


# NASA Report on Cal/Val Activities

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Working Group on Calibration and Validation



## NASA Report on Cal/Val Activities WGCV #45

### NASA Earth Science Missions: Present through 2023

- Flight instruments
- Ground-based
- Science data
- Ground-based

**ISS Instruments**  
AIST (2012-2018)  
AIST-2 (2012-2018)  
AIST-3 (2012-2018)  
AIST-4 (2012-2018)  
AIST-5 (2012-2018)

**ISS-2 Instruments**  
AIST-6 (2012-2018)



Labels in diagram include: AIST (2012), AIST-2 (2012), AIST-3 (2012), AIST-4 (2012), AIST-5 (2012), AIST-6 (2012), AIST-7 (2012), AIST-8 (2012), AIST-9 (2012), AIST-10 (2012), AIST-11 (2012), AIST-12 (2012), AIST-13 (2012), AIST-14 (2012), AIST-15 (2012), AIST-16 (2012), AIST-17 (2012), AIST-18 (2012), AIST-19 (2012), AIST-20 (2012), AIST-21 (2012), AIST-22 (2012), AIST-23 (2012), AIST-24 (2012), AIST-25 (2012), AIST-26 (2012), AIST-27 (2012), AIST-28 (2012), AIST-29 (2012), AIST-30 (2012), AIST-31 (2012), AIST-32 (2012), AIST-33 (2012), AIST-34 (2012), AIST-35 (2012), AIST-36 (2012), AIST-37 (2012), AIST-38 (2012), AIST-39 (2012), AIST-40 (2012), AIST-41 (2012), AIST-42 (2012), AIST-43 (2012), AIST-44 (2012), AIST-45 (2012), AIST-46 (2012), AIST-47 (2012), AIST-48 (2012), AIST-49 (2012), AIST-50 (2012), AIST-51 (2012), AIST-52 (2012), AIST-53 (2012), AIST-54 (2012), AIST-55 (2012), AIST-56 (2012), AIST-57 (2012), AIST-58 (2012), AIST-59 (2012), AIST-60 (2012), AIST-61 (2012), AIST-62 (2012), AIST-63 (2012), AIST-64 (2012), AIST-65 (2012), AIST-66 (2012), AIST-67 (2012), AIST-68 (2012), AIST-69 (2012), AIST-70 (2012), AIST-71 (2012), AIST-72 (2012), AIST-73 (2012), AIST-74 (2012), AIST-75 (2012), AIST-76 (2012), AIST-77 (2012), AIST-78 (2012), AIST-79 (2012), AIST-80 (2012), AIST-81 (2012), AIST-82 (2012), AIST-83 (2012), AIST-84 (2012), AIST-85 (2012), AIST-86 (2012), AIST-87 (2012), AIST-88 (2012), AIST-89 (2012), AIST-90 (2012), AIST-91 (2012), AIST-92 (2012), AIST-93 (2012), AIST-94 (2012), AIST-95 (2012), AIST-96 (2012), AIST-97 (2012), AIST-98 (2012), AIST-99 (2012), AIST-100 (2012)

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**NASA ESD Flight Portfolio through 2023**

- **Extended**
  - Terra (2022), Aqua (2022), Aura (2022), GPM (2022), CloudSat (20119), CALIPSO (2022), OSTM/Jason-2 (2022), SORCE (2019)
- **On-orbit**
  - CYGNSS (2019), DSCOVR (2019), ECOSTRESS (2020), GRACE-FO (2023), ICESat-2, OCO-2 (2022), SMAP (2022), S-NPP (2022), TSIS-1 (2019), SAGE-III (2020)
- **Development**
  - CLARREO Pathfinder, EMIT, GRACE-FO, LIS, MIAI, NISAR, OMPS-Limb, PACE, Jason CS/Sentinel 6A and -B, SWOT, TSIS-2
  - Earth System Science Pathfinder (ESSP) - TEMPO, EVS-2 and -3
  - Venture Technology selections (GrAOWL, Tempest), EVM-2 & 3, EVI-3, 4, 5, and 6
- **Preformulation**
  - TROPICS, GeoCARB, PREFIRE
- **In-Space Validation of Earth Science Technologies (InVEST):**
  - CubeSats



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**Recent Launches: ICESat-2; GEDI; OCO-3**






- **ICESat-2:** Quantify polar ice sheet contributions to sea-level change and measure vegetation canopy height as a basis for estimating large-scale biomass and biomass change
- **GEDI:** Characterize the effects of changing climate and land use on ecosystem structure and dynamics providing the first global, high resolution observations of forest vertical structure
- **OCO-3:** Investigate important questions about the distribution of carbon dioxide on Earth as it relates to growing urban populations and changing patterns of fossil fuel contribution


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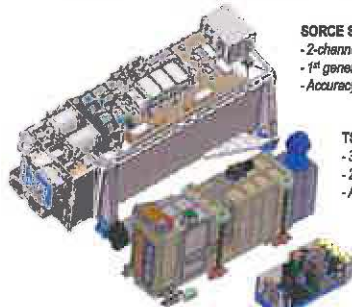
### Compact Spectral Irradiance Monitor CubeSat Launched December 2018 as part of Spaceflight SmallSat Express

rideshared through a 2013 IIP grant at LASP/UC-Boulder

- Ultra- compact, solar spectral irradiance (SSI) monitor covering 200-2400 nm
- SI-traceable accuracy and stability to meet solar input measurement requirements for benchmark climate records
- Will validate performance against SSI measurements being made by **SORCE** and **TSIS SIM**



The CSIM CubeSat



**SORCE SIM (launched 2003)**  
 - 2-channel instrument  
 - 1<sup>st</sup> generation absolute ESR detector (NIP bolometer)  
 - Accuracy: 2-10% wavelength dependent (no SI validation)

**TSIS SIM (2018 planned launch)**  
 - 3-channel instrument  
 - 2<sup>nd</sup> generation absolute ESR detector (NIP bolometer)  
 - Accuracy: 0.2% (SI-traceable validation)

**CSIM (2018 planned launch)**  
 - 2-channel instrument  
 - 3<sup>rd</sup> generation absolute ESR detector (best noise performance to date)  
 - Accuracy: 0.2% (SI-traceable validation)

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### Earth Science Division's Venture Opportunities

**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)


Mission	Mission Type	Release Date	Selection Date	Major Milestones
EV-1, aka EVS-1	6 Suborbital Airborne Campaigns	2009	2010	N/A
EVM-1, CYGNSS	Smallest constellation	2011	2012	Launched Dec 2018
EV-1, TEMPO	Geosynchronous hosted payload	2011	2012	Delivery NLT 2017
EV-2, ECOSTRESS & GEDI	Class C & Class D ISS-hosted instruments	2013	2014	Delivery NLT 2019
EVS-2	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	2016	2016	Launch ~2021
EVI-4, EMIT, PREFIRE	Instrument Only	2016	2017	Delivery NLT 2021
EVS-3	Suborbital Airborne Campaigns	2017	2018	N/A
EVI-5	Instrument Only	2018	2017	Delivery NLT 2021
EVC-1	Radiation Budget Measurement	2018	2019	Delivery NLT 2024
EVM-3	Full Orbital	2018	2020	Launch ~2025
EVS-4	Suborbital Airborne Campaigns	2021	2022	N/A
EVI-6	Instrument Only	2020	2021	Delivery NLT 2026
EVC-2	Continuity Measurement	2021	2022	Delivery NLT 2027

5 investigations selected for EVS-3


Spacecraft/Instrument/Release Completed solicitation

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**2017 Earth Venture Suborbital-3 (EVS-3) solicitation - Five 5-year investigations selected**

- DCOTTS - Dynamics and Chemistry of the Summer Stratosphere – Kenneth Bowman, Texas A&M University: Understand how dynamical and chemical processes interact to determine composition of extratropical stratosphere
- S-MODE (Submesoscale Ocean Dynamics and Vertical Transport) – Thomas Farrar, Woods Hole Oceanographic Institute: Test hypothesis that submesoscale ocean dynamics make important contributions to vertical exchange of climate and biological variables in the upper ocean.
- IMPACTS (Investigation of Microphysics and Precipitation for Atlantic Coast-Threatening Snowstorms) – Lynn McMurdie, University of Washington: High-altitude ER-2 observations to understand snow band formation and evolution
- ACTIVATE (Aerosol Cloud Meteorology Interactions Over the Western Atlantic Experiment) – Armin Sorooshian, University of Arizona: Study interactions of aerosol particles and clouds
- Delta-X: Enabling Deltas to Thrive in a Century of Rising Seas - Marc Simard, Jet Propulsion Laboratory: Calibrate sediment transport and plant productivity models of the Mississippi delta floodplain to understand impacts of sea-level rise

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sector-funded small-satellite constellations (3-satellite minimum constellation, full longitude coverage) for evaluation by NASA researchers to determine value for advancing NASA research

- Planet – three satellite constellations including 200+ satellites supplying imagery and derived products
- DigitalGlobe – five satellite constellations supplying high-resolution (31-50-cm) images
- Spire – constellation of 48 satellites collecting Radio Occultation soundings and ship reports
- Evaluations by broad set of funded researchers chosen from existing funding for a 1 year evaluation period to assess quality of geophysical information; data availability (latency) and subdistribution rights vs. cost; vendor plans for constellation maintenance/evolution

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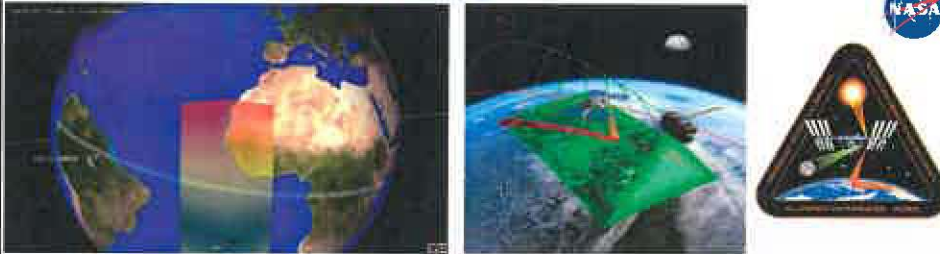
### Designated observables summary as described in recent Decadal Survey

Observable	Science/Applications Summary	Candidate Measurement Approach	ESAS maximum cost
Aerosols	Aerosol properties, aerosol vertical profiles, and cloud properties to understand their effects on climate and air quality	Backscatter lidar and multichannel/multi-angle/polarization imaging radiometer flown together on the same platform	CATE Cap \$800M
Clouds, Convection, and Precipitation	Coupled cloud-precipitation state and dynamics for monitoring global hydrological cycle and understanding contributing processes including cloud feedback	Radar(s), with multi-frequency passive microwave and sub-mm radiometer	CATE Cap \$800M
Mass Change	Large-scale Earth dynamics measured by the changing mass distribution within and between the Earth's atmosphere, oceans, ground water, and ice sheets	Spacecraft ranging measurement of gravity anomaly	Est Cap \$300M
Surface Biology and Geology	Earth surface geology and biology, ground/water temperature, snow reflectivity, active geologic processes, vegetation traits and algal biomass	Hyperspectral Imagery in the visible and shortwave Infrared, multi- or hyperspectral imagery in the thermal IR	CATE Cap \$650M
Surface Deformation and Change	Earth surface dynamics from earthquakes and landslides to ice sheets and permafrost	Interferometric Synthetic Aperture Radar (InSAR) with ionospheric correction	Est Cap \$500M

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### CLARREO Pathfinder is in Phase B



- Demonstrate
  - Essential measurement technologies for the Reflected Solar portion of the full Tier 1 Decadal Survey-recommended CLARREO mission
  - On-orbit, high accuracy, SI-Traceable calibration
  - Ability to transfer calibration to operational sensors
- Formulation, implementation, launch to ISS, and operation of a Reflected Solar (RS) Spectrometer
- Class D Mission with late 2022/early 2023 launch for nominal 1-year mission life
- Additional 1 year science data analysis

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