Life Science Research in Outer Space: New Platform Technologies for Low-Cost, Autonomous Small Satellite Missions

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We develop integrated instruments and platforms suitable for economical, frequent space access for autonomous life science experiments and processes in outer space. The technologies represented by three of our recent "free-flyer small-satellite" missions are the basis of a rapidly growing toolbox of miniaturized biologically/biochemically-oriented instrumentation now enabling a new generation of *in-situ* space experiments.

Autonomous small satellites (~ 1 – 50 kg) are less expensive to develop and build than "full-size" spacecraft and not subject to the comparatively high costs and scheduling challenges of human-tended experimentation on the International Space Station, Space Shuttle, and comparable platforms. A growing number of commercial, government, military, and civilian space launches now carry small "secondary" science payloads at far lower cost than dedicated missions; the number of opportunities is particularly large for so-called cube-sat and multicube satellites in the 1 – 10 kg range. The recent explosion in nano-, micro-, and miniature technologies, spanning fields from telecommunications to materials to bio/chemical analysis, enables development of remarkably capable autonomous miniaturized instruments to accomplish remote biological experimentation. High-throughput drug discovery, point-of-care medical diagnostics, and genetic analysis are applications driving rapid progress in autonomous bioanalytical technology.

Three of our recent missions exemplify the development of miniaturized analytical payload instrumentation: GeneSat-1 (launched: December 2006), PharmaSat (launched: May 2009), and O/OREOS (organism/organics exposure to orbital stresses; scheduled launch: May 2010). We will highlight the overall architecture and integration of fluidic, optical, sensor, thermal, and electronic technologies and subsystems to support and monitor the growth of microorganisms in culture in these small autonomous space satellites, including real-time tracking of their culture density, gene expression, and metabolic activity while in the space environment. Flight data and results will be presented from GeneSat-1, which tracked gene expression levels of GFP-labeled *E. coli* and from PharmaSat, which monitored the dose dependency of an antifungal agent against *S. cerevisiae*. The O/OREOS SESLO instrument, which will study the effects of radiation and microgravity upon the viability and growth characteristics of *B. subtilis* and the halophile *Halorubrum chaoviatoris* for periods of 0 - 6 months in space, will be described as well. The ongoing expansion of the small satellite toolbox of biological technologies will be summarized.