



New Space Panel – NASA perspective

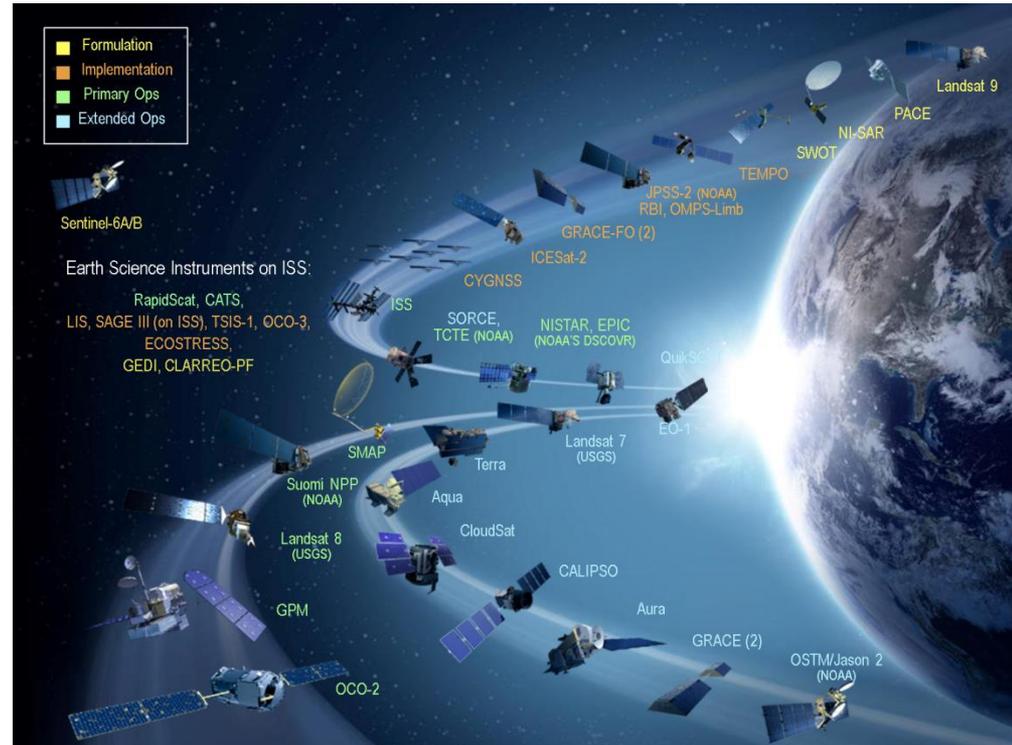
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Research and Operational Sensors

NASA historically has operated large research missions, provides operational systems, and regularly looks to new technology

- Science questions drive sensor design, complexity, and characterization
- Cost, schedule, launch availability play a role in mission concepts
- SmallSats often do not make sense for current programs unless there is a significant change in mission requirements



Recent small-sat initiatives

ESSP missions answer near-term questions with broad impacts with small mission/sensor budgets

- The Earth System Science Pathfinder (ESSP) development missions in this period include:
 - OCO-3, CYGNSS, TEMPO, GEDI, ECOSTRESS, EVS-2 and -3 and Venture Technology selections (GrAOWL, Tempest), EVM-2 & 3, EVI-3, 4, 5, and 6
- The Earth System Science Pathfinder (ESSP) on-orbit missions include:
 - OCO-2 (>2021), GRACE (2018), CALIPSO (>2021), CloudSat (2018), Aquarius (>2021)

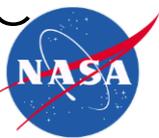
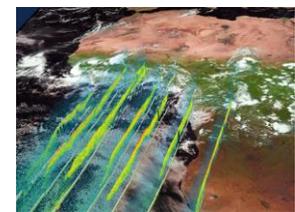
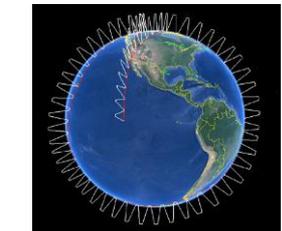
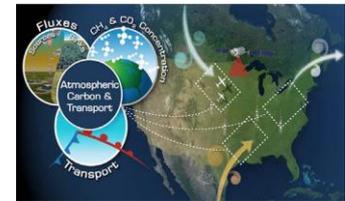
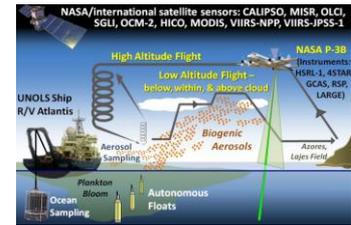
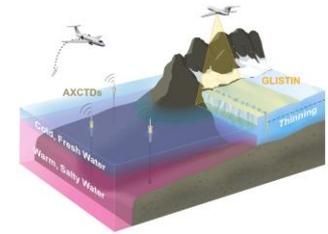
*On-orbit dates correspond to end-of-mission assumptions, consistent with 2015 Sr. Review



Sub-orbital missions

NASA's use of sub-orbitals allows for infusion of new measurement approaches

- **OMG** (Oceans Melting Greenland): Investigate the role of warmer, saltier Atlantic subsurface waters in Greenland glacier melting; Josh Willis, JPL
- **NAAMES** (North Atlantic Aerosols and Marine Ecosystems Study): Improve predictions of how ocean ecosystems would change with ocean warming; Michael Behrenfeld, Oregon State Univ
- **ACT-America** (Atmospheric Carbon and Transport – America): Quantify the sources of regional carbon dioxide, methane, and other gases, and document how weather systems transport these gases; Ken Davis, Penn State Univ
- **ATom** (Atmospheric Tomography Experiment): Study the impact of human-produced air pollution on certain greenhouse gases; Steven Wofsy, Harvard Univ
- **ORACLES** (ObseRvations of Aerosols Above CLouds and Their IntEractionS): Probe how smoke particles from massive biomass burning in Africa influences cloud cover over the Atlantic; Jens Redemann, ARC



CubeSats

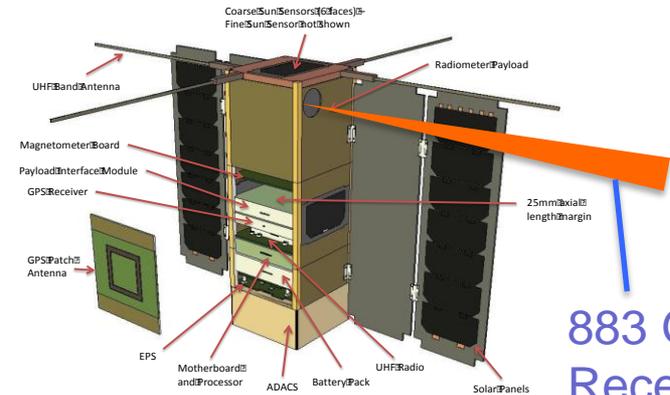
NASA's CubeSat Launch initiative (CSLI) provides opportunities on planned upcoming launches.

- http://www.nasa.gov/directorates/heo/home/CubeSats_initiative
- NASA selected 20 small satellites to fly as auxiliary payloads in recent CSLI selection
- Earth Science measurements include
 - Canopy Near-IR Observing Project (CaNOP) for multispectral imaging of global forests
 - CubeSat Infrared Atmospheric Sounder (CIRAS) for Mid-Wavelength Infrared Radiance Grating Spectrometer
 - RainCube to demonstrate miniaturized Ka-band Atmospheric Radar
 - Micro-size Microwave Atmospheric Satellite CubeSat (MicroMAS-2b) microwave radiometers and cross-track scanning
 - Stratus CubeSat to measure cloud fraction, cloud top height and wind
 - Compact Infrared Radiometer in Space (CIRiS) imaging radiometer for 7 to 13 μm
- Other missions have Earth Science relevance in improving CubeSat platform robustness, platform stability, quality, etc.

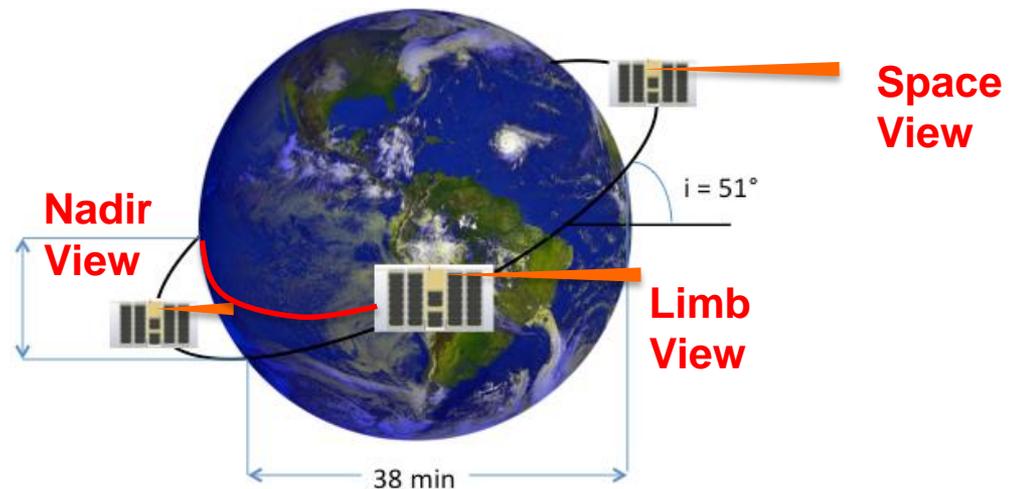




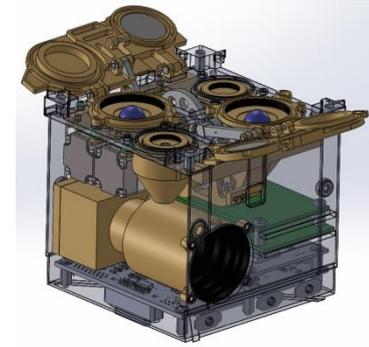
- IceCube is a spaceflight technology demo of a 883-GHz cloud ice radiometer on a 3U cubesat.
- Large uncertainty of cloud ice exists in current climate models, and it has been used as a tuning parameter for global radiation and precipitation.
- Submm-wave remote sensing seeks to improve our understanding how much cloud ice is in the upper troposphere and their role in radiation budget and precipitation.
- The 883-GHz is technologically least mature (lowest TRL) among submm-wave receivers.



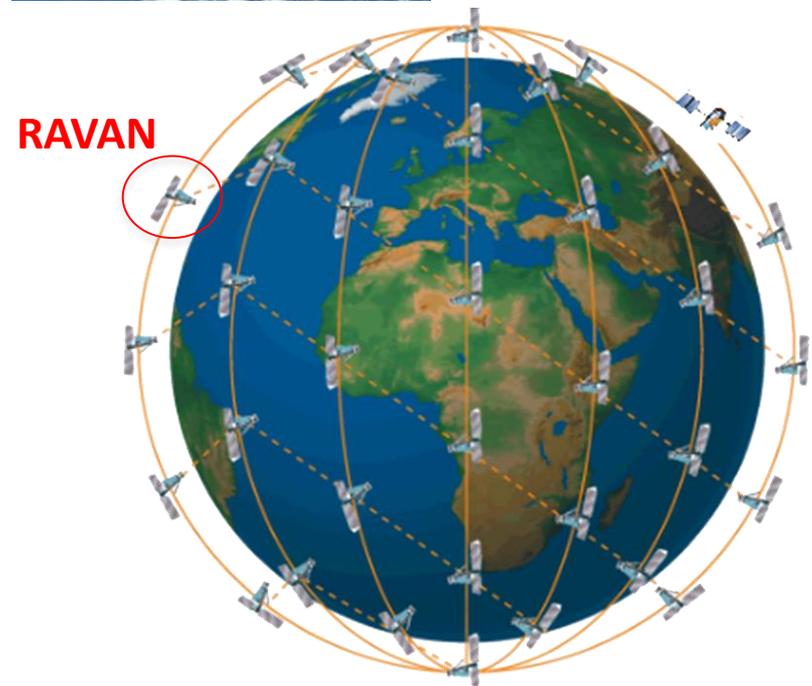
883 GHz Receiver Beam



- RAVAN seeks to provide new, affordable technique to determine accurately total Earth's outgoing radiation at the top of atmosphere.
- Global, simultaneous, 24/7 coverage diurnal sampling of rapidly varying radiation fields are challenging to measure because of clouds, plants, ozone, aerosols and other phenomena.
- The maturation of cubesat/hosted payload and constellation technology provides a unique opportunity for making the next great leap in Earth Radiation Budget (ERB) science.



payload



Summary

NASA will continue to invest on new technologies including SmallSats

- Priority is placed on meeting science requirements
- New questions need new technology and measurement approaches
 - Constellations
 - Distributed architectures
 - Formation flying
 - Sensor improvements
 - Platform improvements
- Choice of measurement approach will always be debated

