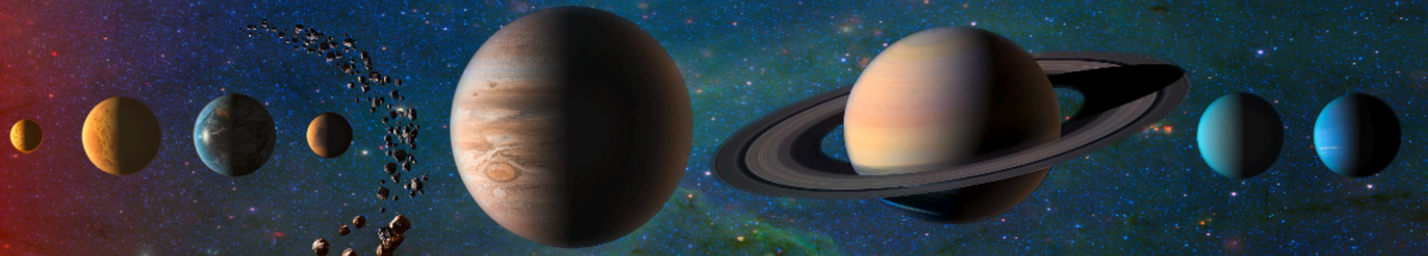
Planetary Science Investigations through SmallSats



David Schurr
NASA, Planetary Science Division
September 26th , 2017

Planetary CubeSat Science Symposium

Planetary CubeSats/SmallSats

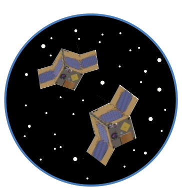
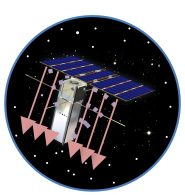
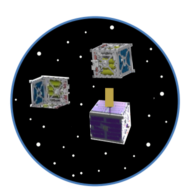
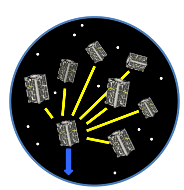
- A National Academies Report (2016) concluded that CubeSats have proven their ability to produce high-value science.
- In particular, CubeSats are useful as targeted investigations to augment the capabilities of larger missions or to make a highly-specific measurement.
- SMD is developing a directorate-wide approach that has four objectives:
  - Identify high-priority science objectives in each discipline that can be addressed with CubeSats/SmallSats
  - Manage program with appropriate cost and risk
  - Establish a multi-discipline approach and collaboration that helps science teams learn from experiences and grow capability, while avoiding unnecessary duplication
  - Leverage and partner with a growing commercial sector to collaboratively drive instrument and sensor innovation
- Planetary Science must also address the unique challenges for Smallsats at Planetary destinations

SmallSats in our Planning

- Mission Studies
  - Getting Ready for the Next Decade
- Solar System Robotic Exploration Technology Initiative
  - Technology that can uniquely enable future planetary science investigations
  - Use of small satellites and cubesats
  - Power and communications at planetary distances
  - Commercial partnerships

Planetary Science Deep Space SmallSat Studies

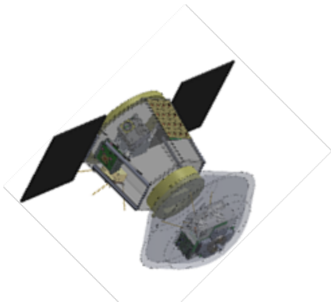
- NASA Research Announcement released August 19, 2016
- Solicited concept studies for potential CubeSats and SmallSats
  - Concepts sought for 1U to ESPA-class missions
  - Up to $100M mission concept studies considered
  - Not constrained to fly with an existing mission
- Objectives:
  - What Planetary Science investigations can be done with SmallSats?
  - What technology development is needed to enable them?
  - What's the anticipated cost range?
- Received 102 proposals

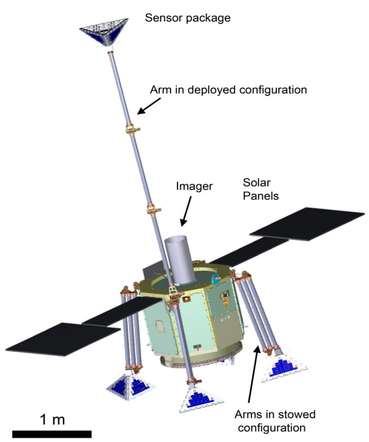
SmallSat Studies

PSDS3: Planetary Science Deep Space Small Satellite Studies

- 19 awards ($6 M investment over one year)
- Concept studies to scope achievable science, technology gaps, and expected cost of small secondary missions



Christophe Sotin (JPL)
Cupid's Arrow spacecraft concept



Jeff Plescia (Purdue)
APEX spacecraft concept

Venus

Valeria Cottini, CUVE - Cubesat UV Experiment
Attila Komjathy, Seismicity Investigation on Venus Using Airglow Measurements
Tibor Kremic, Seismic and Atmospheric Exploration of Venus (SAEVe)
Christophe Sotin, Cupid's Arrow

Moon

David Draper, Innovative Strategies for Lunar Surface Exploration
Charles Hibbitts, Lunar Water Assessment, Transportation, and Resource Mission
Noah Petro, Mini Lunar Volatiles (MiLUV) Mission
Suzanne Romaine, CubeSat X-ray Telescope (CubeX)
Timothy Stubbs, Bi-sat Observations of the Lunar Atmosphere above Swirls (BOLAS)

Small Bodies

Benton Clark, CAESAR: CubeSat Asteroid Encounters for Science and Reconnaissance
Tilak Hewagama, Primitive Object Volatile Explorer (PrOVE)
Jeffrey Plescia, APEX: Asteroid Probe Experiment

Mars

Anthony Colaprete, Aeolus - to study the thermal and wind environment of Mars
Michael Collier, PRISM: Phobos Regolith Ion Sample Mission
Robert Lillis, Mars Ion and Sputtering Escape Network (MISEN)
David Minton, Chariot to the Moons of Mars
Luca Montabone, Mars Aerosol Tracker (MAT)

Icy Bodies and Outer Planets

Kunio Sayanagi, SNAP: Small Next-generation Atmospheric Probe
Robert Ebert, JUpiter MagnetosPheric boundary ExploreR (JUMPER)

Technology Challenges

- Deep Space Environments
  - Temperature, radiation
- Communications over large distances
  - Direct to Earth
  - Data Relays (Mars)
  - Data Relay through Motherships
- Electrical Power
  - Solar far from Sun
  - Radioisotope
- Trajectory
  - Earth escape
  - Orbital capture
  - Aerocapture

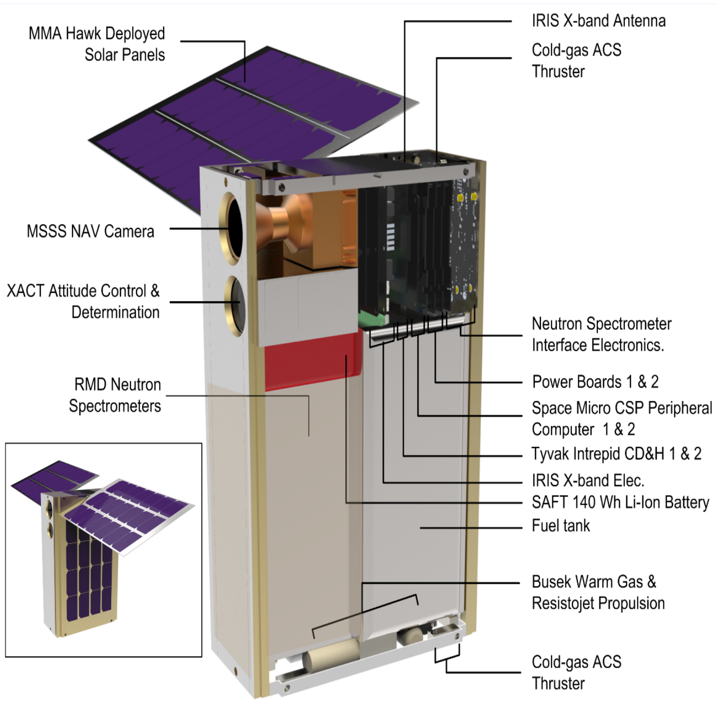
Small Innovative Missions for Planetary Exploration

(SIMPLEx)

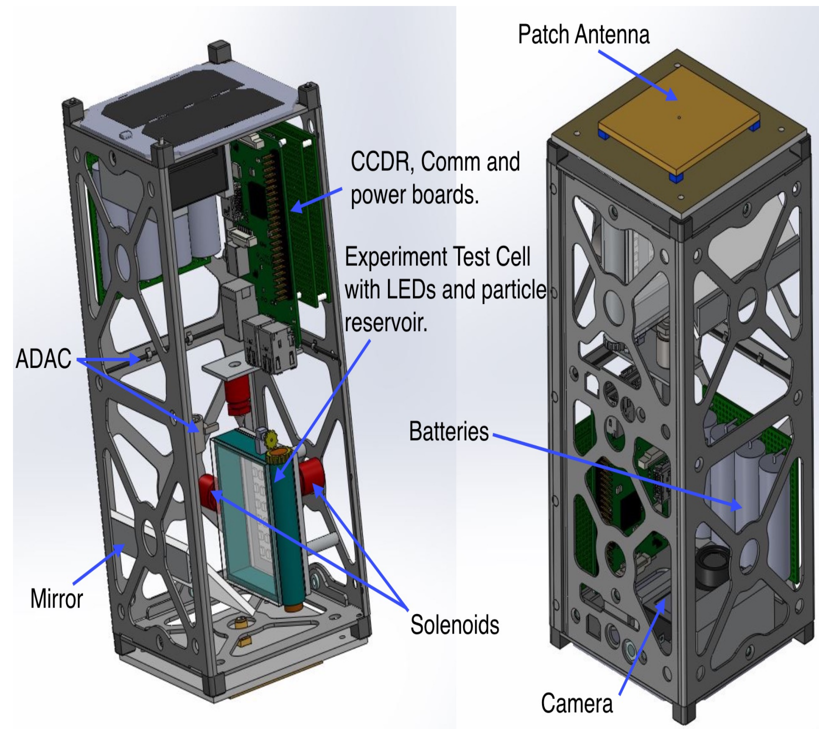
SIMPLEx- 1 : ROSES 2014

- **ROSES Appendix NOTICE was released on 2014**
- **Solicited formulation and development of science investigations that require a spaceflight mission that can be accomplished using small spacecraft**
  - 1U, 2U, 3U, and 6U form factors.
  - Secondary Payload
  - Must utilize the same trajectory as Primary Mission
  - Encouraged to incorporate advanced communication infrastructure
  - Up to ~$5M mission concepts
  - Cost-capped missions; however, optional risk reduction activities will be considered.
  - Duration of awards is FIVE years
  - Number of new awards: 1-2

SIMPLEx- 1 : Selections

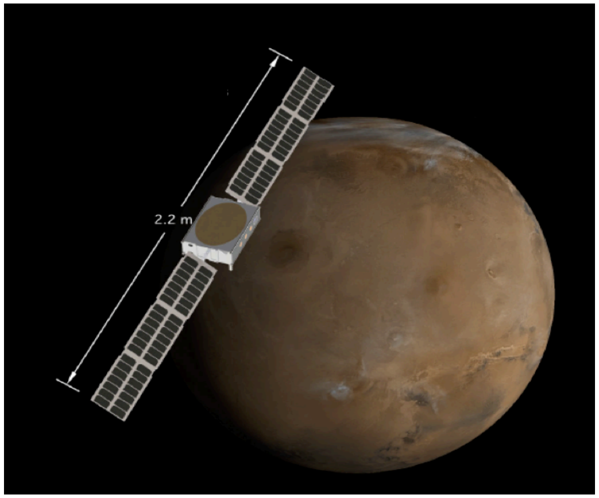


Lunar Polar Hydrogen Mapper (LunaH-Map)
PI: Craig Hardgrove
ASU School of Earth and Space Exploration

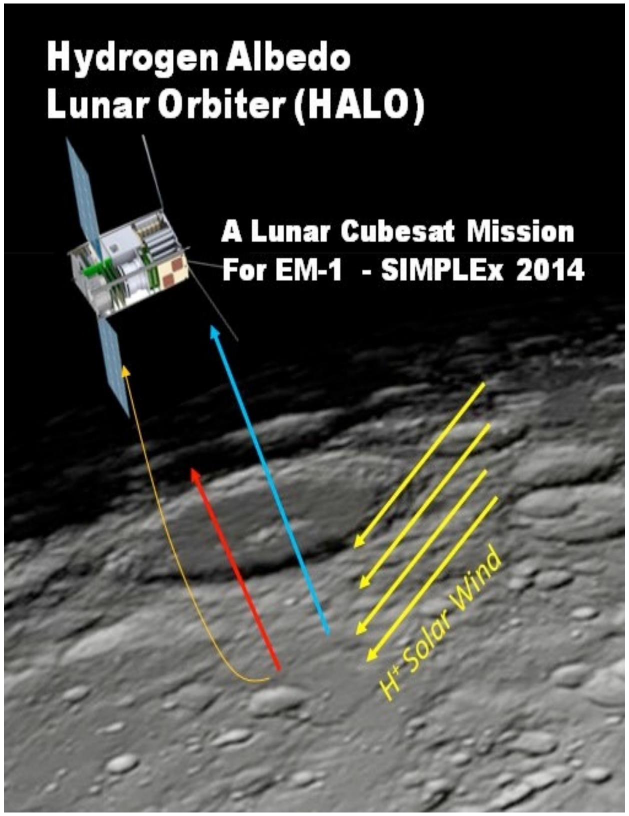


CubeSat Particle Aggregation and Collision Experiment (Q-PACE)
PI: Josh Colwel
University of Central Florida

SIMPLEx -1:
Approved for Tech Development Study



Mars Micro Orbiter
PI: Michael Malin
Malin Space Science Systems



Hydrogen Albedo Lunar Orbiter (HALO)
PI: Michael Collier,
NASA GSFC

Diminutive Asteroid Visitor using Ion Drive (DAVID)
PI: Geoffrey Landis
NASA Glenn Research Center

SIMPLEx-2 : Format

- **SALMON3 – PEA:** Third Stand Alone Missions of Opportunity Notice (SALMON-3) Program Element Appendix (PEA)
- **Small Complete Missions (SCM):** Investigation that can be realized within the PEA-specific Cost Cap.
  - The term "complete" encompasses all appropriate mission phases from project initiation (Phase A), through all phases of development, mission operations (Phase E), which must include analysis and publication of data in the peer reviewed technical literature, delivery of the data to an appropriate NASA data archive, and closeout (Phase F).

SIMPLEx-2 : Overview

- **Solicits formulation and development of science investigations that require a spaceflight mission that can be accomplished using small spacecraft**
  - ESPA-Class or smaller (< 180Kg)
  - Solicitation for secondary payload on either generic (GTO) or specific (escape) primary missions determines:
    - Launch readiness date
    - Initial release trajectory
  - Cost-capped missions
  - Continuously Open call with mission-specific deadlines
  - Foreign Participation will be allowed

SIMPLEx-2 : Process

1) Release Open Call for proposals
2) On-going Regular Panel Reviews of submitted missions

Mission Specific Milestones:

- L-4 years: Cut-off consideration for a specific mission
  - Select and award ~1 year Phase A/B studies; expected product is PDR-level design
  - Launch Vehicle is unknown

- L-3 years: Down-select secondary mission(s) for specific primary mission
  - May be possible to select multiple secondaries for a given primary mission
  - Selectability coordination with LV selection
  - Provided for Phase C design/build:
    - More detailed Launch Vehicle trajectory, environments and interfaces

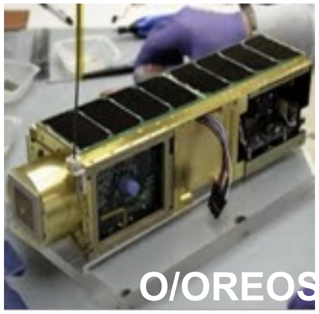
- L-2 years: Build/test secondary payload

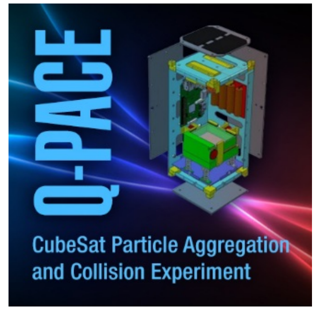
- L-1 years: Build/test/integrate secondary payload

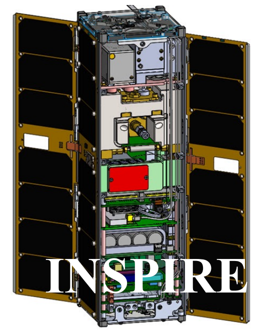
SIMPLEx 2: SUMMARY

- SALMON 3 – PEA – SCM
- Science missions that permit higher risk technology, <u>not</u> technology demonstrations
- Cost Capped Missions
- Foreign Participation Allowed
- Open Call with Multiple Reviews
- Soon to be Released: DRAFT for Community Comments

SMD Planetary CubeSat Missions







Spacecraft	**O/OREOS**	**MARCO**	**Q-PACE**	**INSPIRE**	**LunaH-Map**
PI	Ricco	Asmar	Colwell	Klesh	Hardgrove
Size	3U	6U (2)	3U	3U	6U
Goals	Investigate how microorganisms and organic molecules respond to the space environment	Provide real-time data relay using two redundant 6U CubeSats during InSight EDL at Mars.	Investigate properties of low-velocity particle collision in microgravity	Demonstrate deep space CubeSat in Earth-escape orbit; Demo operations, communications, and navigation in deep space.	Create detailed map of the moon's water content at lunar South Pole in preparation for exploration.
Science Area	Planetary Science; microgravity	Planetary Science / technology demo	Planetary Science	Planetary Science	Planetary Science
Status	Launched Nov. 2010; Mission Success	In Development; LRD May 2018 with Insight to Mars	In Development; LRD Dec. 2017	In Development; LAUNCH: TBD, selected by the Cubesat Launch Initiative, awaiting manifest	In Development; LRD Nov 2018 onboard SLS/EM-1