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Letter to the Editor

CubeSats as innovative science platforms

Dear Editor,

CubeSats are becoming science research and technology development platforms[1,2] that capitalize on the latest technologies. The low cost and short time frame from development to operation and data analysis, a consequence of their university heritage, make them ideal tools for science education, as well as for technology advancement in developing nations.[3] CubeSats offer increasingly sophisticated analytical measurement capabilities in small, lightweight, low-power, inexpensive packages that are adaptable to many spaceflight and planetary applications suitable for "hitchhiker" missions on lunar and Mars orbiters and landers, science in Earth orbit, and on missions to near-Earth objects.

The NASA Ames Research Center (ARC) has demonstrated successful fundamental biology and space biology spaceflight missions utilizing 1U and 2U payload systems (one "U" is a 10-cm cube) which measured bacterial gene expression via protein fluorescence and light scattering and antifungal drug dose dependence, via 3-color measurements, of microbe population and metabolic activity.[4,5] Additional 2U spaceflight instruments are presently under development at ARC to monitor photosynthetic efficiency in microalgae as a function of gravitational level, to study antibiotic resistance changes in uropathogenic bacteria subjected to microgravity, and to determine the gravitational threshold for gravitropism in fern spores. The recent NASA science 3U cubesat O/OREOS (Organism/Organic Exposure to Orbital Stresses), launched in November 2010, achieved its overall goal to utilize autonomous instrumentation and sensors for a 6-month in-situ study of microbes and biomarkers in space conditions using a free-flying nanosatellite (Figure 1).

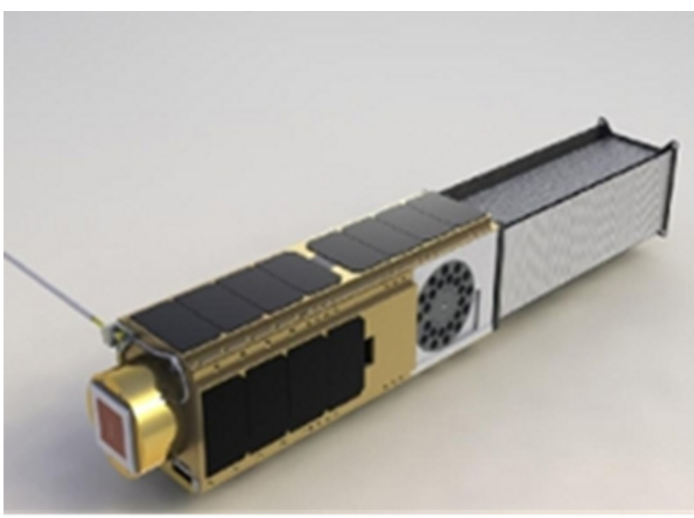

Figure 1. NASA Ames's O/OREOS triple-CubeSat (shown with de-orbit mechanism deployed) achieved full mission success in May 2011, and the first science results from both astrobiology payloads were recently published.[6,7] Credit: NASA

The new concept of a CubeSat "planetary hitchhiker" consists of a payload system or a complete small satellite, which is carried along on a mission to a planet, moon, or other solar system body, with science or technology goals that are separate and independent from the primary mission. A hitchhiker payload may simply make measurements while in transit in a beyond-low-Earth-orbit environment (e.g., cosmic radiation effects on living organisms or engineering materials) or a hitchhiker may be deployed as a self-sufficient small satellite while in transit or upon arrival at a destination orbit. In the latter scenarios, the small satellite typically must be in communication with a larger spacecraft that can relay its results to Earth with a larger, higher-gain antenna.

One application envisioned for using small satellite and CubeSat technologies for planetary missions is an oxidation sensor system for Mars exploration. Chemical and biochemical sensors and arrays have been proposed as cost-effective tools for Mars exploration. Using the O/OREOS 1U thin-film spectroscopy instrument and packaging technology, thin-film samples can be used as sensors, or probe molecules, to directly analyze martian samples (i.e., regolith, soil, ice), passively sampled dust, and the atmosphere. Using samples provided by drilling or excavating operations, or by "passive" surface sample delivery (dust storms) to fill a microfabricated capture device, microliter-volume analytical sample cells (adapted from those included in the O/OREOS payload)[8] could be combined with a multi-wavelength array of wet-chemical indicator reactions to implement a sensitive assay of the biochemical reactive hazards of local surface environments.

Isotachophoresis, an electrokinetic sample preconcentration method that provides million-fold concentration enhancement using microcapillary networks in microfludic devices, has been identified as a suitable lab-on-a-chip technology to enable detection of biosignatures or trace-level organic matter in dust.[9] To prepare for human exploration or habitation of deep space, Mars, or the Moon, risk mitigation strategies need to be developed. The GeneSat-1, PharmaSat, and O/OREOS payload systems[10] supported and characterized living model microorganisms (*E. coli, S. cerevisiae, B. subtilis*) that share many fundamental characteristics with mammalian cells. By monitoring, for example, DNA damage and repair due to high-energy particle radiation in appropriate model organisms or cell cultures, a better understanding of the extent of damage in higher animals exposed to radiation in deep space, lunar, or planetary environments is anticipated.

The number of research areas utilizing CubeSats is increasing. In particular, progress in the field of astrobiology has been achieved with the success of the O/OREOS mission. Additionally, future hitchhiker opportunities for CubeSat technology under consideration include: planetary exploration missions in the framework of P-POD dispensers on Mars orbiters, cube accommodation slots on various landers, and possible outer-solar system research activities. Potential NanoSat science conducted with CubeSats deployed during flyby of Jupiter's Moon Europa could enable ocean conductance measurements, radio science, high-resolution descent imagery, and magnetometry. The technical capabilities of CubeSats are rapidly expanding in conjunction with the demands of research fields with science applications in LEO and beyond.

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