APPLICABILITY OF NANOSATELLITES TO DEEP SPACE EXPLORATION. A. T. Klesh[1] and J. C. Castillo-Rogez, [1]Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Blvd, Pasadena, CA 91109, julie.castillo@jpl.nasa.gov, andrew.t.klesh@jpl.nasa.gov

Introduction: CubeSats have become widely popular for low-cost Earth orbit science and technology missions, in part due to the large availability of launch slots as secondary payloads. This availability comes from a simple standard that provides the launch provider a minimal risk interface (from repeated testing) that can be used on multiple vehicles - if one ride or CubeSat doesn't work out, it can be swapped out. We have investigated a similar concept for solar system exploration: **the regular inclusion of standard secondary nanosatellites on deep space missions to provide in-situ measurements in risky and inhospitable locations.**

The Importance of Nano-satellites: The current planetary-object surface-science state-of-the-art primarily comes from remote sensing. However, key constraints on early solar system chemistry come from volatile composition and isotopic ratios, which require sampling material, either through in situ surface or atmospheric characterization or sample return, yet accessing planetary surfaces is very expensive and risky. Without a more systematic characterization of the chemical composition of planetary bodies visited by spacecrafts, the search for our origins is likely to progress at a slow pace. However, at this stage, such a scientific endeavor is primarily limited by the lack of adequate observational strategies that can fit within mission cost caps. Nano-spacecraft may help establish a program to characterize planetary chemistry all across the solar system that will be key to constraining the early solar system conditions (temperature, tedox). NanoSats, these tiny (and disposable) spacecrafts may be used to access high-science/high-risk sites, like cometary vents, Enceladus' jets, tectonic features, Io's volcanoes, Venus' upper atmosphere, etc, which provide information on the internal chemistry of the object rather than solely surface composition.

A Strategy for Implementation: There are many different types of nanosatellites with specific capabilities and limitations. In order to evaluate which of these spacecrafts are best suited for different targeted investigations, we have initiated a study of the science return expected for each type of nanosats**.**

In support of this goal, a workshop was held at JPL to investigate the science applications and implementation challenges of nanosatellites at small-body objects and in general use throughout the solar system. The primary results of this study are presented in the poster associated with this abstract, and include a prioritized list of science applications and a strategy to address the current limitations preventing implementations. Another key focus of the workshop was the definition of experiments to support the implemenation of NASA's Human exploration program (e.g., soil characterization, risk associated with dust and electrostatic charging, etc) as part of precursor missions aiming at the evaluation of the environment and the surface reconnaissance of prospective targets.

After preliminary discussions, we have found that significant challenges and questions yet remain as obstacles to the use of nanosatellites in deep space missions. Studies to be conducted include mitigation of risk to the primary spacecraft, nanosatellite deployment and disposal, communications / power strategies, umbilical or coupling needs, assessment and modeling of the impact of these elements on mission design (cost, risk, mission design), identification of partnership opportunities with educational institutions, identifying the correct form-factor / standard for reuse, and designing an appropriate science payload that may be used on multiple objects. Testing technology readiness may be in large part accomplished at low-Earth orbit. There are many systems needed for deep space that may be tested in this environment, including relay communications, propulsion, and mothership deployment. While we do not consider single instrument NanoSats as likely to complete entire *Discovery*-class missions alone, we believe that NanoSats can augment larger missions to significantly increase science return. Thus a portfolio of possible secondary missions, especially focused toward chemistry characterization, was a by-product of this study.

Deep space NanoSats may also provide a new avenue for Education and Public Outreach, where academic institutions or others might provide a secondary spacecraft with limited risk to the primary. The inclusion of an EPO deep-space spacecraft is another opportunity for study.

Steps Forward: The study carried out for this work emphasized the many applications nanosatellites can be used for, and how they provide capabilities that extend the scientific outcome of a mission beyond that of a primary spacecraft. Detailed workshop results and recommendations will be provided in collaboration with the members of the workshop team in several upcoming publications, including [1] and [2], where the authors hope to engage both the scientific and engineering communities to enable the use of nano-spacecraft in deep space.

References:

[1] A. Klesh, J. Castillo-Rogez, et al. , "Nano-satellite Secondary Spacecraft on Deep Space Missions," GLEX Workshop, 2012. [2] A. Klesh and J. Castillo-

Rogez, "Applications of Nano-satellites at Small-body Objects," CubeSat Workshop, 2012.

Acknowledgements: This work has been carried out at the Jet Propulsion Laboratory, California Institute of Technology, under contract to NASA. Government sponsorship acknowledged.