EPSC Abstracts
Vol. 10, EPSC2015-744, 2015
European Planetary Science Congress 2015

CLIpSAT for Interplanetary Missions: Common Low-cost Interplanetary Spacecraft with Autonomy Technologies

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Abstract

Blue Sun Enterprises, Inc. is creating a common deep space bus capable of a wide variety of Mars, asteroid, and comet science missions, observational missions in and near GEO, and interplanetary delivery missions. The spacecraft are modular and highly autonomous, featuring a common core and optional expansion for variable-sized science or commercial payloads.

Initial spacecraft designs are targeted for Mars atmospheric science, a Phobos sample return mission, geosynchronous reconnaissance, and en-masse delivery of payloads using packetized propulsion modules. By combining design, build, and operations processes for these missions, the cost and effort for creating the bus is shared across a variety of initial missions, reducing overall costs.

A CLIpSAT can be delivered to different orbits and still be able to reach interplanetary targets like Mars due to up to 14.5 km/sec of delta-V provided by its high-ISP Xenon ion thruster(s). A 6U version of the spacecraft form fits PPOD-standard deployment systems, with up to 9 km/s of delta-V. A larger 12-U (with the addition of an expansion module) enables higher overall delta-V, and has the ability to jettison the expansion module and return to the Earth-Moon system from Mars orbit with the main spacecraft. CLIpSAT utilizes radiation-hardened electronics and RF equipment, 140+ We of power at earth (60 We at Mars), a compact navigation camera that doubles as a science imager, and communications of 2000 bps from Mars to the DSN via X-band. This bus could form the cornerstone of a large number asteroid survey projects, comet intercept missions, and planetary observation missions.

The TugBot architecture uses groups of CLIpSATs attached to payloads lacking innate high-delta-V propulsion. The TugBots use coordinated trajectory following by each individual spacecraft to move the payload to the desired orbit - for example, a defense asset might be moved from GEO to lunar transfer orbit in order to protect and hide it, then returned to a useful GEO orbit as a replacement for a failed GEO asset.

Interplanetary payload delivery can be undertaken by arraying these spacecraft buses, then staging each one. This approach is implemented by using CLIpSATs as propulsion "packets", delivered independently to low earth orbit and directed to rendezvous individually with a structure. Once all packets have attached themselves, the ensemble burns to follow a trajectory, delivering the payload to the desired planetary or heliocentric orbit.

Autonomy technologies in CLIpSAT software include Virtual Machine Language 3 (VML 3) sequencing, JPL AutoNav software, optical navigation, ephemeris tracking, trajectory replanning, maneuver execution, advanced state-driven sequencing, expert systems, and fail-operational strategies. These technologies enable small teams to operate large numbers of spacecraft and lessen the need for the deep knowledge normally required.

The consortium building CLIpSAT includes Blue Sun Enterprises, the Jet Propulsion Laboratory, Millennium Space Systems, the Laboratory for Atmospheric and Space Physics, and the Southwest Research Institute.