# Primitive Object Volatile Explorer (PrOVE): Waypoints to Comets

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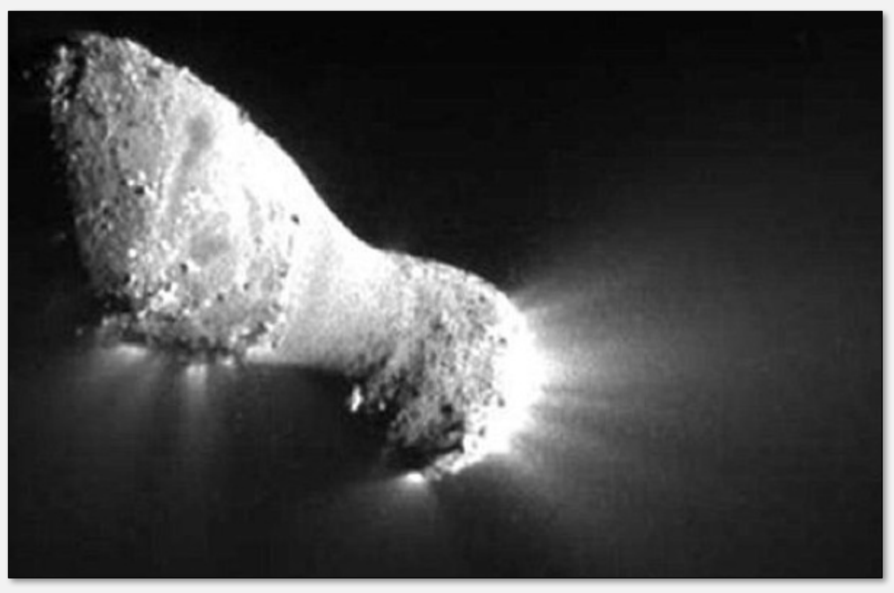
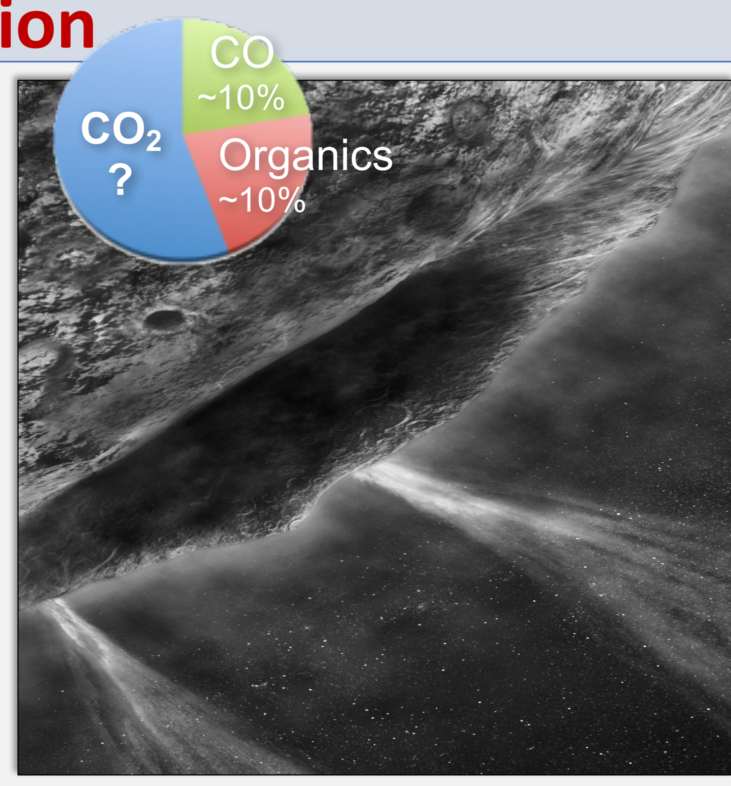
## Introduction



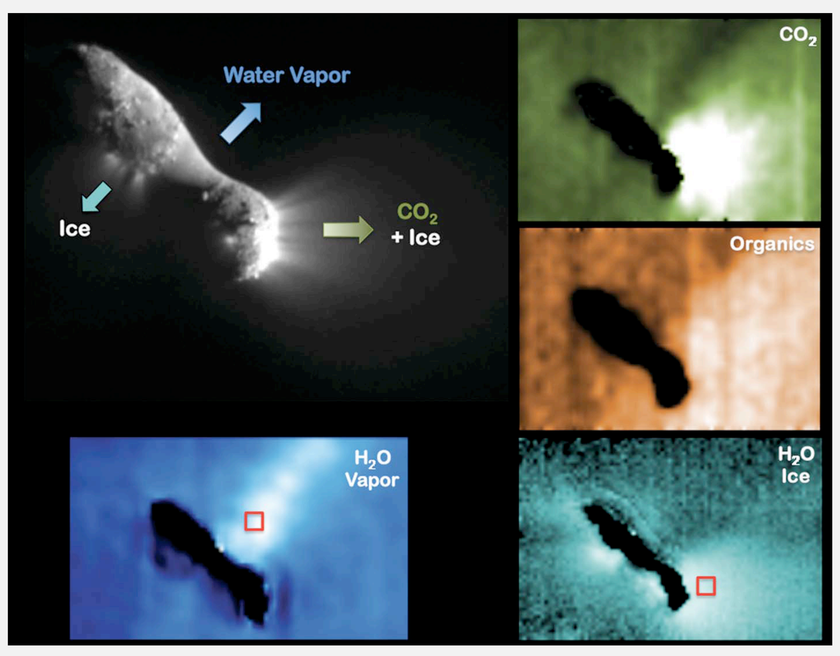
Comets are **primordial bodies**, and inform us about the **origins** of our Solar System and the **delivery of water and organics** to Earth.

The **$CO_2$ and organic** abundance (w.r.t $H_2O$) are prime metrics in establishing their formation origin and evolution.

PrOVE will measure $CO_2$ outgasssing from the cometary nucleus.



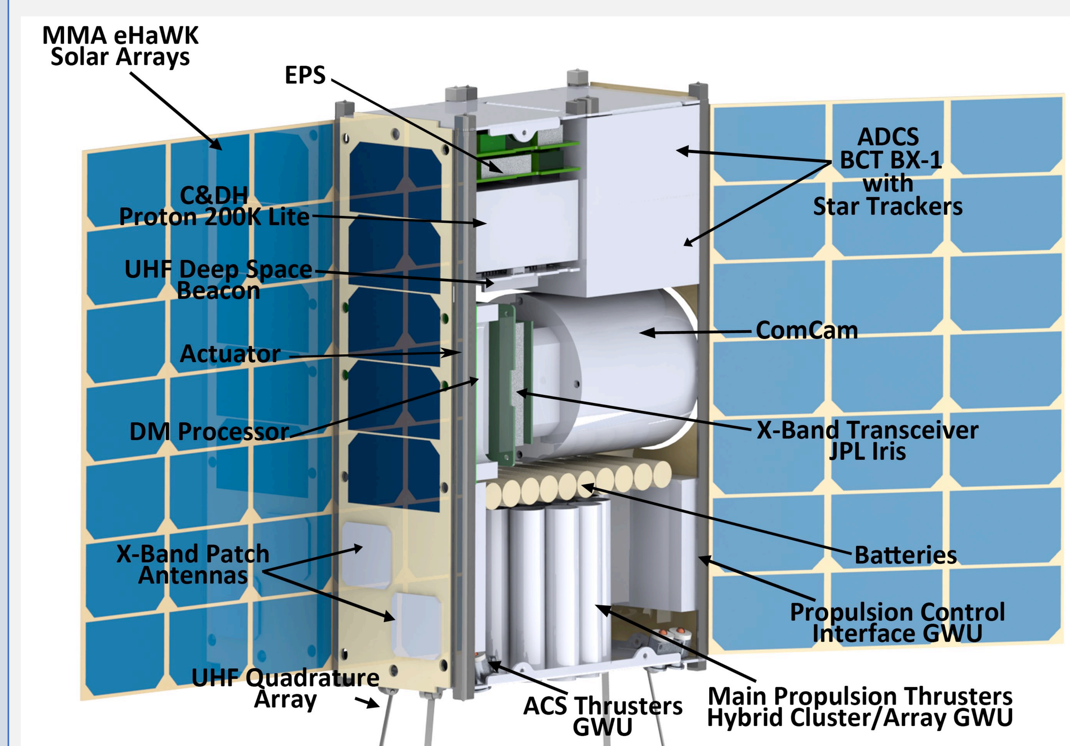

Little is known about the **second most abundant** molecule in comets ($CO_2$). **$CO_2$ cannot be measured directly from ground**; only Akari, Deep Impact, Rosetta, Spitzer, and NEOWISE have measurements. **Future: JWST, OSIRIS-REx.**




- *Deep Impact* investigation of 103P/Hartley 2 showed $CO_2$ sublimation driving comet activity. The spatial scale shown in red boxes (275 m) can be matched by a CubeSat mission.
- Maps of $CO_2$, water, organics, and thermal structure will provide information on comet volatile content, density, structural stability and outgassing.

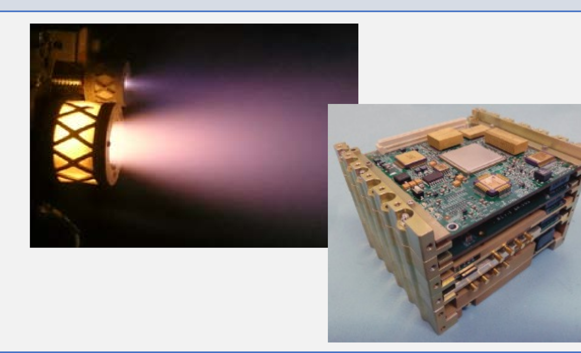
PrOVE is a low-cost design with critical **reconnaissance** capabilities that can be deployed in multiple copies to characterize new or periodic comets using a uniform set of measurements.

## Spacecraft




- Under a PSDS3 grant, a 12U deep space bus is being evaluated for missions to comets within 0.4 AU of Earth.
- Early design was for a 6U Cubesat bus (*left*) for a mission to 46P/Wirtanen (December-2018 apparition with 0.1 AU of Earth). Spacecraft was based on 6U deep space bus developed by Morehead State University for Lunar IceCube.

- Propulsion options: Busek BIT-3
- Communications: Iris v.2 transponder



## SmallSats suited for comet reconnaissance

- Rapid development to launch is possible.
- Frequent Rideshare opportunities.
- Cost efficient for focused science missions.
- Low cost spacecraft can reside in a parked orbit and wait for a **new** comet with pristine primordial composition.

## Preparing for Opportunity

To mitigate launch delay risk, we propose to park the spacecraft in a parking orbit – a **Waypoint**. At a navigationally appropriate time, the spacecraft will launch on the cruise phase en route to the comet and the flyby mission. In the PSDS3 study, we are investigating these waypoints.

## Science Instruments

### Science Objectives

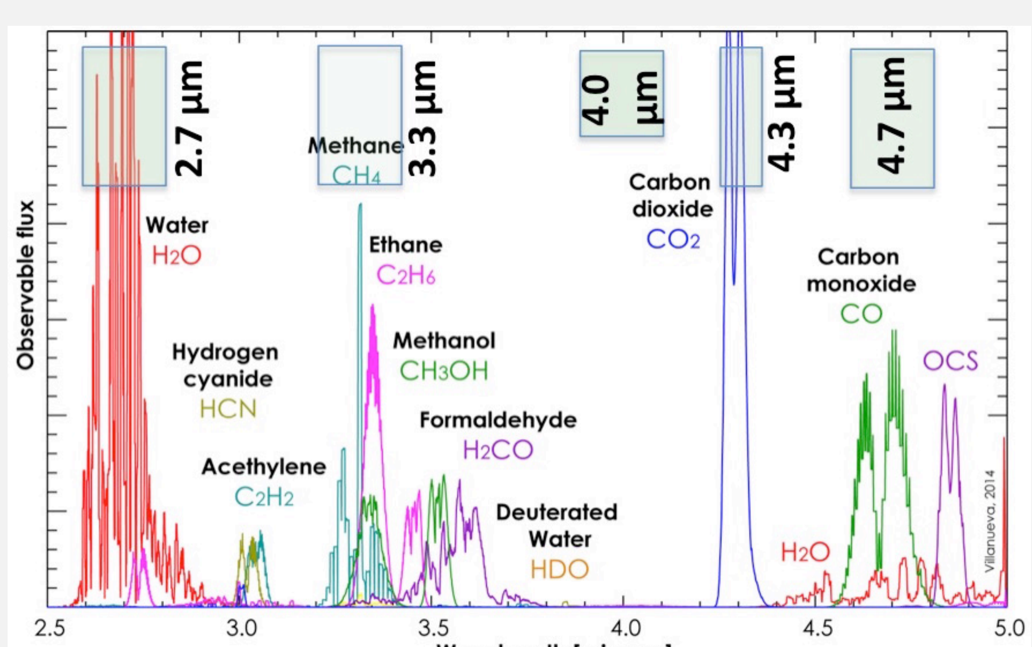
*PrOVE* will perform a close flyby of a Jupiter-family or new comet near perihelion when volatile activity is maximum, to probe the origin of the nucleus and the formation and evolution of our Solar System.

- *Investigate* chemical heterogeneity of nucleus by quantifying volatile species abundances and how these depend on solar insolation;
- *Map* spatial distribution of volatiles, especially $CO_2$ (which cannot be measured from ground based telescopes), and determine any variations;
- *Determine* the frequency and distribution of outbursts.

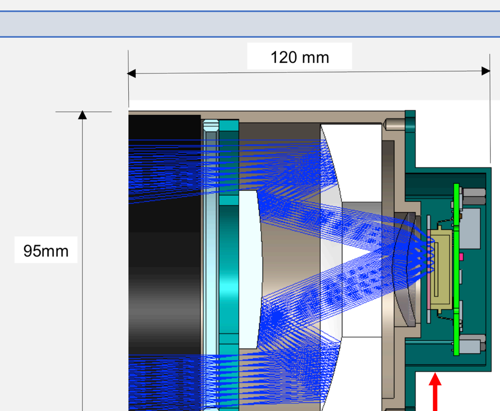
PrOVE Comet Camera (ComCAM) has seven filter channels. Four channels will image the distribution of molecular emission at

- 2.7 µm (H2O)
- 3.3 µm (organics)
- 4.3 µm (CO2)
- 4.7 µm (CO).

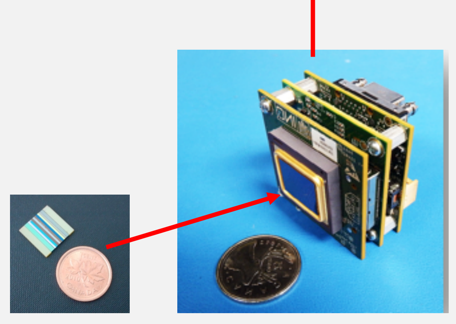
The 4.0 µm channel control for nonmolecular continuum, and 7-10 µm and 8-14 µm channels measure thermal structure (not shown here).




ComCAM 80 mm aperture optical layout is a cost-effective solution that meets point spread function and modulation transfer function requirements. ComCAM will fit neatly into a 1.3U volume.



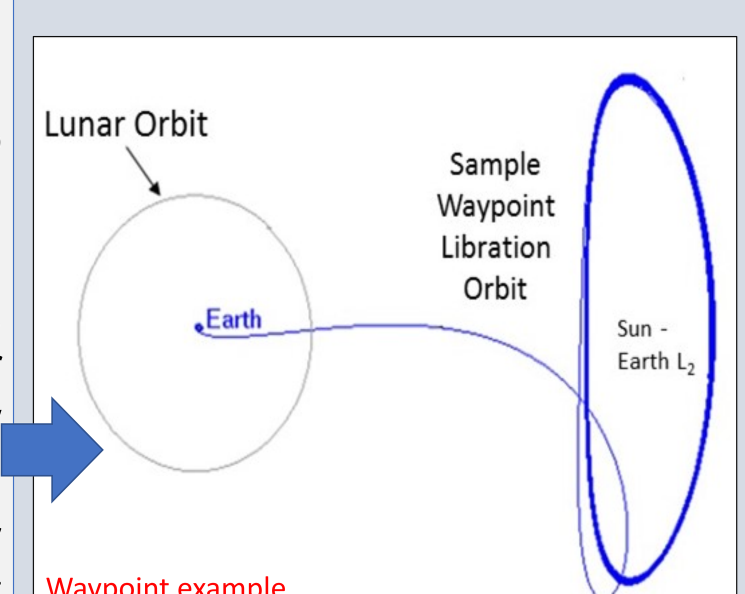

ComCAM will be built around the INO µXCAM OEM microbolometer sensor. (*right*) Example of Multi-Zone filters manufactured (*left*). Seven discrete filters matching the above spectral bands will be integrated onto the sensor focal plane. The optical assemblies are not shown.

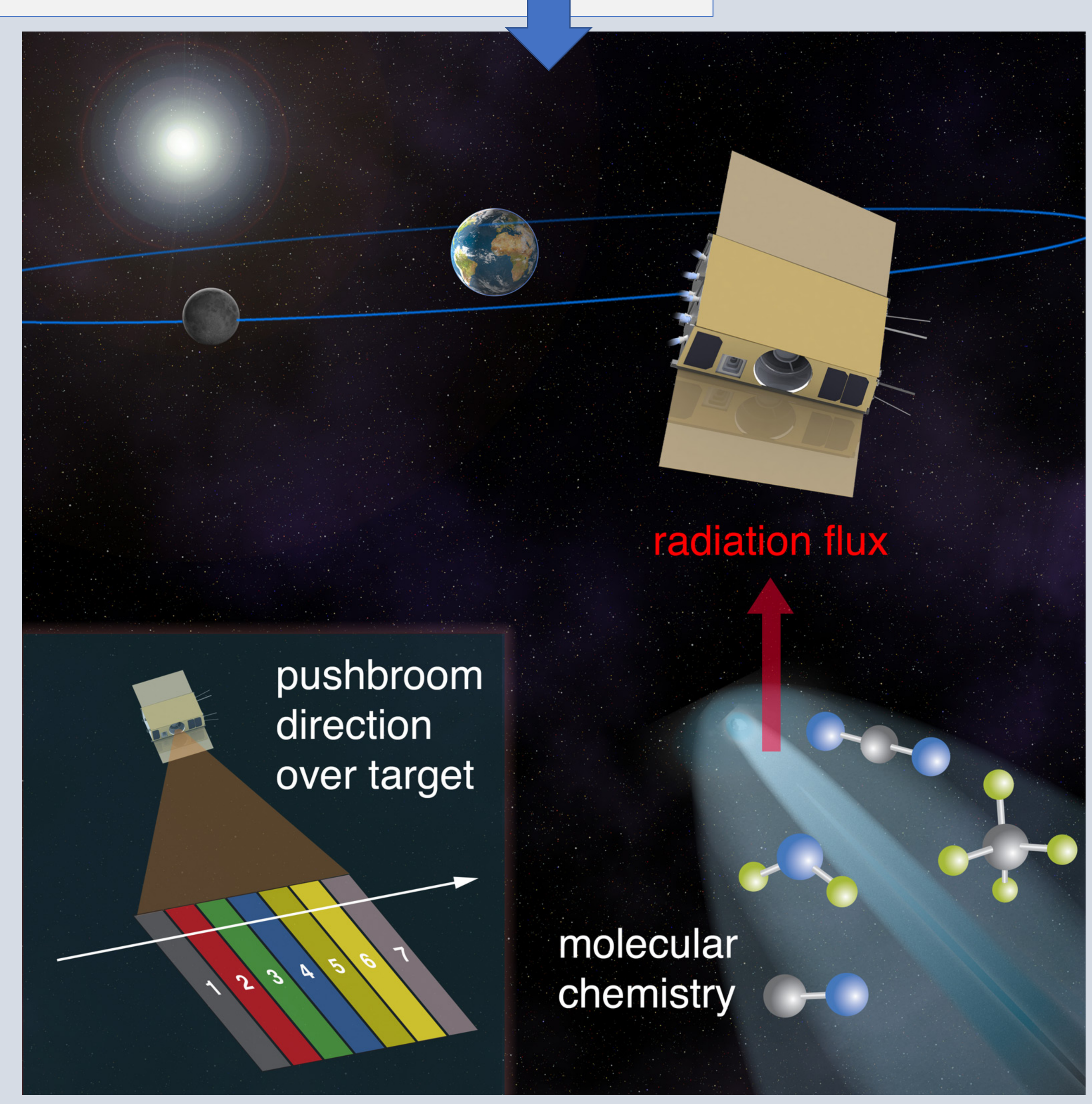


## Mission Concept

### Mission Overview

- *PrOVE* will be deployed from any launch platform.
- Using onboard propulsion, *PrOVE* will navigate to a waypoint in space.
- *PrOVE* will remain at the waypoint until commanded to a transfer trajectory to intercept a known comet as it approaches encounter or hibernate indefinitely until an opportunistic new comet is identified and transfer orbit is uploaded.
- The *PrOVE* trajectory will be designed for a flyby encounter the comet at the ascending/descending node to mitigate large off-plane distances.




**Acknowledgements**

We acknowledge the support of

- NASA Planetary Science Deep Space SmallSat Studies (PSDS3) program
- NASA/GSFC