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Report on Cal/Val Activities

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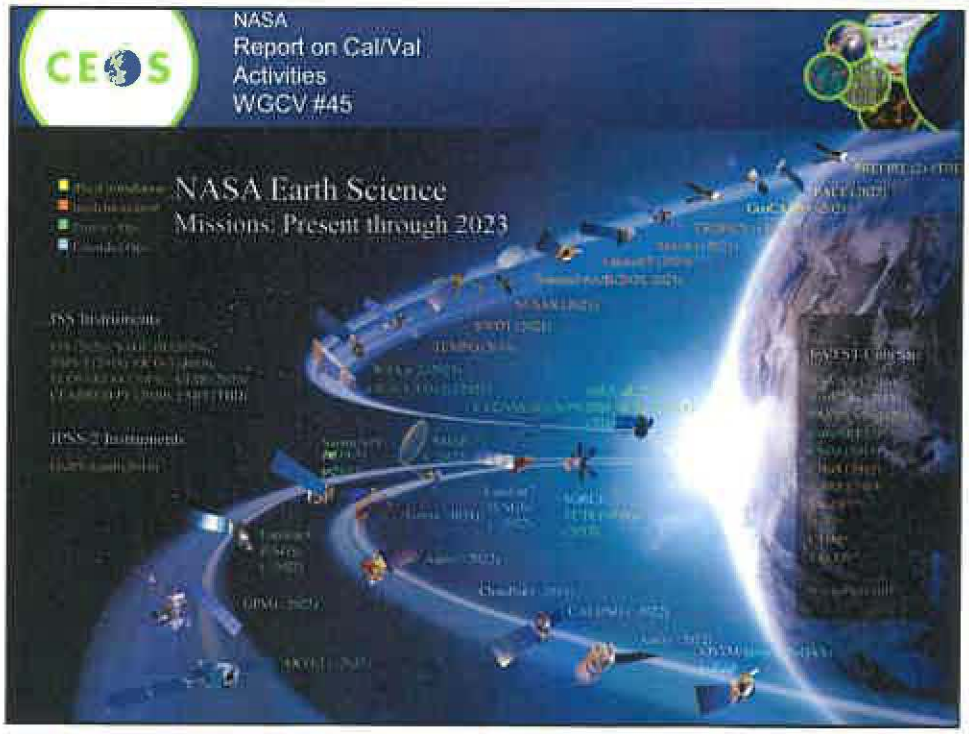
WGCV Plenary # 45
CSIRO, Perth
July 16-19, 2019

Working Group on Calibration and Validation



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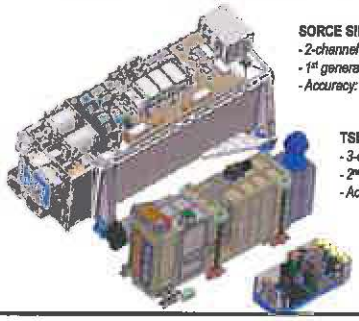
Compact Spectral Irradiance Monitor CubeSat Launched December 2018 as part of Spaceflight SmallSat Express rideshare

developed 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
- 1st generation absolute ESR detector (NIP bolometer)
- Accuracy: 2-10% wavelength dependent (no SI validation)

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

CSIM (2018 planned launch)
- 2-channel instrument
- 3rd 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 Milestone
EVI-1, aka EVS-1	5 Suborbital Airborne Campaigns	2009	2010	N/A
EVM-1, CYGNSS	Smallsat constellation	2011	2012	Launched Dec 2016
EVI-1, TEMPO	Geosynchronous hosted payload	2011	2012	Delivery NLT 2017
EVI-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	2015	2016	Launch ~2021
EVI-4, EMIT, PREFIRE	Instrument Only	2016	2017	Delivery NLT 2021
EVS-3	Suborbital Airborne Campaigns	2017	2018	N/A
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
EVC-1	Radiation Budget Measurement	2018	2019	Delivery NLT 2024
EVM-3	Full Orbital	2019	2020	Launch ~2025
EVS-4	Suborbital Airborne Campaigns	2021	2022	N/A
EVI-6	Instrument Only	2020	2021	Delivery NLT 2026
EVC-2	Continuity Measurment	2021	2022	Delivery NLT 2027

5 investigations selected for EVS-3

[illegible]
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

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 48satellites 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; sata 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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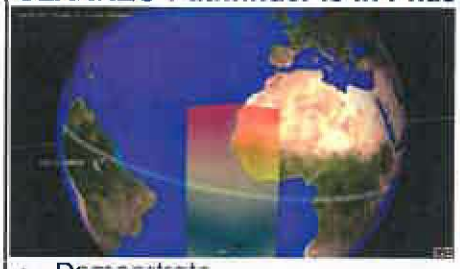
CLARREO Pathfinder is in Phase B



- 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