Earth Science Division
Decadal Survey Briefing with Stakeholders

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Nov. 14, 2019

Outline

- Earth Science Division Overview
- Designated Observables Annual Review Summary
- Review Status of DOs
  - ACCP
  - MC
  - SBG
  - SDC
- Earth Science Applications
- Industry Engagement
- International Engagement
- Cross Benefits of Applications and Research
- 2007 Decadal Tier 2/3
- Calendar
- Q&A
  - Please email questions to Amy Treat at Amy.A.Treat@nasa.gov; the operator will open phone lines for questions at the end of the presentation

Earth Science Division Overview

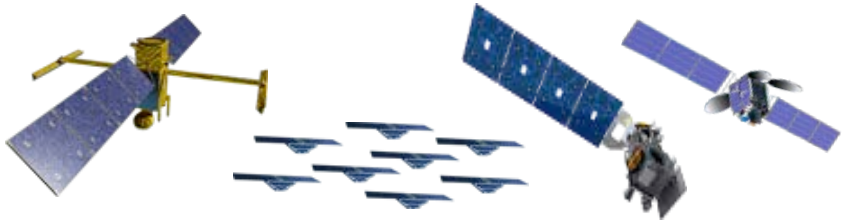
2017 Decadal Survey Progress

Earth Venture-Continuity

- DS recommended new Earth Venture Continuity Measurement strand ($150M full mission cost cap)
- In December 2018, ESD released EVC-1 solicitation targeted for radiation budget measurements
- Proposals were received in July 2019

Earth Science Explorers

- DS recommended a new competed Explorer flight line with $350M cost constraint
- Framework for program established
- Implementation on hold pending budget developments



Designated Observables

- DS identified 5 Designated Observables for mandatory acquisition (*Aerosols; Clouds, Convection & Precipitation; Mass Change; Surface Biology & Geology; Surface Deformation & Change*)
- In 2018 ESD initiated 4 multi-center Designated Observables studies, continued in 2019:
  - Combined: Aerosols-Clouds, Convection & Precipitation
  - Mass Change
  - Surface Biology & Geology
  - Surface Deformation & Change

Decadal Incubation

- DS calls for Incubation Program to mature specific technologies for important — but presently immature — measurements (preparation for *next* Decadal)
- Framework for program established
- Solicitations for Study Teams (PBL and STV) released on March 14, 2019, selections made, AGU Town Halls set up for each

Targeted Observables Priorities

Targeted Observable	Science/Applications Summary	Candidate Measurement Approach	Designated	Explorer	Incubation
Aerosols	Aerosol properties, aerosol vertical profiles, and cloud properties to understand their direct and indirect effects on climate and air quality	Backscatter lidar and multi-channel/multi-angle polarization imaging radiometer flown together on the same platform	X		
Clouds, Convection and Precipitation	Coupled cloud-precipitation state and dynamics for monitoring global hydrological cycle and understanding contributing processes	Radar(s), with multi-frequency passive microwave and sub-mm radiometer	X		
Mass Change	Large-scale Earth dynamics measured by the changing mass distribution within and between Earth's atmosphere, oceans, ground water, and ice sheets	Spacecraft ranging measurement of gravity anomaly	X		
Surface Biology and Geology	Earth surface geology and biology, ground/water temperature, snow reflectivity, active geological processes, vegetation traits and algal biomass	Hyperspectral imagery in the visible and shortwave infrared, multi- or hyperspectral imagery in the thermal IR	X		
Surface Deformation and Change	Earth surface dynamics from earthquakes and landslides to ice sheets and permafrost	Interferometric Synthetic Aperature Radar (InSAR) with ionospheric correction	X		
Greenhouse Gases	CO2 and methane fluxes and trends, global and regional with quantification of point sources and identification of source types	Multispectral short wave IR and thermal IR sounders; or lidar **		X	
Ice Elevation	Global ice characterization including elevation change of land ice to assess sea level contributions and freeboard height of sea ice to assess sea ice/ocean/atmosphere interaction	Lidar **		X	
Ocean Surface Winds and Currents	Coincident high-accuracy currents and vector winder to assess air-sea momentum exchange and to infer upwelling, upper ocean mixing, and sea-ice drift	Radar scatterometer		X	

*** Could potentially be addressed by a multi-function lidar designed to address two or more of the Targeted Observables*

Targeted Observables Priorities

Targeted Observable	Science/Applications Summary	Candidate Measurement Approach	Designated	Explorer	Incubation
Ozone and Trace Gases	Vertical profiles of ozone and trace gases (including water vapor, CO, NO2, methane, and N20) globally and with high spatial resolution	UV/IR/microwave limb/nadir sounding and UV/IR solar/stellar occultation		X	
Snow Depth and Snow Water Equivalent	Snow depth and snow water equivalent including high spatial resolution in mountain areas	Radar (Ka/Ku band) altimeter; or lidar**		X	
Terrestrial Ecosystem Structure	3D structure of terrestrial ecosystem including forest canopy and above ground biomass and changes in above ground carbon stock from processes such as deforestation and forest degradation	Lidar**		X	
Atmospheric Winds	3D winds in troposphere/PBL for transport of pollutants/carbon/aerosol and water vapor, wind energy, cloud dynamics and convection, and large-scale circulation	Active sensing (lidar, radar, scatterometer); passive imagery or radiometry-based atmos. motion vectors (AMVs) tracking; or lidar**		X	X
Planetary Boundary Layer	Diurnal 3D PBL thermodynamic properties and 2D PBL structure to understand the impact of PBL processes on weather and AQ through high vertical and temporal profiling of PBL temperature, moisture and heights	Microwave, hyperspectral IR sounder(s) (e.g., in geo or small sat constellation), GPS radio occultation for diurnal PBL temperature and humidity and heights; water vapor profiling and DIAL lidar; and lidar** for PBL height			X
Surface Topography and Vegetation	High-resolution global topography including bare surface land topography, ice topography, vegetation structure, and shallow water bathymetry	Radar; or lidar**			X

*** Could potentially be addressed by a multi-function lidar designed to address two or more of the Targeted Observables*

Other ESAS 2017 Targeted Observables not allocated to a Flight Program element: Aquatic Biogeochemistry, Magnetic Field Changes, Ocean Ecosystem Structure, Radiance Intercallibration, Sea Surface Salinity, Soil Moisture

See: https://science.nasa.gov/earth-science/decadal-surveys

ESD has decided to treat Atmospheric Winds as Explorer

Earth Science Division's Venture Opportunities

Mission	Mission Type	Release Date	Selection Date	Major Milestone
EVS-1 (EV-1) (AirMoss, ATTREX, CARVE, DISCOVER-AQ, HS3)	5 Suborbital Airborne Campaigns	2009	2010	N/A
EVM-1 (CYGNSS)	SmallSat Constellation	2011	2012	Launched Dec. 2016
EVI-1 (TEMPO)	Geostationary Hosted Payload	2011	2012	Delivered to storage Dec. 2018
EVI-2 (ECOSTRESS & GEDI)	Class C & Class D ISS-hosted Instruments	2013	2014	Launched June & Dec. 2018
EVS-2 (ACT-America, ATOM, MAAMES, ORACLES, OMG, CORAL)	6 Suborbital Airborne Campaigns	2013	2014	N/A
EVI-3 (MAIA & TROPICS)	Class C LEO Instrument & Class D CubeSat Constellation	2015	2016	Delivery NLT 2021
EVM-2 (GeoCarb)	Geostationary Hosted Payload	2015	2016	Launch ~2021
EVSI-4 (EMIT & PREFIRE)	Class C ISS-hosted Payload & Class D Twin CubeSats	2016	2018	Delivery NLT 2021
EVS-3 (ACTIVATE, DCOTTS, IMPACTS, Delta-X, SMODE)	5 Suborbital Airborne Campaigns	2017	2018	N/A
EVI-5 (GLIMR)	Geostationary Hosted Payload	2018	2019	Delivery NLT 2024
EVC-1	Radiation Budget Measurement	2018	2019	Delivery NLT 2024
EVM-3	Full Orbital	2019	2020	Launch ~2025
EVI-6	Instrument Only	2020	2021	Delivery NLT 2025
EVS-4	Suborbital Airborne Campaigns	2021	2022	N/A
EVC-2	Continuity Measurements	2021	2022	Delivery NLT 2027
EVM-4	Full Orbital	2021	2024	Launch ~2029
EVI-7	Instrument Only	2023	2024	Delivery NLT 2028
EVC-3	Continuity Measurements	2024	2025	Delivery NLT 2030
EVS-5	Suborbital Airborne Campaigns	2025	2026	N/A

EVS
Sustained sub-orbital investigations
(~4 years)

EVM
Complete, self-contained, small missions
(~4 years)

EVI
Full function, facility-class instruments Missions of Opportunity (MoO)
(~18 months)

Open solicitation - In Review

Completed solicitation

Personnel Changes

- Charles Webb
  - Associate Director for Flight (Acting)
- ESD Director
  - Announcement will go out at the end of November 2019

DO Study Points of Contact

Study	Program Executive	Program Scientist	Program Applications Lead	Technology POC	Centers Study Coordinator
ACCP	Tahani Amer	Hal Maring (*Alternates*: Gail Skofronick-Jackson, Barry Lefer)	John Haynes (*Alternate*: David Green)	Amber Emory (*Alternate*: Bob Connerton)	Vickie Moran (GSFC)
SBG	Marissa Herron	Woody Turner (*Alternates*: Ben Phillips, Laura Lorenzoni)	Woody Turner (*Alternate*: Brad Doorn)	Bob Connerton (*Alternate*: Mike Little)	Jamie Nastal (JPL)
SDC	Mitra Dutta	Gerald Bawden (*Alternates*: Hank Margolis, Mike Falkowski)	David Green	Bob Bauer (*Alternate*: Bob Connerton)	Paul Rosen (JPL)
MC	Amanda Whitehurst	Lucia Tsaoussi (*Alternate*: Jared Entin)	Brad Doorn	Bob Connerton (*Alternate*: Parminder Ghuman)	Bernard Bienstock (JPL)

Flight Program
Accomplishments Since July 2019

- SORCE KDP-F: July 11, 2019
  - Transition to Phase F: Feb. 25, 2020
- GeoCarb KDP-C: July 18, 2019
  - Continuation Review planned for December 2019
- Received EVC-1 Proposals: July 26, 2019
  - Currently under evaluation
- OCO-3 Post-Launch Assessment Review: Aug. 9, 2019
- PACE KDP-C: Aug. 15, 2019
- OSTM/Jason-2 KDP-F: Nov. 4, 2019

Research & Analysis Accomplishments Since July 2019

- Airborne Field Campaigns (Selected)
  - *SNOWEx* – Grand Mesa November campaign completed, including NASA SWESARR instrument, NOAA Gamma Airborne Survey, and significant ground work
  - *NASA/ISRO L/S Radar Campaign* – instrument arrived in US, first phase (snow, solid Earth, ocean first)
  - *ACT-AMERICA* – flew over 200 hours (B200, C-130)
  - *FIREX-AQ* (joint with NOAA) – flew over 200 hours (DC-8, ER-2) from ID and KS (DC-8) and CA (ER-2)
  - *CAMP^{2}Ex* – flew 150 science flight hours on the P-3 and 40 science flight hours on the SPEC, Inc. Lear 35
  - *ABoVE* – flew 55 hours on GIII from locations in Alaska and Canada
  - *OIB* – flying final campaign (Antarctic) using G-V
- DS Modeling Recommendations – initial telecon with NOAA (9/17) on DS recommendation 4.2, including participation from multiple line offices and laboratories; follow-up meeting between NASA GMAO and NOAA NGGPS (10/21)

Research & Analysis Accomplishments Since July 2019

- Community Activities (Selected)
  - GLOBE Annual Meeting – July 14-18 (Detroit, MI)
  - AGU Chapman Conference on Carbon and Climate Feedbacks - August 26-29 (San Diego, CA)
  - Solid Earth Team Meeting – November 4-6 (San Diego, CA)
- Upcoming Events
  - AGU Town Halls (selected)
    - Surface Deformation and Change (DO) – Monday 12:30-1:30 (Moscone West 3005)
    - Aerosols, Clouds, Convection and Precipitation (DO) – Monday 6:15-7:15 (Moscone West 3004)
    - NASA/ESD – Tuesday, 12:30-1:30 (Moscone West 2002)
    - Incubation ST&V – Tuesday, 6:15-7:15 (Moscone West 3004)
    - NASA Sea Level Change Team – Tuesday 6:15-7:15 (Moscone West 2016)
    - Mass Change (DO) – Thursday 12:30-1:30 (Moscone West 2004)
    - NASA SnowEx Planning – Thursday 12:30-1:30 (Moscone West 2005)
    - Incubation PBL – Thursday 6:15-7:15 (Moscone West 3004)

Applied Sciences Accomplishments Since July 2019

Community Activities (Selected)

- Health & Air Quality Applied Sciences Team Meeting (July 10-12; Pasadena, CA)
- Earth Science Information Partners Summer Meeting (July 16-19; Tacoma, WA)
- Western Water Applications Office Meeting (July 16; Portland, OR)
- Water Resources Team Meeting (July 17-19; Portland, OR)
- Kick-off Meeting for New Disaster Applications Projects (July 18-19; Boulder, CO)
- Summer Applications Showcase featuring DEVELOP projects (August 1-2; Washington, DC)
- Health & Air Quality Team Meeting (Sept; Rapid City, SD)
- International Space Apps Challenge (Oct.; Worldwide)
- Applied Sciences Advisory Committee meeting (Nov 12 & 15, telecon)
- VALUABLES Workshop (Oct; Washington, DC and Livestream)

Notables

- 10-year anniversary of ARSET (Applied Remote Sensing Training) arset.gsfc.nasa.gov
- 10-year anniv. of LANCE (Land, Atmosphere Near real-time Capability for EOS)
- Space For U.S. site awarded two gold medals

nasa.gov/spaceforus

Earth science applications stories for each U.S. State, DC, PR, and major bodies of water

Notable Town Halls at AGU

SERVIR: Wed 12:30 M-West 2007
Global Agriculture: Thurs 12:30 M-West 2008
Upcoming EO & Apps.: Thurs 12:30 M-West 3014
SAR & Capacity Building: Thurs 12:30 M-West 3002
Soil Moisture: Fri 12:30 M-West 2016
ICESat-2 Applications: Fri 12:30 M-West 3004

USGEO: Monday 12:30 M-West 2005

Earth Science Technology Office (ESTO) Accomplishments Since July 2019

- HARP launch on NG-12: Nov. 2, 2019
  - Expect to be deployed from ISS in January 2020
- AIST-18 awarded 22 projects, with relevance across the DS Targeted Observables http://bit.ly/AIST18_Awards
- IIP-19 awarded 19 projects, with relevance across the DS Targeted Observables http://bit.ly/IIP-19
- Decadal Survey Incubation Study Teams Solicitation, *led by R&A*, will be announced in time for team members to participate at relevant AGU town halls (PBL and ST&V)
- In the process of augmenting a few ongoing ESTO and R&A activities that are highly relevant to PBL and ST&V Targeted Observables
- Collecting requirements from DO study teams for tech demo/risk reduction activities
  - We may augment existing ESTO, SBIR projects that fit requirements
  - We are looking into a quick turn around solicitation that could fit into FY20

Earth Science Division

- In a Continuing Resolution (CR) until Nov. 21, 2019
- FY20 Appropriations Bill has not been passed
- The current CR continues funding at FY19 levels
  - ~$1.931 Billion for ESD
  - Continues operations and development of FY17 Program of Record (including DSCOVR EPIC/NISTAR, PACE, CLARREO-PF)

Notable Town Halls at AGU

- NASA ESD Town Hall, Tuesday 12:30-1:30, Moscone West 2002
- Meet the Chief Scientists from NASA Centers, Tuesday 18:15-19:15 Moscone West 2020
- NASA's Earth Observations from the Private-Sector Small Constellation Satellite Data Product Pilot Project, Tuesday 18:15-19:15 Moscone West 2007

Designated Observables (DO) Annual Review Summary

DO Annual Review Summary

- On Sept. 26, the DO Study Teams presented their year-one activities to the Earth Science Division
  - Teams have developed Science and Applications Traceability Matrices (SATMs)
  - Initial architectures and instrument capabilities have been developed
  - Teams have developed value frameworks to assess architectures
  - Some teams have identified (and/or issued) RFIs and/or needs for industry solicitations
  - Initial international engagement has started
  - Industry Engagement Working Group with members of the DO Teams will be established
  - Teams are ready to update their future plans
- The next DO meeting will be Jan. 29, 2020 to present the ESD process for down selecting to the final architecture

Aerosol, Cloud, Convection and Precipitation (ACCP)

Mission Study on Aerosol and Clouds, Convection & Precipitation

ACCP Science

8 Science Objectives (see SATM for # Mapping)
Traceable to the 2017 Decadal Survey

Low Cloud Feedback *(1)*

Convective Storm Systems *(3)*

Aerosol Redistribution *(6)*

High Cloud Feedback *(2)*

Cold Cloud & Precipitation *(4)*

Aerosol Absorption, Direct & Indirect Effects on Radiation *(7,8)*

Aerosol Attribution & Air Quality *(5)*

Mission Study on Aerosol, Clouds, Convection & Precipitation

ACCP Applications

13 Enabled Applications

Climate Modeling

Aviation Industry and Safety

Storm Forecasting and Modeling

Improved Numerical Weather Prediction

Aerosols and Precipitation Interaction

Operational Air Quality Forecasting

Inform Air Quality Regulation

Human Health Studies & Health Risk Estimation

Wildfires

Disasters

Energy Planning

Hydrologic Modeling

Agricultural Modeling & Monitoring

Health and Ecological Forecasting/Monitoring

ACCP: Architecture Construction

- Architecture Construction Phase nearly complete
  - Architecture Construction Workshop (ACW) 1-3 at JPL in May, June and July 2019
    - 19 Architectures were constructed to explore trade space from more capable (1-2 spacecraft) to less capable but distributed spacecraft (up to 4 spacecraft augmented with SmallSat and CubeSats) with a range of costs
  - Defining Sweet Instrument Suites (DSIS) Workshop Aug. 8, 2019
    - Discuss how the architectures constructed to date fit overarching goals of ACCP and constructed new Instrument Suites and modifications to existing Instrument Suites (13 total)
  - ACW 4 at GSFC Sept. 16-20, 2019 refined Technical Margins and the Ground System Architectures
  - All architectures utilized Payload/Instrument Library consisting of >50 responses received from RFI and considered contributed instruments from potential international partners (JAXA, CNES, CSA)

ACCP: Architecture Evaluation

- Architecture Evaluation Phase in progress
  - Architecture Evaluation Workshop (AEW) 1 held Aug. 7, 2019
    - Discussed the Qualitative Science Benefit Scores and Programmatic Cost/Risk associated with the Architectures studied in ACWs 1-3 and selected the first Architecture for further design definition in a Collaborative Design Center (CDC)
      - Architecture 8G: 1 Polar Orbiting and 1 GPM Orbiting Spacecraft
  - Results/Lessons Learned:
    - Costing of instruments is challenging (particularly for radar and lidar instruments using NICM)
    - Refined Costing and Full Value Framework Science Benefit Assessments will be done post CDC

ACCP: Architecture Design & Definition

- Architecture Design & Definition Phase in progress
  - Architecture 1 of 6 in progress
    - CDC 1 was completed Sept. 30-Oct. 11, 2019 at GSFC
    - Independent Technology Readiness Assessments (TRAs) is underway for all non-contributed instruments in Architecture 8G (expected completion January 2020)
    - Independent Cost Modeling (Price-H) is underway for all instruments for which a Master Equipment List (MEL) is available (expected completion December-January 2020)
  - Architecture 2 of 6 Plan
    - The next Architecture for CDC 2 will be selected in AEW 2 on Dec. 6, 2019 near Colorado State University in Ft. Collins *after* hearing the independent Science Community Committee's (SCC) input and feedback on the Science and Applications Traceability Matrix (SATM) and Science Priorities
    - CDC 2 will be conducted at JPL in mid-January 2020

ACCP: Community and Industry Engagement

- ACCP potential international partnerships
  - JAXA and CSA participation on SALT, SIT and SCC
  - Technical expertise provided for potentially contributed instruments
  - Bilateral discussions planned for Dec. 3, 2019 in Ft. Collins, Colorado
- ACCP community engagement
  - Quarterly Community Forums (first, Sept. 20; next, at AGU)
    - Provides more detailed status on ACCP science, instrumentation and architectures to interested community
  - AGU ACCP Town Hall, Dec. 9
  - AGU ACCP Splinter Meeting on Architectures, Dec. 10
  - AGU ACCP Splinter on Science, Dec. 11
- ACCP industry-university engagement
  - 16 Engineering/Technology Development Proposals submitted and under evaluation

ACCP: Study Status and Timeline

Date	Milestone
October 2018	Study Plan Start (completed)
April 2-4, 2019	Community Workshop in Pasadena (2 month delay due to shutdown) (SATM Rev C) (completed)
April 19, 2019	RFI for Instrument Libraries (~50 Responses, including International Contributions) (completed)
May 7, 2019	Release SATM Rev D (for Architecture Construction) (completed)
May-September 2019	Architecture Construction Workshops I-III, Architecture Refinement, & Architecture Evaluation Workshop 1 (completed)
Sept. 16, 2019	Release SATM Rev E for SCC Review (revised post Architecture Construction refinements)
CDC Sept. 30-Oct. 11, 2019 Costing, Evaluation through December	Collaborative Design Center (CDC) Run #1 (at Goddard), Value Framework, & Costing
March 2020	Sub-Orbital Workshops & Sub-Orbital Inclusion Into Architectures
January, March, May, July, September 2020	Remaining CDCs (JPL, LaRC, MSFC, GRC, GSFC), Value Framework, & Costing
September 2021	Final Report & Presentations

Mass Change (MC)

Mass Change (MC) Study Update

Current and upcoming plans and events:

- Study identified drivers and constraints, key MC candidate architectures and technology readiness
- Work on simulations for selected architectures across the three architecture types is ongoing
- Discussion on value framework and metrics
- Effort has begun with Analyses-of-Alternatives (AoA)
  - Currently defining details of architecture options as the input to the AoA
- Assessing contract options for investments in promising technologies

The MC Study team will hold community telecons, identified by scientific discipline, focused on the further refinement of the Mass Change Designated Observable Science and Applications Traceability Matrix.

- If you would like to attend any of the scheduled telecons, please send an email requesting an invitation to masschange@jpl.nasa.gov. The schedule is as follows:
  - Oct. 30 at 4 p.m. EST: Earth Surface and Interior
  - Nov. 15 at 2 p.m. EST: Global Hydrological Cycle and Water Resources
    Nov. 19 at 2 p.m. EST: Climate Variability and Change

Mass Change Designated Observables Study AGU Town Hall

- AGU 2019 Fall Meeting, Thursday, Dec. 12, from 12:30-1:30 p.m. (PT)

Mass Change (MC) Study Update *(cont'd)*

Community Engagement Workshop July 30-Aug. 1, 2019, Washington, D.C.

- 80 participants from NASA, other USG agencies, private sector, universities and international partners
- Presentations by MC team and community in plenary and breakout sessions for 2.5 days
- Presentations and discussion on the Science and Applications Traceability Matrix (SATM), Observing Architectures (including SmallSats) and Technology
  - Workshop Report available on the MC Website, https://science.nasa.gov/earth-science/decadal-mc
  - All presentation materials available upon request to masschange@jpl.nasa.gov

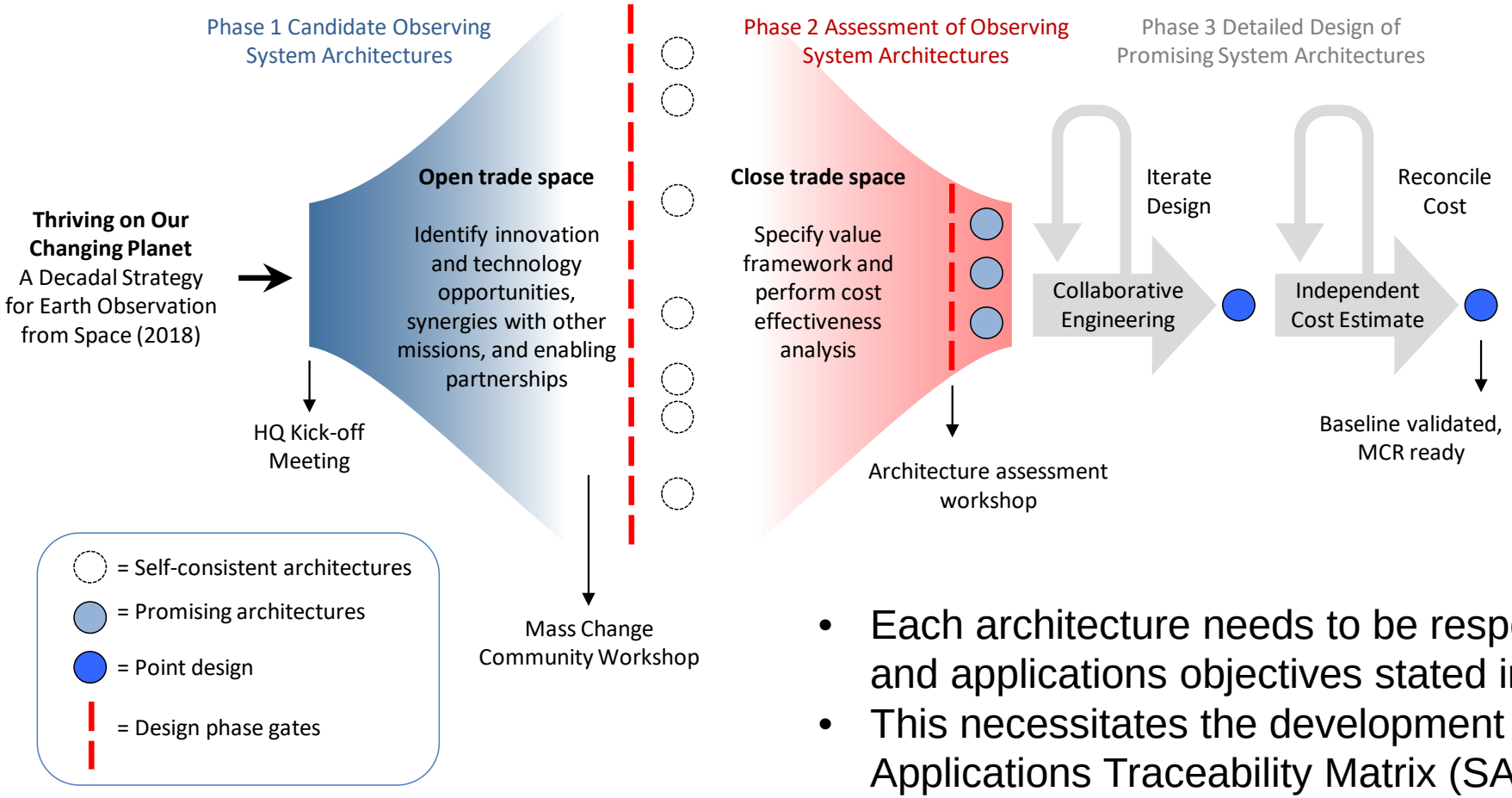
Applications

- Mass Change Applications Survey released online June 14, 2019
  - Survey remains open at https://tinyurl.com/MassChangeSurvey
- Mass change applications poster at AGU
  - Dec. 13, 8 a.m.-12:20 p.m., Session G51B-0575, Moscone South Poster Hall

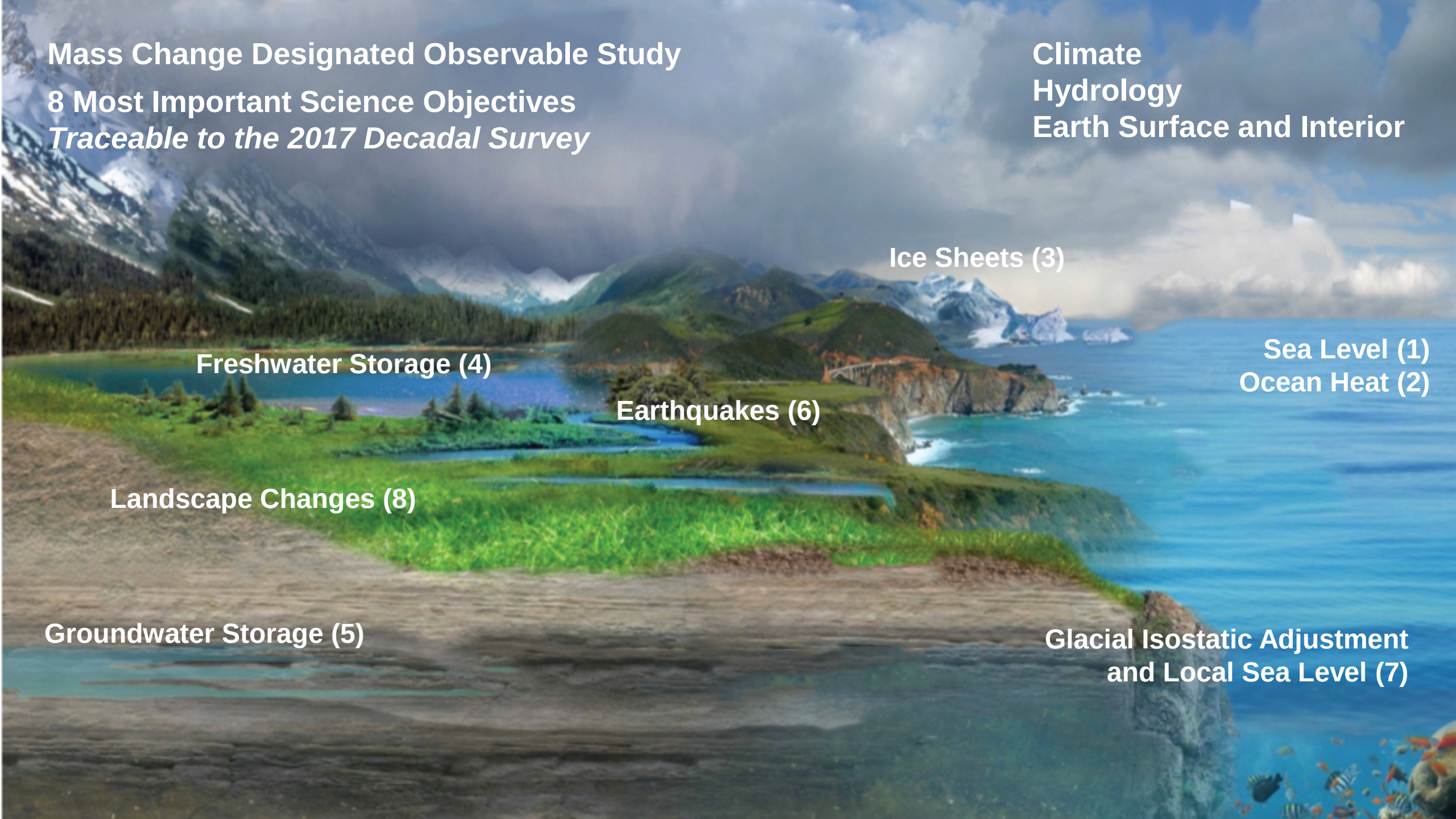
Team engagement with potential partners, including industry and international

- Ongoing NASA/ESA dialogue for joint studies

Study Phases

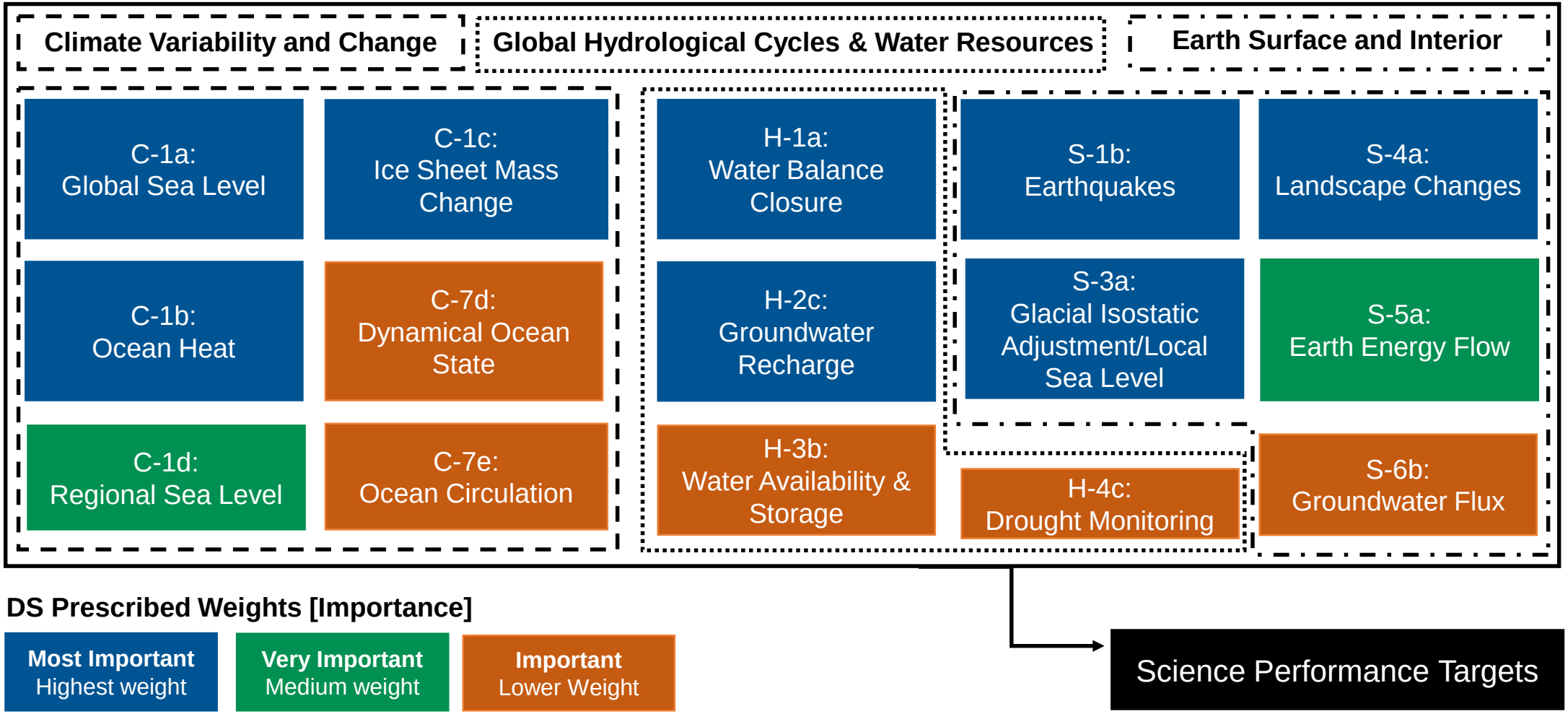


- Each architecture needs to be responsive to the science and applications objectives stated in the Decadal Survey
- This necessitates the development of a Science and Applications Traceability Matrix (SATM)

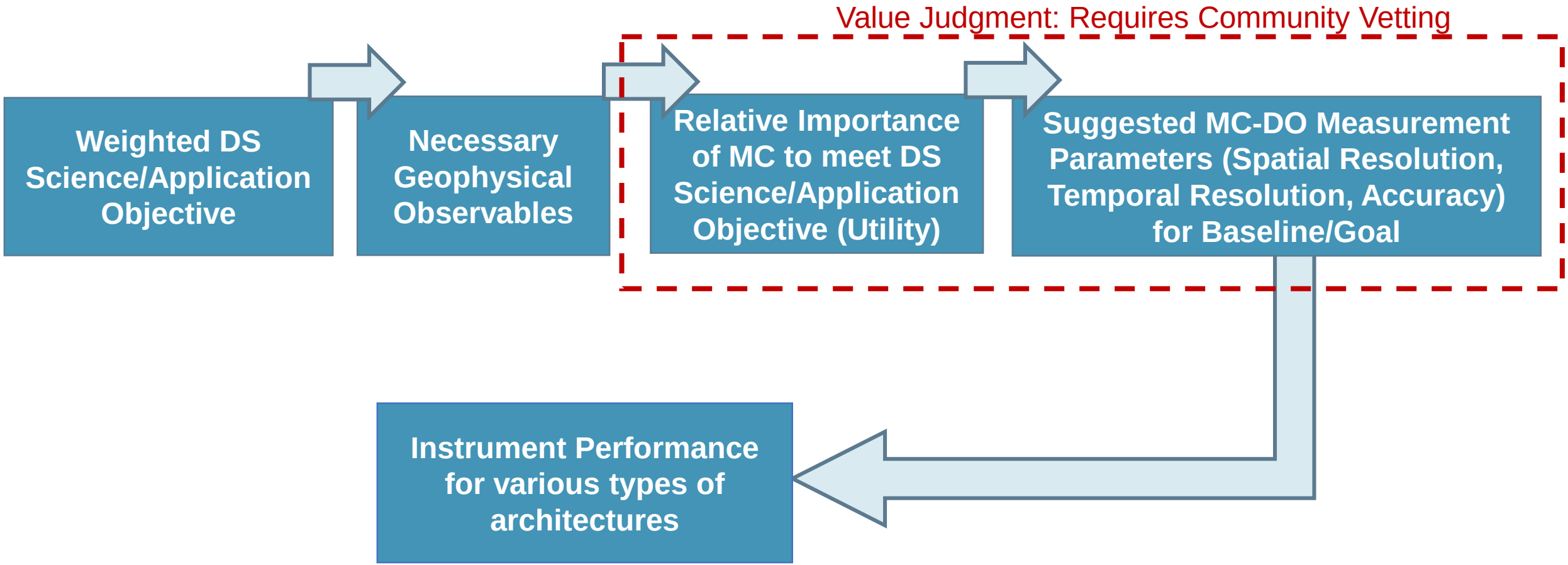

Mass Change Designated Observable Study
8 Most Important Science Objectives
Traceable to the 2017 Decadal Survey
Climate
Hydrology
Earth Surface and Interior
Ice Sheets (3)
Sea Level (1)
Ocean Heat (2)
Freshwater Storage (4)
Earthquakes (6)
Landscape Changes (8)
Groundwater Storage (5)
Glacial Isostatic Adjustment
and Local Sea Level (7)

Decadal Survey Science and Application Objectives for Mass Change

A Diverse Set of Objectives Spanning Three Panels



MC Interpretation of DS Objectives



MC Workshop Architecture breakout: Summary

Study plan timeline and expected outcomes:

- Nominal length of ~3 years, could extend to ~5 years total, if necessary
- Upcoming Phase 2
  - Begin with very open trade space; we will need to rely on previously-published simulations and simulations performed outside the NASA MC team – we need inputs
  - All architecture classes will be considered at this point, detailed and consistent simulations will need to be run within NASA MC team for some architectures
- Final delivery to NASA HQ: Timeline of observing system options
  - Includes ~3 candidate architectures for the MC observing system
  - Could include existing platforms, other data sets, data buys, tech demos, other agency platform(s), contingency/gap-bridging observing system as future budget is unknown
  - Should include the development of a technology road map

Architecture classes:

- 1. SST, 2. Gravity gradiometer, 3. SmallSat/CubeSat, 4. POD (in no particular order)

Key discussion points:

- Spacecraft system/instrument-coupled simulations needed. Some simulations could be done jointly (e.g. NASA/ESA)
- GRACE/GRACE-FO define the threshold performance?
- Continuity is of high importance as made clear in the Decadal Survey objectives.

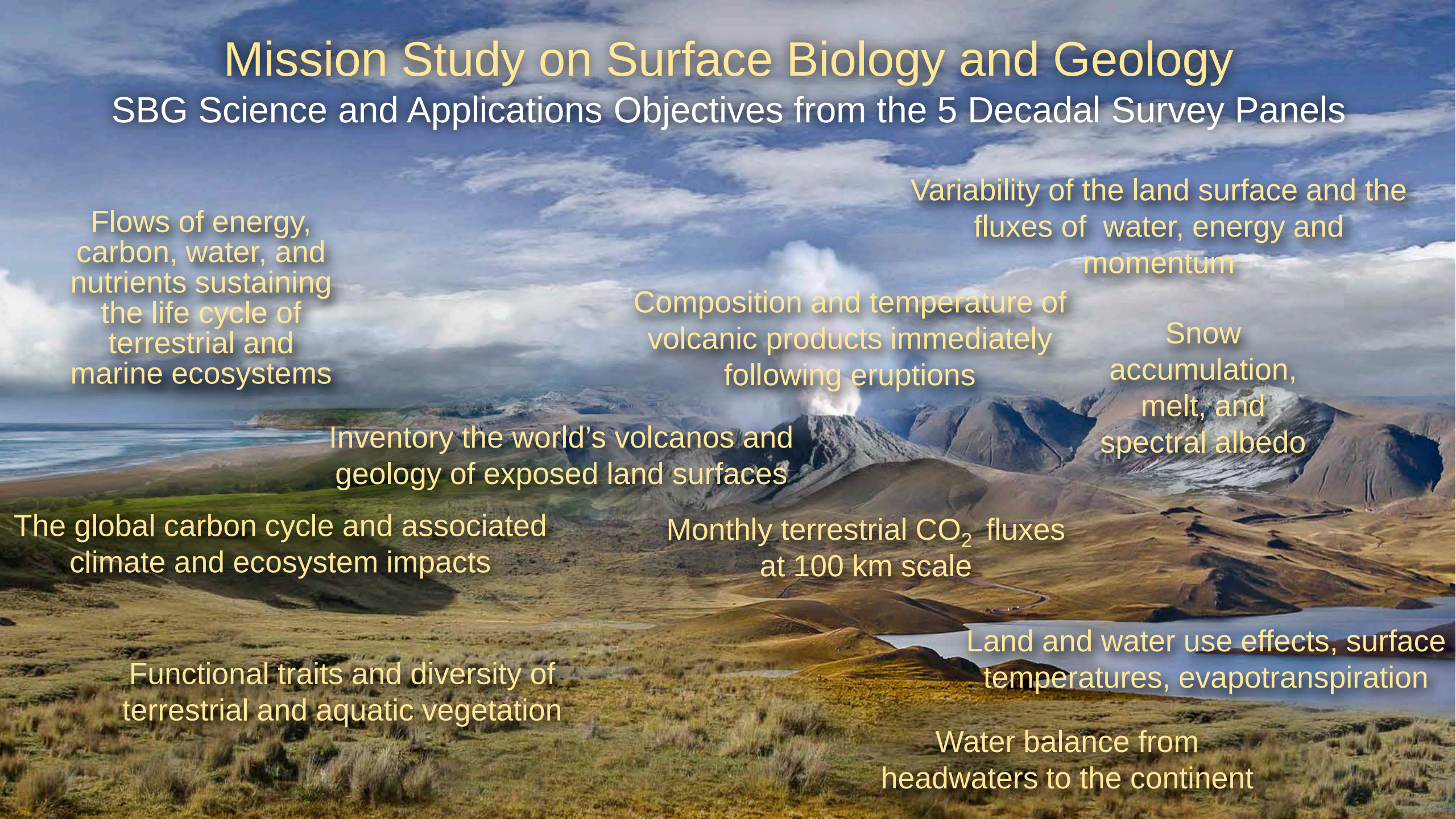
MC Workshop Technology Breakout Summary

- Strong support for advancements and improvements in accelerometer technology
- Strong support and apparent consensus for Laser Ranging as the path forward for SST measurements
- Gradiometer technology is the likely far reaching path forward for significant advancements
  - Will look at Atomic Interferometry (Cold Atom) and Superconducting gradiometers
- Support for Tech Demo opportunities to advance future technologies:
  - CubeSat and SmallSat technologies
  - Gradiometer and Quantum Sensing technologies
- The three main technology areas noted in first three bullets were assigned POCs to summarize technology based on agreed metrics and criteria
- Other technologies noted include: drag free, attitude control, reference frame tech

Surface Biology and Geology (SBG)

Mission Study on Surface Biology and Geology

SBG Science and Applications Objectives from the 5 Decadal Survey Panels



Surface Biology and Geology (SBG) Update

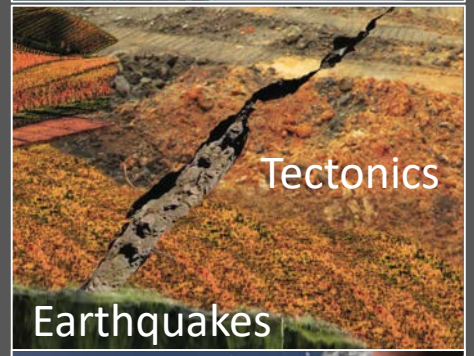
- September 5 – SBG website live at https://sbg.jpl.nasa.gov, integrating with NASA Decadal Survey website
- October 1 – Transition from Study Phase 1 (Candidate Architectures) to Study Phase 2 (Assessment)
- October 29-31 – Team-X Architecture Study
  - Determined first-order feasibility based on **financial** (cost), **technical resources** (volume, mass, power), and **performance** (radiometric, spatial, spectral, temporal range and resolution) constraints that make the instruments viable for their respective architectures
  - Research and Applications (R&A) WG was well represented during all 3 sessions
  - Participating centers included ARC, GSFC, JPL, and LaRC
  - A total of 14 instrument cases for TIR and VSWIR instruments studied, these captured key elements of the 60+ architectures arising from Phase 1
- November 11-15 – Bilateral discussions in Japan with HISUI team
- December 3-4 – Status meeting at HQ
- February 3-4 – Co-Leads meeting
- March 12-13 – Bilateral discussions, ESA and ASI
- April (tentative) – Team-X study

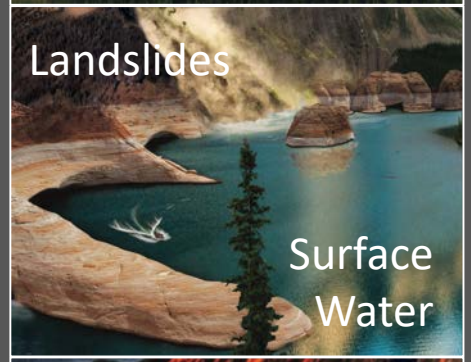
SBG: Key Dates

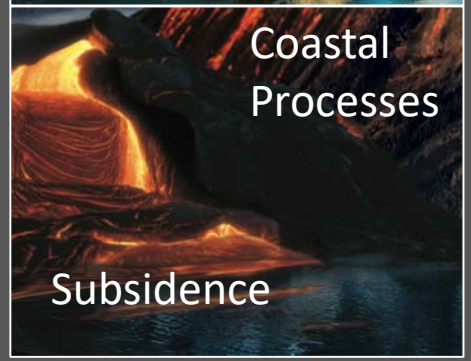
Date	Milestone
October 2018	Study Plan Start
February 2019	A Team Study
March 2019	WG Co-leads meeting, DC
April 2019	Phase 1 Option Tree and Costs
June 2019	Community Workshop
August 2019	WG Co-leads meeting, Ames
September 2019	DO annual Review
January-March 2020	Design Center Studies
July 2020	Phase II Delivery to HQ
August 2020	Community Workshop
May 2021	Final SBG Study Report and Findings
September 2021	MCR Preparation

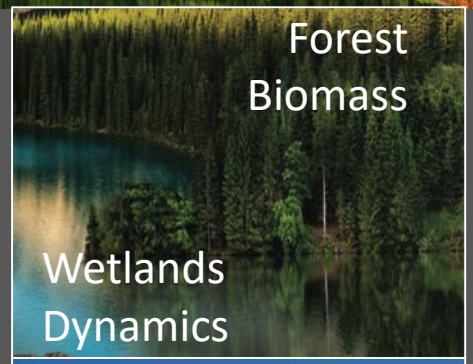
Surface Deformation and Change (SDC)

Surface Deformation and Change Observables



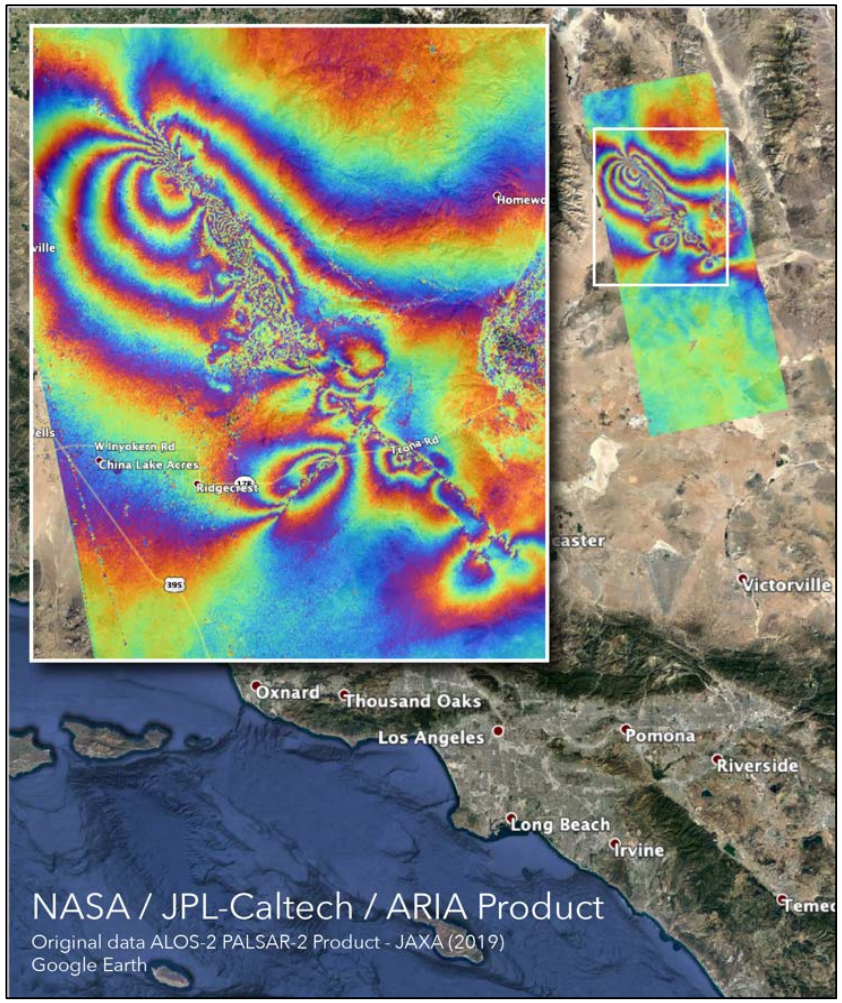






SDC Science is Perennially Relevant

- Ridgecrest earthquakes were top news in the U.S. for days after the earthquakes July 4 and 5, 2019
- Image (*left*) generated from ALOS-2 data acquired well before the events, and again after several large earthquakes occurred
    - More noise than necessary and conflated signals
- In recommending the Surface Deformation and Change Designated Observable, the Decadal Survey recognized the **need for higher precision and more frequent estimates** to reliably differentiate immediate afterslip from longer term relaxation events from temporally and spatially interconnected system of faults



Year 1 Objectives Completed: Team, Community and SATM Building

Year 1 Objective () = Schedule Task Names	Activities to Reach Objective () = centers engaged in activity
Build an Effective SDC Team	• Leadership meeting in February 2019 to define plan and achieve consensus (All) • Weekly telecon between Program Scientist and Study Coordinator (JPL/NASA) • Bi-weekly Phase 1 Leads coordination telecons (JPL/GSFC) • Bi-weekly R&A telecons (JPL/MSFC/GSFC) • Bi-weekly SDC team coordination telecons (All) • NASA G-Suite document sharing
First Round of Science and Applications Traceability Refinement (DSATS/CDC)	SDC Research and Applications Workshop April 29-May 1, 2019 (JPL/MSFC/GSFC + All)
Build Connections to Relevant Communities (ECA)	• Fall AGU 2018 ESI Town Hall (JPL/MSFC/GSFC + All) • Living Planet Symposium 2019 SDC presentation and SAR WG Meeting • IGARSS 2019 SDC presentation (All) • SAR WG regular telecons with DLR and ESA (JPL) • Establish SDC website in coordination with NASA HQ (JPL/GSFC)
Assess the State of the Art in Technology and Trends that are Usable for SDC (ECA)	SDC Technology Workshop May 20-22, 2019 (JPL/ARC + All)

Schedule Task Acronyms: **DSATS** = Define Science/Apps Trade Space **CDC** = Compile Driving Capabilities
ECA = Explore Candidate Architectures **DCA** = Define Candidate Architectures **PT** = Performance Tool

Year 1 Objectives Completed: Toward Architecture Definition and Assessment

Year 1 Objective	Activities to Reach Objective () = centers engaged in activity
First Assessment of New Space Applicability for SDC (ECA)	• Literature search (JPL) • Developed SmallSat science potentials model based on Bearden paper (JPL) • Established relationship with U.S. Defense Innovation Unit (JPL/ARC) • Established relationship with Capella Space, ICEye (JPL/GSFC/ARC)
First Assessment of International Partnership Possibilities (ECA)	• Living Planet Symposium 2019 SAR WG Meeting (JPL) • IGARSS 2019 interactions (JPL/MSFC/ARC) • SAR WG regular telecons with DLR and ESA (JPL)
Augment the NISAR Performance Tool Technologies to Create SDC Constellation Performance Tool (PT)	• Engaged Mission Planning Group responsible for NISAR mission planning to augment CLASP for SDC-specific targeting attributes for constellations (JPL/ARC/LaRC) • Engaged NISAR Performance Tool Team to augment interfaces for constellations (JPL/ARC/LaRC)
First thoughts on Architectures (DCA)	• SDC Technology Workshop May 20-22, 2019 report outcomes (JPL/ARC/LaRC) • A-Team Constellation Concept Brainstorming Study June 2019 (All)

- SDC Team is well integrated, with *all centers* engaged
- Team is making excellent progress and is on track for defining architectures

JPL A-Team Session

Fifteen scientists, engineers, and program managers identified opportunities if we consider *timely* international engagement.

General Outcomes:

- ROSE-L (ESA) and/or Tandem-L (DLR) go a long way toward meeting SDC observables
  - Two NISAR-like spacecraft 6-day separated (ROSE-L) or Tandem orbital configurations
- NASA contribution or augmentation would add capability
  - Faster revisit by adding an additional satellite in a time-spaced orbit
  - Vector diversity in bistatic configuration
  - Baseline diversity in bistatic configuration
- Commercial constellations could offload some science observables particularly in cryosphere
- SmallSat constellation could help resolve Solid Earth science versus geohazard latency and global versus localized conflicts

Preliminary Architectures/Approaches

The SDC study has until mid 2021 to define architectures

SAR-based solutions lead to a natural set of architectures that we will choose from

1. NISAR follow-on with ISRO or equivalent partner
2. Constellation of SmallSats equaling NISAR capability
3. N of #1 and m of #2 above, where n,m = 1,2,3…
4. ESA's ROSE-L Mission or equivalent: Two NISAR-like L-band systems planned for ~2028 launch
5. ROSE-L + #1 above
6. ROSE-L + #2 above
7. ROSE-L + a co-flier or two
8. Add a complement of commercial X-band SAR data for polar regions and geohazards
9. Add a complement of drone/high altitude platforms to address persistence/fast sampling

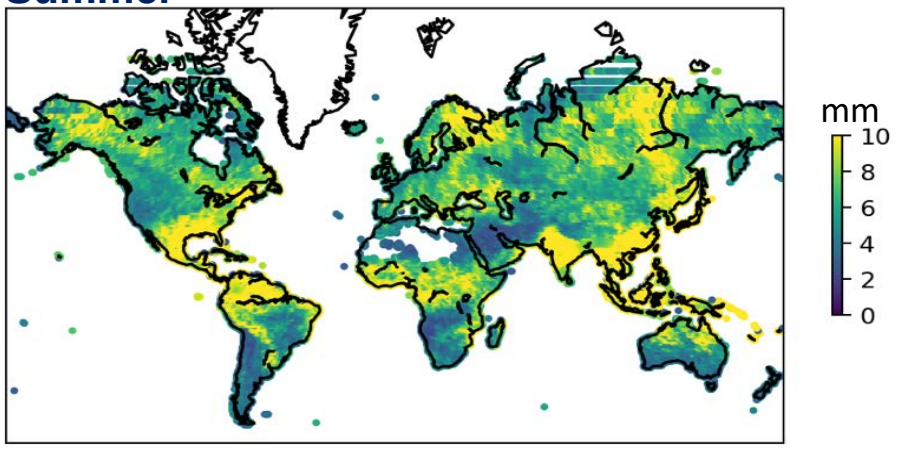
Performance Tool: Overview

Designed to provide the performance metrics of a given SAR satellite or constellation.

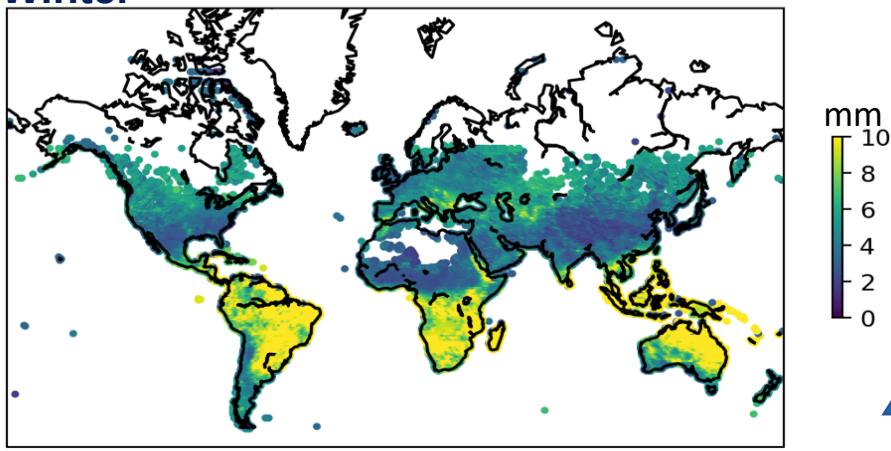
- Inputs:
  - **Target** points on the ground, chosen for global coverage or specific to a focus group (cryosphere, solid Earth, etc.)
  - **Architecture** viewing geometry, data acquisition repeat time, beam parameters, orbits
  - **Model** noise parameters related to EM wave propagation delays, target surface conditions (e.g., snow, vegetation cover), data correlation.
- Outputs: seasonally-dependent coverage and measurement uncertainty, over a set of ground targets

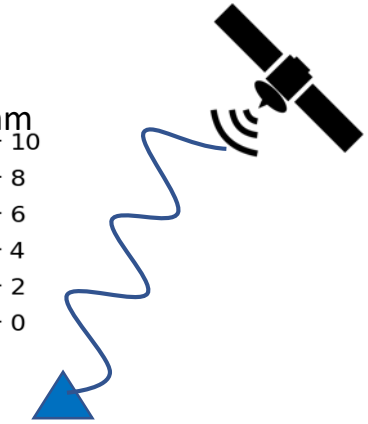
Example: Data coverage and average surface deformation measurement uncertainty for NISAR over 24 days

Summer



Winter





Upcoming Activities and Milestones

Date	Activity/Milestone
November 2019	CEOS Plenary (NASA's report of Decadal Activities)
Dec. 9, 2019*	SDC Town Hall, Fall AGU, San Francisco
February/March 2020*	SDC/SNWG Stakeholder meeting
April 2020	Completion of Primary Performance Tool
June 2020	Preliminary evaluation of architectures
June 2020*	Research & Applications Community Workshop
August 2020	Final Capabilities Document

**Activities open to international research, applications, and technical communities*

Applications

Earth Science Missions & Applications

Primary goal is to maximize the benefit of NASA's investments by enhancing the applications value and overall societal benefits of projects

Direct Use

Uses of data/info. products to improve decisions for societal/economic benefits; feedback from non-trad. audiences; increase ROI

Research Results

Increased awareness and familiarity with research pursuits of DOs & researchers; anticipation of results

Advocacy

Broaden the range of communities and orgs. interested in the DOs and potential voices to support them

Earth Science Missions & Applications

Community Assessment Report

As part of the efforts to have applications considerations in the Pre-Phase A time frame for missions/observing systems (and throughout the lifecycle), NASA is conducting Community Assessments, which are systematic efforts to gather information to assess and characterize applications user communities for the missions/observing systems. Supports the mission concept, trade-off decisions, and more.

A Community Assessment Report (CAR) serves to document the information gathered concerning applications communities for a mission/observing system. The CAR serves as a reference document for the project team, PE, PS, PAL, and others throughout the lifecycle.

CAR Outline *

Exec. Summary (Optional)

Introduction

Observing System

User Communities

Assessment & Characterization

Analysis

Findings & Implications

Conclusion

Appendix

Methods; References; Contacts

** Annotated outline provided to DO Study Teams*

Industry Engagement

DO Industry Engagement: Updates on Solicitations

	Description	Supported Activity	Date of solicitation
Category 1	Cross-cutting expertise in specific areas	All of the DOs	November 2019
Category 2	Support to HQ	HQ Decadal Strategy	TBD
Category 3	Technology Demonstrations	Specific to each DO	We are now receiving inputs from study teams*
Category 4	Applications Support	All of the DOs	Oct/Nov 2019

* We will evaluate if any of the team requests overlap with existing ESTO or SBIR tasks, if so we will consider augmentations. We are also looking into how to do a quicker solicitation (2-3 months in lieu of 6-9 months) in order to have a solicitation in FY20.

Category 1: Crosscutting support to DOs

- ESD is working with JPL to release the Category 1 solicitations in support of the DO Architecture Studies in cross-cutting areas (i.e. capabilities that could apply to multiple DOs) where industry has unique expertise:
  - SmallSat/CubeSat Constellations (one contract)
  - Payload hosting on Commercial Satellites (one contract)
  - Ground System Architectures (one contract)
  - Data Processing/Data Storage/Cloud Computing (one contract)
  - Market Research on out-of-the-box enabling commercial technologies (one contract)

- One-year period of performance with options to renew on an annual basis
- Release of RFP is imminent

Category 4: Applications Support to DOs

- ESD is working with JPL & LaRC to release the Category 4 solicitations to fund industry to help in the assessment of Applications Communities in support of the DO studies.
  - JPL is handling the Category 4 for SBG
  - LaRC is handling the Category 4 for A-CCP, SDC, and MC
- This industry support complements work by the DO team in identifying new users, preparing the Community Assessment Report, and on-going engagement with non-research users.
- Intent is to broaden engagement with user communities beyond traditional and customary ones (e.g., federal agencies) and reach new users and audiences, especially private sector and non-profits.

- One-year period of performance with options to renew on an annual basis

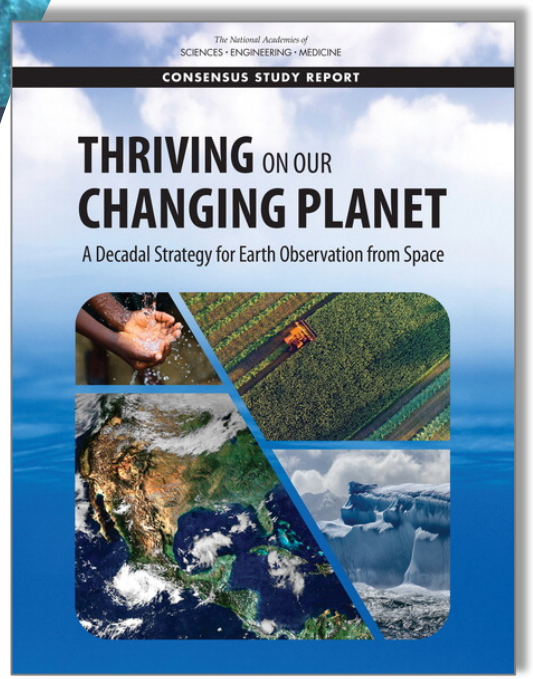
International Engagement

International Engagement

- ESD leadership conducted focused Decadal Survey telecons/meetings with international partners
  - JAXA, CNES, DLR, ESA, EUMETSAT, CSA
  - Further discussions with the broader international community continue
- Discussions are ongoing to explore potential international partnerships
  - Some directed international partnerships may originate from ESD
  - Multi-center DO studies are engaging potential international partners
- ESD will make final partnership determinations and then codify necessary international agreements

Cross-Benefits of Applications and Research

Decadal Survey: "Amplify the Cross-Benefits of Research and Applications"



	ELEMENTS OF DECADAL STRATEGY
I.	Embrace **Innovative Methodologies** for Integrated Science/Applications
II.	Commit to **Sustained Science and Applications**
III.	Amplify the **Cross-Benefit of Science and Applications**
IV.	Leverage **External Resources and Partnerships**
V.	Institutionalize **Programmatic Agility and Balance**
VI.	Exploit **External Trends** in Technology and User Needs
VII.	Expand Use of **Competition**
VIII.	Pursue **Ambitious Science**, Despite Constraints

"[Programs] with both science and applications elements need to explicitly identify the connection, and define opportunities to amplify the cross-benefit, and organization structures and processes need to be adapted when possible to integrate, rather than segregate, science and operations/applications"

ESD Response to Decadal Survey Statement to “Amplify the Cross-Benefits of Research and Applications”

- R&A and Applied Sciences program had meeting on September 23 to share ideas from groups of HQ program staff on current and potential opportunities for enhanced interactions
  - Foci included both transition of research results towards applications as well as how applications can help define and/or sharpen questions and activities that can be carried out by research programs
- Additional internal meeting to be scheduled to complete discussion (including ideas that could not be discussed in original meeting) and develop a forward plan
- R&A and Applied Sciences programs will also identify any activities where current activities within their programs might be considered as straddling research and apps.
- R&A and Applied Sciences communications personnel are developing “end-to-end story ideas” for communicating examples of successful connections and transitions between research and applications
- Further discussion planned on leading efforts in broader Earth community on this topic

2007 Decadal Survey Tier 2

2007-2017 Correspondence Tier 2

- ASCENDS → Potential Explorer Class Observable (wide swath passive mapper, similar to Sentinel plan) + OCO-2 (2016) and OCO-3 (ISS, 2019)
- ACE → PACE (Climate Initiative, POR, LRD 2022) & ACCP (DS II, preformulation)
- SWOT – LRD 2022
- HyspIRI → ECOSTRESS (2018), EMIT (ISS, 2024) & SBG (DS II, preformulation)
- GEO-CAPE → TEMPO (EVI-1, 2020) and GLIMR (EVI-5, NET 2025)

What’s Next?

What's Next?

ESD Leadership Team continues to address additional DS topics

Check the ESD Decadal Survey web page to:

- Find meeting schedules and details
- Ask questions and see answers as they become available
- Review information in previous sets of charts
- https://science.nasa.gov/earth-science/decadal-surveys

2020 Community Forums

- Forums will be held from 1-3 p.m. (Eastern)
- WebEx and telecon information, in addition to other updates, will be posted on the NASA ESD Decadal Survey website
  - https://science.nasa.gov/earth-science/decadal-surveys
- Next forums slated for:
  - March 12, 2020
  - July 16, 2020
  - Nov. 12, 2020
- For information about future Decadal Survey Community Forums, please send an email to Amy Treat at Amy.A.Treat@nasa.gov

Questions Process

- This call is monitored by an operator
  - When you join the call, the operator will ask for your name
- When it is time for questions, please press *1 on your phone to indicate to the operator that you have a question
- The operator will introduce you by name and un-mute your line
  - Then you can ask your question and any follow up questions
- When done, the operator will re-mute your line and introduce the next person
- Please also email questions to **Amy Treat** at Amy.A.Treat@nasa.gov so we can post the question and its answer on our website

How to Get Involved

- To join a working group or sign up for updates, send an email to:
  - **SBG:** sbg@jpl.nasa.gov
  - **MC:** masschange@jpl.nasa.gov
  - **SDC:** sdc-study@lists.nasa.gov
  - **ACCP:** a-ccp-comments@lists.nasa.gov
- General updates can be found on our website:

https://science.nasa.gov/earth-science/decadal-surveys/

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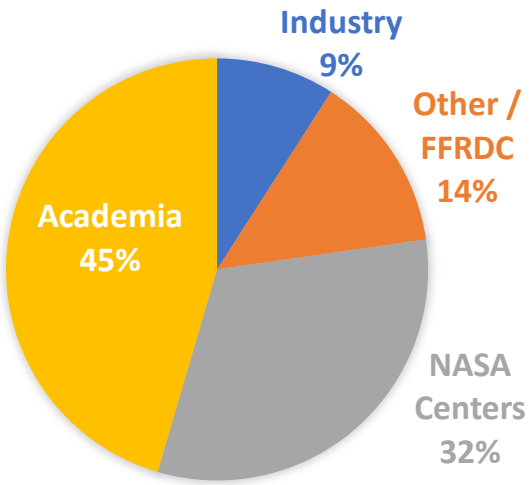
Backup

Earth Science Technology Highlight:
41 New Technology Development Projects to Begin in FY2020

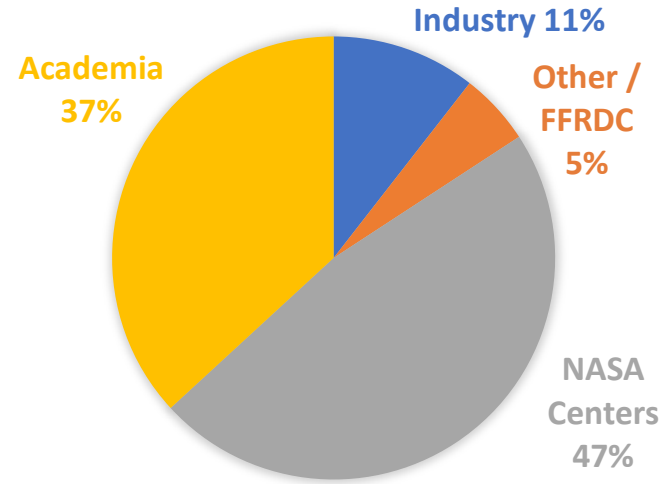


22 Advanced Information Systems Technology (AIST) Awards (September 2019)
Proposals received: 100. Total funding: ~$28M over two years.

The AIST-18 solicitation sought proposals around two primary thrusts, the Analytic Center Framework (ACF) and the New Observing Strategy (NOS). The ACF thrust is intended to harmonize tools, data, and computing environments to meet the needs of Earth science investigations. ACF projects will integrate new or previously unlinked datasets, tools, models, and a variety of computing resources together into a common platform to address previously intractable scientific questions. The NOS thrust provides a framework for identifying technology advances needed to exploit newly available observational capabilities, including high-quality instruments on Smallsats, CubeSats, and commercial space platforms. The NOS projects will develop information technologies to support planning, evaluating, implementing, and operating a dynamic set of observing assets. AIST selections can be found here: **http://bit.ly/AIST18_Awards**

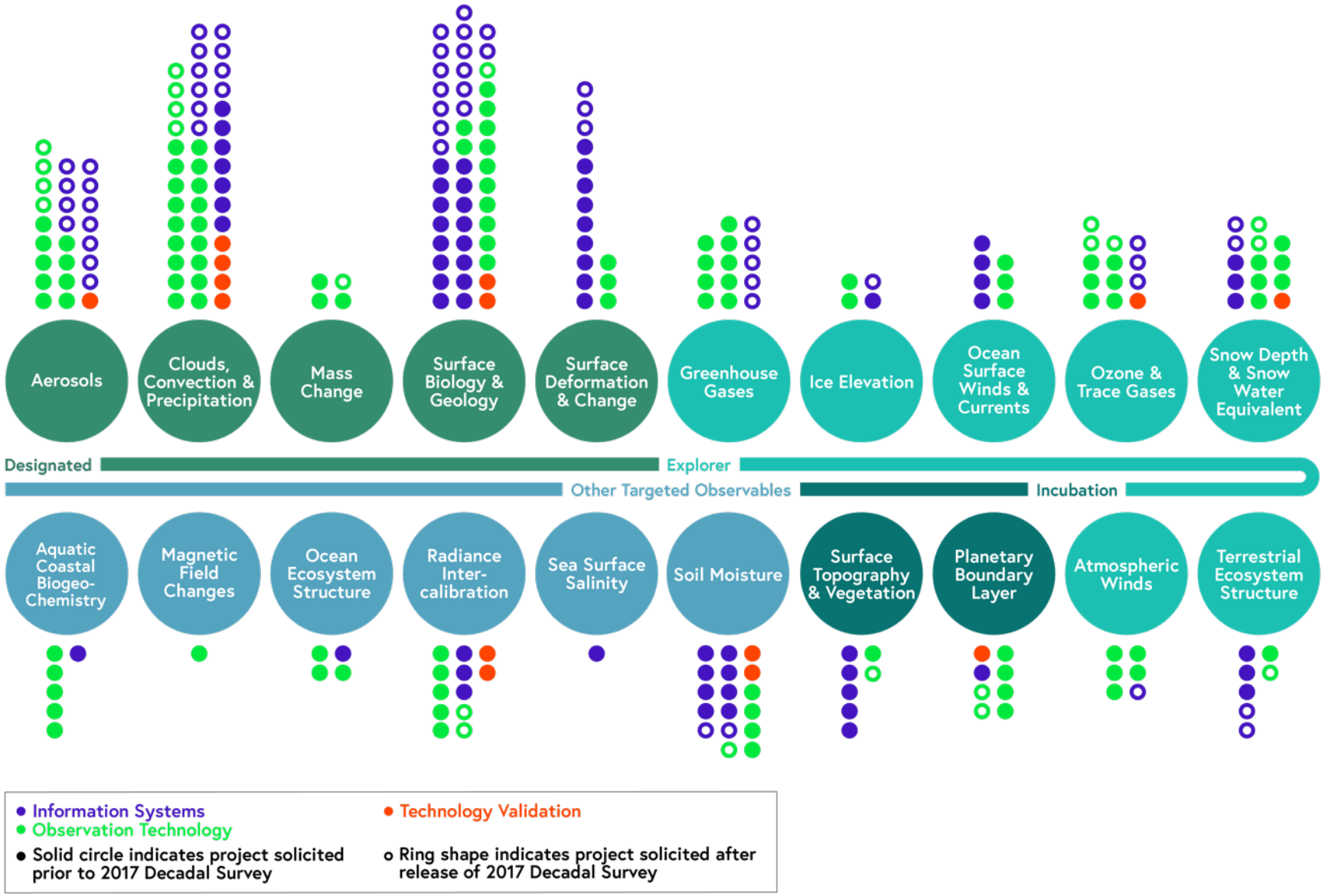
19 Instrument Incubator Program (IIP) Awards (October 2019)
Proposals received: 70. Total funding: ~$58M over three-four years.

The IIP-19 solicitation sought instrument concepts as well as development/demonstration projects that offer the potential for new or improved ways to observe Earth. These new projects will develop smaller, more affordable instruments, and seek to include novel component technologies and architectures as well as incorporate onboard intelligence to take advantage of recent strides in algorithm development and processing power. The IIP selections can be found here: **http://bit.ly/IIP-19**



Supporting the 2017 Decadal Survey

Supporting the 2017 Decadal Survey



Mass Change (MC)

MC Workshop Architecture Breakout: Classes

SST

- Large trade space includes low-low, high-low, number of pairs, orbit planes, altitude, ranging technology, accelerometer technology, drag compensation, formations
- New technology could facilitate advancing the spatial resolution (drag compensation)
- Heritage makes it lower risk than other options

Gravity Gradiometer

- Technology not quite ready for prime observing system that meets continuity desire, but should be studied and considered for observing system timeline and technology development road map
- Possible tech demo

SmallSat/CubeSat

- “Obvious” solution to increase spatiotemporal resolution
- Individual components have high TRL, but need to assessed. *Comment: “components are not an observing system.”*
- Larger system is resistant to systematic errors to an extent depending on architecture
- Is center-of-mass knowledge good enough? Thermal environment?
- Lower cost and redundant
- Another funding vehicle? EVC?

POD

- Already available to some extent
- Potential “bridging-the-gap” component of a timeline of observing systems
- Not expected to advance the positioning precision beyond ~1 cm
- Potential capabilities of megaconstellations are unknown: hypothesized that systematic effects still dominate, but requires a closer look.
- Lower cost and redundant

2007 Decadal Survey Tier 2

The Connections Between DS 2007 and DS 2017 Recommendations

ACE – Aerosol, Cloud and ocean Ecosystem (DS 2007)

to

PACE – Plankton, Aerosol, Cloud, ocean Ecosystem (Climate Initiative)

and

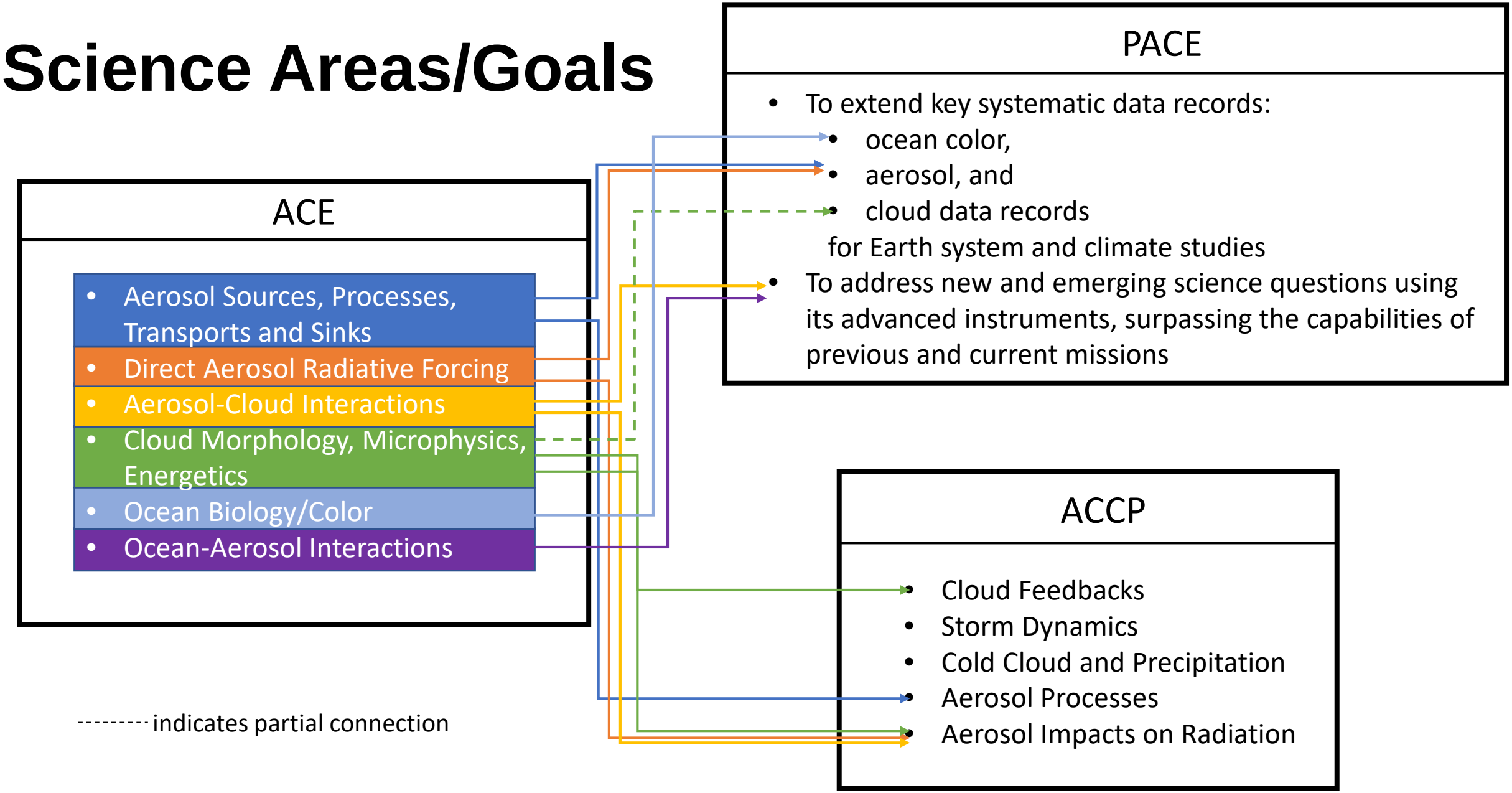
ACCP – Aerosol, Cloud, Convection and Precipitation (DS 2017)

Areas of Connection

- Science Areas/Objectives*
- People/Team Members
- Data
  - Measurement campaigns (e.g, RADEX, PODEX, ACEPOL)
  - Model data (e.g., GEOS 5 nature runs)
- Sensors
  - Instrument concepts/designs*
  - Instrument simulators (i.e., for OSSEs)

**see following slides for detail*

Science Areas/Goals



Sensor Concepts

ACE

- Multi-angle Imaging Polarimeter
- Lidar (HSRL)
- Multi-frequency Doppler Cloud Radar
- Ocean Ecosystem Spectrometer

PACE

- Ocean Color Instrument (GSFC)
- Multi-angle Polarimeter
  - SPEXone (SRON)
  - HARP (UMBC)

ACCP

- Multi-angle Imaging Polarimeter
- Lidar (HSRL and/or Backscatter)
- Multi-frequency Doppler Cloud-Precipitation Radar
- Microwave Radiometer
- Other Contributed Sensors
- Suborbital Measurements

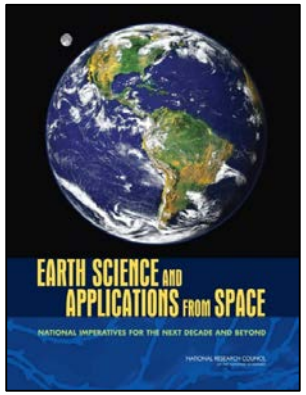
The Connections Between DS 2007 and DS 2017 Recommendations

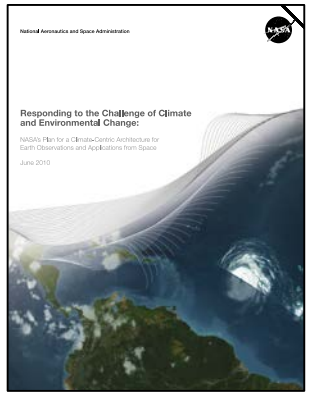
GRACE-II - (DS 2007)

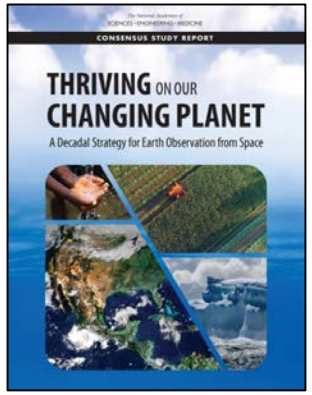
to

MC – Mass Change (DS 2017)

Mass Change in recent ESAS Decadal Surveys and NASA reports







2007 Decadal Survey

- **GRACE-II** included among *Missions Recommended to NASA*, as a **Tier 3** mission that advances the capability of GRACE to a spatial resolution of 100 km
- Climate, Water Resources, and Solid Earth panels recommended **GRACE-II**
- Importance of continuity is established: “Any gap in coverage between GRACE and **GRACE-II** will disrupt the time series of observations, complicating its interpretation.”

2010 NASA Climate Architecture Report

- **GRACE-FO** included among *Climate Continuity Missions*
- “This plan provides for the development and launch of selected, high-priority climate data continuity measurements whose importance has become clearer since the release of the 2007 Earth Science Decadal Survey.”
- Plan includes the “Development of a **GRACE-FO** mission as a gap-filler between the operating GRACE and the recommended higher-capability GRACE-II Decadal Survey Tier 3 mission.”

2017 Decadal Survey

- **Mass Change Mission** included among five *Designated Observables*
- Climate, Hydrology, and Solid Earth panels recommended **Mass Change Mission**
- Continuity of data record identified as the “Basis for Being Foundational”:

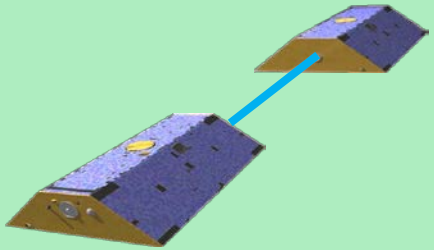
  “Ensures continuity of measurements of ground water and water storage mass change, land ice contributions to sea level rise, ocean mass change, ocean heat content (when combined with altimetry), glacial isostatic adjustment, and earthquake mass movement.”

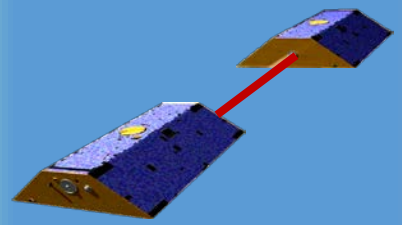
Gravity/Mass Change Missions

Past observations

Continuity of observations

Continuity of observations





?

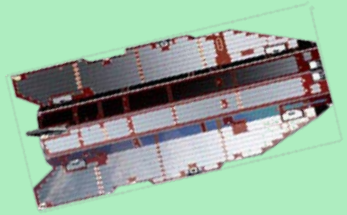
GRACE

GRACE−FO

Mass Change DO

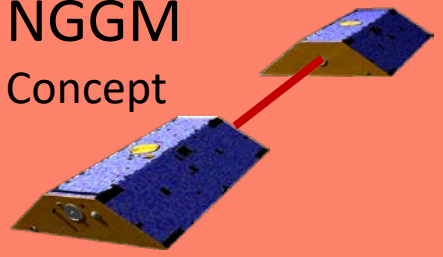
2002 2009 2013 2017 2018 2023 202X

GOCE



NGGM

Concept



Sustained observations at higher resolution

The Connections Between DS 2007 and DS 2017 Recommendations

HyspIRI – Hyperspectral Infrared Imager (DS 2007)

to

ECOSTRESS – Ecosystem Spaceborne Thermal Radiometer Experiment on Space Station (EVI-2)

and

EMIT – Earth Surface Mineral Dust Source Investigation (EVI-4)

and

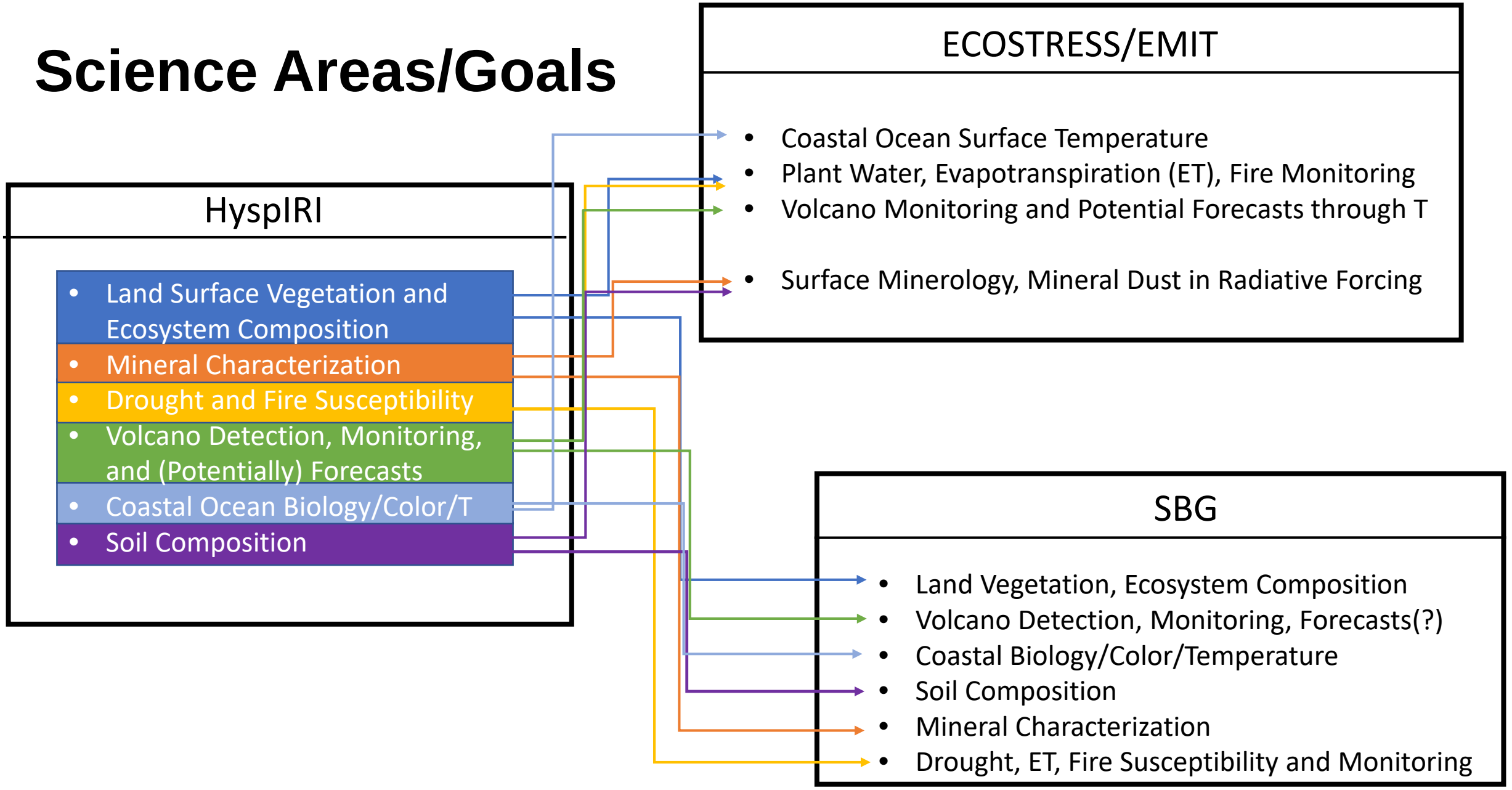
SBG – Surface Biology and Geology (DS 2017)

Areas of Connection

- Science Areas/Objectives*
- People/Team Members
- Data
  - Airborne measurement campaigns (e.g., HyspIRI Preparatory CA, HyspIRI Preparatory HI, AVIRIS-NG in India & Europe, HyTES in Europe)
- Sensors
  - Instrument concepts/designs/development (e.g., ESTO)*
  - Hardware development

**see following slides for detail*

Science Areas/Goals



Sensor Concepts

HyspIRI

- Visible to Shortwave Infrared (VSWIR) Imaging Spectrometer
- Multispectral Thermal Infrared (TIR) Imager

ECOSTRESS/EMIT

- Multispectral TIR Imager (ECOSTRESS)
- VSWIR Imaging Spectrometer (EMIT)

SBG

- VSWIR Imaging Spectrometer(s)
- Multispectral (or Hyperspectral) TIR Imager(s)

The Connections Between DS 2007 and DS 2017 Recommendations

ASCENDS – (DS 2007)

to

OCO-2 – Ecosystem Spaceborne Thermal Radiometer Experiment on Space Station (EVI-2)

and

OCO-3 – Earth Surface Mineral Dust Source Investigation (EVI-4)

and

Explorer – Surface Biology and Geology (DS 2017)