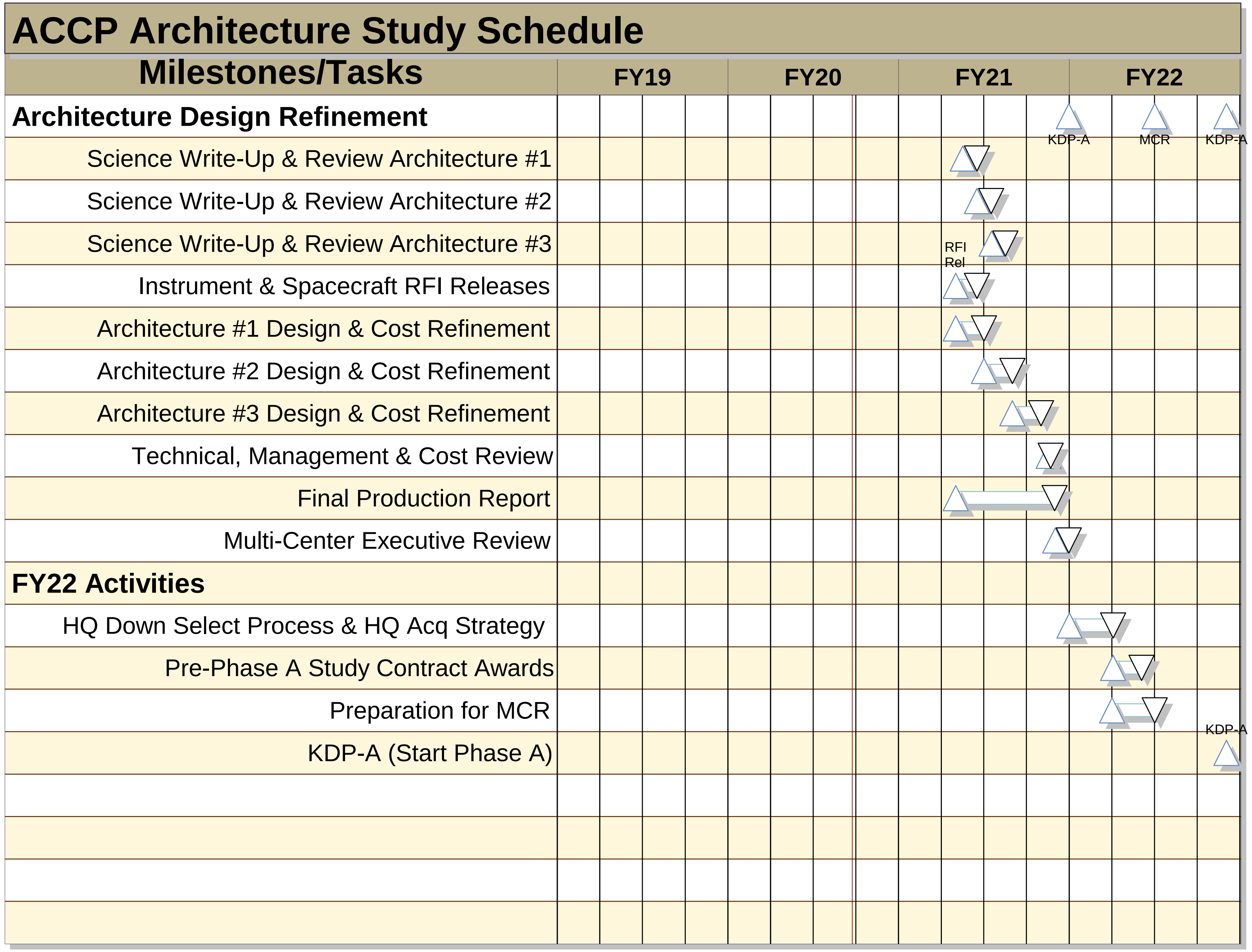
ACCP Major Work Areas In Progress In June/July

- Lidar Special Study with French Contribution of UV Receiving Channel for a 3+2 HSRL & ACCP Trade Study All Lidar Options
  - Formal Trade Study started early March 2020
  - SIT Simulations 3 Lidars with Polar07 (2WL Back-Scatter, 2+1 HSRL, 3+2 HSRL)
  - SMT Costing: 3 Lidars including Spacecraft Accommodation
  - SET/SMT Risk Analysis 3 Lidars
  - SET Technology Readiness Assessment 3 Lidars
- ACCP JAXA Special Studies looking at including Radar 17 (Ku Band Doppler Radar)
  - ✓SMT--Case I Adding Radar 17 and Radar 12 in place of Radar 13 on Architecture 8G SSG Spacecraft
  - JAXA Technology Readiness Assessment
  - ✓May 19-June 4 CDC #4 @ LaRC--Case II—Dedicated Spacecraft Bus for Radar 17
- July forming a Ground System Architecture Working Group
- SATM Development (ongoing)
  - Release F finalization
  - Discussion of how to capture Science Benefit of Sampling (diurnal and delta t)
  - Discussion of horizontal resolution for Lidar
  - Discussion of vertical time resolution for Radar
  - Discussion of Radiation measurements

Key Milestones/Upcoming Events—2020

June 16-18	Architecture Evaluation Review #3
June 22	ACCP Community Forum
July	Ground System Architecture Development
August 11-13	Architecture Evaluation Review #4 Part 1 (Architecture Freeze)
Sept 1-3 (TBV)	Architecture Evaluation Review #4 Part 2 (SIT-A (Lidar/Polarimeter) Scoring per Objective)
Sept 22 or 23	HQ Annual Review
Sept 29	Next ACCP Quarterly Forum
Oct 14-15	Architecture Evaluation Review #5 (SIT-CCP Radar/Radiometer Scoring & Sampling Scoring per Objective)
Dec 2-3	Architecture Evaluation Review #6 (Narratives on ACCP Science Flow To Objective Scoring)
Jan 27-28	ACCP Down Select Meeting

ACCP Study Plan FY21



Following Down Select To Final 3 Architectures in January 2021…

Will re-issue more specific RFIs for Instruments and Spacecraft to increase Technical and Cost Confidence

Will refine designs and costs and do Technical, Management, and Cost (TMC) Reviews with Independent Technical and Cost Teams (CEMA, RAO, Aerospace)

Will develop Instrument and Spacecraft Capabilities for Future AO/RFPs

Will include Center and HQ representatives in Reviews and Recommend 1 of 3 Architectures for Final Selection

Plan Multi-Center Executive Review(s) prior to submitting Final Report to HQ end FY21

Key Milestones/Upcoming Events—2020

March 2021	Science/TMC Review Architecture #1
May 2021	Science/TMC Review Architecture #2
July 2021	Science/TMC Review Architecture #3
August 2021	Team Down-Select To 1 Architecture Recommendation
September 2021	Center/Executive Reviews
October 1, 2021	Final Report Submission

Aerosols, Clouds, Convection, and Precipitation (ACCP) Science

Scott Braun[1], A. da Silva[1], R. Ferrare[2], M. Kacenelenbogen[4], W. Petersen[3], G. Stephens[5], D. Waliser[5], D. Winker[2], G. Mace[6], J. Redemann[7]

1) NASA Goddard Space Flight Center
2) NASA Langley Research Center
3) NASA Marshall Space Flight Center
4) NASA Ames Research Center
5) Jet Propulsion Laboratory
6) University of Utah
7) University of Oklahoma

ACCP Overview

The *2017 Decadal Survey* (DS) recommended cost-capped missions with specified caps, creating challenge for team to envision new science but ensure an implementable observing system

	Aerosols	Clouds, Convection, and Precipitation
Observable Priorities	Aerosol properties, aerosol vertical profiles, and cloud properties to understand their effects on climate and air quality	Coupled cloud-precipitation state and dynamics for monitoring global hydrological cycle and understanding contributing processes including cloud feedback
Desired Observables	Backscatter lidar and multichannel, multi-angle/polarization imaging radiometer	Radar(s), with multi-frequency passive microwave and sub-mm radiometer

Diverse Range of Science in the Decadal Survey

Aerosol Impacts On Clouds

Weather/Climate Variability

Aerosol properties

Extreme Precipitation

Boundary Layer Processes

Aerosol Speciation

Microphysical Processes

Precipitation Rate and Phase

Snow Accumulation

Air Quality

High and Low Cloud Feedback

Convective Vertical Motion

Long Term Trends

Aerosol Emissions

Water and Energy Cycles

Radiative Forcing

Integrated Earth System Analysis

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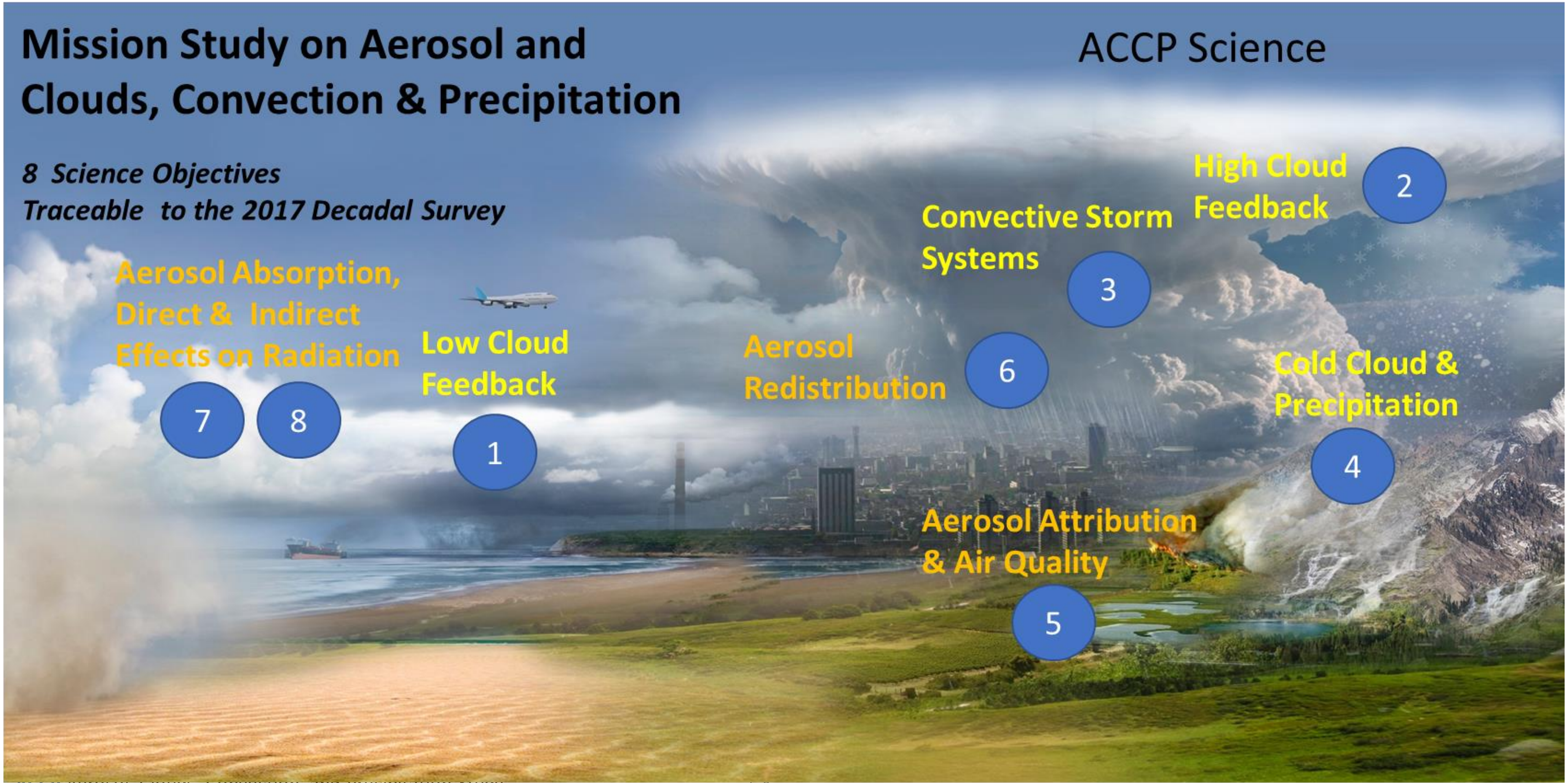
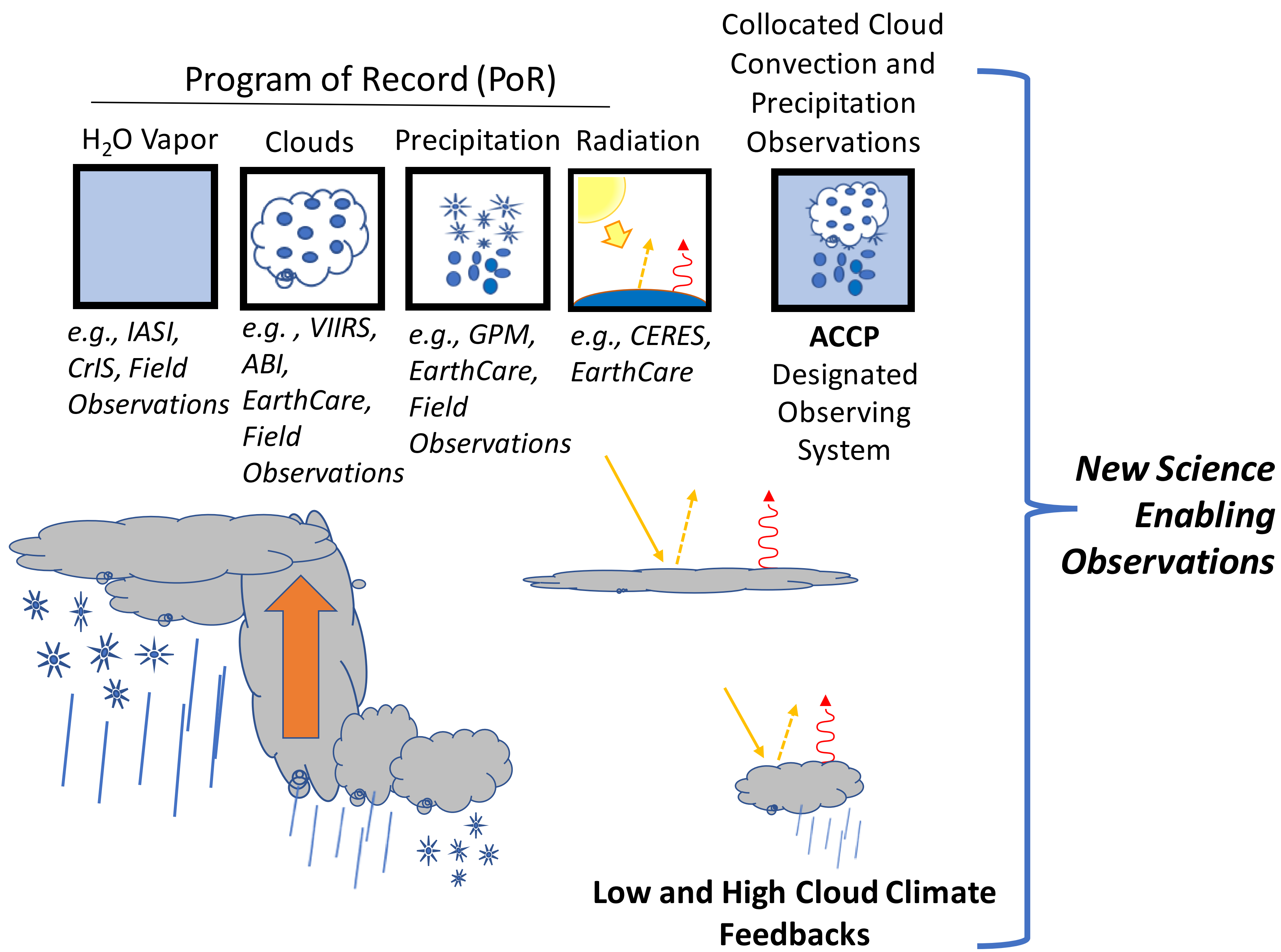
ACCP Science Objectives



Clouds, Convection and Precipitation



Cloud, Storm and Precipitation Development and Lifecycles

1. WATER VAPOR + CLOUDS + PRECIPITATION + RADIATION

Previous / PoR measurements have not provided collocated measurements of clouds and precipitation; combined with PoR water vapor & radiation, these measurements are key to understanding:

- **Low Cloud Climate Feedback**
- **High Cloud Climate Feedback**
- **Cloud and Precipitation Development**
- **Atmospheric Water Cycle**

2. VERTICAL MOTION IN CONVECTIVE STORMS

There are no global measurements of vertical motion inside convective storms; these are key to understanding:

- **Storm Development & Life Cycle**
- **Hydration of the Upper Troposphere**
- **Precipitation Extremes**

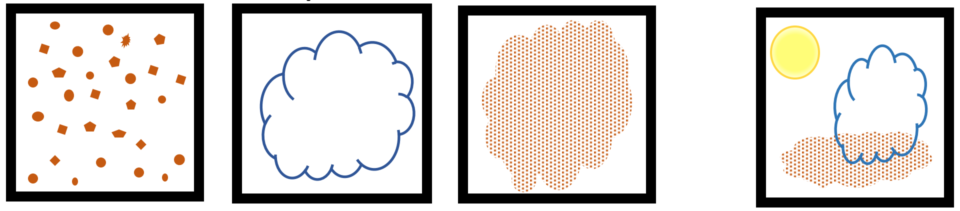
3. HIGH LATITUDE CLOUDS AND SNOWFALL

Previous / PoR measurements provide inadequate information to constrain snowfall estimates. Relevant to:

- **Polar Hydrometeorology**
- **Sea Ice and Ice Sheet Surface Mass Balance**

Aerosols

Program of Record (PoR)			Aerosol DO
Aerosol Distribution	Aerosol Properties	Trace Gases	Vertical Profiles Enhanced properties



e.g. ABI,AHI VIIRS	e.g. 3MI PACE	e.g. Trop-OMI TEMPO	**Lidar Polarimeter**

ACCP will <u>augment</u> the future Program of Record (PoR)

1. 4D AEROSOL SAMPLING & LIFE CYCLE

Previous PoR measurements have not provided collocated temporal and vertical measurements of aerosol distribution and properties; key to understanding:

- **Aerosol Sources and Transport**
- **Aerosol Processing**
- **Aerosol Removal and Redistribution**
- **Modeling and Forecast Skill**

New Science Enabling Observations

2. AEROSOL AMOUNT

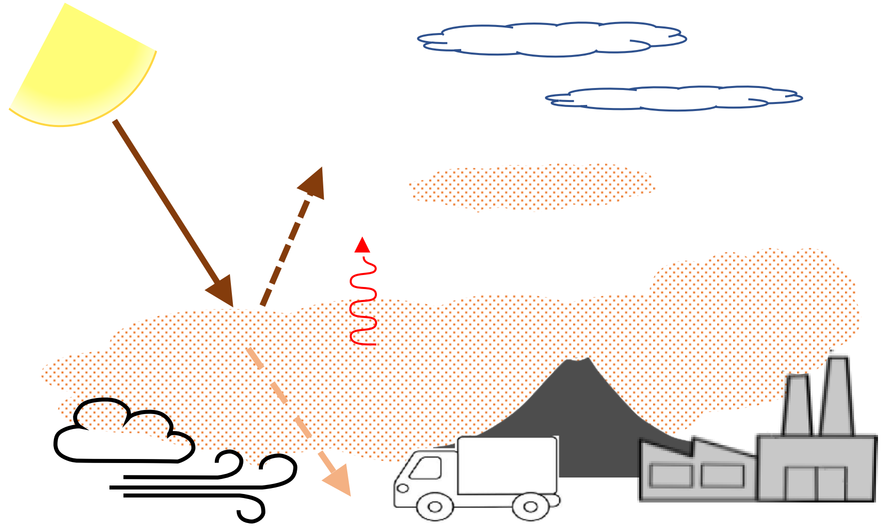
Improved measurements of AOD, AAOD, and aerosol extinction profiles to advance understanding of:

- **Aerosol Direct Radiative Effects at TOA & Surface**
- **Air Quality**
- **Aerosol Atmospheric Heating & Hydrologic Sensitivity**

3. AEROSOL PROPERTIES

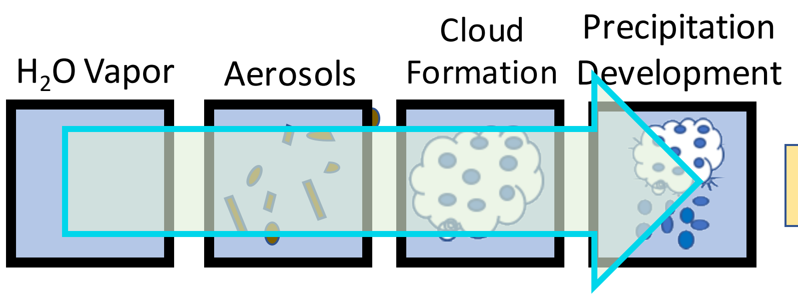
New and improved measurements of aerosol *single scatter albedo* and *size* to:

- **Discriminate Anthropogenic and Natural Aerosols**
- **Improve Understanding of Aerosol Sources**
- **Evaluate Modeling and Air Quality**



Links Between A & CCP

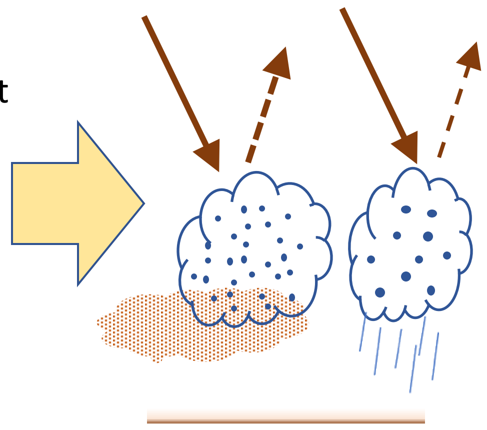
I. Aerosol Effects on Cloud Microphysics and Precip



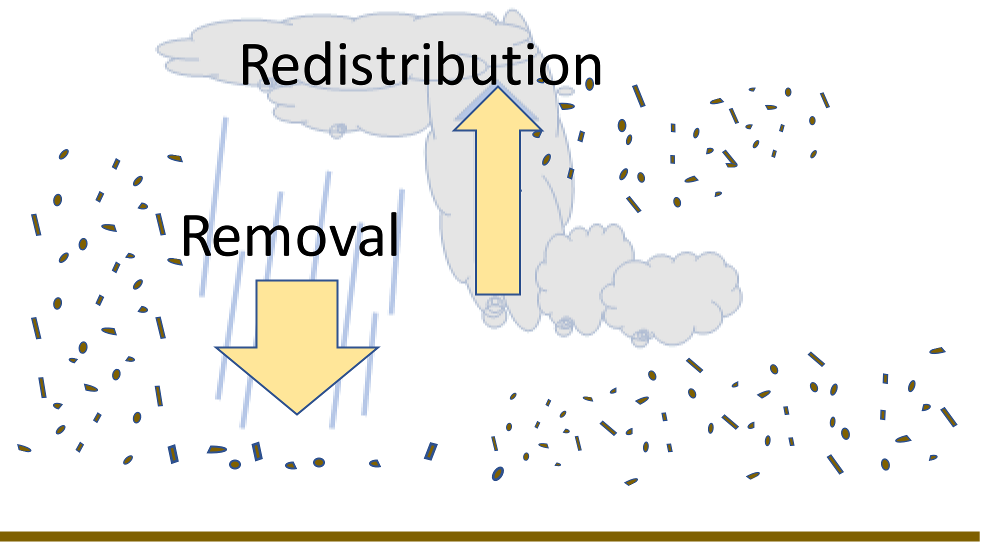
Aerosols are fundamental to the formation of clouds and precipitation, and thus relevant to all CCP objectives.

These aerosol impacts on clouds and precip lead to impacts on radiation, thus further linking Aerosol and CCP objectives.

II. Aerosol Indirect Radiative Effects

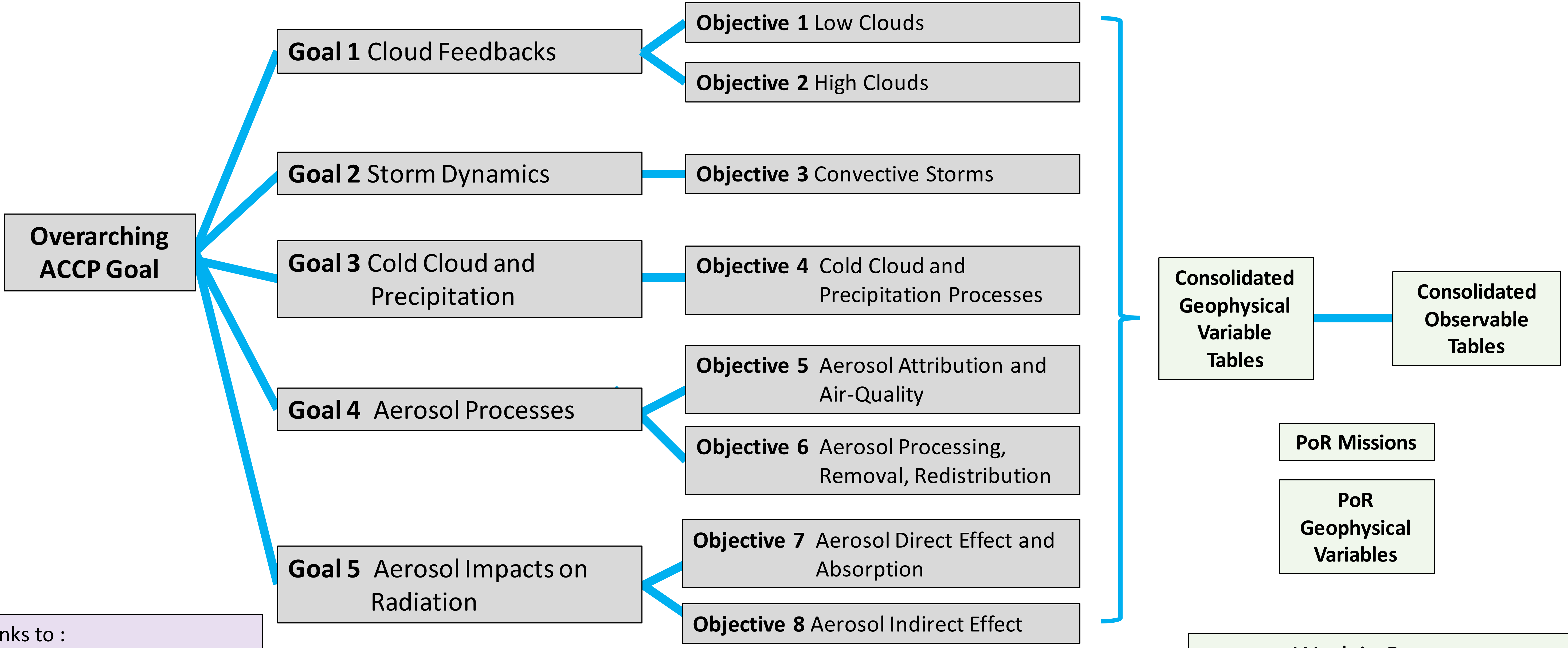


III. Aerosol Processing, Removal and Redistribution by Cloud



Precipitation removes aerosols, convection and storms loft and redistribute aerosols
Chemical processing of aerosol occurs within cloud droplets

ACCP Science and Applications Traceability Matrix



Work in Progress

Links to :
- Geophysical Variable Tables
- Observable Tables
- Enabled Application Tables
- Decadal Survey Tables
- Acronyms

https://science.nasa.gov/science-pink/s3fs-public/atoms/files/ACCP_SATM_Rel_E_TAGGED.pdf

ACCP Aerosol, Clouds, Convection, and Precipitation Study

Goal 2: Storm Dynamics

A+CCP	A	CCP	Goal	Example Science Question	Objectives
			G2 Storm Dynamics *Improve our physical understanding and model representations of cloud, precipitation and dynamical processes within convective storms*	*1) How does convective mass flux relate to the vertical distribution and microphysical properties of clouds and precipitation in deep convection?* *2) How do different convective storm systems contribute to vertical transports of heat, water, and other constituents within the atmosphere and how do these transports relate to storm environment and lifecycle?*	**O3** Convective Storm Systems **Minimum:** Relate vertical motion within convective storms to their a) cloud and precipitation structures, b) microphysical properties, c) local environment thermodynamic and kinematic factors such as temperature, humidity, and large-scale vertical motion, and d) ambient aerosol loading. **Enhanced:** Improve measurements of convective storm vertical motion and storm characteristics in (a) and (b) of the Minimum objective to better address deep convection and diurnal variability. Further relate items in the Minimum objective to latent heating profiles, storm life cycle, ambient aerosol profiles, and surface properties.

Objectives

O3 Convective Storm Systems

Minimum: Relate vertical motion within convective storms to their a) cloud and precipitation structures, b) microphysical properties, c) local environment thermodynamic and kinematic factors such as temperature, humidity, and large-scale vertical motion, and d) ambient aerosol loading.

Enhanced: Improve measurements of convective storm vertical motion and storm characteristics in (a) and (b) of the Minimum objective to better address deep convection and diurnal variability. Further relate items in the Minimum objective to latent heating profiles, storm life

Approach

General Approach - Establish global convective structure climatologies that statistically characterize convective processes through measurement of convective scale vertical motion, cloud, precipitation, and surrounding column aerosol properties. Leverage temporal/spatial coverage of GEO and LEO PoR with ground-based observations and global/regional analysis systems.

Role of models - testing and evaluation of ACCP observational impacts on improved model physical representation of convective cloud processes.

Role of Sub-orbital - In situ and improved space-time sampling of convective processes, especially for strong to severe storms, and perturbations in the ambient cloud environment. Cal/val for satellite measurements and retrieval algorithms.

New and Improved - a) global convective scale vertical motion profiles and correlated process metrics, and b) measurements of hydrometeor structure and environment aerosol properties, PoR measurements and capabilities, and global model analysis resolution/physics.

Geophysical Variables (1 of 2)		Qualifiers
Minimum	**Enhanced**	
In-cloud vertical air velocity		Profile, measure above melting layer at a minimum; Velocity minimum |>2 m/s|
Hydrometeor vertical feature mask		Cloud top height
Cloud geometric-top temperature		
Cloud top phase		
Diurnally resolved cloud cover		PoR Primary; Context
Diurnally resolved cloud top height		PoR Primary; Context
Precipitation rate		Profile
Precipitation phase		Profile, liquid/ mixed/frozen
Ice water path		
Convective classification		Org./intensity/depth; PoR for org. context
Precipitation Discrimination (stratiform/convective)		
Environmental temperature		Profile, used for stability parameters as well
Environmental humidity		Profile, used for stability parameters as well
Environmental horizontal wind		Profile, used for shear calculation
Environmental vertical wind		Profile
Aerosol Optical Depth		Column and PBL

Consolidated Geophysical Variable Table

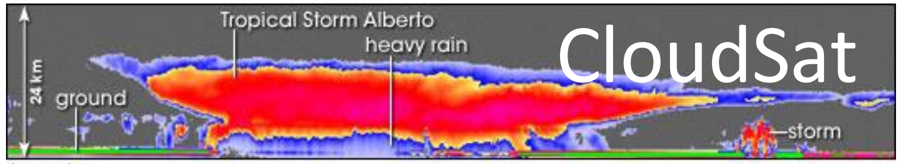
<table>
<tr><th colspan="2" rowspan="3">Consolidated Geophysical Variables (14 of 17)</th><th rowspan="3">Science Objectives</th><th colspan="6">Desired Capability</th><th rowspan="3">Examples of Observables Notes</th><th rowspan="3">Enabled Apps</th></tr>
<tr><th rowspan="2">Range</th><th rowspan="2">Uncertainty</th><th colspan="4">Scales</th></tr>
<tr><th>XY</th><th>Z</th><th>T</th><th>Swath</th></tr>
<tr><td>Minimum</td><td>Enhanced</td><td colspan="9">IMPORTANT: Desired Capabilities and Observables are preliminary. Click here for additional information.</td></tr>
<tr><td rowspan="2">PR.z</td><td rowspan="2">Precipitation rate profile</td><td>O1, O3, O4, O6</td><td>O1: 0.1 - 2 mm/hr
O3:2 - 50 mm/hr
O4:.01-10 mm/hr
O6: 0.1 - 2mm/hr</td><td>O1, O3, O6 <100%
O4: 200%</td><td>3 km</td><td>250 m</td><td>I</td><td>Nadir</td><td rowspan="2">Radar reflectivity; μwave radiances, submm radiances

Lower freq radar needed in enhanced for intense rains;
Includes near surface precipitation estimate.</td><td rowspan="2">1, 5, 7</td></tr>
<tr><td>O2, O6</td><td>2-100 mm/hr</td><td><100%</td><td>1 km</td><td>125 m</td><td>I, ΔT, R</td><td>≥250km</td></tr>
<tr><td rowspan="2">PR2D</td><td rowspan="2">Precipitation rate, 2D @surface</td><td>O6</td><td>0.1-2 mm/hr</td><td>100% below 1 mm/hr, 50% above</td><td>≤ 25 km</td><td>N/A</td><td>I, ΔT, R</td><td>>500 km</td><td rowspan="2">Scanning passive μwave, >85 GHz, Submm

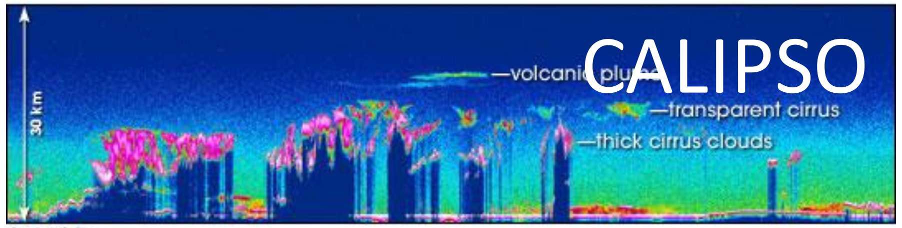
Contributes to horizontal mapping of precip.;
Applications desires footprint of 10 km or less.</td><td rowspan="2">1, 5, 7, 8, 9, 10, 11</td></tr>
<tr><td>O3, O4</td><td>(O3): 0.5-50 mm/hr
(O4): 0.01-10 mm/hr</td><td>O3: < 50% @1 mm/hr;
< 25% @>10 mm/hr
O4: 200%</td><td>≤ 25 km</td><td>N/A</td><td>I, ΔT, R</td><td>>500 km</td></tr>
</table>

ACCP seeks to provide transformative space-based and suborbital observations of essential cloud, precipitation, and aerosol processes, leading to improved predictions of weather, air quality, and climate for the benefit of society

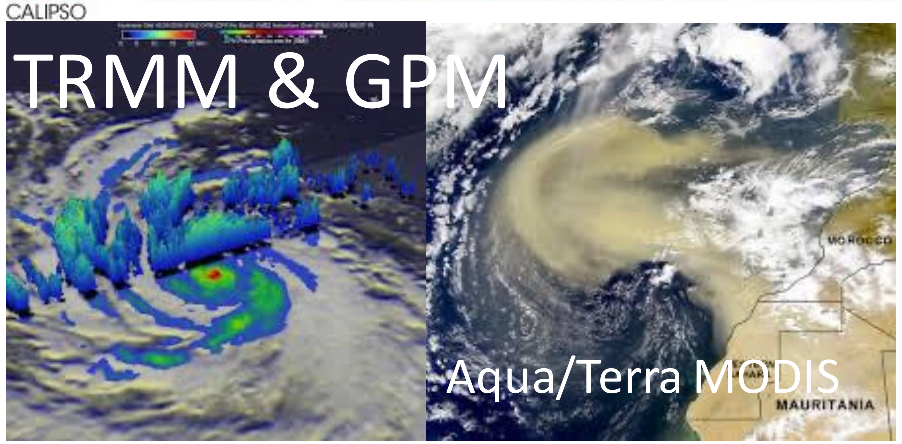
Continuity with the Past ✚ Combined with Sensor Advancements of the Present → An integrated global observing system of the future

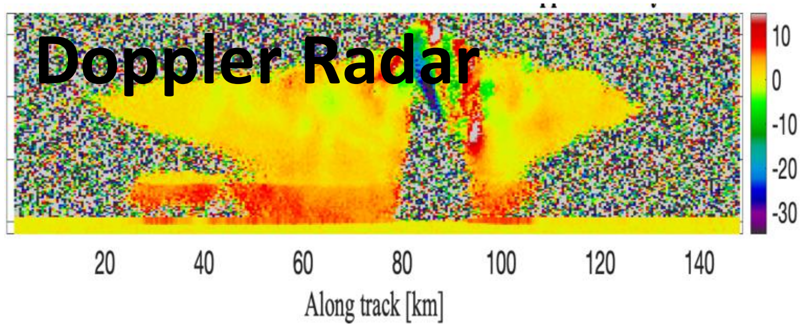


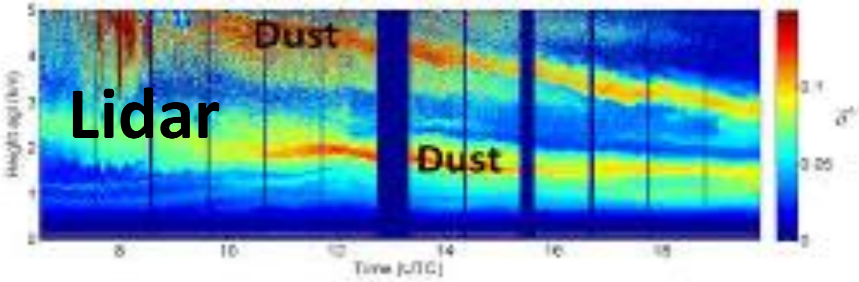
CloudSat

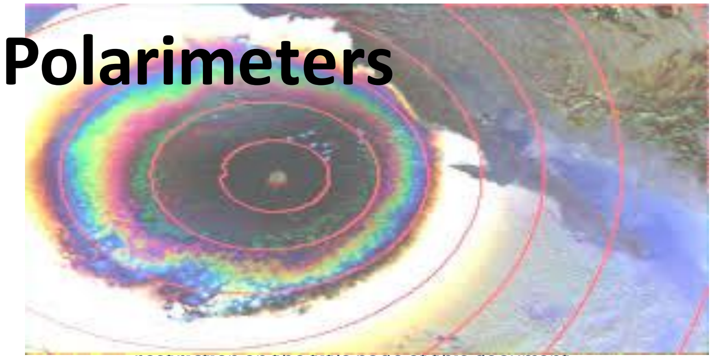


CALIPSO









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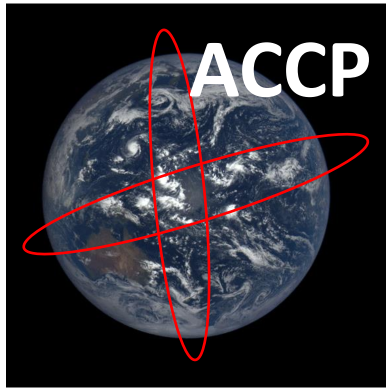
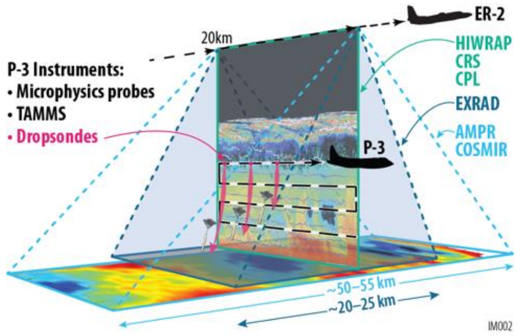
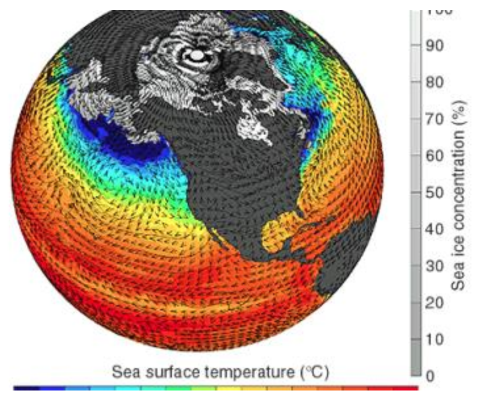


Suborbital Science



Earth System Models



Aerosols and Clouds, Convection, and Precipitation (ACCP) Architectures

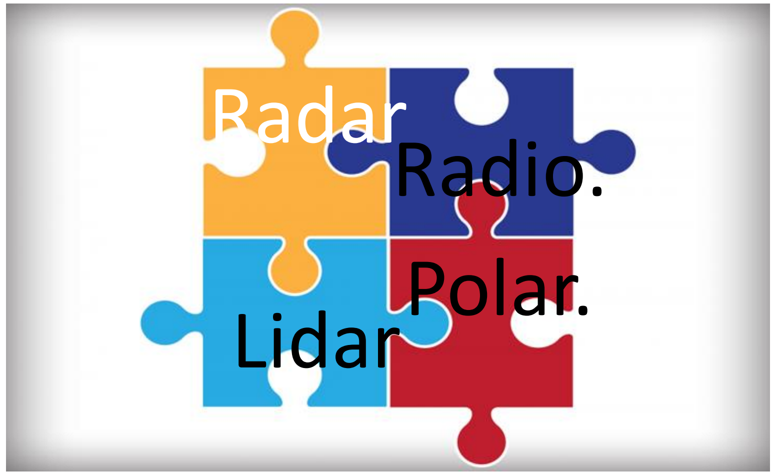
ACCP Architecture Study

Broad range of science measurement capabilities being considered:

- Radars include W, Ka, Ku bands, Doppler and non-Doppler, scanning and nadir only
- Radiometers include cross-track and conically scanning, frequencies ranging from 10 to 883 GHz
- Lidars include 2 and 3 frequencies, backscatter and HSRL
- Polarimeters include varying channels (5 to hyperspectral) and angles (5 to 255)
- Spectrometers include VIS, NIR, SWIR, LWIR, TIR

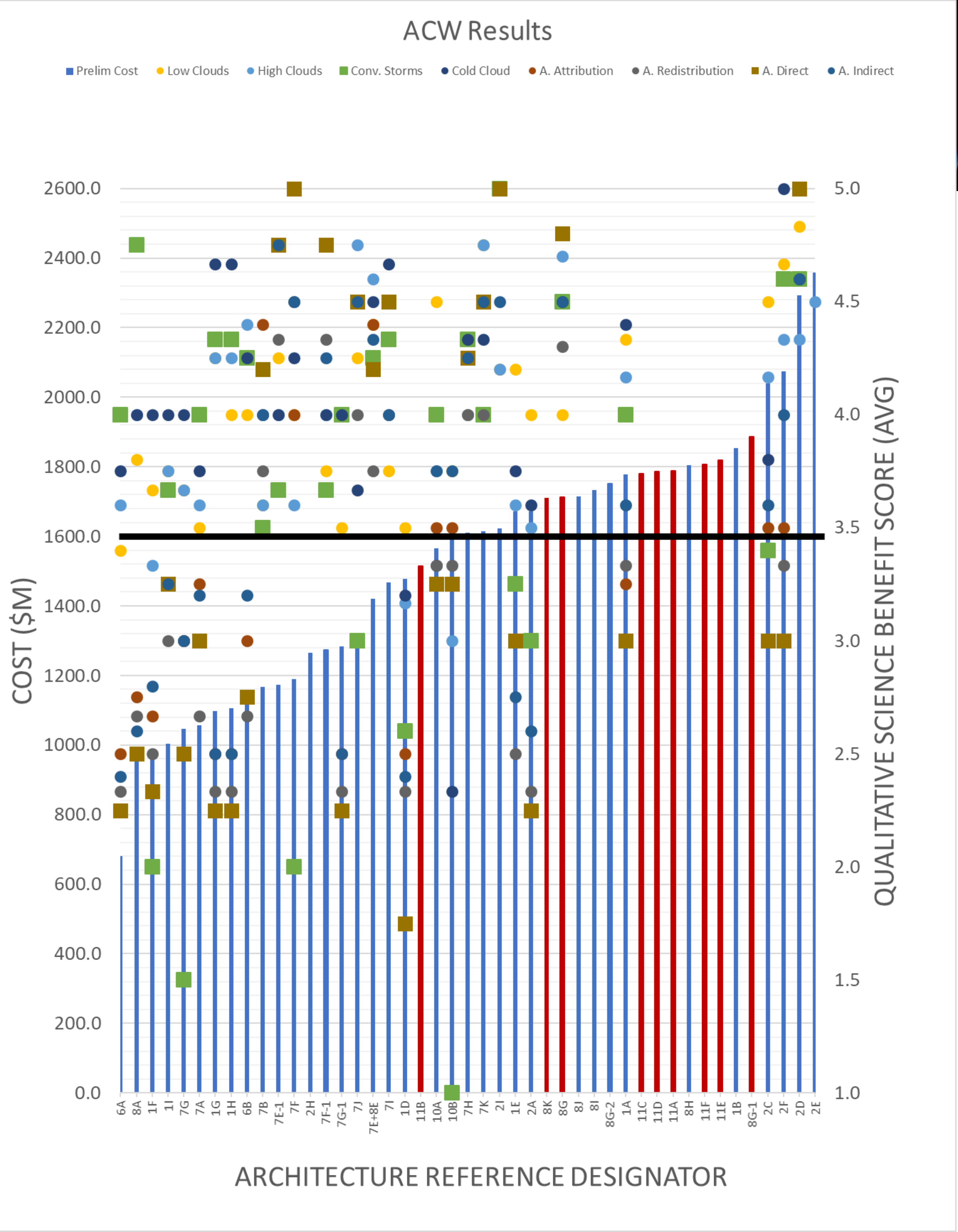
Key science drivers to balance

- High latitude coverage
- Diurnal cycle
- Data continuity
- Radiation measurements
- Consideration of new approaches
  —Time-differencing of satellite obs



Architectures Constructed To Date (Initial Costing)

- *The chart to the right provides a summary of the 45 Observing Systems that have been constructed to date*
- *The cost numbers were preliminary and were used for relativistic assessment*
- *The Science Benefit scores were preliminary and were used for relativistic assessment*
- *We selected the 9 Architectures in Red for deeper study which is in progress*
- *The 9 Architectures are associated with ~3 distinct Science Implementations*

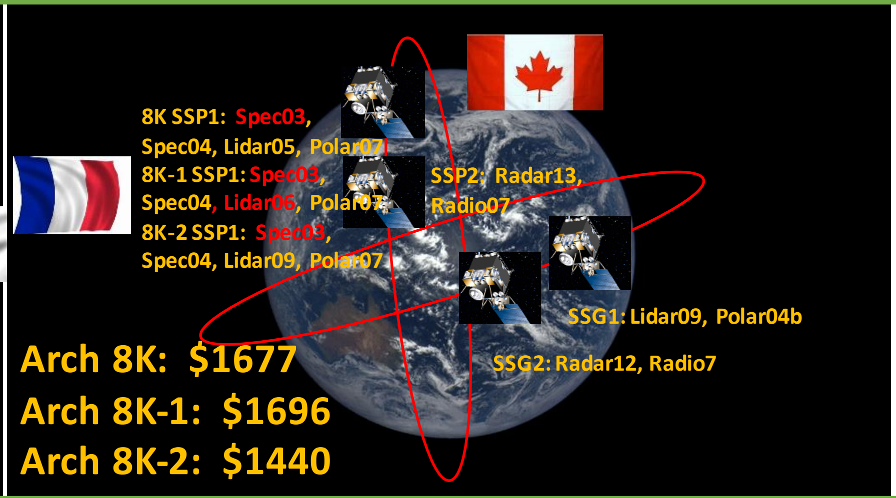


SATM Rel F/5 Goals/8 Objectives

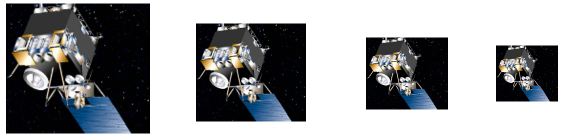
Science Implementation Strategies

1.Seasonal Vertically Resolved Cloud & Aerosol Processes At Various Times of Day

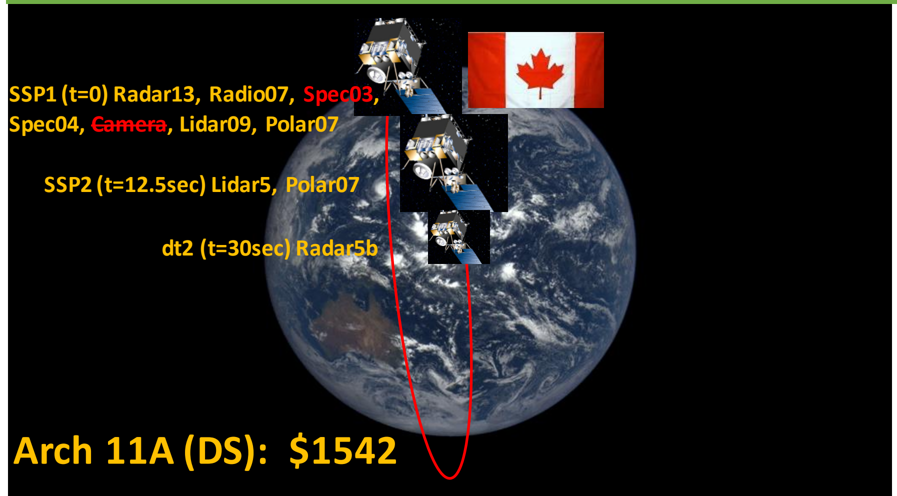
Rev 2 Costing

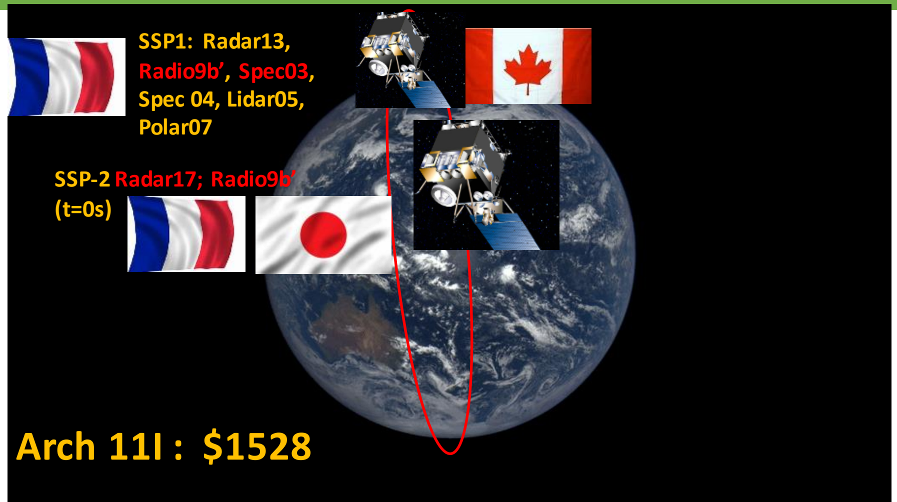


Mission Implementations

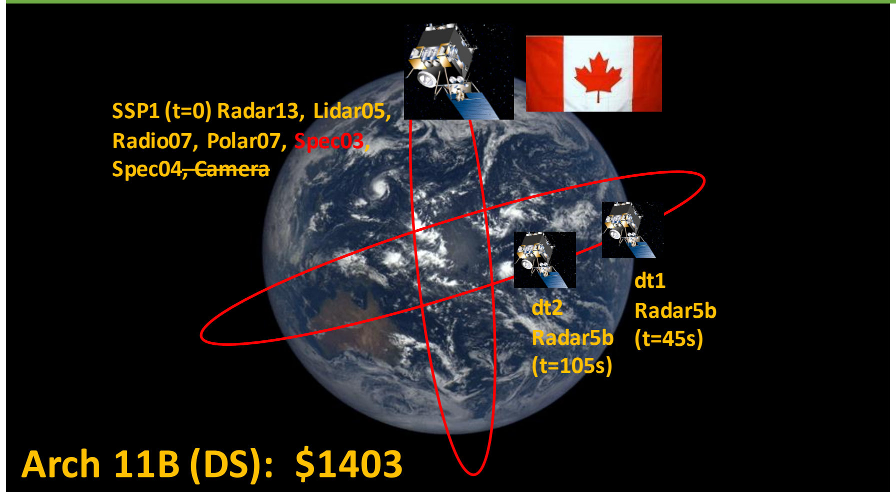


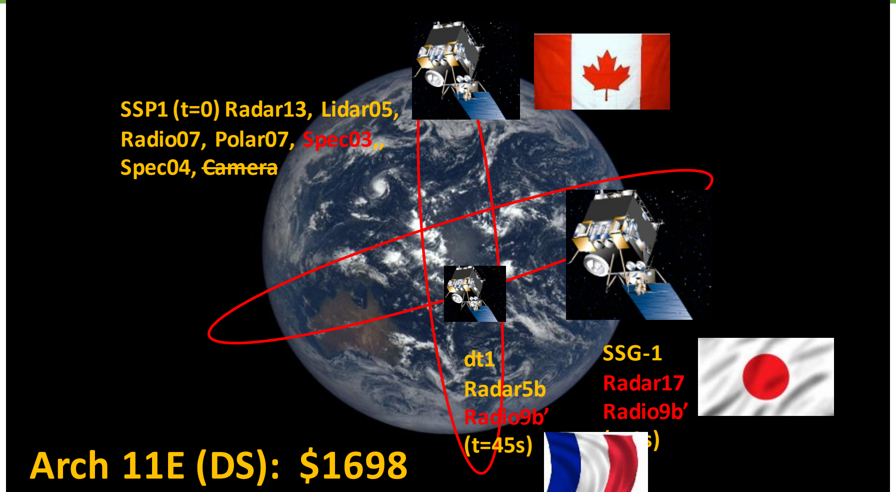
2.Seasonal Vertically Resolved Cloud & Aerosol Processes Over Several Min Time Scales for Process Evolution With De-Scopes

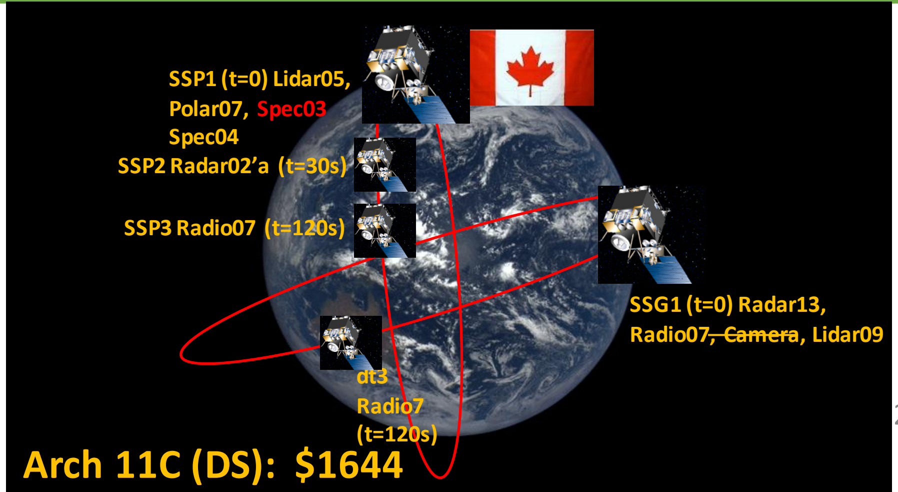


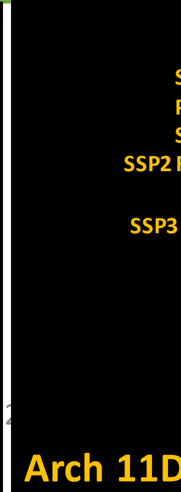


3.Seasonal Vertically Resolved Cloud & Aerosol Processes Over Several Min Time Scales for Process Evolution & At Various Times of Day With De-Scopes









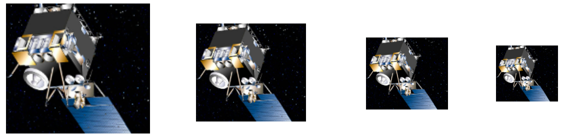
SATM Rel F/5 Goals/8 Objectives

Science Implementation Strategies

1.Seasonal Vertically Resolved Cloud & Aerosol Processes At Various Times of Day

Rev 2 Costing

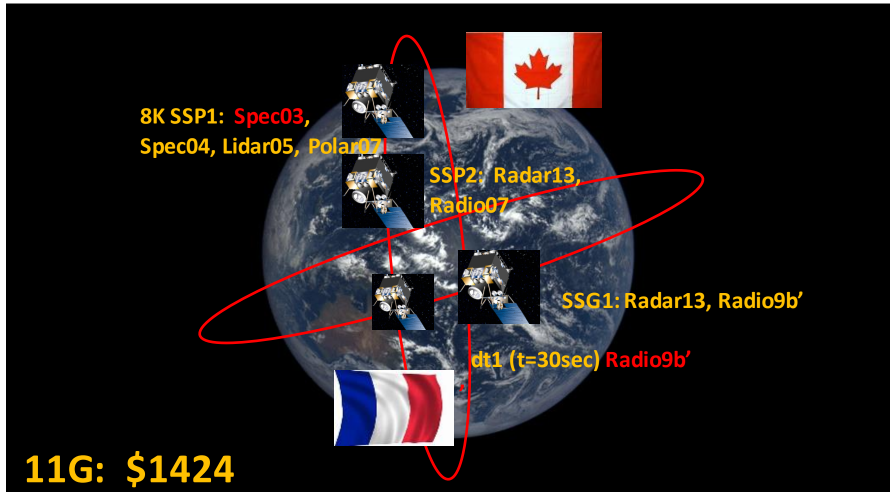
Mission Implementations

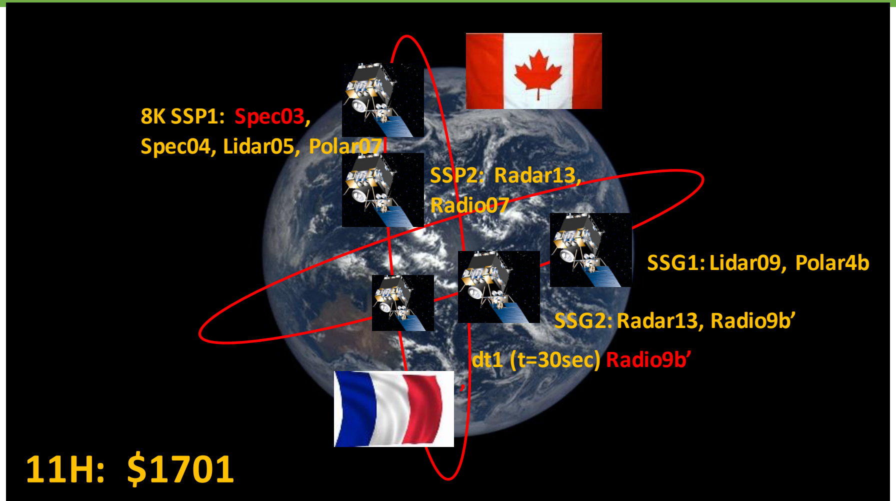


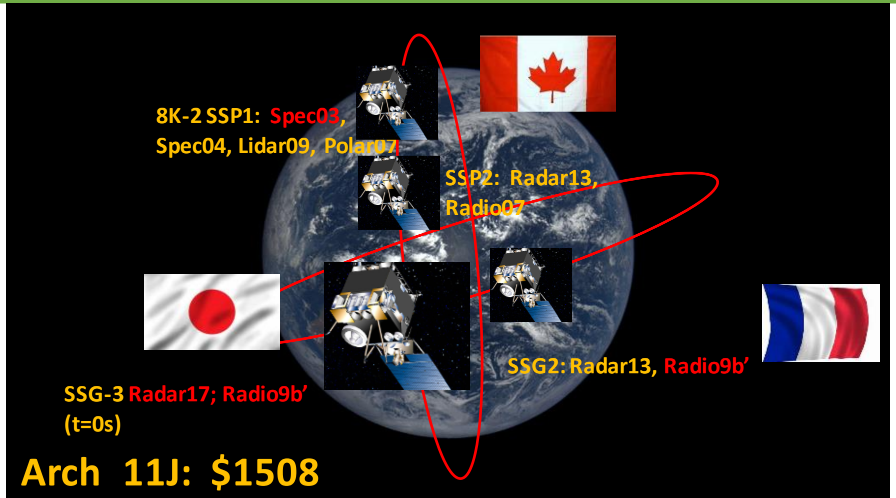
Large *Med* *ESPA Grande* *ESPA <~160kg*

2.Seasonal Vertically Resolved Cloud & Aerosol Processes Over Several Min Time Scales for Process Evolution With De-Scopes

3.Seasonal Vertically Resolved Cloud & Aerosol Processes Over Several Min Time Scales for Process Evolution & At Various Times of Day With De-Scopes







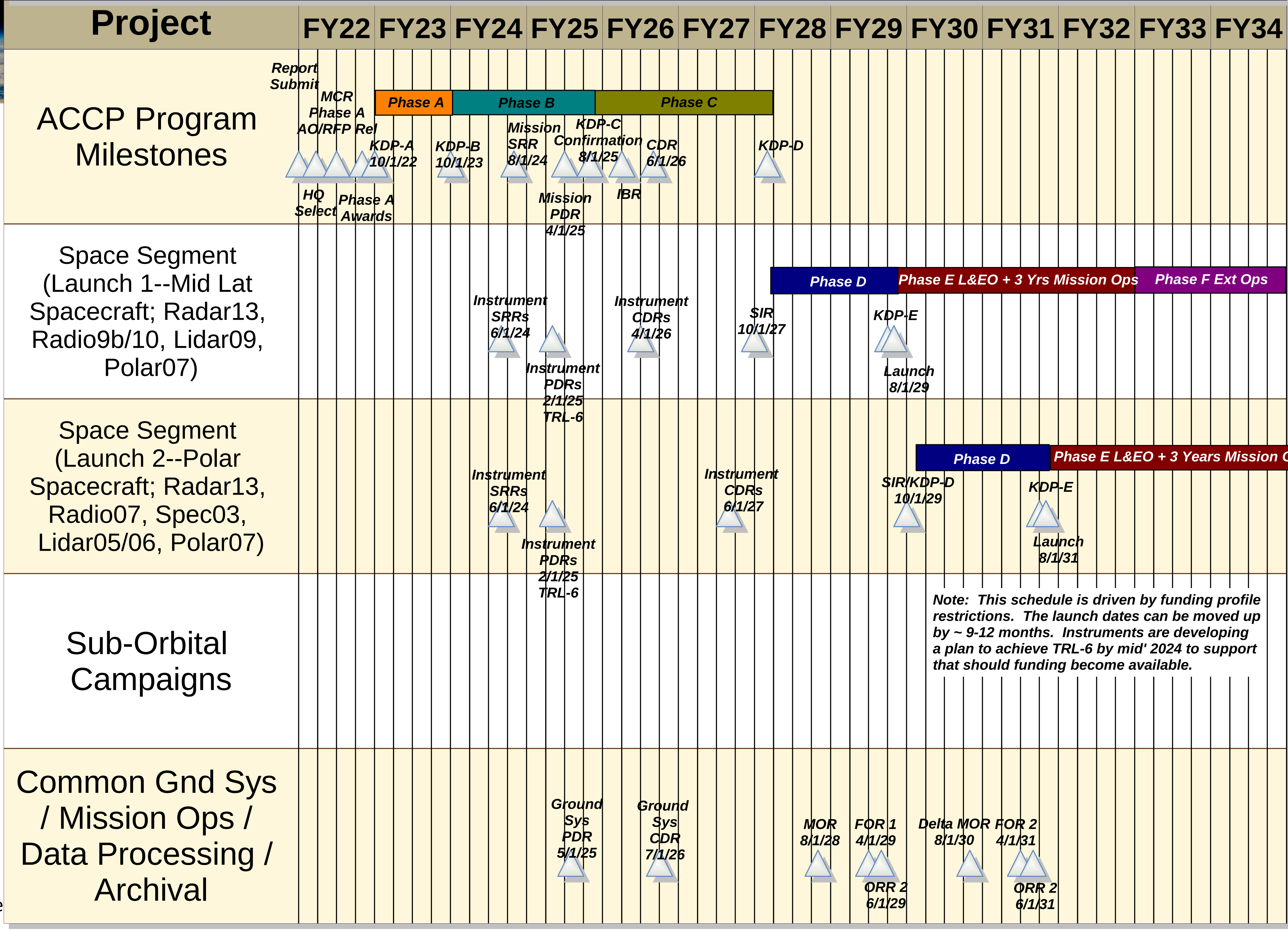
ACCP Notional Mission Schedule

Funding profile forces separate launches 2 yrs apart

We need to consider the Science Benefit of

1. the 1st Launch assets alone
2. the 1 year period of overlap
3. the 2nd Launch assets alone

ACCP Program High Level Schedule For Architecture 8G and 8K



Doppler & Lidar In Both Orbit Planes/Diurnal / No Delta t

Architecture	Radar			Lidar			Programmatic Pros	Cost (*Meets Funding Profile)
	Ka	Ku	W	2+0	2+1	3+2		
8G GPM Orbit	D		D	✓			CSA Contribution	$1640* > Cap
8G Polar Orbit	D		D		✓			
8G-1 GPM Orbit	D	D	ND	✓			CSA & JAXA Contribution	$1859 >> Cap
8G-1 Polar Orbit	D		D		✓			
8K GPM Orbit	D		ND	✓			CSA Contribution	$1677* > Cap
8K Polar Orbit	D		D		✓			
8K-1 GPM Orbit	D		ND	✓			CSA Contribution CNES	$1696 >> Cap
8K-1 Polar Orbit	D		D			✓		
8K-2 GPM Orbit	D		ND	✓			CSA Contribution	$1444* < Cap
8K-2 Polar Orbit	D		D	✓				

Single Orbit Plane With Doppler & Lidar / No Diurnal / Delta t

Architecture	Radar			Lidar			Delta t Method	Programmatic Pros	Cost (*Meets Funding Profile)
	Ka	Ku	W	2+0	2+1	3+2			
11A Launch 1	D		D	✓			Radar	CSA Contribution	$1542* < Cap
11A Launch 2					✓				
11F Launch 1	D		D	✓			CNES Radiometer	CSA & CNES Contribution	$1500* < Cap
11F Launch 2					✓				
11I Single Launch—Defers ACCP Science 1-2 yrs	D	D	D		✓		CNES Radiometer	CSA, CNES, & JAXA Contribution CNES & JAXA in Polar Orbit Not Ideal; GPM Orbit Desired would add Diurnal	$1528* < Cap

Doppler & Lidar In One Orbit Plane/Diurnal / Delta t

Architecture	Radar			Lidar			Delta t	Programmatic Pros	Cost (*Meets Funding Profile)
	Ka	Ku	W	2+0	2+1	3+2			
11B GPM Orbit	ND						Radar	CSA Contribution	$1403* < Cap
11B Polar Orbit	D		D		✓				
11E GPM Orbit	ND	D					CNES Radiometer	CNES, CSA & JAXA Contribution	$1698 >> Cap
11E Polar Orbit	D		D		✓				
11C GPM Orbit	D		D				Radiometer	CSA Contribution	$1644* > Cap
11C Polar Orbit	ND		ND		✓				
11D GPM Orbit	D		D	✓			CNES Radiometer	CNES & CSA Contribution	$1668* > Cap
11D Polar Orbit	ND		ND		✓				
11G GPM Orbit	D		D				CNES Radiometer	CNES & CSA Contribution	$1424* < Cap
11G Polar Orbit	D		D		✓				
11H GPM Orbit	D		D	✓			CNES Radiometer	CNES & CSA Contribution	$1701 >> Cap
11H Polar Orbit	D		D		✓				
11J GPM Orbit	D		D				CNES Radiometer	CNES, CSA & JAXA Contribution	$1508* < Cap
11J Polar Orbit	D	D	D	✓					

Assessment of Architectures

- Architectures 8G and 8K, 8K-1, 8K-2 have been preliminarily scored for Science Benefit; however, the simulations are still maturing to include more comprehensive and complex scenes with use cases which will provide discrimination between Lidar configurations for August 2020 Architecture Review that can be used for scoring all Architectures
  - 532/1064nm Backscatter/Polarimeter (in Architecture 8K-2)
  - 2+1 532(HSRL)/1064nm / Polarimeter (in Architecture 8K)
  - 3+2 355(HSRL)/532(HSRL)/1064nm / Polarimeter (in Architecture 8K-1)
- Programmatic aspects of Lidar Trade Study (Final Costs, Independent Technology Readiness Assessments, Risk Assessments) will conclude in July for August 2020 Architecture Review
- Science Benefit Scoring of the Radar/Radiometer combinations in Architecture 11s will conclude in October 2020.
  - These will include methods for scoring the benefit of sampling including Diurnal and Delta t measurements
- Flow down from ACCP Science Goals and Objectives to Instrument Capabilities and final Science Benefit scoring may continue into the Fall 2020 for Architectures which are possible within cost cap
- Final 3 Architectures will provide different Science Emphases / Implementation Strategies within the cost cap

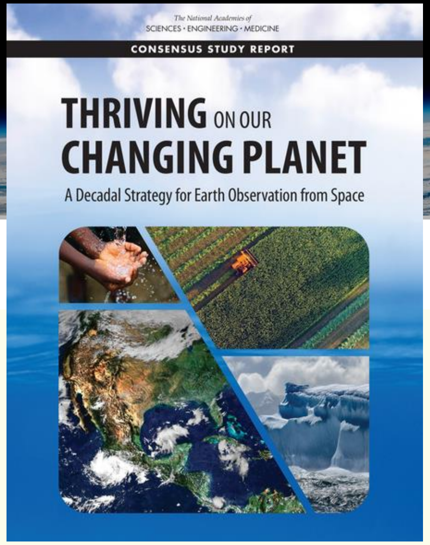
Aerosols and Clouds, Convection, and Precipitation (ACCP) Science Evaluation of Architectures

Arlindo da Silva & Scott Braun
On behalf of the SALT

Based on SATM and SIT Q-scores as Compiled by Value Framework Team

ACCP Community Forum
22 June 2020

Role of Science Assessments

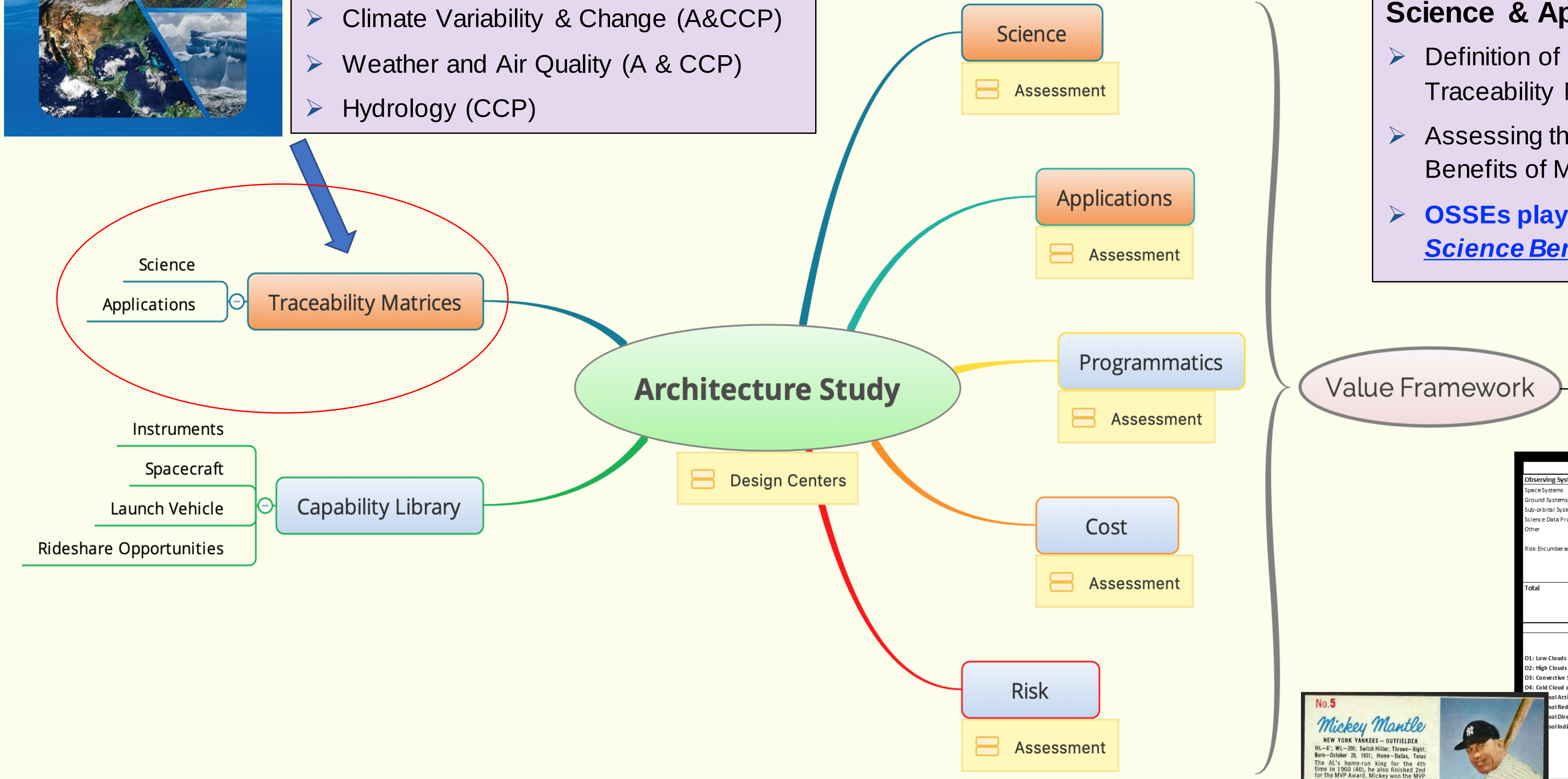


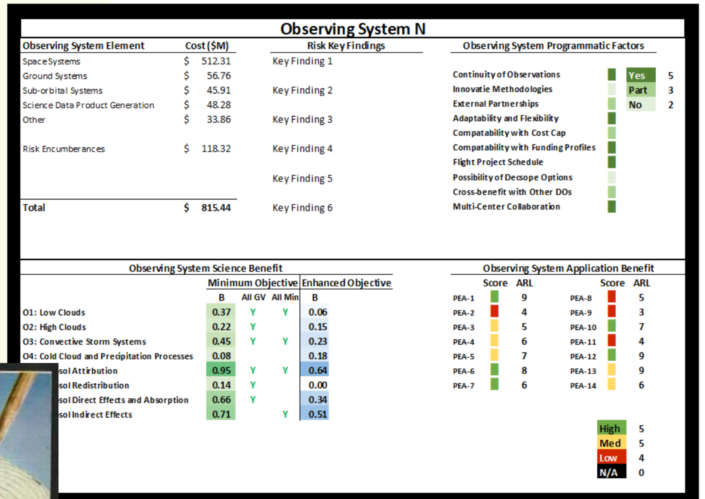
Relevant Decadal Survey Themes

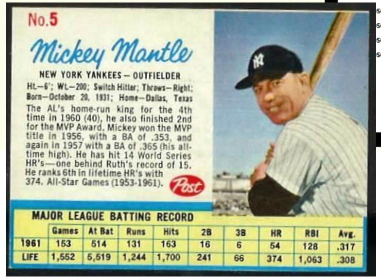
- Climate Variability & Change (A&CCP)
- Weather and Air Quality (A & CCP)
- Hydrology (CCP)

Science & Applications Activities

- Definition of Science & Applications Traceability Matrices
- Assessing the Science & Applications Benefits of Measurement Architectures
- **OSSEs play a critical role assessing the *Science Benefit* scores of Architectures**







VF Baseball Cards

Previous Architecture 8G

Inclined Orbit

SSG

Radar13
Ka/W Doppler, nadir only, microsat

S_Polar07
35 kg, V, VNIR-SWIR Pol; .5% DOLP; 550km Swath; 60/10 angles

S_Lidar09
532 backscatter, 1064 backscatter, 4500 Hz, 5/3 mJ, 0.6 m

S-Radio09b
183.3 SSB FI-DC-7GHz, 325.5 SSB FI-DC-10Gzh, small, 35kg

S-Radio10
670, H&V-pol, cubesat (1.3 kg; 8W; TRL 6 by 2024)

1500 kg

Polar Orbit

SSP

Radar13
Ka/W Doppler, nadir only, microsat

S_Polar07
35 kg, V, VNIR-SWIR Pol; .5% DOLP; 550km Swath; 60/10 angles

S_Lidar05
532 HSRL, 1064 backscatter

S-Radio07
118(8 channels), 240, 310, 380(8 channels), 660, 880, cubesat, 3kg

S-Spec03
21kg, Nadir LWIR/FIR, Limb LWIR

1900 kg

Architecture 8K Series

Inclined Orbit

SSG

Radar13
Ka/W Doppler, nadir only, microsat

8G→8K
Radar: WD,KaD —> W,KaD

S_Polar07
35 kg, V, VNIR-SWIR Pol; .5% DOLP; 550km Swath; 60/10 angles

8G→8K:
Polarimeter: 500m —> 1km

S_Lidar09
532 backscatter, 1064 backscatter, 4500 Hz, 5/3 mJ, 0.6 m

S-Radio09b
183.3 SSB FI-DC-7GHz, 325.5 SSB FI-DC-10Gzh, small, 35kg

S-Radio10
670, H&V-pol, cubesat (1.3 kg; 8W; TRL 6 by 2024)

8G→8K: Radio09b, 10 —> Radio07

1500 kg

Same for 8K, 8K-1, 8K-2

Polar Orbit

SSP

Radar13
Ka/W Doppler, nadir only, microsat

S_Polar07
35 kg, V, VNIR-SWIR Pol; .5% DOLP; 550km Swath; 60/10 angles

S_Lidar05
532 HSRL, 1064 backscatter

8K→8K-1: VIS HSRL —> UV&VIS HSRL

8K→8K-2: VIS HSRL —> Backscatter

S-Radio07
118(8 channels), 240, 310, 380(8 channels), 660, 880, cubesat, 3kg

S-Spec03
21kg, Nadir LWIR/FIR, Limb LWIR

1900 kg

3 Lidar Configurations

Scoring the Science Benefits of Architectures

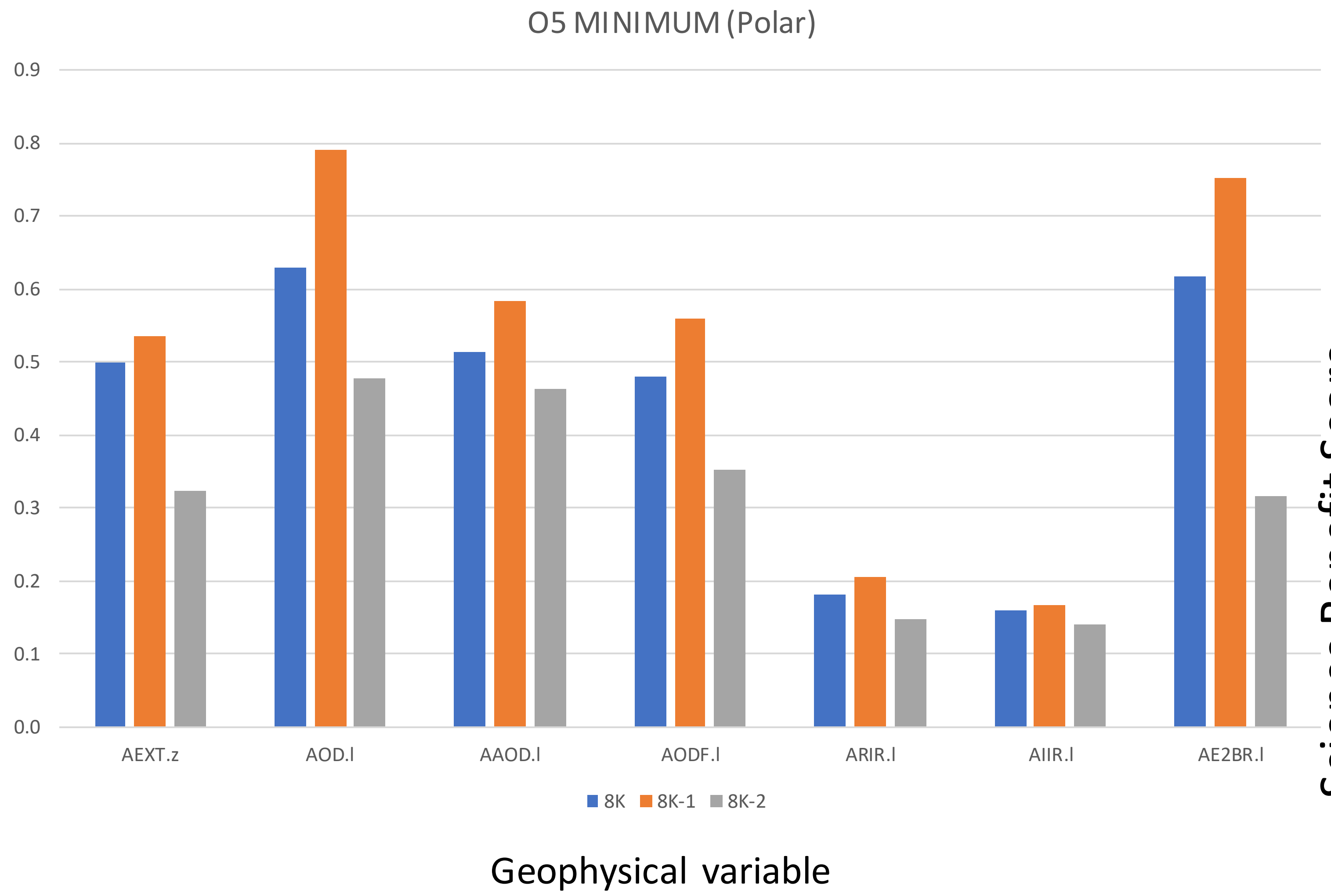
Utility: degree to which Geophysical Variable (GV) addresses the objective if it were measured within the uncertainties specified in the SATM.

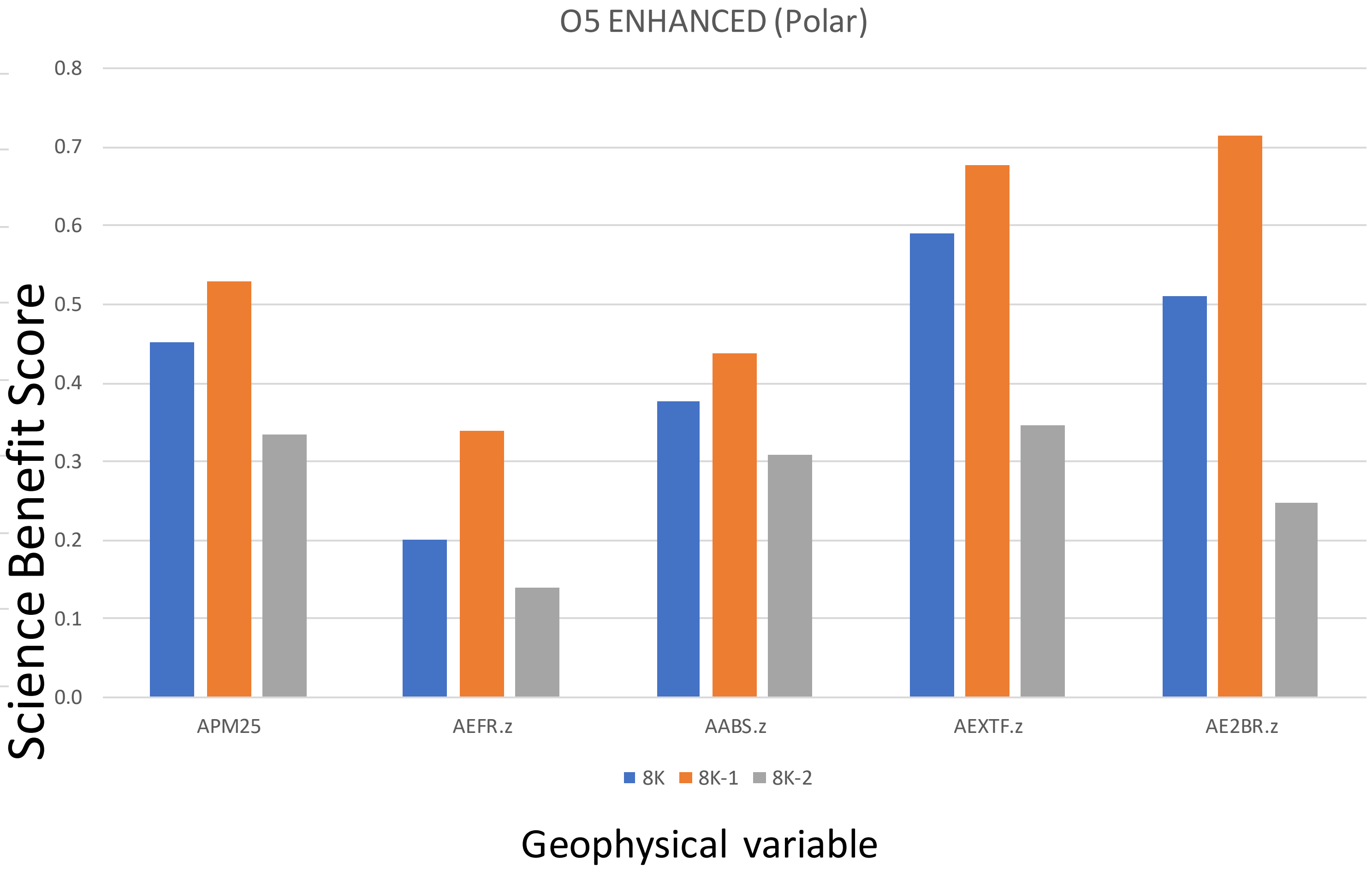
$$\text{Science Benefit Score (for Objective)} = \frac{1}{N}\sum_{\text{GVs}} \underbrace{\text{Utility of GV for Objective}}_{\text{(SALT)}} \times \underbrace{\text{Quality of GV given Measurements}}_{\text{(SIT)}}$$

Quality: degree to which measurements provide the desired geophysical variable. OSSEs inform the quality assessment.

Similar to approach outlined on *Continuity of NASA Earth Observations from Space* report (NAS 2015)

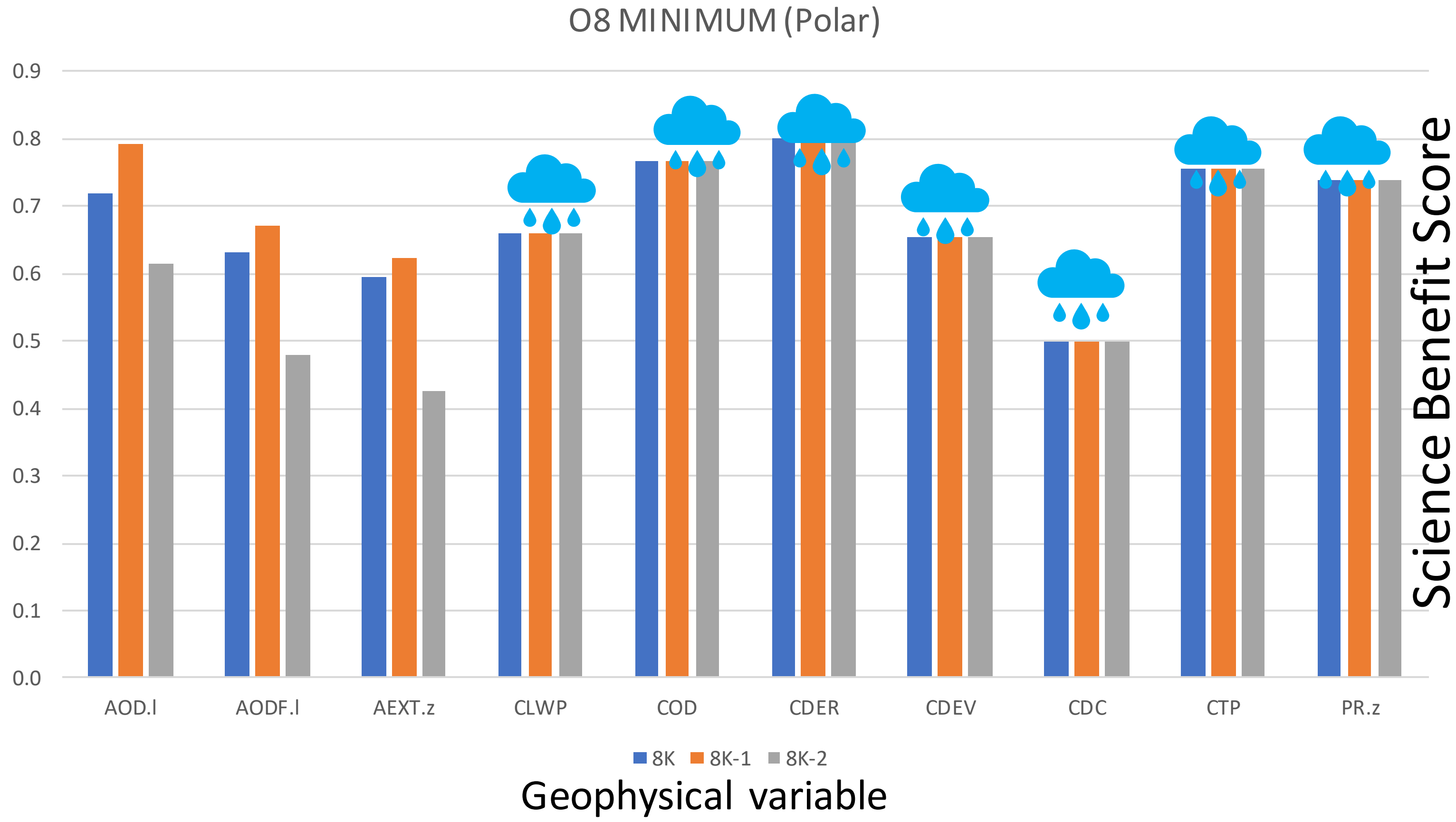
Example: O5 Aerosol Attribution & AQ (Polar)

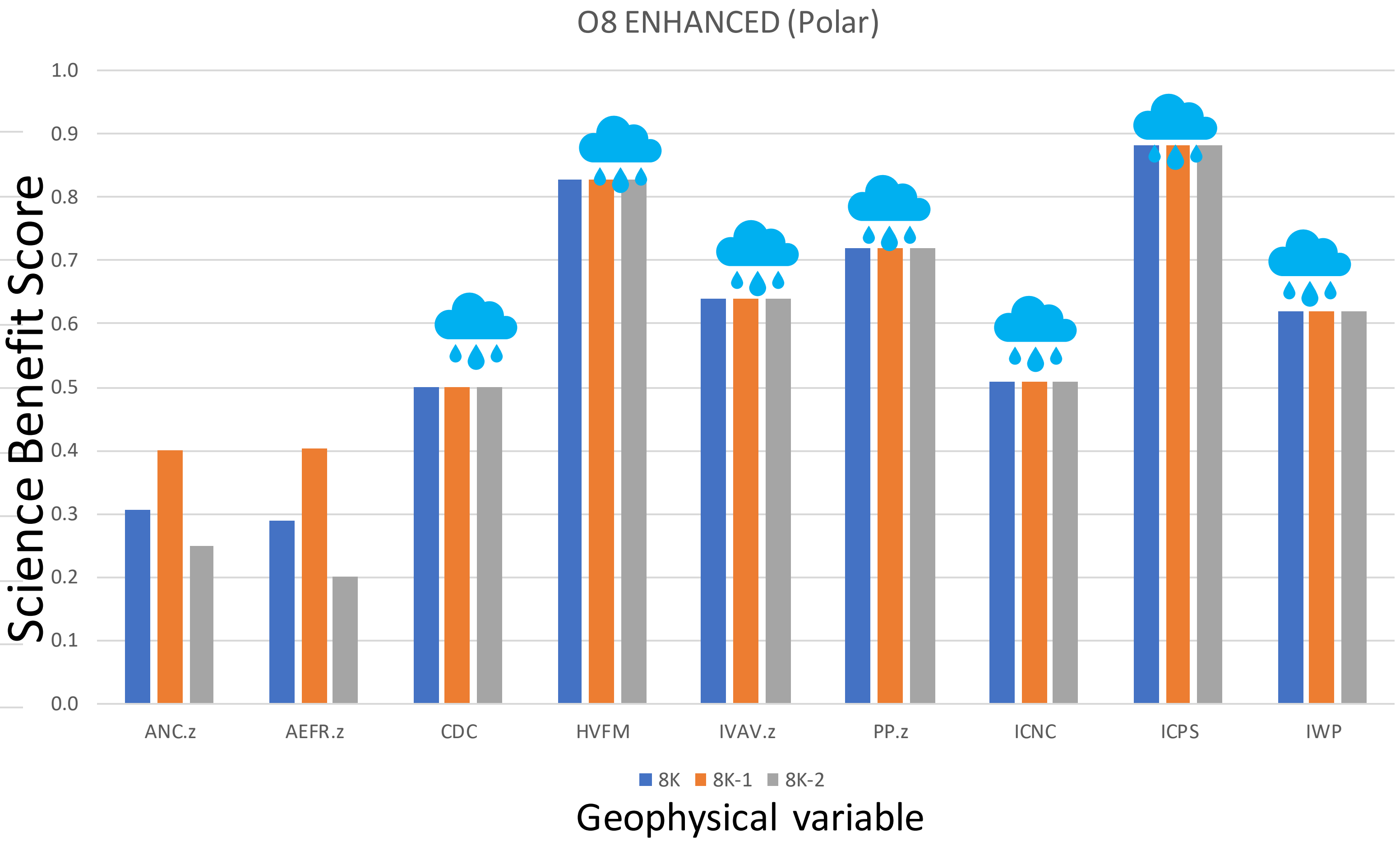




Weights: Land = 0.7 Ocean = 0.3

Example: O8 Aerosol Indirect Effects (Polar)





Notice Impact of CCP Variables

Weights: Land = 0.5 Ocean = 0.5

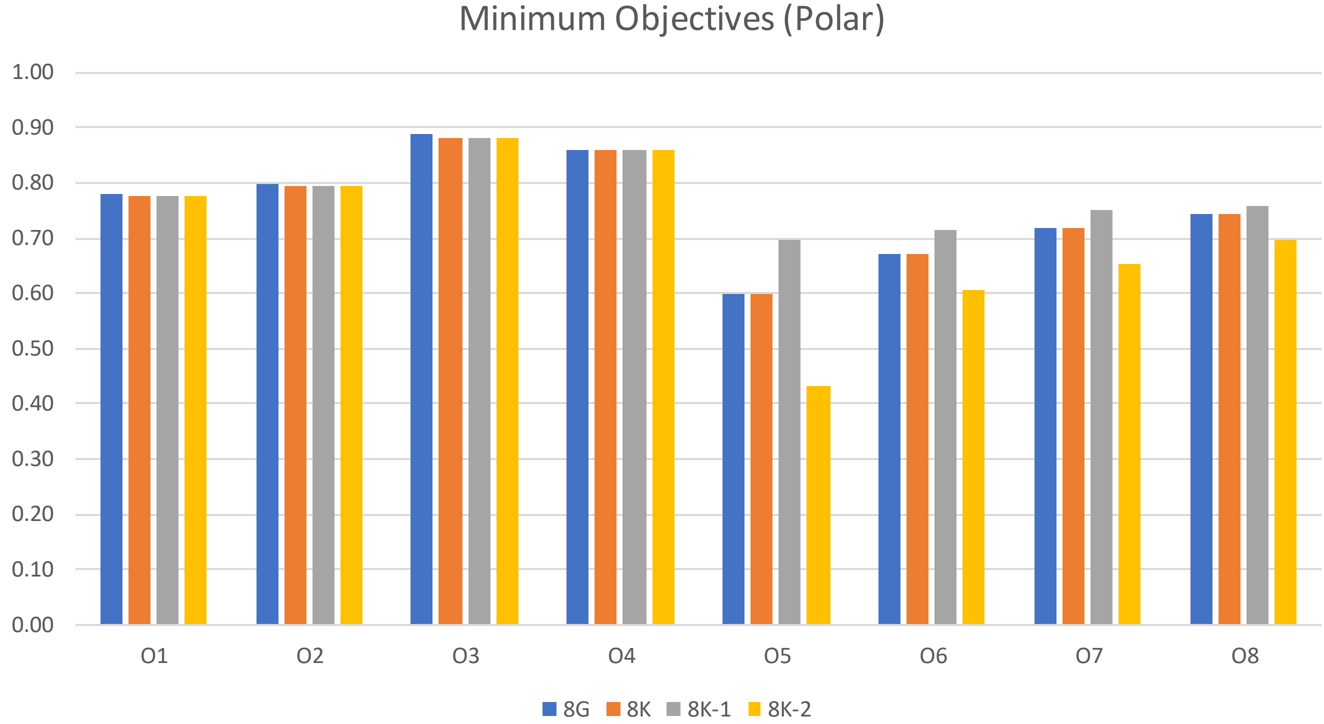
Summary: Polar Orbit

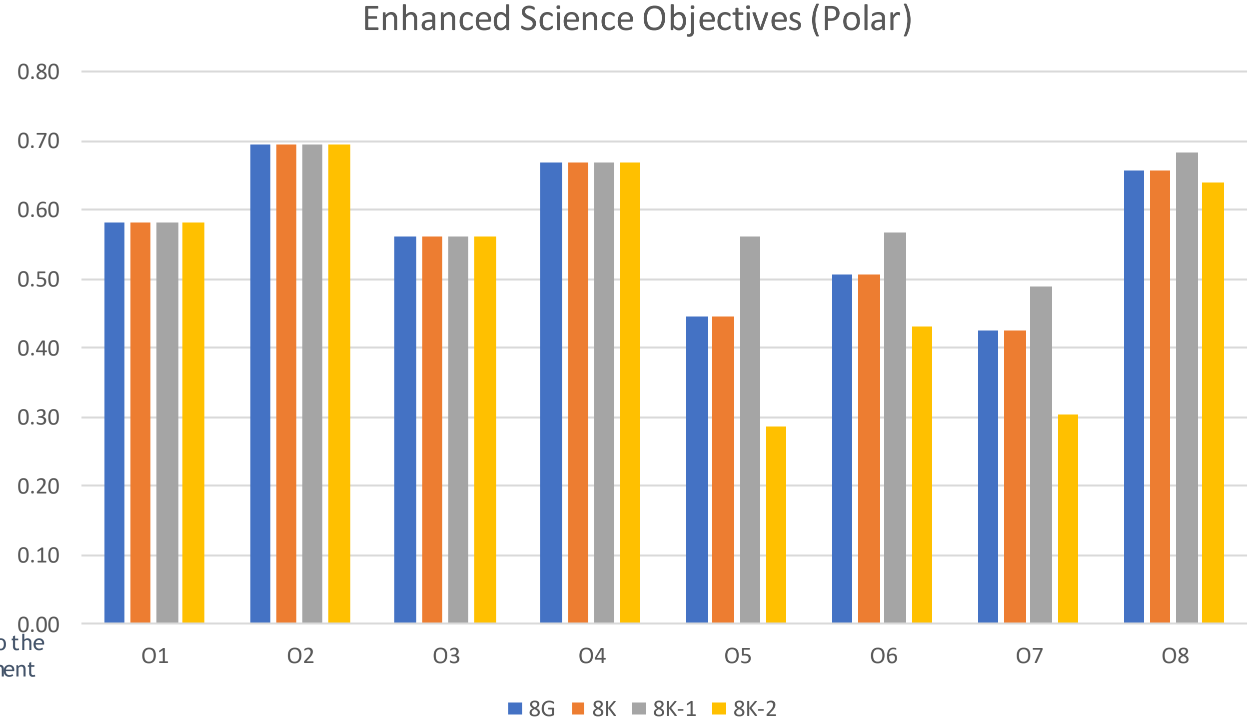
Minimum:

- ❑ Essentially same score for CCP O1-O4 for all architectures
  - ➢ Impact of Lidar on cloud not fully accessed
  - ➢ Aerosol GVs only appear in O3!
- ❑ Scores for Aerosol O5-O8 consistent with lidar capabilities:
  - ○ Lidar 06 (UV/VIS HSRL) slightly better than Lidar 05 (VIS HSRL)
  - ○ Backscatter lidar shows a greater degradation of scores for O5-O7
  - ○ O8 dominated by CCP GVs!

Enhanced:

- ❑ Same scores O1-O4 scores for 8G & 8K series
- ❑ Aerosol scores O5-O8 consistent with Minimum





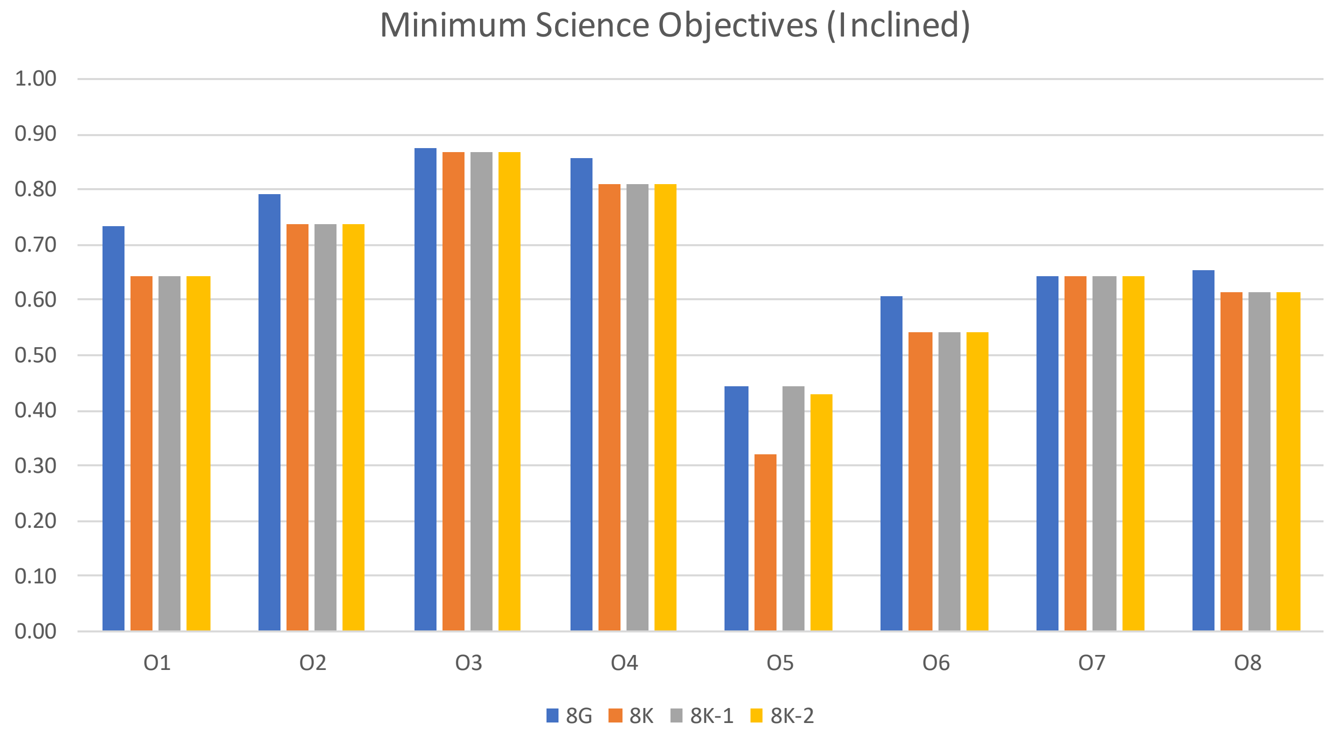
Summary: Inclined Orbit

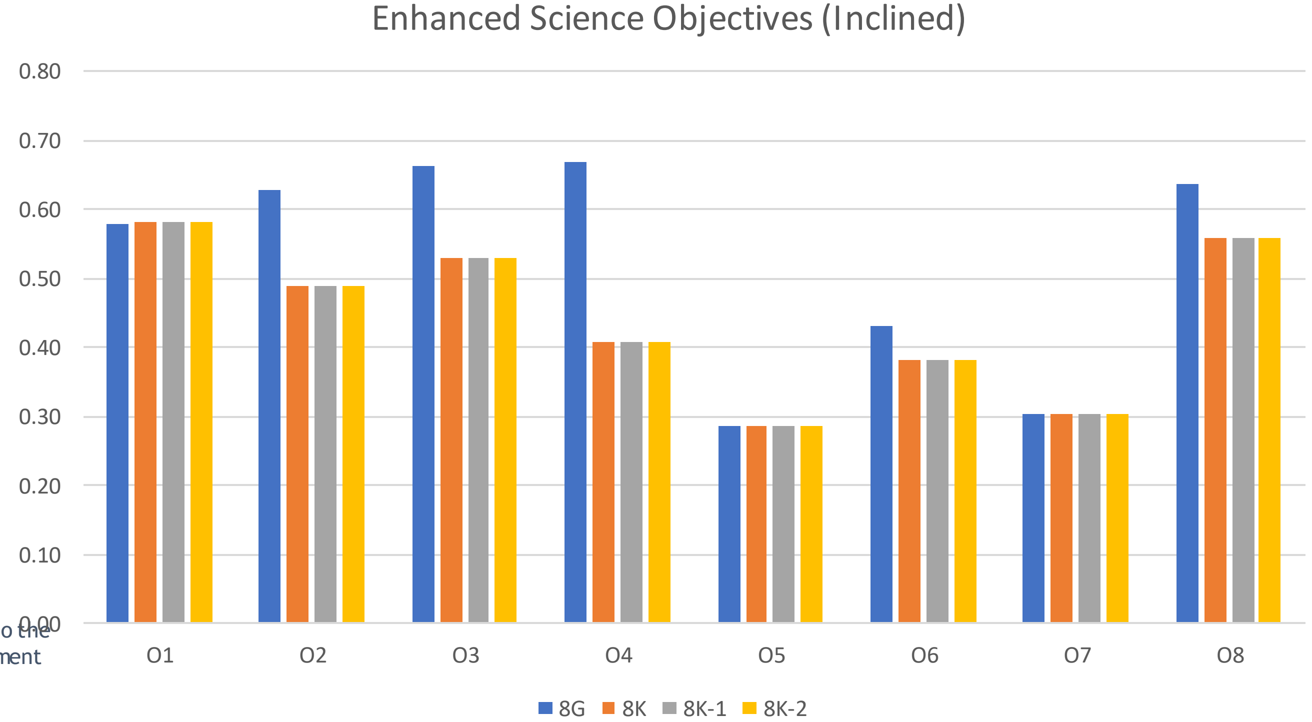
Minimum:

- 8G→8K: Loss of W Doppler (and perhaps lower spatial resolution polarimeter) impact the scores for O1, O2 & O4 (but not O3)
- 8G→8K: Loss of scores for O5 attributed to lower resolution polarimeter
- Otherwise, flat for 8K series as expected

Enhanced:

- 8G→8K: loss of W Doppler possible culprit for loss of scores for O2, O3, O4, O6 & O8
- Otherwise, flat for 8K series as expected





Preliminary Assessments

- Not every GV listed in SATM has been scored by SITs
  - Missing GVs were skipped in calculation of Benefit scores
  - It implicitly assumes that missing GV has same benefit score as the average benefit of the others
- All *Benefit Scores* reported are based on adjusted *Quality Scores* by means of “Expert Elicitation” by SIT study teams.
- Impact of different lidars on CCP O1-O4 objectives have not been assessed.
- Only individual satellites (Polar and GPM-orbit) have been scored; full sampling considerations have not been included: there are no scores for when both satellites are in space.
- Realism of OSSE scenarios is *work in progress* with improvements planed for the next assessment (August 2020):
  - ➢ Clouds, non-sphericity, vertical variability, etc.
  - ➢ Better account for spatial and temporal sample
  - ➢ Explicit assessment of Δt measurements

Aerosols and Clouds, Convection, and Precipitation (ACCP) Independent Science Community Committee (SCC) Feedback

Updates from the SCC

Co-Chairs:

Greg Carmichael and Sue van den Heever

National SCC:

Ana Barros, Andy Dessler,, Graham Feingold, Mike Fromm, Andrew Gettelman, Colette Heald, Steve Klein, Mark Kulie, Ruby Leung, Yang Liu, Johnny Luo, Allison McComiskey, James Nelson, Steve Nesbitt, Jeff Reid, Lynn Russell, Courtney Schumacher, Armin Sorooshian, and Rob Wood

International SCC:

Helene Chepfer, Yi Huang, Olivier Jourdan, Jean-François Leon, Hiro Masunaga, Rema Roca, and Kenta Suzuki

Overarching Comments: SCC – SALT - SIT Successes

1. Need to properly address radiation
2. Consider inclined orbits
3. Consider delta-t concepts
4. Need to enhance Overarching Goal
5. SIT-CCP graphical representations of multi-frequency Doppler capabilities and their close interactions with SCC WG O3

Overarching Comments – on Current Architectures

1. Polar spacecraft with complement HSRL, polarimetry, Doppler radars, radiometer and spectrometer is necessary to collectively advance all the objectives
2. Inclined orbit spacecraft to enable diurnal sampling is most important to some objectives, but adds significant value to all objectives.
3. Delta-time capabilities extends the science significantly by extending the capabilities to look at shorter time-scale processes.

Overarching Comments - Ongoing SCC Concerns

1. Objectives need be refined further, with narratives developed which provide specific illustrative use cases for how the measurements will be used to address the science questions associated with each objective. This will enable more meaningful evaluation of the different architectures.
2. Further discussion/evaluation of the value added by Delta-time sampling.
3. Continued efforts to refine overarching A-CCP goal to better convey how this mission will transform the science and the benefits to society.
4. Moving forward more reliance on small SCC-SALT-SIT teams working more closely together.
5. Planning modeling workshops – stay tuned for further information.

Aerosols and Clouds, Convection, and Precipitation (ACCP) Community Engagement

Plan Forward and Community Engagement Opportunities

- To follow ACCP activities and download materials relevant to study, check-out https://earth-dev.gsfc.nasa.gov/missions/accp

Sub-Orbital Working Group

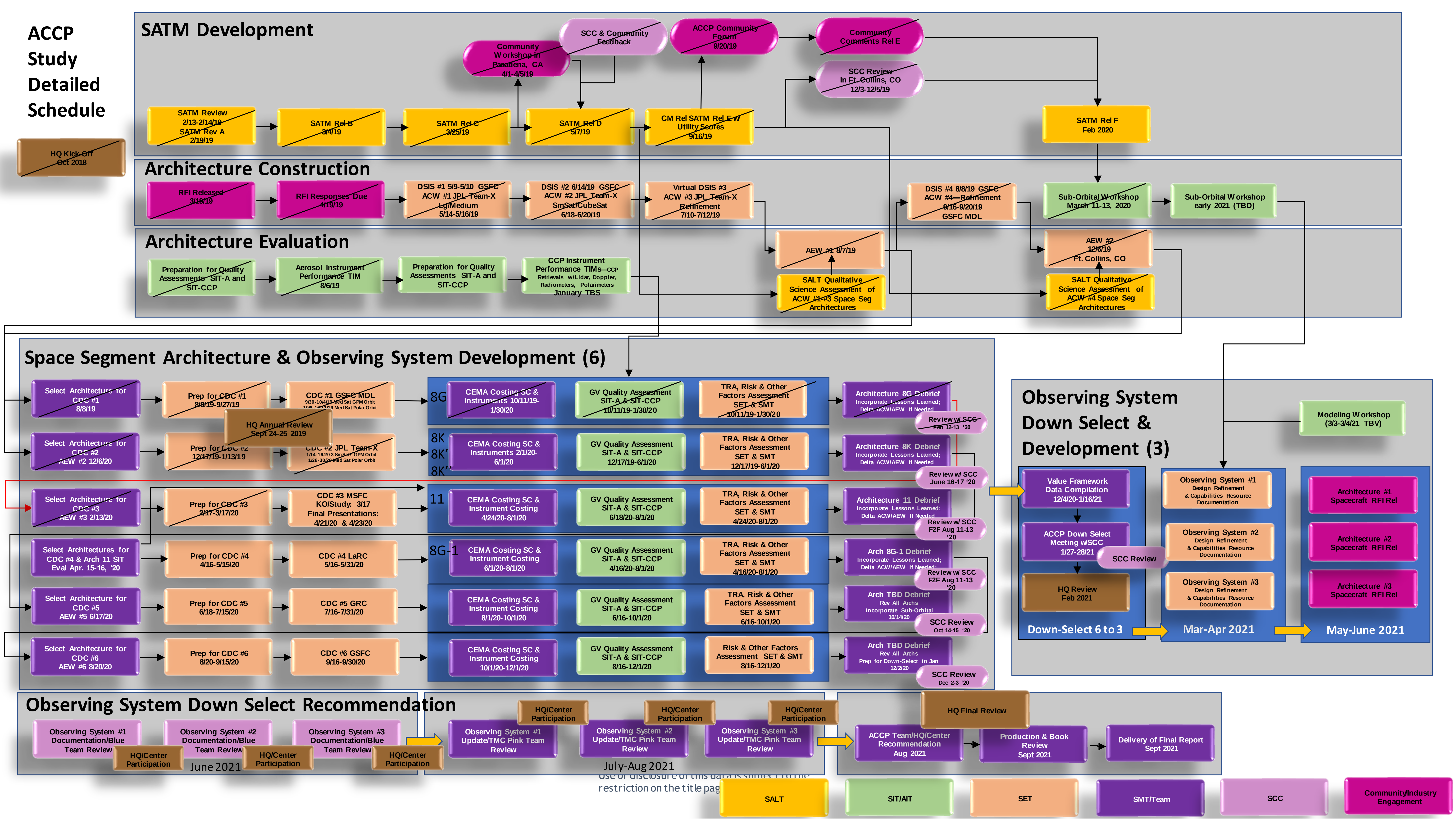
- **Strategy**: Science components, measurement approach(es)/methods, cal/val synergies
- **1st Sub-Orbital Workshop: 3/11-3/13/2020 (Virtual)-** Objective: science priorities for sub-orbital measurement element
  - Outcomes: Comprehensive list of science targets for each of 8 objectives; some common themes:
  - Coupled in situ/remote sensing linking process to dynamics; improved model physics to bridge local to global; process evolution and lifecycle; high space/time resolution; sub-cloud/near surface sampling in "satellite blind zones"(e.g., PBL); transitions between targeted environments
  - Synergies between science objectives identified;
  - Some common platform needs identified
  - Potential international contributions (sub-orbital and ground-based platforms/networks)
- **Current Activity:** Integrating science inputs across the 8 Objective templates…..
  - Combine, focus, and prioritize science inputs into a reduced set of impactful ACCP sub-orbital science targets consistent with SATM and recognizing program constraints (uncertainty in final architecture, budget etc.).
  - Synergies: [Low-Cloud, aerosol, radiation] [convection, high-clouds, radiation]
  - Distinct: Aspects of O4 (snowfall) and O5 (air quality) and O7 (DRE)
- **Moving Forward:** Summer- complete draft integration, consult with SALT/SCC, refine; Fall: Plan 2nd Workshop
  - 2nd Workshop: Implementation/approach focus: Given science priorities- what do approaches look like? (e.g., targeted field campaign analogues, systematic measurements ground/air, instruments etc.)
  - Larger, community meeting
  - Date : ~March 2021 (after down select); location TBD, but likely East or West Coast.

Modeling Working Group

- ACCP is planning a series of Virtual Modeling Workshops "Bringing models and observations together for Clouds and Aerosols".
  - The first will be in the Fall 2020 to
    - solicit community feedback on the architectures which best serve modeling and observational scientists prior to down-selection to final 3 architectures in January 2021
    - encourage interactions between the satellite and modeling community
  - More details will be coming from the Workshop Organizing Committee lead by Andrew Gettelman

Questions/Comments/Feedback?

Back-Up



ACCP Study Detailed Schedule
HQ Kick Off Oct 2018
SATM Development
SATM Review 2/13-2/14/19 SATM Rev A 2/19/19
SATM Rel B 3/4/19
SATM Rel C 3/25/19
Community Workshop in Pasadena, CA 4/1-4/5/19
SCC & Community Feedback
SATM Rel D 5/7/19
CM Rel SATM Rel E w Utility Scores 9/16/19
ACCP Community Forum 9/20/19
Community Comments Rel E
SCC Review In Ft Collins, CO 12/3-12/5/19
SATM Rel F Feb 2020
Architecture Construction
RFI Released 3/19/19
RFI Responses Due 4/19/19
DSIS #1 5/9-5/10 GSFC ACW #1 JPL Team-X Lg/Medium 5/14-5/16/19
DSIS #2 6/14/19 GSFC ACW #2 JPL Team-X SmSat/CubeSat 6/18-6/20/19
Virtual DSIS #3 ACW #3 JPL Team-X Refinement 7/10-7/12/19
DSIS #4 8/8/19 GSFC ACW #4 Refinement 9/16-9/20/19 GSFC MDL
Sub-Orbital Workshop March 11-13, 2020
Sub-Orbital Workshop early 2021 (TBD)
Architecture Evaluation
Preparation for Quality Assessments SIT-A and SIT-CCP
Aerosol Instrument Performance TIM 8/6/19
Preparation for Quality Assessments SIT-A and SIT-CCP
CCP Instrument Performance TIMs—CCP Retrievals w/Lidar, Doppler, Radiometers, Polarimeters January TBS
AEW #1 8/7/19
SALT Qualitative Science Assessment of ACW #1-#3 Space Seg Architectures
AEW #2 12/6/19 Ft. Collins, CO
SALT Qualitative Science Assessment of ACW #4 Space Seg Architectures
Space Segment Architecture & Observing System Development (6)
Select Architecture for CDC #1 8/8/19
Prep for CDC #1 8/8/19-9/27/19
CDC #1 GSFC MDL
HQ Annual Review Sept 24-25 2019
8G
CEMA Costing SC & Instruments 10/11/19-1/30/20
GV Quality Assessment SIT-A & SIT-CCP 10/11/19-1/30/20
TRA, Risk & Other Factors Assessment SET & SMT 10/11/19-1/30/20
Architecture 8G Debrief Incorporate Lessons Learned; Delta ACW/AEW If Needed
Review w/ SCC Feb 12-13 '20
Select Architecture for CDC #2 AEW #2 12/6/20
Prep for CDC #2 12/17/19-1/13/19
CDC #2 JPL Team-X
8K 8K' 8K''
CEMA Costing SC & Instruments 2/1/20-6/1/20
GV Quality Assessment SIT-A & SIT-CCP 12/17/19-6/1/20
TRA, Risk & Other Factors Assessment SET & SMT 12/17/19-6/1/20
Architecture 8K Debrief Incorporate Lessons Learned; Delta ACW/AEW If Needed
Review w/ SCC June 16-17 '20
Select Architecture for CDC #3 AEW #3 2/13/20
Prep for CDC #3 2/17-3/17/20
CDC #3 MSFC KO/Study: 3/17 Final Presentations: 4/21/20 & 4/23/20
11
CEMA Costing SC & Instrument Costing 4/24/20-8/1/20
GV Quality Assessment SIT-A & SIT-CCP 6/18/20-8/1/20
TRA, Risk & Other Factors Assessment SET & SMT 4/24/20-8/1/20
Architecture 11 Debrief Incorporate Lessons Learned; Delta ACW/AEW If Needed
Review w/ SCC F2F Aug 11-13 '20
Select Architectures for CDC #4 & Arch 11 SIT Eval Apr. 15-16, '20
Prep for CDC #4 4/16-5/15/20
CDC #4 LaRC 5/16-5/31/20
8G-1
CEMA Costing SC & Instrument Costing 6/1/20-8/1/20
GV Quality Assessment SIT-A & SIT-CCP 4/16/20-8/1/20
TRA, Risk & Other Factors Assessment SET & SMT 4/16/20-8/1/20
Arch 8G-1 Debrief Incorporate Lessons Learned; Delta ACW/AEW If Needed
Review w/ SCC F2F Aug 11-13 '20
Select Architecture for CDC #5 AEW #5 6/17/20
Prep for CDC #5 6/18-7/15/20
CDC #5 GRC 7/16-7/31/20
CEMA Costing SC & Instrument Costing 8/1/20-10/1/20
GV Quality Assessment SIT-A & SIT-CCP 6/16-10/1/20
TRA, Risk & Other Factors Assessment SET & SMT 6/16-10/1/20
Arch TBD Debrief Rev All Archs Incorporate Sub-Orbital 10/14/20
SCC Review Oct 14-15 '20
Select Architecture for CDC #6 AEW #6 8/20/20
Prep for CDC #6 8/20-9/15/20
CDC #6 GSFC 9/16-9/30/20
CEMA Costing SC & Instrument Costing 10/1/20-12/1/20
GV Quality Assessment SIT-A & SIT-CCP 8/16-12/1/20
Risk & Other Factors Assessment SET & SMT 8/16-12/1/20
Arch TBD Debrief Rev All Archs Prep for Down-Select in Jan 12/2/20
SCC Review Dec 2-3 '20
Observing System Down Select & Development (3)
Modeling Workshop (3/3-3/4/21 TBV)
Value Framework Data Compilation 12/4/20-1/16/21
ACCP Down Select Meeting w/SCC 1/27-28/21
SCC Review
HQ Review Feb 2021
Down-Select 6 to 3
Observing System #1 Design Refinement & Capabilities Resource Documentation
Observing System #2 Design Refinement & Capabilities Resource Documentation
Observing System #3 Design Refinement & Capabilities Resource Documentation
Mar-Apr 2021
Architecture #1 Spacecraft RFI Rel
Architecture #2 Spacecraft RFI Rel
Architecture #3 Spacecraft RFI Rel
May-June 2021
Observing System Down Select Recommendation
Observing System #1 Documentation/Blue Team Review
Observing System #2 Documentation/Blue Team Review
Observing System #3 Documentation/Blue Team Review
HQ/Center Participation
HQ/Center Participation
HQ/Center Participation
June 2021
HQ/Center Participation
HQ/Center Participation
HQ/Center Participation
Observing System #1 Update/TMC Pink Team Review
Observing System #2 Update/TMC Pink Team Review
Observing System #3 Update/TMC Pink Team Review
July-Aug 2021
HQ Final Review
ACCP Team/HQ/Center Recommendation Aug 2021
Production & Book Review Sept 2021
Delivery of Final Report Sept 2021
SALT
SIT/AIT
SET
SMT/Team
SCC
Community/Industry Engagement

Lidar Trade Study Milestones

	Estimated Completion
Updated Lidar Costing (3 Lidar Types)	Estimates Provided 6/8
	Updates in Work (due mid' July)
Technology Readiness Assessment (TRA) Presentations	
To TRA Panel	6/17-6/18 (completed)
TRA Panel Final Report	due mid' July
SIT-A/SALT Updated Science Benefit Scores	Initial Results 6/16 (completed)
	Updates for August 11-13 Review

JAXA Special Study Milestones

	Estimated Completion
Design Spacecraft with Radar 17/Radio07	Completed CDC #4 @ LaRC in June 4)
Updated Costs For Architectures with Radar 17	Preliminary Estimates 6/16 Updates in Work (due mid' July)
JAXA provide Technology Readiness Assessment for Radar 17 and plan to achieve TRL-6 by Mission PDR	due mid' July
SIT-CCP/SALT Updated Science Benefit Scores	due for August 11-13 Review

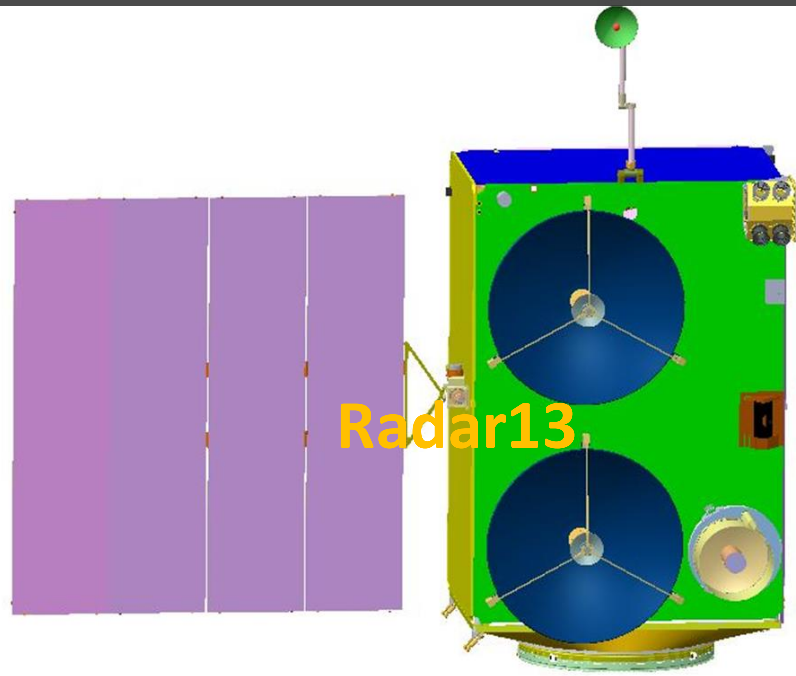
Key Decision Meeting August 11-13

August 11-13 Architecture Evaluation Review

- *Results of Science Benefit for JAXA Ku Doppler Radar*
- *Results of Science Benefit for Diurnal*
- *Results of Science Benefit for Delta t Measurements*
- *Update on all Architectures*
- *Status of Sub-Orbital Element of Observing System*
    - *Plans for March 2021 Sub-Orbital Workshop*
- *Plans for Modeling Working Group Meetings & Plans for Modeling Workshop(s)*
- *Decision on what to study in last CDC at GSFC in October 2020*
- *Plan leading up to January 2021 Decision on Final 3 Space Segment Architectures*

8G SSG Instruments

Parameter	S-Radar13
Center Frequencies (GHz)	35.6 / 94.05 (Ka / W)
Doppler Measurement (Yes/No?)	Yes / Yes
Swath Width (Km)	12.5 / NA
Range Resolution (m)	250 / 500
Horizontal Resolution @ nadir (along-track x cross-track, km x km)	2.5 x 2.5 (Ka) 2.0 x 1.0 (W)
Horizontal Resolution @ swath edge (along-track x cross-track, km x km)	2.5 x 2.5 (Ka) NA (W)
Noise-Equivalent Reflectivity (dBZ) (Single-shot reflectivity at 0 dB SNR)	+17.0 / -16.0
Minimum Detectable Reflectivity (dBZ) (Multi-shot reflectivity at 0 dB SNR)	+7.0 / -26.0
Reflectivity Measurement Accuracy (dB)	1.5 / 1.5
Reflectivity Measurement Dynamic Range	80 / 80
Doppler Measurement Precision (m/s) @ specified SNR	0.5 m/s @ 6dB SNR (Ka) 0.2 m/s @ 6dB SNR (W)
Doppler Measurement Unambiguous Range (min – max m/s)	-8.4 to +8.4 (Ka) -3.4 to +3.4 (W)
Range profiling measurement window (km) above surface	25 / 25



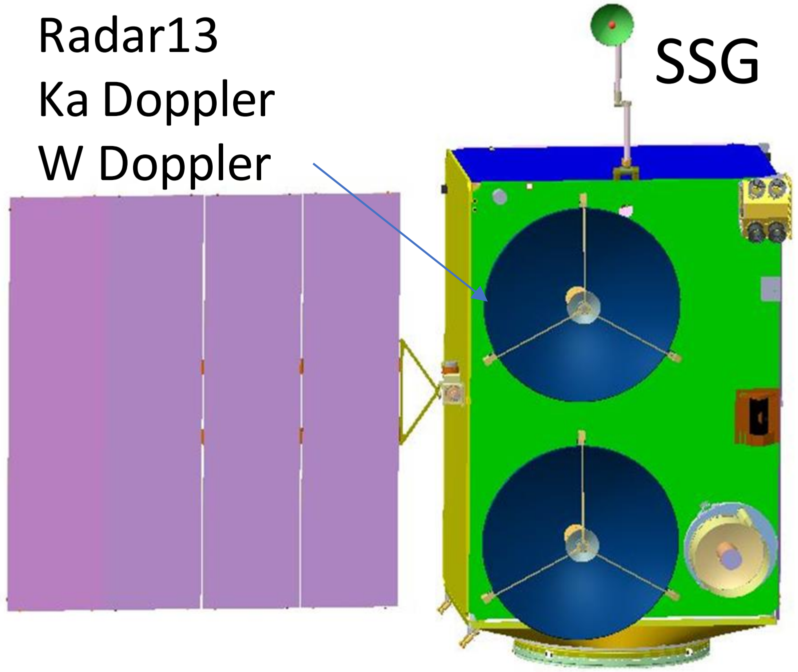
407km
65 deg incl

Parameter	S-Polar07
Wavelength range Visible	360*, 380*, 410*, 550*, 670*
Wavelength range VNIR-SWIR	870*,940*,1230*,1380*,1550*,1650*
Radiometric	3%
DOLP	0.50%
Stokes Parameters	I,Q,U
Spatial	0.5 cross
Cross-track swath (km)	550
Cross-track swath (deg	72
Along track viewing	±57º at spacecraft
Number of Angles	60 at 670nm, 10 at others
Calibration	on-board rad & pol

Parameter	S-Lidar09		
Number of beams	1		
Laser Pulse Repetition Rate (Hz)	4500		
Telescope Diameter (m)	0.6		
Receiver Field-Of-View (FOV; mrad)	125		
Wavelengths (nm)	l1 (nm)	l2 (nm)	l3 (nm)
	1064	532	
Lidar Measurement Techique (i.e., Backscatter, HSRL, other)	Backscatter	Backscatter	
Depolarization (Yes/No)	Yes	Yes	
Depolarization Purity (e.g., > 100:1)	>100:1	>100:1	
Laser Energy Per Pulse (mJ)	3	2	
Optical Transmission of Receiver, Excluding Filters, and Field Stop (%)	60%	60%	
Number of Detector Channels	2	4	
Detector Quantum Efficiency (%)	2	60%	
Range Bin Length or Vertical Resolution (m)	30-60	30-60	
Footprint Diameter (m)	28-42	28-42	

Parameter	S-Radio09 (b)	S-Radio10
Center Frequencies (GHz)	183.31 GHz channel: SSB FI band: DC-7GHz 325.5 GHz channel: SSB FI band: DC-10GHz	670
Polarization (HH, VV, HV, LCP, RCP, etc)	V or H Nadir, H or V Nadir	V, H
Integration Time(s) (ms)	2, 1	10
Bandwidth(s) (MHz)	7000, 10000	17000
NEDT (K)	1 to 2, 2 to 3	0.5
On board calibration targets	sky reflector + blackbody	cold space + black body
Swath Width (km)	770	2000

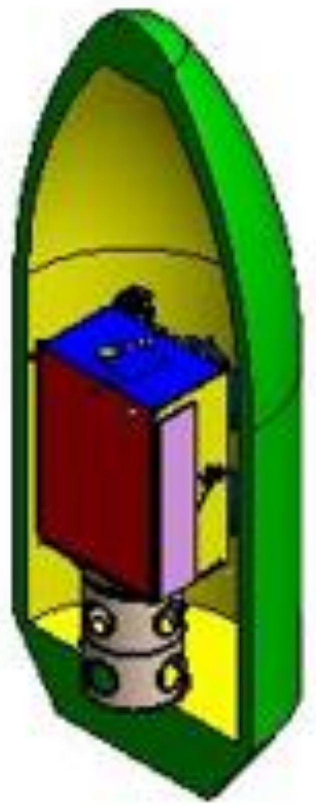
Architecture 8G SSG Fact Sheet



	Dry Mass/Fuel kg	*Load Power W*
SSG SC	***1103/304***	***420***
Payload		
Radar13	*44.2*	*78*
Lidar09	*74.1*	*341.9*
Polar07	*61.1*	*59.8*
Radio9b	*45.5*	*48.1*
Radio10	*1.69*	*10.4*
Total P/L	***227***	***538***

Total Obs Mass=1634kg; Pwr=958W

Launch Options: ACCP Single SC Dedicated or Shared Ride with Another Program on ESPA Grande & Falcon-9 to 65 deg Inclined Orbit



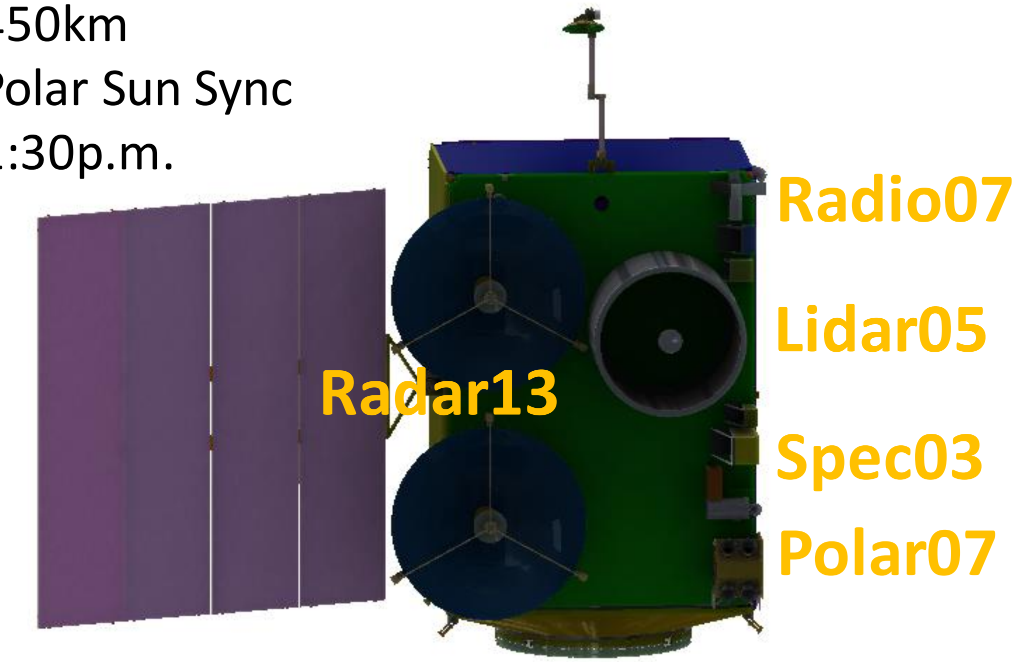
8G SSP Instruments

Parameter	S-Radar13
Center Frequencies (GHz)	35.6 / 94.05 (Ka / W)
Doppler Measurement (Yes/No?)	Yes / Yes
Swath Width (Km)	12.5 / NA
Range Resolution (m)	250 / 500
Horizontal Resolution @ nadir (along-track x cross-track, km x km)	2.5 x 2.5 (Ka) 2.0 x 1.0 (W)
Horizontal Resolution @ swath edge (along-track x cross-track, km x km)	2.5 x 2.5 (Ka) NA (W)
Noise-Equivalent Reflectivity (dBZ) (Single-shot reflectivity at 0 dB SNR)	+17.0 / -16.0
Minimum Detectable Reflectivity (dBZ) (Multi-shot reflectivity at 0 dB SNR)	+7.0 / -26.0
Reflectivity Measurement Accuracy (dB)	1.5 / 1.5
Reflectivity Measurement Dynamic Range	80 / 80
Doppler Measurement Precision (m/s) @ specified SNR	0.5 m/s @ 6dB SNR (Ka) 0.2 m/s @ 6dB SNR (W)
Doppler Measurement Unambiguous Range (min – max m/s)	-8.4 to +8.4 (Ka) -3.4 to +3.4 (W)
Range profiling measurement window (km) above surface	25 / 25

Parameter	S-Polar07
Wavelength range Visible	360*, 380*, 410*, 550*, 670*
Wavelength range VNIR-SWIR	870*,940*,1230*,1380*,1550 *,1650*
Radiometric	3%
DOLP	0.50%
Stokes Parameters	I,Q,U
Spatial	0.5 cross
Cross-track swath (km)	550
Cross-track swath (deg	72
Along track viewing	±57º at spacecraft
Number of Angles	60 at 670nm, 10 at others
Calibration	on-board rad & pol

Parameter	S-Lidar05		
Number of beams	1		
Laser Pulse Repetition Rate (Hz)	70		
Telescope Diameter (m)	1		
Receiver Field-Of-View (FOV; mrad)	TBD by the SALT. Currently		
Wavelengths (nm)	l1 (nm)	l2 (nm)	l3 (nm)
	1064	532	
Lidar Measurement Techique (i.e., Backscatter, HSRL, other)	Backscatter	HSRL	
Depolarization (Yes/No)	Yes	Yes	
Depolarization Purity (e.g., > 100:1)	250:1	250:1	
Laser Energy Per Pulse (mJ)	125	125	
Optical Transmission of Receiver, Excluding Filters, and Field Stop (%)	35%	37%	
Number of Detector Channels	2	3	
Detector Quantum Efficiency (%)	40%	25%	
Range Bin Length or Vertical Resolution (m)	60	1	
Footprint Diameter (m)	93	93	

450km
Polar Sun Sync
1:30p.m.

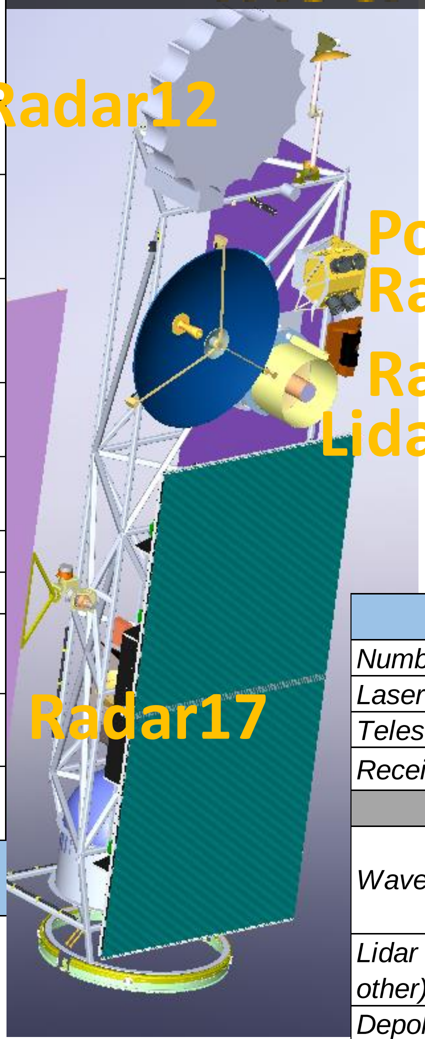


Parameter	S-Spect03
Spectral Regions (e.g., UV,VIS, SWIR)	LWIR, FIR
Wavelengths of channel(s) (µm)	8.7, 11, 13, 17.75, 19.5, 21.5, 25, 40
Channel bandwidths for radiometry (µm)	1.6, 2, 2, 1.5, 2, 2, 5, 20
Cross-track swath width seen in common at all view angles (km)	400
Instantaneous cross-track field of view (deg)	0.44 deg (single pixel, iFOV), 35.2 deg FOV
Footprint per pixel at nadir, center of field (cross-track x along-track) (i.e., best case)	5km x 5km
Footprint per pixel at most oblique view angle, edge of field (cross-track x along-	~7.5 km x 5 km
Along-track spatial coverage (continuous, intermittent, targeted) (km)	100 km (along-track, continuous)
Radiometric calibration technique (e.g., on-board, vicarious)	warm black body on-board (310 K), deep space view needed

Parameter	S-Radio07
Center Frequencies (GHz)	118 +/- 1.1, +/- 1.5, +/- 2, +/- 5, 183 +/- 1, +/- 2, +/- 3, +/- 6, 240, 310, 380 +/-0.75, +/-1.5, +/-3, +/-6, 660, 880
Polarization (HH, VV, HV, LCP, RCP, etc)	H (all channels)
Integration Time(s) (ms)	10 (118 & 183 channels)
Bandwidth(s) (MHz)	400, 400, 10000, 10000, 400,
NEDT (K)	0.5 (118 & 183 channels)
On board calibration targets	blackbody, cold sky
Swath Width (km)	750

8G-1 SSG Instruments

Parameter	S-Radar12	S-Radar17
Center Frequencies (GHz)	35.6 / 94.05 (Ka / W)	13.6 (Ku)
Doppler Measurement (Yes/No?)	Yes / No	Yes
Swath Width (Km)	12.5 / NA	10 (Doppler) 76 (high lat & polar, non-Doppler) 349 (low & mid lat, non-Doppler)
Range Resolution (m)	250 / 500	500
Horizontal Resolution @ nadir (along-track x cross-track, km x km)	2.5 x 2.5 (Ka) 2.0 x 1.0 (W)	2.5 x 5.0 (Doppler) 5.0 x 5.0 (non-Doppler)
Horizontal Resolution @ swath edge (along-track x cross-track, km x km)	2.5 x 2.5 (Ka) NA (W)	2.5 x 5.0 (Doppler) 5.0 x 5.1 (high lat & polar, non-Doppler) 5.0 x 6.0 (low & mid lat, non-Doppler)
Noise-Equivalent Reflectivity (dBZ) (Single-shot reflectivity at 0 dB SNR)	+17.0 / -16.0	+8.1 (nadir) +0.2/+1.7 (polar/low & mid lat)
Minimum Detectable Reflectivity (dBZ) (Multi-shot reflectivity at 0 dB SNR)	+7.0 / -26.0	-2.6 (nadir) -8.9/-7.2 (polar/low & mid lat)
Reflectivity Measurement Accuracy (dB)	1.5 / 1.5	1
Reflectivity Measurement Dynamic Range	80 / 80	80
Doppler Measurement Precision (m/s) @ specified SNR	0.5 m/s @ 6dB SNR (Ka) NA (W)	1.0 (high lat & polar, 10dB SNR) 1.9 (low & mid lat, 10dB SNR)
Doppler Measurement Unambiguous Range (min – max m/s)	-8.4 to +8.4 (Ka) NA (W)	-52 to +52
Range profiling measurement window (km) above surface	25 / 25	10 (high lat & polar, Doppler & non-Doppler)



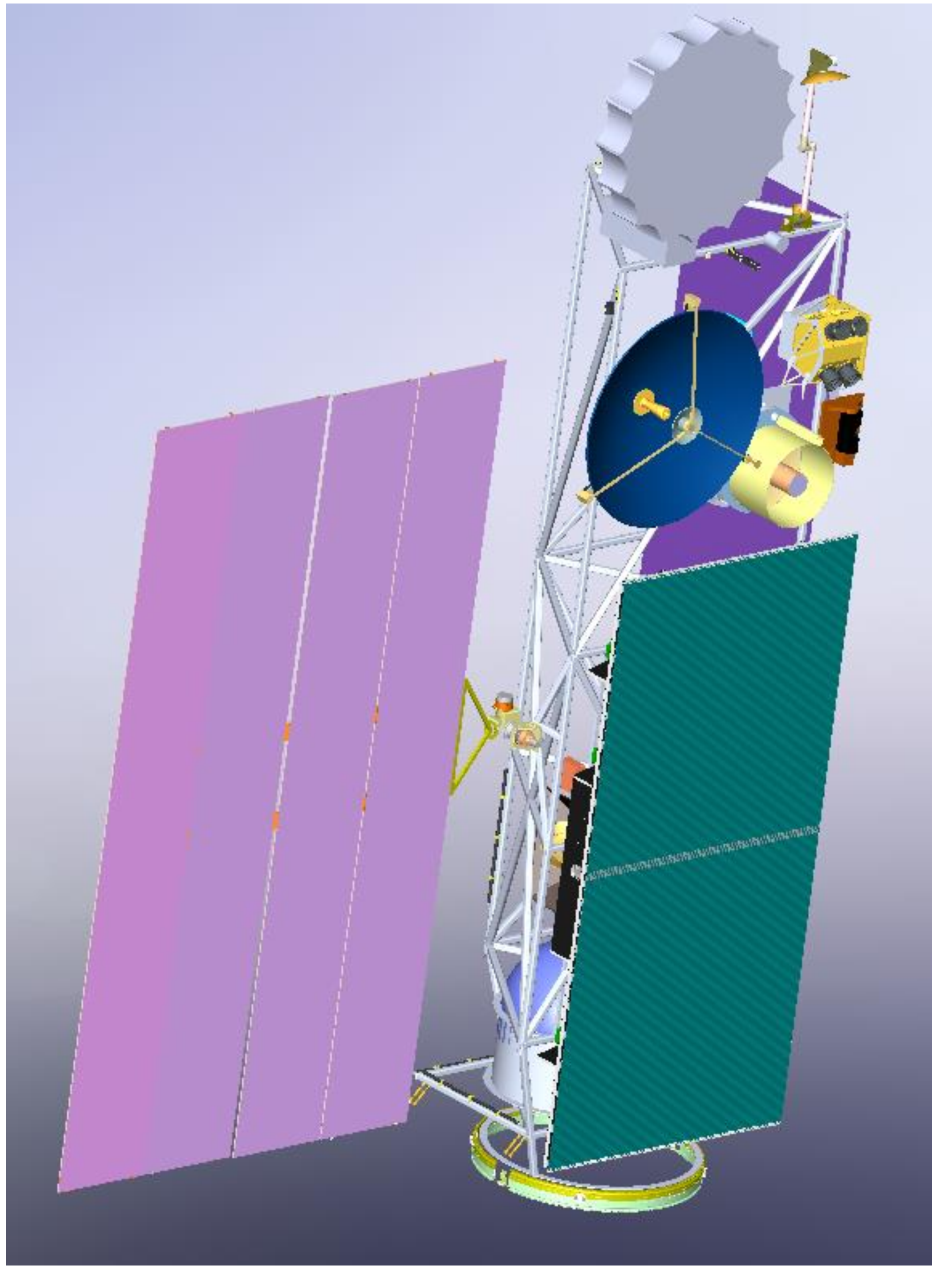
Parameter	S-Polar07
Wavelength range Visible	360*, 380*, 410*, 550*, 670*
Wavelength range VNIR-SWIR	870*,940*,1230*,1380*,1550*,1650*
Radiometric	3%
DOLP	0.50%
Stokes Parameters	I,Q,U
Spatial	0.5 cross
Cross-track swath (km)	550
Cross-track swath (deg	72
Along track viewing	±57º at spacecraft
Number of Angles	60 at 670nm, 10 at others
Calibration	on-board rad & pol

Parameter	S-Radio09 (b)	S-Radio10
Center Frequencies (GHz)	183.31 GHz channel: SSB FI band: DC-7GHz 325.5 GHz channel: SSB FI band: DC-10GHz	670
Polarization (HH, VV, HV, LCP, RCP, etc)	V or H Nadir, H or V Nadir	V, H
Integration Time(s) (ms)	2, 1	10
Bandwidth(s) (MHz)	7000, 10000	17000
NEDT (K)	1 to 2, 2 to 3	0.5
On board calibration targets	sky reflector + blackbody	cold space + black body
Swath Width (km)	770	2000

407km
65 deg incl

Parameter	S-Lidar09		
Number of beams	1		
Laser Pulse Repetition Rate (Hz)	4500		
Telescope Diameter (m)	0.6		
Receiver Field-Of-View (FOV; mrad)	125		
Wavelengths (nm)	l1 (nm)	l2 (nm)	l3 (nm)
	1064	532	
Lidar Measurement Techique (i.e., Backscatter, HSRL, other)	Backscatter	Backscatter	
Depolarization (Yes/No)	Yes	Yes	
Depolarization Purity (e.g., > 100:1)	>100:1	>100:1	
Laser Energy Per Pulse (mJ)	3	2	
Optical Transmission of Receiver, Excluding Filters, and Field Stop (%)	60%	60%	
Number of Detector Channels	2	4	
Detector Quantum Efficiency (%)	2	60%	
Range Bin Length or Vertical Resolution (m)	30-60	30-60	
Footprint Diameter (m)	28-42	28-42	

Architecture 8G-1 SSG Fact Sheet



Total Obs Mass=1873kg dry 2313kg wet; Pwr=1803W

	Dry Mass/Fuel	*Load Power*
SSP SC	***1085/440***	***484***
Payload		
Radar12	*28.6*	*78*
Lidar09	*74.1*	*341.9*
Polar07	*61.1*	*61.1*
Radio09b /10	*47.2*	*58.5*
Radar17	*577.2*	*780*
Total P/L	***788.2***	***1319***

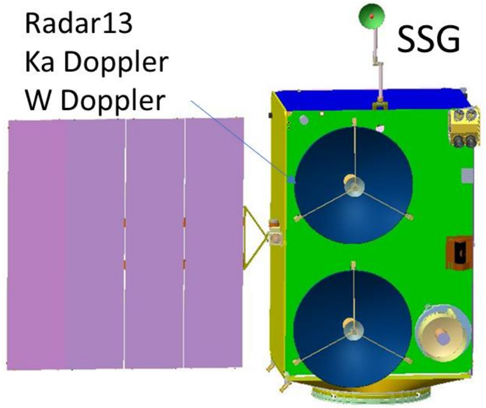
Payload: (Radar17&Radio9b contributed)
Note: 8G-2 SSG (option without Lidar09 and Polar07 has not been studied in detail)
Launch Options: ACCP Single SC Dedicated H-3 Contributed Launch

Large / Medium Spacecraft Summaries—Stacked/Dedicated Launches

8G SSG

Radar13
Ka Doppler
W Doppler

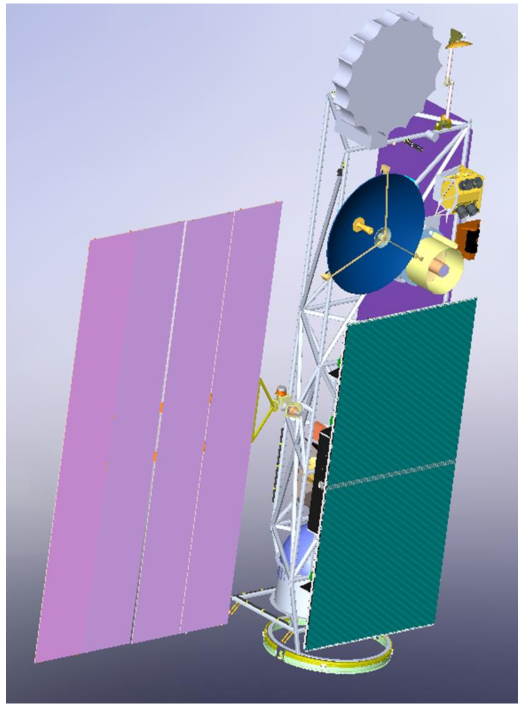
SSG



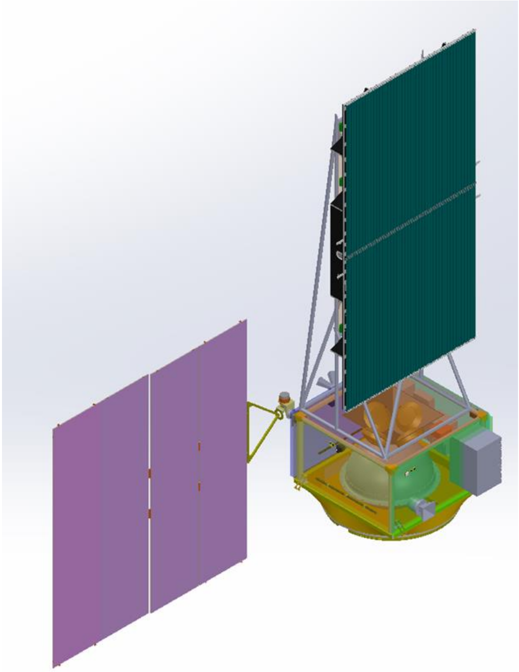
Polarimeter 07
60 Angle
Radiometer 10
Radiometer 9b
Lidar09
532, 1064 nm
Back-Scatter

4mx2.6m

8G-1 SSG
8G-2 SSG—without Lidar/Polarimeter

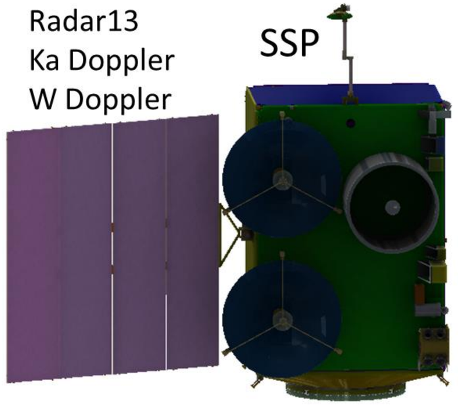


11E SSG-1



Radar13
Ka Doppler
W Doppler

SSP

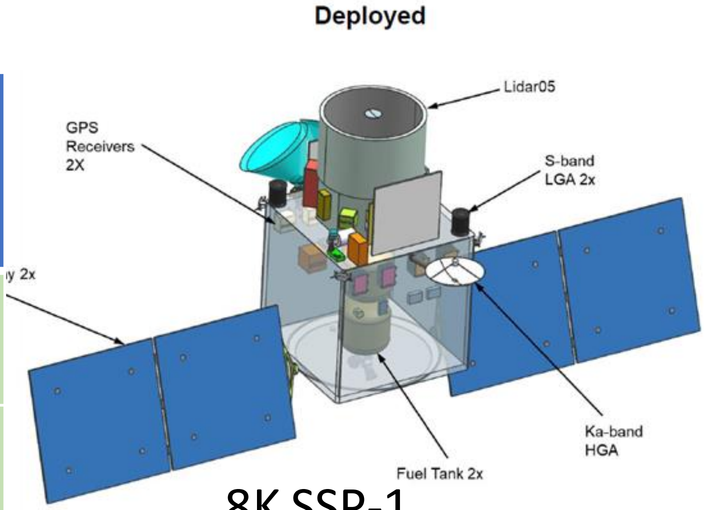


Lidar05
532, 1064 nm
532 HSRL
Radiometer07
Spectrometer 03
Polarimeter 07
60 Angle

4mx2.6m

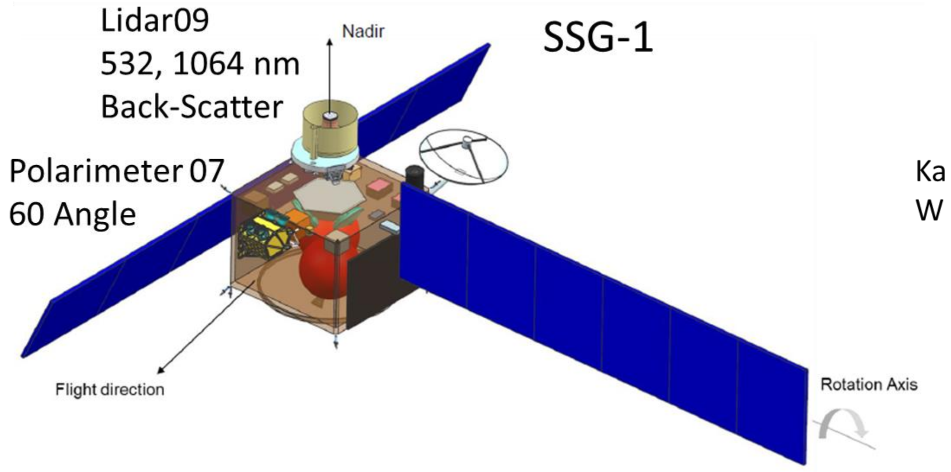
8G SSP

	8G-1 SSG (JAXA Case 1)	11I SSP1 (JAXA Case 2)	8G-2 SSG (JAXA Case 1 Variant)	11E SSG-1 (JAXA Case 2)	8G SSP, 11B, 11E	8K SSP-1; 11A/C/D/F/H/8K-1; 8K-2
Payload Mass	788	655	651	623	607	558.4
Payload Power	1318	968	906	828	932	838

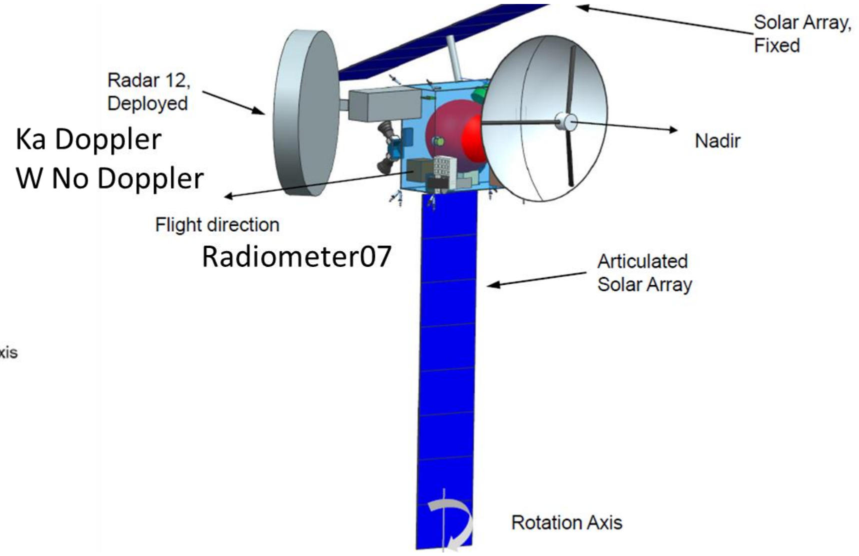


8K SSP-1

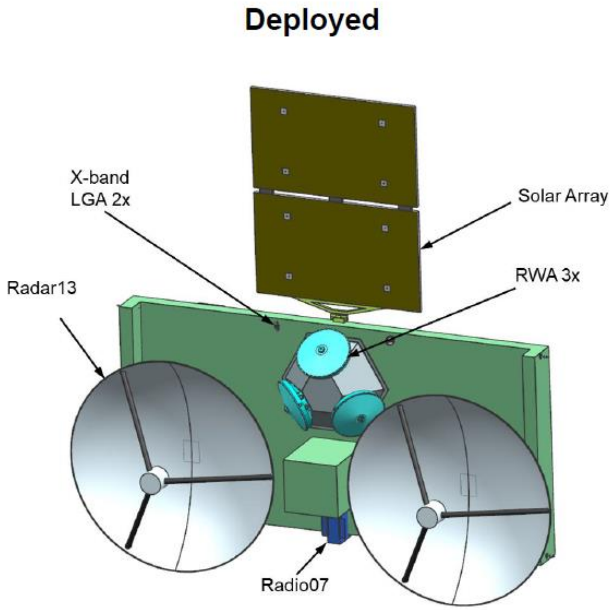
ESPA Grande Spacecraft (<320kg) Summaries



8K SSG-1



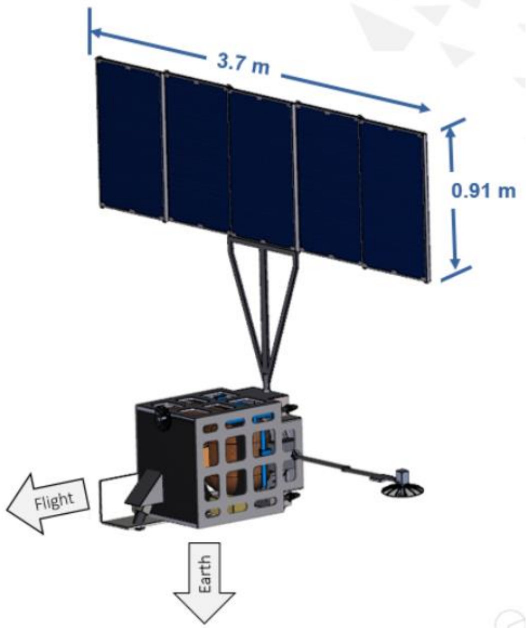
8K SSG-2



8K SSP-2

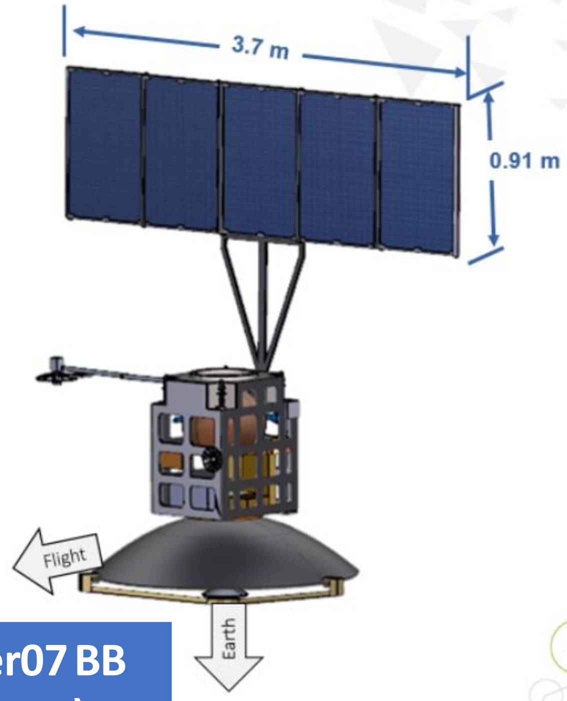
	8K SSG-2	8K SSP-2	8K SSG-1	8G SSG	11A, 11F
Payload Mass	32.5	48.1	101.4	227	245-300
Payload Power	94	94	402	538	630-677

ESPA Small Spacecraft (<182kg) Summaries



Baby Bird Design 1
Radar05b/Camera
Polar

Baby Bird Design 2
Radar05b/Camera
GPM Orbit



	Radar05b/Camera BB Design 1 (Polar)	Radar05b/Camera BB Design 2 (GPM)	Radiometer07 BB Design 3 (Polar)	Radiometer07 BB Design 4 (GPM)
Payload Mass	101.4	32.5	48.1	48.1
Payload Power	402	94	94	94

Baby Bird Design 3/4
Radiometer07
Polar