Towards the Use of Commercial-off-the-Shelf Small-Satellite Components for Deep-Space CubeSats: a Feasibility and Performance Analysis

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Mission Scenario

• SSGTO injection orbit, Earth escape and NEA fly-by (~300 km altitude)
• NASA-JPL Small Body Search Engine for ∆V budget, departure date and time-of-flight
• Improve NEAs dataset (dimension, shape, rotational parameters, composition, ephemerides)
• Payload composed of visible and IR cameras
• Compact CubeSat architecture (3U if possible)

Components Evaluation and Selection

• Payload requirements: <0.8U, <500g, GSD @ 300km < 50 m/pixel
• Deployable and orientable solar panels are needed at large distances from the Sun
• Autonomous GNC via star trackers and payload camera
• Selection of other components via Analytic Hierarchy Process (AHP)

AHP for Trade-Off

• Mass and Volume selection driven parameters for all subsystems
• Each component has characterizing parameters for trade-off
• EPS – Battery Capacity (minimum required: 18.5 Wh)
• ADCS – Pointing Accuracy (required below 0.15°) and Power Consumption
• X-Band Transmitter – Transmitting Power and Power Consumption
• OBC – Clock Frequency, Power Consumption and Memory Storage

Background and Motivation

• Deep-space exploration demands can be fulfilled with CubeSats
• Near-Earth Asteroids offer multiple mission targets
• Main trends to follow: miniaturization, standardization and automation

Propulsion System evaluation chart

• Increasing CubeSat BOL mass from left to right (1-12 kg)
• Total ∆V = 400 m/s for Earth escape and small correction maneuvers
• MPS-130 is the best compromise in terms of mass, volume, propellant toxicity and CubeSat mass for this application

Conclusions and remarks

• Fully COTS CubeSat configuration is possible (<4kg, <3U)
• Few visible range cameras with sufficient resolution to provide a good scientific return at fly-by altitude
• Only one IR spectrometer meeting the requirements is currently available. For larger applications, integrated VIS-IR optical payloads are available
• Many optical payloads have their dedicated processor, which simplifies the design
• Available star trackers offer excellent performances for attitude determination (few arcsec accuracy), while their capabilities in detecting line-of-sight of visible bodies for autonomous navigation need to be assessed
• Integrated ADCS provide sufficient pointing accuracy both for payload and data downlinking
• Wheel desaturation and de-spinning cannot rely on magnetorquers in deep-space. Available micro-propulsion systems offer very limited desaturation capabilities and as of today an additional device shall be included (such as a resistojets-based AOCS)
• Micro-propulsion systems still limit these applications in terms of available ∆V
• Some OBC options appear mature and very performant for advanced on-board processing
• Wide range of EPS both for compact and larger applications, but few options for completely deployable and orientable solar arrays
• X-Band transmitters and antennas allow a small transmittable dataset at large distances, which shall be improved to increase the scientific return
• Mission radiation profiles different from LEO shall be described for proper radiation hardening