ACCP Applications Overview

Applications Impact Team (AIT):

A-Team: Ali Omar (LaRC), Bryan Duncan (GSFC), Melanie Follette-Cook, Amber Soja (LaRC), Aaron Naeger (MSFC), Olga Kalashnikova (JPL)

CCP-Team: Dalia Kirschbaum (GSFC), Emily Berndt (MSFC), Svetla Hristova-Veleva (JPL), Anita LeRoy (MSFC), Patrick Gatlin (MSFC)

Applications Coordinator: Andrea Portier

ACCP Framing Assumptions For SATM

- ACCP is a combined Aerosols and CCP process-oriented Earth Observing System consisting of
  a) A space-based mission (payload, spacecraft, launch vehicle)
  b) A fully integrated, sustained sub-orbital component
  c) Program of Record, models, data assimilation, synergistic algorithms needed to extract maximum benefits from the ACCP measurements
- Payload may consist of:
  a) Active sensors (lidars and radars)
  b) Several passive sensors (passive MW radiometer, polarimeter, spectrometer)

Background – ACCP Study

- HQ initiated a request for a Study Team and Plan to address the Aerosol (A) and Clouds, Convection, and Precipitation (CCP) Designed Observables (DOs) called out in the 2017 Earth Science Decadal Survey (DS).
- Study Plan was submitted in July 2018 for a NASA HQ-sponsored, multi-center (GSFC, LaRC, JPL, MSFC, ARC, and GRC), 3-year pre-formulation study commencing Oct. 1, 2018.
- Study goal: to submit to NASA HQ 3 candidate Observing Systems to address the integrated A and CCP goals/objectives by the end of FY21.
- In February 2021, the Study Team submitted its candidate observing systems and identified a preferred observing system

ACCP Status & Plan

- In Year 1, the Study Team developed a preliminary SATM, developed an extensive Instrument Library (>50 RFI submissions), worked with 3 potential International partners participating in the study, formulated numerous (>19) candidate Observing Systems (OS) or Architectures to address the combined DOs for A and CCP,
- In Year 2, the Study Team selected ~6 of these Architectures to assess the scientific and applications benefit, technical and programmatic feasibility.
- In Year 3, the Study Team down selected to ~3 and submitted these to NASA Headquarters refining the details for each working towards Mission Concept Review (MCR) maturity and completing the Study Report.
  - ❖ All the candidate Observing Systems will provide minimum science objectives with any enhancements consistent with the SATM, cost and risk constraints

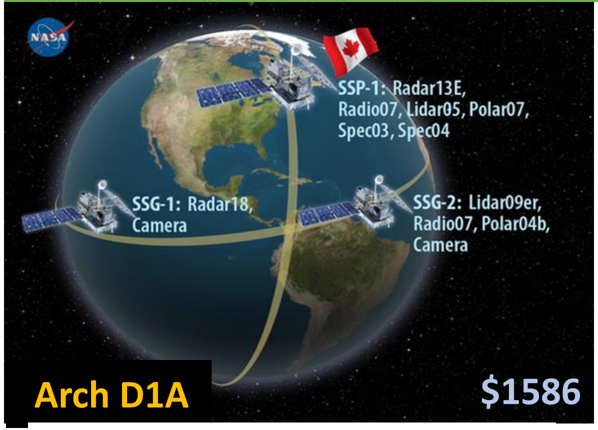
ACCP Study - Outcomes

- The recommended architectures provide multiple breakthrough technologies that will answer fundamental questions about how microscopic particles interact in the atmosphere to fuel severe storms, impact air quality, and influence our changing climate
- In this era of increasing weather and air quality extremes, the recommended architectures provide unique observations to reveal complex global processes
- ACCP will enable decision-making that impacts people around the world, from short-term crises to long-term plans. It will advance:
  - ✓ Weather Forecasting, Climate Modeling, Air Quality Modeling, Disaster Monitoring

SATM 3 Key Science Questions/5 Goals/8 Objectives

Science Implementation Strategies

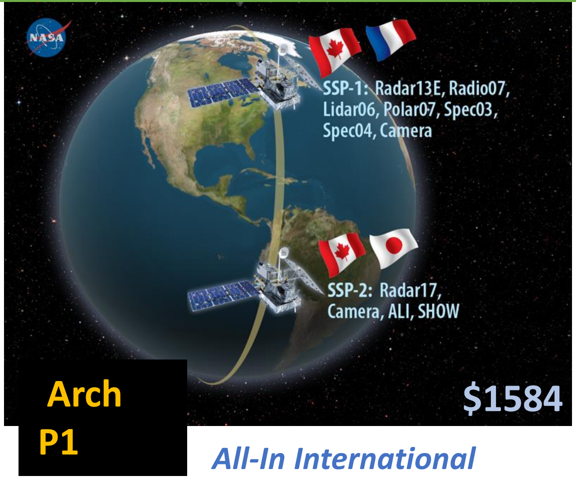
Top Candidates for Final 3 Architectures—Programmatic Factors Cost, De-Scopes & Risk



Early Science Option
1st Launch As Early as 2027-2028
Lowest Risk

Why? Polar Orbit covers the poles for global scale measurement of integrated ACCP longer time scale processes tied to radiation and climate. Lower inclination orbit provides diurnal sampling critical for convection, precipitation and delta t measurements for shorter time scale processes.

First Mission: $579M
Second Mission: $1006M



All-In International
Only 1 Launch 2031,
Highest Risk

Why? Polar Orbit covers the poles for global scale measurement of integrated ACCP longer time scale processes tied to radiation and climate. Instruments in polar provide increased Information with 3 frequency radar and 3 wavelength lidar vs. 2 for each in D1A and a wide swath precipitation radar beneficial for context and applications.

Single Mission: $1.584B

Note: If prohibited from International LV then this option exceeds cap

US Alternative To JAXA Radar
Only 1 Launch 2031

Why? Polar Orbit covers the poles for global scale measurement of integrated ACCP longer time scale processes tied to radiation and climate. Instruments in polar provide increased Information with 3 frequency radar and 3 wavelength lidar vs. 2 for each in D1A without wide swath precipitation radar beneficial for context and applications to reduce cost.

Single Mission: $1.419B

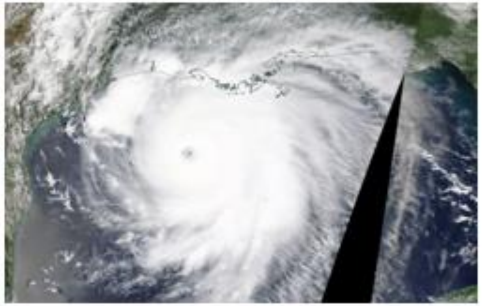
Architecture D1A stands above the rest offering the benefits of Constellation science, opportunities for Earlier Science at lower initial cost, and potential opportunities for additional International Collaboration

- **The ACCP Applications Impact Team (AIT)** is charged with ensuring that applications are considered to the greatest extent possible in mission design

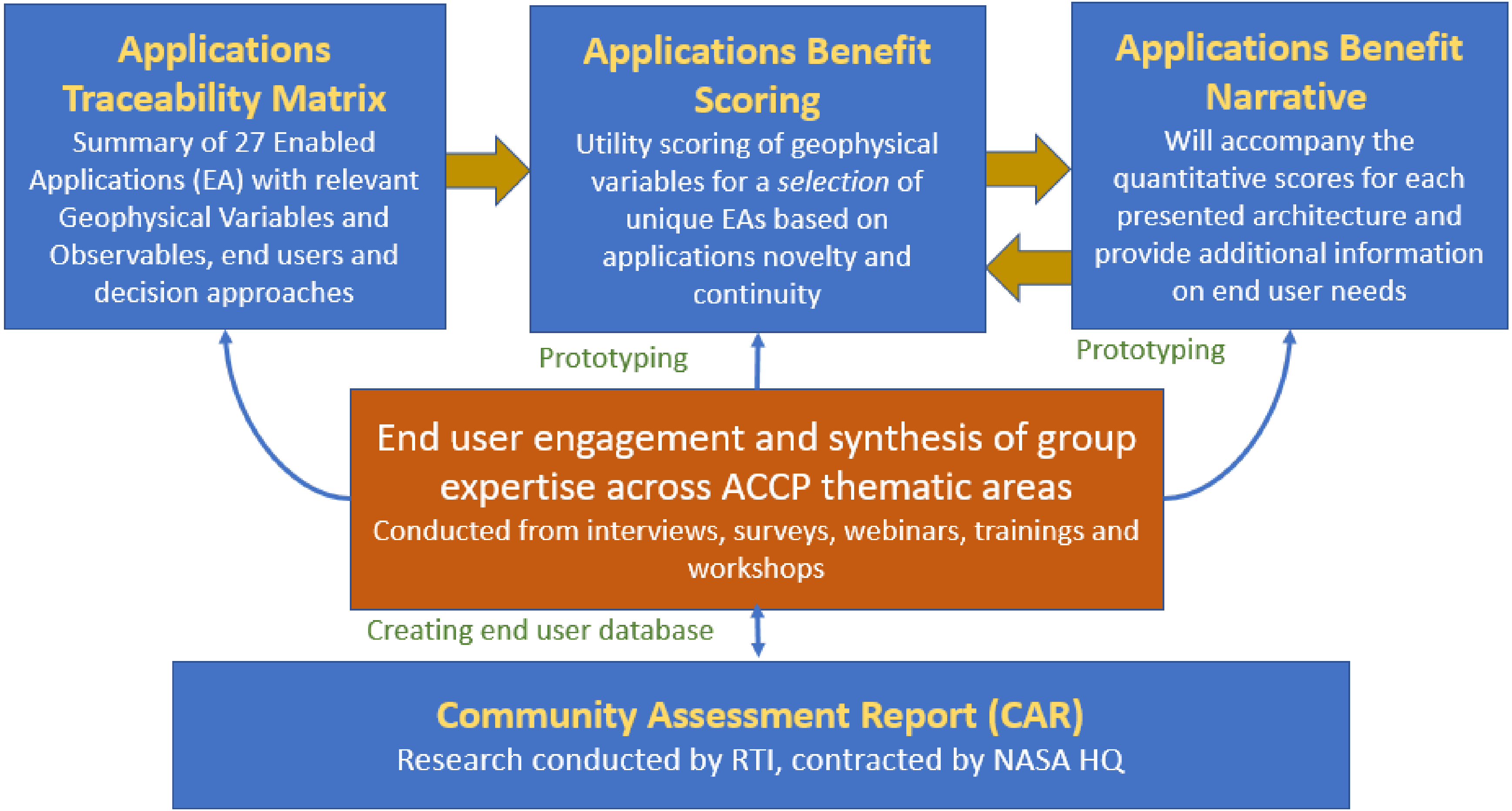
- **ACCP AIT objectives include:**
    - Define the key applications criteria to be considered in the final mission concept
    - Identify applications and their readiness relevant to the ACCP mission early in its lifecycle (Pre-Phase A)
    - Assess the feasibility of integrating end-user needs in mission design and development
    - Engage users and solicit feedback to integrate user needs in the ACCP mission design concept and grow an Early Adopter Program
    - Develop a **Community Assessment and Report** (CAR) and characterize applications communities who currently use NASA products and those who could potentially use NASA products, i.e., **Communities of Practice and Potential**, respectively.

California Wildfires: Sep. 6

Hurricane Laura: Aug. 26

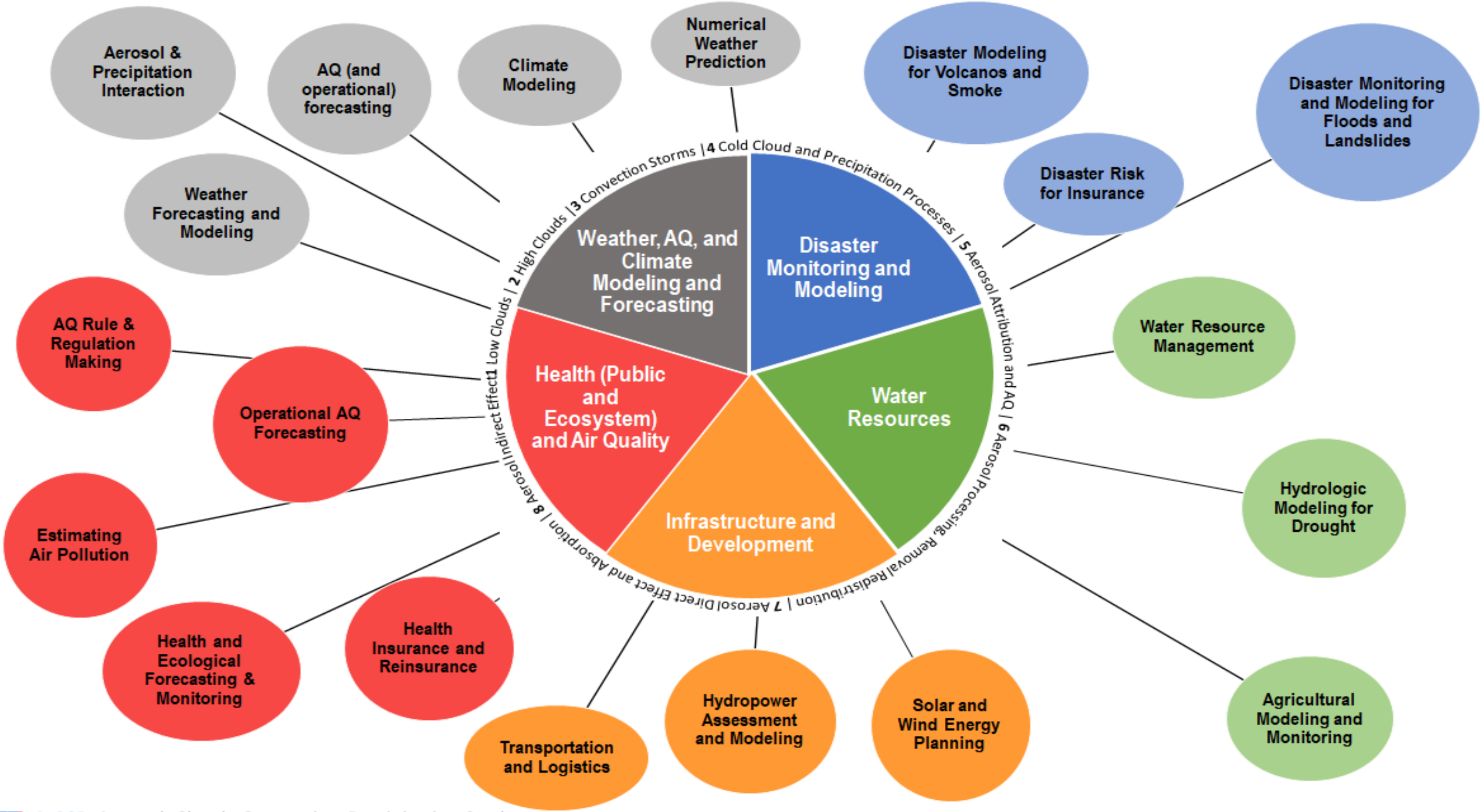


Applications Impact Team Deliverables and Approaches



Engaging with RTI to identify 12 thematic groups/companies to interview as part of this effort

Applications Thematic Areas and High-level Enabled Applications



Polarimeters

Radiometric accuracy ~ 3%
1130 km @ 500 km altitude
1 km spatial resolution

550 km @ 500 km altitude
0.5 km spatial resolution

Instrument Library Summary

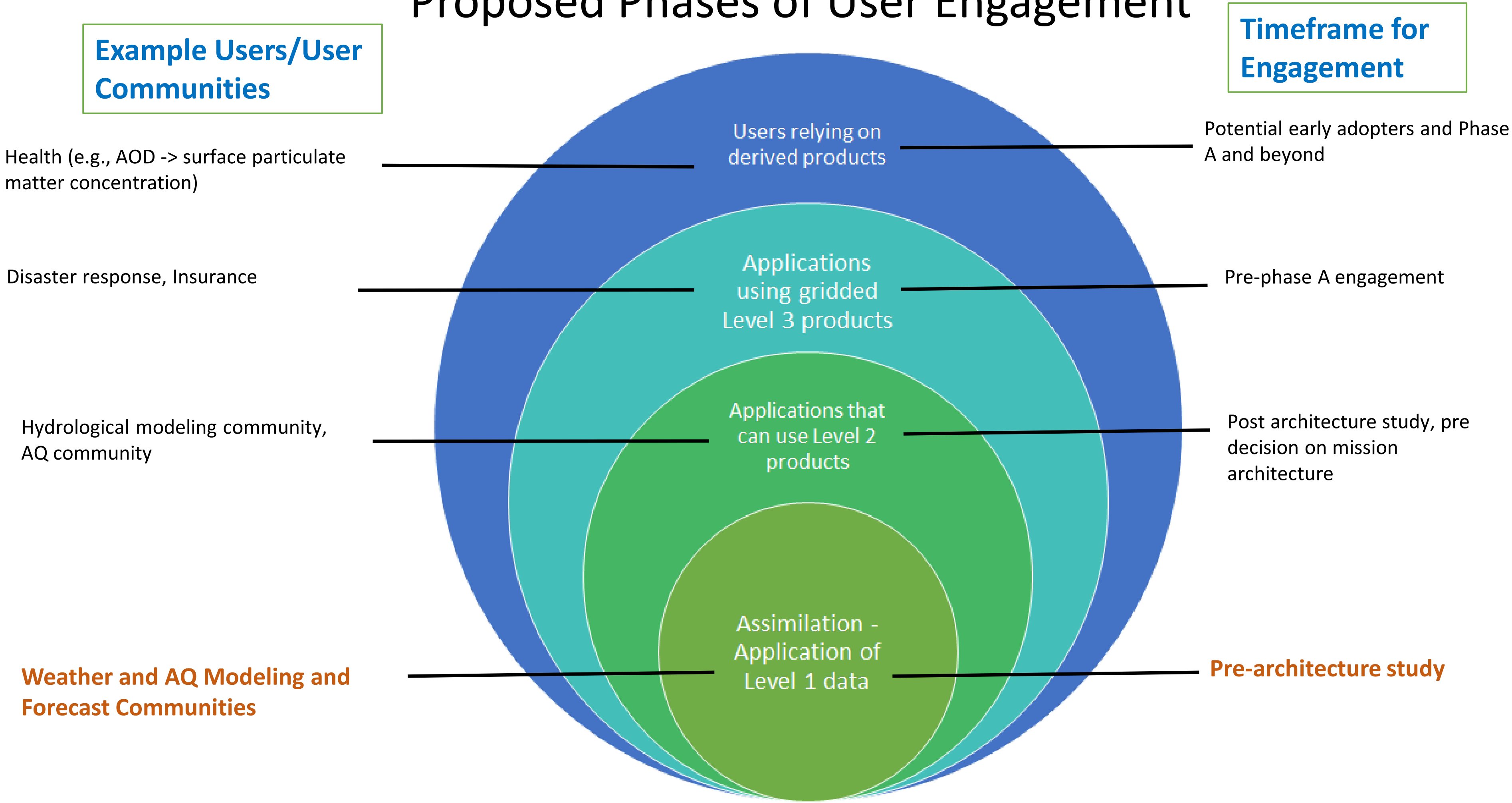
Radars	Radiometers	Lidars	Polarimeters	Spectrometers
W, Ka, Ku, scanning, Doppler	11, 19, 24, 37, 89, 166, 183	**532 bs, 1064 bs**	14 channels, 5 angles	**LWIR, 3 channels**
W, Ka, scanning, Doppler	11, 19, 24, 37, 89	532 bs, 1064 bs	**14 channels, 5-9 angles**	**VIS/NIR/SWIR, hyperspectral**
W, Ka, nadir, Doppler	**24, 31, 55, 89, 166, 183**	355 HSRL, 532 HSRL	Hyperspectral, 1 angle	**LWUV/VIS/NIR/SWIR, hyperspectral**
W, Ka, nadir, Ka Doppler	**19, 24, 34**	532 bs, 1064 bs	**Hyperspectral, 5 angles**	**LWIR/FIR, 8 channels**
W, Ka, nadir, no Doppler	118, 183	532 HSRL, 1064 bs	**10 channels, 60 angles**	
Ka, Ku, scanning, Ku Doppler	**87, 164, 174, 178, 184**	355 HSRL, 532 HSRL, 1064 bs	**11 channels, 60 angles**	
Ka, Ku, scanning, no Doppler	**118, 183, 240, 310, 380, 660, 880**	355 HSRL, 532 bs, 1064 bs	**12 channels, 60 angles**	
W, scanning, Doppler	**883**	**1064 bs**	**15 channels, 60 angles**	
W, nadir, no Doppler	**183**	**532 bs, 1064 bs**	**9 channels, 255 angles**	
Ka, nadir, Doppler	**183, 326**			
Ka, scanning, no Doppler	**670**			
Ka, nadir, no Doppler	**220, 680 GHz/ 8.6, 11, 12 microns**			
Ku, nadir, Doppler	**91, 118, 183, 205**			
Ku, scanning, no Doppler	Radiometer channels in GHz	bs=backscatter HSRL=High Spectral Resolution Lidar	Channels in VIS, VNIR, SWIR	LWIR=Longwave infrared LWUV=Longwave ultraviolet VIS=visible NIR=near IR SWIR=Shortwave IR FIR=Far IR

Small satellite capable sensors indicated in bold.

Lidars

HSRL /Backscatter Lidars
10 m vertical res.
100 m horizontal res.

Proposed Phases of User Engagement



Potential Geophysical Variables to be measured by ACCP

Observables

UV backscatter	Microwave Brightness Temperature
VIS backscatter	Microwave Radiance
NIR backscatter	UV Reflectance
Multi-angle radiance	VIS Reflectance
Multispectral radiance	NIR Reflectance
Radar Reflectivity	Thermal IR brightness temperature
Radar Radial Velocity	Thermal IR radiance
Doppler Radar Reflectivity	

Potential Geophysical Variables to be measured by ACCP

Aerosols

Aerosol Absorption Coefficient Profile	Aerosol Extinction to Backscatter Ratio Profile
Aerosol Absorption Optical Depth (Column and PBL)	Aerosol Fine Mode Extinction Profile
Aerosol Angstrom Exponent (Column and PBL)	Aerosol Fine Mode Optical Depth (Column and PBL)
Aerosol Angstrom Exponent Profile	Aerosol Imaginary Index of Refraction (Column and PBL)
Aerosol Asymmetry Parameter	Aerosol Non-spherical AOD Fraction (Column)
Aerosol-Cloud Feature Mask	Aerosol Non-spherical AOD Fraction Profile
Aerosol Effective Radius (PBL)	Aerosol Number Concentration (PBL)
Aerosol Effective Radius Profile	Aerosol Optical Depth (Column and PBL)
Aerosol Extinction Profile	Aerosol PM2.5 Concentration (surface)
Aerosol Extinction to Backscatter Ratio (Column)	Aerosol Real Index of Refraction (Column and PBL)
Aerosol Extinction to Backscatter Ratio (Column and PBL)	Aerosol vertical extent
	PBL aerosol number concentration
	Particle shape (aspect ratio, roughness)

A-CCP AIT Team and Experience

Designated Observable:
Aerosols
Clouds, Convection & Precipitation
Both

Name	Center	Contact	Mission Experience
Leads			
Ali Omar*	LaRC	ali.h.omar@nasa.gov	CALIPSO, PACE
Dalia Kirschbaum*	GSFC	dalia.b.kirshbaum@nasa.gov	GPM
Emily Berndt*	MSFC	emily.b.berndt@nasa.gov	Terra/Aqua, S-NPP/JPSS, GOES-R, GPM, TROPICS
Bryan Duncan	GSFC	bryan.n.duncan@nasa.gov	Aura
Team Members			
Amber Soja	LaRC	amber.j.soja@nasa.gov	CALIPSO, ASP Associate Program Manager- Fire
Olga Kalashnikova	JPL	olga.kalashnikova@jpl.nasa.gov	MISR, MAIA, EMIT, PACE
Abigail Nastan	JPL	abigail.m.nastan@jpl.nasa.gov	MAIA
Aaron Naeger	MSFC	aaron.naeger@nasa.gov	CALIPSO, TEMPO, MAIA, AHI, GOES-R, Terra/Aqua, S-NPP/JPSS
Patrick Gatlin	MSFC	patrick.gatlin@nasa.gov	GPM
Anita LeRoy	MSFC	anita.leroy@nasa.gov	TRMM, GPM, TROPICS

* SALT Representative

Back Up Slides

Instrument Nomenclature Key

Active Sensors

ACCP Identifier		Spectrum	Architecture		
			D1A	P1	P2
Doppler Radars	Radar_13E	KaD, WD	✓	✓	
	Radar_13E+1	KuD, KaD, WD			✓
	Radar_18	KuD, W	✓		
	Radar_17DN	KuD		✓	
Lidars	Lidar_05	532 nm HSRL 1064 nm	✓		
	Lidar_06	355 nm HSRL 532 nm HSRL 1064 nm		✓	✓
	Lidar_09er	532 nm 1064 nm	✓		

Passive Sensors

ACCP Identifier		Spectrum	Architecture		
			D1A	P1	P2
Spectro-meters	Spec_03	LWIR, FIR	✓	✓	✓
	Spec_04	UV,VIS,NIR,SWIR	✓	✓	✓
Radio-meters	Radio_07	118/183/240/310/380/660/880 GHz	✓	✓	✓
	Radio_09x	89/183/325 GHz	Possible substitute for Radio_07	Possible substitute for Radio_07	Possible substitute for Radio_07
Polari-meters	Polar_04b	UV/VIS, VNIR/SWIR	✓		
	Polar_07	UV/VIS, VNIR/SWIR	✓	✓	✓
Other	ALI	VNIR, SWIR		✓	✓
	SHOW	NIR		✓	✓
	Camera	VIS	✓	✓	✓

Study Plan & Process for Selecting Observing System Architectures

RFI #1 – General call for Instrument Capabilities

Filters: Qualitative Science Benefit Scoring and Initial Cost Estimates

Filters: Science Value vetted with community team; and Risk and Cost Assessments

Completed 8 Months Early: *Ready To Recommend 1 Architecture and To Move To Pre-Phase A*

~100 Potential Options

- Large number of constellations with Large to Small Sats required to accommodate Instruments
- Perform building-block level design center sessions (JPL, LaRC, MSFC, GSFC)
- Identify primary drivers and iterate against SATM

~12 Feasible Options

- Refine Science Scoring with OSSEs
- Refine Cost with parametric- and analogy-based models
- Instrument Technical Readiness Reviews
- Quantified Risk
- Programmatic Factors

3 Recommended Options To HQ

- Highest Science and Applications Value Within Cost
- Quantified Risk
- Programmatic Fa

We are here

1 Recommended Option to HQ

RFI #2 – Specific call for instrument technical information

June 2019

Sept 2020

Jan

2021

Original Plan: Summer 2021

FY22: Start Pre-Phase A

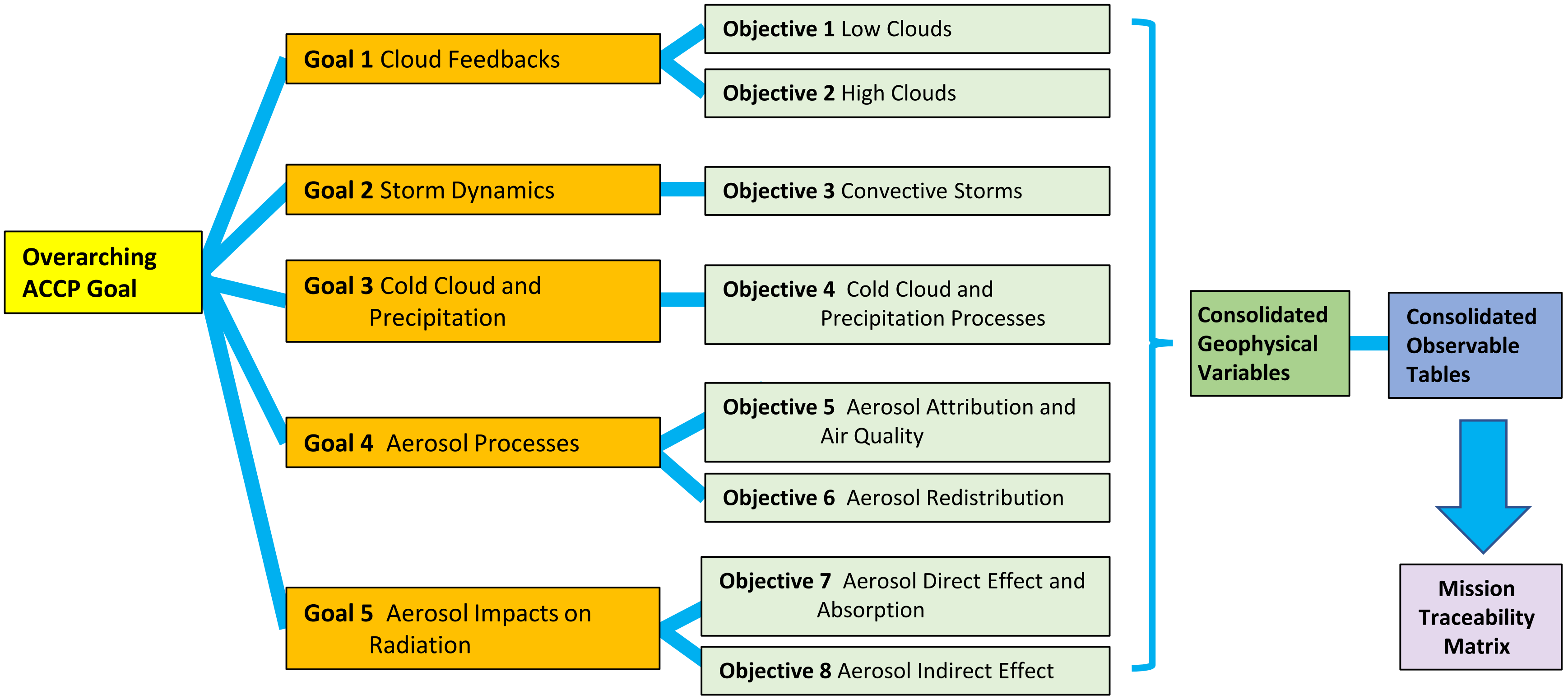
Overarching ACCP Goal	ACCP	A	CCP	2017 DS Most Important Very Important	Goals
Understand the processing of water and aerosol through the atmosphere and develop the societal applications enabled from this understanding.				C-2a, C-2g, W-1a, W-2a	**G1** Cloud Feedbacks Reduce the uncertainty in low- and high-cloud climate feedbacks by advancing our ability to predict the properties of low and high clouds.
				C-2g, C-5c, H-1b, W-1a, W-2a, W-4a	**G2** Storm Dynamics Improve our physical understanding and model representations of cloud, precipitation *and dynamical* processes within deep convective storms.
				H-1b, W-1a, W-3a, S-4a	**G3** Cold Cloud and Precipitation Improve understanding of cold (supercooled liquid, ice, and mixed phase) cloud processes and associated precipitation and their coupling to the surface at mid to high latitudes and to the cryosphere.
				W-1a, W-5a, C-5a	**G4** Aerosol Processes Reduce uncertainty in key processes that link aerosols to weather, climate and air quality related impacts.
		D I		C-2h, C-5c	**G5** Aerosol Impacts on Radiation Reduce the uncertainty in Direct (D) and Indirect (I) aerosol-related radiative forcing of the climate system.

Goal only fully realizable via combined mission.

A or CCP makes meaningful contribution to goal

ACCP Science and Applications Traceability Matrix

Schematic of ACCP SATM flow from goals to objectives to desired capabilities



What is the AIT and its Charter

- The overarching objective of the AIT is to ensure that applications considerations are taken into account as much as possible within mission design parameters
  - Define the key applications criteria to be considered in the final mission concept
  - Identify applications and their readiness levels relevant to the A-CCP mission early in its lifecycle (Pre-Phase A)
  - Assess the feasibility of integrating end-user needs in mission design and development *(Applications have never been considered this early!)*
  - Engage users and solicit feedback to integrate user needs in the A-CCP mission design concept and grow an Early Adopter Program
  - Characterize **Community of Practice** and **Potential** and develop a **Community Assessment and Report** (CAR)
- Members of the AIT have a wide array of experience with NASA and NOAA missions related to A-CCP and have worked with diverse end users

A+CCP	A	CCP	Potential Enabled Apps	Enabled Applications: 1-6	Partners	Geophysical Properties	Relevant Objective(s)
			1	**Severe Storm Forecasting and Modeling:** Observations of aerosols, cloud properties, and precipitation are used by the weather modeling and forecasting communities to predict hurricane and mid-latitude cyclone development, intensity, and track and associated precipitation type and amount.	NOAA, FAA, NCAR, EPA and State Agencies	Aerosol, cloud, and precipitation properties, brightness temperatures	O1, O2, O3, O4, O5, O8, O10
			2	**Aerosol & Precipitation Interaction in Modeling & Forecasting:** Observations of aerosols and clouds enable the air quality modeling and forecasting communities to improve modeling/forecasting the impact of aerosols on precipitation including aerosol transport, scavenging, deposition, and chemical transformation.	NWS, NOAA, CTM, EPA, state AQ agencies, other modeling communities	Vertical velocity, aerosol, cloud, and precipitation properties	O1, O3, O5
			3	**Climate Modeling:** Observations of clouds, aerosols, and precipitation enable the climate modeling community to improve model initialization and simulations which inform international reports and policy makers decisions.	NWS, NOAA, CTM, EPA, state AQ agencies, other modeling communities, IPCC, UN, WMO	Vertical velocity, aerosol, cloud, and p recipitation properties	O3, O5
			4	**Energy Planning:** Cloud and aerosol optical depths are used to estimate radiative fluxes for applications, such as estimating available photosynthetically active radiation (PAR) for air quality modeling, attenuated solar insolation for solar power companies, and agricultural forecasting. Solar power companies use estimates of size-resolved aerosol concentrations and precipitation to model dry and wet deposition on the panels, respectively.	NWS, NOAA, CTM, EPA, state AQ agencies, other modeling communities	Aerosol Optical Depth, Aerosol Extinction Profiles, Aerosol Speciation, cloud properties	O1, O2, O5, O9, O10
			5	**Geospatial Information & Analytics:** Big data for planetary resource surveillance: Data fusion techniques through geospatial analytics and "big data" management rely on aerosol, cloud and precipitation properties to provide continuous, detailed, multidimensional, and global monitoring as an invaluable tool for planetary resource surveillance such as food security, disaster relief planning, and aerosol health exposure.	Air quality modelers (EPA, NOAA, state agencies), solar energy companies, agricultural communities	Aerosol Optical Depth, Aerosol Extinction Profiles, Aerosol Speciation, cloud properties	O1-O10
			6	**Aviation Industry and Safety:** Observations of aerosol and cloud properties enable the aviation industry to predict and monitor hazards, such as visibility, icing, volcanic eruptions, and the impact to flights planning and aircraft engines.	NOAA, FAA, DoD, DoE, Volcanic Ash Advisory Centers, Airlines, private industry (e.g., General Electric, Pratt and Whitney, Rolls Royce, Northrop Grumman)	Cloud phase, height, depth, radius, and amount, Aerosol Optical Depth, Aerosol Extinction Profiles, Aerosol Speciation	O1, O2, O3, O4, O6, O10

A+CCP	A	Pote CCP	ntial Enable d Apps	Enabled Applications: 7-12	Partners	Geophysical Properties	Relevant Objective(s)
			7	**Wildfire Pre-, Active-, and Post-fire Operations and Management:** Observations of aerosols, cloud properties and precipitation enable the wildfire management, air quality managers, and hydrologic communities to detect and model smoke plume height and vertical distribution to improving air quality forecasts, estimate exposure to wildfire PM and co-emitted trace gas pollutants, and anticipate debris flows in affected communities.	Federal AQ agencies (EPA, NOAA, Forest Service), state agencies, other modeling communities	Precipitation properties, Aerosol Cloud, layer heights, Extinction Profiles, AOD, and Speciation	O1, O2, O5, O6, O7
			8	**Improved Numerical Weather Prediction:** Cloud and precipitation properties enable the weather prediction communities to enhance parameterizations of clouds to improve NWP output for weather forecasting.	NWP Centers (NOAA, NRL, ECMWF, JMA, NCAR), USDA, AFWA, IBM, Private Companies	Cloud height, depth, radius, phase, precipitation rate and phase	O1, O2, O3, O4, O7
			9	**Hydrologic Modeling:** Estimates of total water volume and long-term surface precipitation observations are critical for water resource managers, agricultural communities, and energy companies for estimating streamflow, flooding and inundation impacts, and assessing drought conditions.	FEWS NET, World Bank, FAO, USDA, Water Resource/Management community	Surface precipitation (Level 2-4)	O3, O4
			10	**Agricultural Modeling and Monitoring:** Surface precipitation observations enable the agricultural communities to model, forecast, and track watershed conditions that impact crop estimation, yields, irrigation, and supply.	USDA, ClimateCorp., PrecisionAG, agricultural communities and planners	Surface precipitation (Level 3/4)	O3, O4
			11	**Health and Ecological Forecasting & Monitoring:** Surface precipitation observations are used by a range of public and private communities, international and domestic governmental organizations and NGOs as inputs into hydrologic models, vector and water borne disease modeling, animal migration tracking, insurance models, and disasters applications.	CDC, NOAA, Red Cross, reinsurance, World Bank and agricultural communities, public and private companies (e.g., Johnson & Johnson, Agvesto, MiCRO)	Surface precipitation (Level 3-4)	O3, O4
			12	**Disaster Monitoring, Modeling and Assessment:** Observations of precipitation and long-term precipitation records are used by emergency response communities for modeling/estimating flooding and landslide hazards, developing parametric risk models for (re)insurance, and identifying high risk areas for hydrometeorological extremes.	FEMA, NOAA, Red Cross, FAO, US Army, reinsurance, NGOs	Surface precipitation (Level 2-4)	O3, O4

A+CCP	A	Poten CCP	tial Enabled	Apps Enabled Applications: 13-15	Partners	Geophysical Properties	Relevant Objective(s)
			13	**Human Health Studies & Health Risk Estimation:** Observations of aerosol are used to infer spatio-temporal variations & trends of speciated surface-level PM (PM_1, $PM_{2.5}$, PM_{10}), which are used for health studies, such as to associate the effects of exposure to PM with specific health outcomes, and to calculate health risks and longevity.	CDC, WHO, NIH, health researchers at universities (e.g., Global Burden of Disease), reinsurance industry	Aerosol Optical Depth, Aerosol Extinction Profiles, & Aerosol Speciation to infer surface PM (L3/L4).	O6, O7, O8,O9,O10
			14	**AQ Rule & Regulation Making:** Observations of aerosol are used to infer spatio-temporal variations & trends of speciated surface-level PM (PM_1, $PM_{2.5}$, PM_{10}), which used to support AQ rule-making, define exceptional events, etc. Aerosol observations are also used to support modeling of interhemispheric transport.	EPA, state AQ agencies	Aerosol Optical Depth, Aerosol Extinction Profiles, & Aerosol Speciation to infer surface PM (L3/L4).	O6, O7, O8,O9,O10
			15	**Operational AQ forecasting:** Aerosol observations are used for operational AQ forecasting (e.g., forecast initialization), tracking dust plumes, and issuing AQ alerts.	Federal (NOAA) and state AQ agencies	Aerosol Optical Depth, Aerosol Extinction Profiles, & Aerosol Speciation	O5, O6, O7, O8,O9,O10

Other AIT activities: Community Assessment Report

- CAR serves to document the information gathered concerning applications communities for an observing system/mission.
- CAR Updates and Moving Forward:
  - Developed profile of current and future potential uses and end-users: AIT User Directory and AIT Contact "Wishlist"
  - Identified 12 user communities to engage and build use case and user profiles

- **As our Earth system changes rapidly, NASA capabilities and observations add significant value to inform stakeholder decisions and policy**

- **Introducing applications in Pre-Phase-A mission studies such as ACCP ultimately amplifies the societal benefit of NASA missions**

- **The ACCP Applications Impact Team (AIT) is charged with ensuring that applications are considered to the greatest extent possible in mission design**
    - Applications Traceability Matrix
    - Architecture Applications Benefit Scoring and Narrative
    - Community Assessment Report

- ***Interaction with stakeholders is key to anticipating and developing the applications potential of ACCP in the future***

ACCP Study Overview and Applications Activities