

## **IAA Study Group Status Report 9-25-2014**

**Responsible Commission: IV**

### **Study Number and Title: The Applications of Micro-Satellites and Cube-Sats to Planetary Science and Exploration Missions**

**Short Study Description** (repeat from Study Group Proposal):

Whereas CubeSats and various forms of Micro-Sats have been in existence for the past 20-30 years, they have been primarily focused on Earth-bound applications and primarily developed by universities and small businesses. In light of recent advances in spacecraft and science instrument technologies, Cube-Sats and small satellites can now be considered for very low cost planetary missions. COTS components utilization and accessibility of miniaturized technologies and devices make small satellites a more powerful and cheaper tools than in the past to carry out low cost exploration.

This study will focus on developing a clear vision and a consensus on the future use of such small (~ 1-10kg) satellites for science and technology demonstration missions beyond Earth orbit, including but not limited to the exploration of the Earth's Moon, Mars, Outer Planets, Small Bodies (asteroids and comets) and other destinations.

#### **Progress in past six months:**

During the past 6 months the following progress has been made:

The study group is focused on four aspects of the Study as follows:

1. History and Background, Charles Norton and others
2. Science and Exploration using Small/Micro Satellites, Julie Castillo-Rogez
3. Mission Design approach
4. Missions, Andrew Klesh and others
5. Keck Institute of Space Studies (KISS) workshop results on "Small Satellites – A Revolution in Space Exploration"

A detailed outline of the Science section has been received from Science Section Lead Julie Castillo-Rogez at JPL. This outline, copied here and included as an attachment is going to be reviewed in the coming months and then the writing will proceed, in parallel to the development of the other 4 theme areas listed above.

**Website Study Information up to date?** Yes.

**Issues requiring resolution?** (recommend approach): NONE.

**Product Deliveries on Schedule?**

**Study Team Member Changes? YES. See expanded list above.**

**Name of person providing Study Group Status: Leon Alkalai, Chair**

**Status Report Date: 3-17-2014**

**Section: Micro/Nano Sats – Overview of KISS study**

**Section: A Historic Perspective on CubeSats, Jordi Puig-Suari, Robert Twiggs**

**Section: Small Satellites – A Revolution in Space Science**

**Lead Author: Charles Norton, JPL**

- 1. Motivation for Small Satellites in Space Science**
- 2. Goals and Objectives of the Keck Institute Study on Revolutionary Space Science**
- 3. Science Driven Mission Concepts**
  - 3.1 Astrophysics**
  - 3.2 Heliophysics**
  - 3.3 Planetary Science**
- 4. Technology Advancements and Future Challenges**
- 5. Findings and Recommendations**

**Section: Micro/NanoSat: A new way of mission design and formulation: Team-Xc**  
**Lead Author: Pez Zarifian, JPL**

## **Section XX. SCIENCE APPLICATIONS: Julie Castillo**

### **6. Introduction**

### **7. Smallsat application to Space Exploration – Novel Take on Long-Standing Questions**

Vision statement (or part of Introduction)

### **8. Astronomy and Astrophysics Applications**

#### *8.1 Key Science Objectives and Measurements*

8.1.1 Cosmic Origins and physics of the Cosmos

8.1.2 Exoplanet detection and characterization

To be completed by expert

#### *8.2 State of the Art in Space-Based Astrophysics*

#### *8.3 Gaps and Needs for Novel Observational Strategies*

#### *8.4 Smallsats as Enabling Platforms for Discovery in Astrophysics*

Examples of Emerging Concepts

#### *8.5 The Way Forward*

### **9. Heliophysics Applications**

#### *9.1 Key Science Objectives and Measurements*

9.1.1 Solar and Heliospheric Physics

9.1.2 Solar Wind/Magnetosphere Interactions

9.1.3 Atmosphere/Ionosphere/Magnetosphere Interactions

#### *9.2 State of the Art in Space-Based Heliophysics*

#### *9.3 Gaps and Needs for Novel Observational Strategies*

#### *9.4 Smallsats as Enabling Platforms for Discovery in Heliophysics*

Examples of Emerging Concepts

#### *9.5 The Way Forward*

### **10. Planetary Science Applications**

#### *10.1 Key Science Objectives and Measurements*

- 10.1.1 Origins Science
- 10.1.2 Searching for Planetary Habitats
- 10.1.3 Understanding the Workings of Solar Systems

10.2 *State of the Art in Planetary Exploration*

10.3 *Gaps and Needs for Novel Observational Strategies*

10.4 *Smallsats as Enabling Platforms for Discovery in Planetary Science*  
Examples of Emerging Concepts

10.5 *The Way Forward*  
Mention the development of miniaturized instrumentation

## **11.Applications to Human Exploration**

11.1 *Strategic Knowledge Gaps and Exploration Science*

11.1.1 Finding and Characterizing New Targets

11.1.2 Retiring risk (journey and at target)

11.1.3 Preparing for Operations

11.2 *State of the Art*

11.3 *Gaps and Needs for Novel Observational Strategies*

11.4 *Smallsats as Robotic Precursors to Exploration*  
Examples of Emerging Concepts

11.5 *The Way Forward*

## **12.Conclusion**

Enabling Discovery in Space Exploration

Science return vs. cost and risk posture – A change in paradigm

## **13.References**

Bahcivan, H., Cutler, JW, Bennett, M., Kempke, B., Springmann, JC, Buonocore, J., Nicolls, M., Doe, R. (2012) First measurements of radar coherent scatter by the Radio Aurora Explorer CubeSat, Geophys. Res. Lett. 39, L14101.

Bannister, N. (2013) Wide Field UV Imaging For Space Weather Cubesats, Low Cost Planetary Mission Conference 10, Pasadena, June 2013.

Brown, P., Carr, C., Horbury, T., O'Brien, H., Oddy, T. (2009) Miniaturised magnetometer experiments for Cubesats, Europlanet Science Conference, #809.

Castillo-Rogez, J. C., (2013) Next Generation SmallSat - Dare to Explore Where No Craft Has Gone Before, Low Cost Planetary Mission Conference 10, Pasadena, June 2013.

Castillo-Rogez, J. C., Pavone, M., Nesnas, I., Hoffman, J. Expected Science Return of Spatially-Extended In-Situ Exploration at Small Solar System Bodies, IEEE Proceedings.

Castillo-Rogez, J. C. (2012) Current State of Knowledge about Origins from Remote, In Situ and Returned Sample Exploration, KISS Workshop on In Situ Science and Instrumentation for Primitive Bodies ,  
<http://kiss.caltech.edu/workshops/primitivebodies2012/presentations/castillo.pdf>

Duncan, C. B., Dennis, M. S., Kalman, A. E., Stein, K. A., Tesfaye, J., I-Ming Lin, B., Truong-Cao, E., Foster, C. (2010) LMRST-Sat: A Small, High Value-to-Cost Mission, IEEEAC paper #1228.

Elvis, M., Landau, D., Kasper, J., Lantoine, G., Marrese-Reading, C., Mueller, J., Russell, R. P., Strange, N., Ziemer, J. K., Nash, A., Yeomans, D. (2012) A Swarm Of Micro-satellites For In Situ NEO Characterization, Division for Planetary Science Meeting.

Garrick-Bethell, I. (2013) Lunar magnetic field measurements with a cubesat impactor, Low Cost Planetary Mission Conference 10, Pasadena, June 2013.

Hedman, M., Tiscareno, M., Burns, J., Nicholson, P., Johnson, M. (2012) Scouting Saturns Rings with Small Spacecraft, First Interplanetary CubeSat Workshop, <http://icubesat.org/papers/2012us/2012-b-1-1/>

Jaumann, R. et al. (2013) A Mobile Asteroid Surface Scout (MASCOT) for the Hayabusa 2 Mission, Low Cost Planetary Mission Conference, Pasadena, June 2013.

Klesh, A. T., Castillo-Rogez, J. C. (2012) Nano-satellite secondary spacecraft on deep space missions, Proceedings Global Exploration Conference 2012, GLEX-2012,05,P,14.p1,x12645.

Klesh, V. Angelopoulos, B. Betts, C. Bidby, J. Cutler, M. Desai, L. Friedmann, P. Liewer, D. Spencer, R. Staehle, Y. Tsuda (2012b) SolWise: Sailing On Light With Interplanetary Science and Exploration, CubeSat Workshop.

Klesh, A., Castillo-Rogez, J. C. (2012) Applications of NanoSats to Planetary Exploration, Earth and Space Science Conference, AIAA.



- Klesh A. T. Castillo-Rogez J. C. (2012) Secondary NanoSpacecraft Survey of the Martian Moons, Concepts and Approaches for Mars Exploration, #4124.
- Komarek, T. (2013) Novel ideas for exploring Mars with CubeSats, Low Cost Planetary Mission Conference 10, Pasadena, June 2013.
- Lang, J., Baker, J., Castillo-Rogez, J., McElrath, T. P., Piacentine, J. S., Snyder, S., Phobos exploration using two small Solar electric propulsion spacecraft, Proceedings Global Exploration Conference 2012, GLEX-2012.03.2.4x12737.
- Nicholson, W. and co authors (2011) The O/OREOS Mission:First Science Data from the Space Environment Survivability of Living Organisms (SESLO) Payload, Astrobiology, Vol. 11, pp. 951958.
- NRC (2011) Vision and Voyages for Planetary Science in the Decade 2013-2022, The National Academies Press, 400 pp.
- Pavone, M., Castillo-Rogez, J. C., Hoffman, J. A., Nesnas, I. A. D., Strange, N. J. (2013) Spacecraft/Rover Hybrids for the Exploration of Small Solar System Bodies, IEEE Proceedings, #2425.
- Poncy, J., Couzin, P., Billot, C. (2013) Maximizing the science return of fly-by missions thanks to ancillary smallsats and cubesats, Europlanet Science Conference, id.EPSC2013-966.
- Smith, M.W., Seager, S., Pong, C.M., Villasenor, J.S., Ricker, G.R., Miller, D.W., Knapp, M.E., Farmer, G.T., Jensen-Clem, R. (2010) ExoplanetSat: detecting transiting exoplanets using a low-cost CubeSat platform, SPIE Proceedings.
- Staehele, R., Puig-Suari, J., Svitek, T., Friedman, L., Blaney, D. (2012) Interplanetary CubeSats: Some Missions Feasible Sooner than Expected, Interplanetary CubeSat Workshop, <http://icubesat.org/papers/2012us/2012-a-1-1/>
- Strange, N. J., Klesh, A. T., Marrese-Reading, C. M., Oh, D. Y., Ziemer, J. K., McElrath, T. P., Landau, D. F., Grebow, D. J. (2012) Interplanetary Sample Canister for Mars Sample Return, Concepts and Approaches for Mars Exploration, #4277.
- van Amerom F. H. W. Chaudhary A. Short R. T. Roman P. Brinckerho\_ W. Glavin D. Maha\_y P. (2012) Micro-Ion Traps for Detection of (Pre)-Biotic Organic Compounds on Comets, International Workshop on Instrumentation for Planetary Missions, Abstract #1040.
- Vannitsen, J., Segret, B., Miao, J. J., Juang, J.-C. (2013) CubeSat on an Earth-Mars Free-Return Trajectory to study radiation hazards in the future manned mission, Europlanet Science Conference, id.EPSC2013-1088.

Wargo, M. (2012) Strategic Knowledge Gaps: Enabling Safe, E\_ective, and E\_cient Human Exploration of the Solar System, presentation to Small Bodies Assessment Group, Washington, D.C., January 18, 2012.

Willis P. A. \* Stockton A. M. Mora M. F. Cable M. L. Bramall N. E. Jensen E. C. Jiao H. Lynch E. Mathies R. A. (2012) Planetary In Situ Capillary Electrophoresis System (PISCES), International Workshop on Instrumentation for Planetary Missions, Abstract #1038. American Institute of Aeronautics and Astronautics

Woellert, Kirk, Ehrenfreund, Pascale, Ricco, Antonio J., Hertzfeld, Henry (2011) Cubesats: Cost-effective science and technology platforms for emerging and developing Nations, *Advances in Space Research* 47, 663-684.

Worden, P. A. (2011) The large capability of small satellites, <http://www.space-itt.eu/failai/SEMWO2011/Presentations/The%20Large%20Capability%20of%20Small%20Satellites%20-%20Nov.%202017,%202011.pdf>