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CubeSats to Explore Volatiles in Comets

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Abstract

Close approach comets (<0.4 AU to Earth) are accessible to CubeSat and NanoSat missions that can return unique data not obtainable from ground-based telescopes. Primitive bodies such as comets are key to understanding Solar System formation. A low-risk, versatile, multispectral camera with integrated filters in a 6U spacecraft bus is capable of high spatial resolution mapping of the four primary volatile species CO_2, H_2O, CO, and organics. Simultaneous mapping of these bands and two thermal channels will enable studying the dynamical activity of the nucleus. Assuming deployment from a launch platform above the Earth's gravity well, we find intercept trajectories using current propulsion systems.

1. Introduction

The Dec-2018 apparition of comet 46P/Wirtanen (0.08 AU) and P/2014 U2 (Kowalski, 0.3 AU) in Sep-2019 present opportunities for a small satellite to perform a close flyby to study the nucleus and inner coma regions at high spatial resolution (Fig. 1). Measurements of volatiles in comets are required to establish their formation and evolution. For example, CO_2 is now recognized as one of the most abundant of volatiles in comets as a result of the *Akari* and *Deep Impact* mission results, yet we know relatively little of its diversity among comets. The target volatile have spectral signatures are best observed in the 2-5 μm Mid-Wave Infrared (MWIR) spectral region. Thermal emission dominates spectral wavelengths >5μm in the inner coma, which enables the Comet Camera (ComCAM) to map the inner coma temperature distribution by measuring 7-10 and 8-14 μm Long-Wave InfraRed (LWIR) emission. In the case of 46P/Wirtanen, the flyby will discriminate measured quantities at high spatial resolution of ~0.3 km, comparable to 0.005" angular resolution for a ground-based observatory when the comet is nearest to Earth.

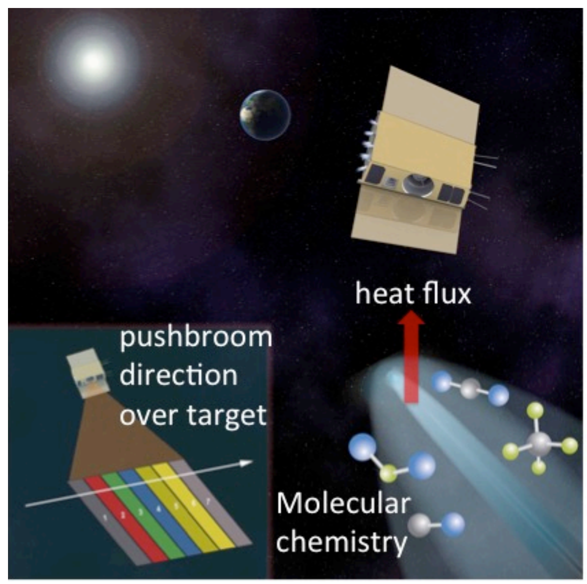

Figure 1: A close flyby of a comet yields unique and unprecedented mapping of the inner coma region.

2. ComCAM Concept

ComCAM is a low-risk multichannel multispectral camera concept based on a COTS product developed by Institut National d'Optique (INO), Canada. The baseline design uses an uncooled 384×288 pixel microbolometer array with an FPGA and digital processor (Fig. 2). The array is partitioned into seven 18×288 pixel spectral channels defined by filters mounted on the sensor array. The seven linear arrays are scanned across the target body as a push-broom to build spectral images, Fig. 1. The ComCAM payload, including 80 mm telescope and electronics, fits within a 1.3 U CubeSat volume (Fig. 2).

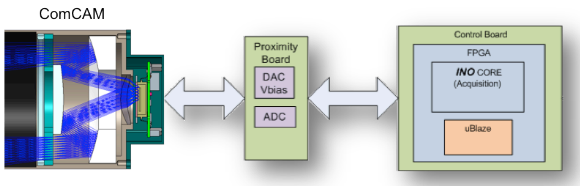

Figure 2: ComCAM telescope, sensor and electronics fits neatly into a 1.3 U volume.

3. Spacecraft Bus

The 6U CubeSat bus incorporates new nanosatellite technologies to mature an evolved, radiation-tolerant infrastructure designed to support interplanetary investigator science (Fig. 3). The 6U deep space design is based on Morehead State bus heritage and incorporates high power generation (72 W of continuous power), a radiation-tolerant, distributed multiple processor-based payload processor system, a highly-capable micronized GNC system designed for lunar missions, an innovative propulsion system, and a high throughput X-band communication system designed by JPL for lunar CubeSat missions.

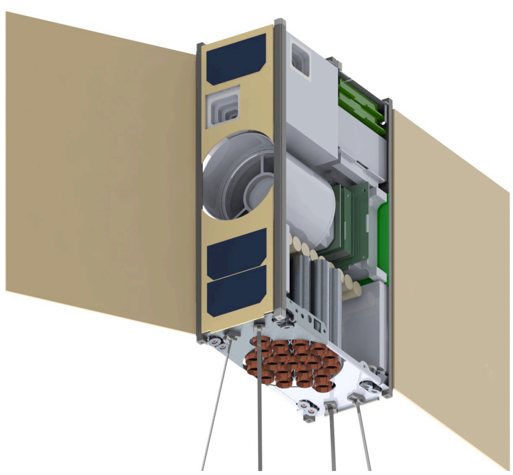

Figure 3: The 6U CubeSat bus with payload, propulsion, power, and other infrastructure.

4. Propulsion System

The Cubesat mission will utilize a multi-channel Micro-Cathode Arc Thruster (µCAT) micropropulsion subsystem that is an outgrowth of GWU Micropropulsion and Nanotechnology Laboratory (MpNL) research in scalable small spacecraft electric propulsion (Fig. 4). The µCAT is an electric propulsion device, based on the well-researched ablative vacuum arc process, enhanced by an external magnetic field that uses its own thruster cathode as propellant. The cathode terminal can be any conductive material. The applied magnetic field extends operation lifetime while reliance on a thruster element for propellant reduces system mass for micropropulsion compatible with 1-50 kg class satellites, including all CubeSat forms. The µCAT generic subsystem architecture consists of the controller incorporating control unit, power management, power distribution, and thruster boards incorporating plasma power units, and connections to off-board thruster heads, which contain: miniature anode/cathode elements, springs, insulators, electromagnet coils and connectors.

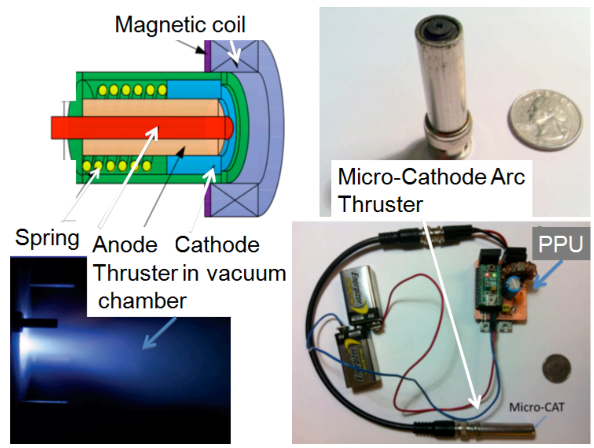

Figure 4: µCAT schematic and components.

5. Spacecraft Parameters

Payload: Multispectral camera
Mass: ~12.0 kg
Volume: 6U form factor
Prime Power: ~72 W
Data Rate: ~60 bps
Mission Data Volume: ~100 Mbits
Operational Lifetime: >2 years

6. Summary and Conclusions

We have designed a 6U CubeSat bus capable of interplanetary flight and close flyby of comets with Earth approaches of <0.4 AU to study volatile species and thermal structure of the nucleus and inner coma regions.