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OPtical Imager for Comets (OPIC) for proposed F mission Comet Interceptor

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Abstract

Comet Interceptor is a proposed F-class mission to a dynamically new Solar System object. Enabled by recent advances in observational surveys which will cover the sky more deeply, coherently and rapidly, the spacecraft will be parked at the Sun–Earth Lagrange Point L2 waiting for a suitable target to be discovered. It will be a multi-element spacecraft comprising a primary platform which also acts as the communications hub, and sub-spacecraft, allowing multi-point observations around the target during a flyby. The B2 sub-spacecraft will carry OPtical Imager for Comets (OPIC) whose goal is mapping of the nucleus and its dust jets at visible and infrared wavelengths. Here we present the preliminary design and considerations. The instrument is named after an Estonian astronomer Ernst Öpik who proposed a reservoir of comets which is now called the Öpik–Oort cloud, from where the *Comet Interceptor* target would originate.

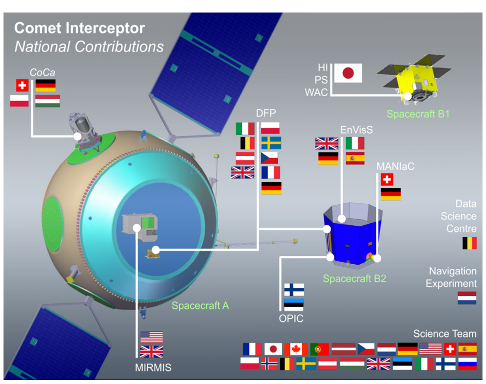

Figure 1: *Comet Interceptor* overview.

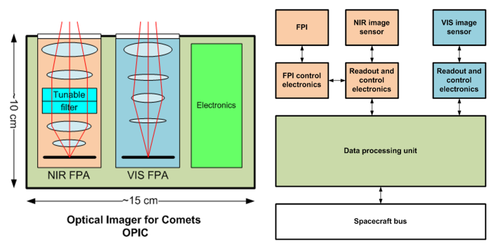

Figure 2: Instrument concept.

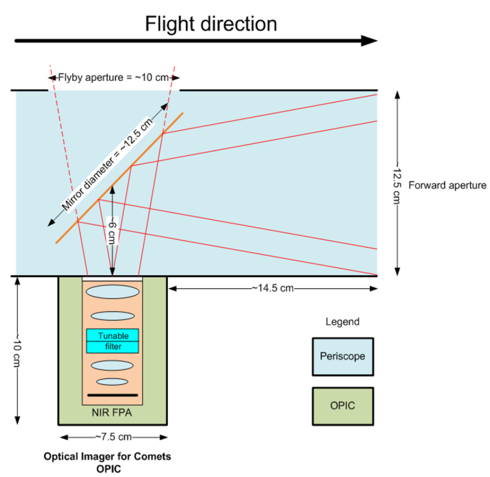

Figure 3: Side view.

1. Introduction

The visible (VIS) camera will be a monochrome imager with a wavelength range of 400–800 nm, while the near-infrared (NIR) camera will be a spectral imager capable of imaging the comet at 5–20 different wavelength bands in the 1000–1600 nm region with the spectral resolution of 20 nm. The spectral imaging is realized with a tunable passband filter. The effective aperture for both cameras is in the range of 1.5–3 cm. The OPIC instrument will provide images continuously as the B2 spacecraft approaches the comet.

As it is considered too risky to point the cameras directly at the direction of travel, OPIC will be pointed to the side of the spacecraft (i.e., perpendicular to the flight direction) and a folding mirror is used to point the instrument towards the flight direction (similar to a periscope). During the closest flyby, the mirror is moved aside and, if the flyby geometry allows, the instrument will point sideways to the comet as the B2 flies past the closest approach.

The instrument also includes a Data Processing Unit (DPU) to prioritize the images for transfer to the main spacecraft during the flyby. The DPU will be capable of storing the collected raw data, which can then be transferred onwards if the spacecraft survives the flyby.

2. Instrument Design

The NIR spectral imager is based on VTT's tunable Fabry Perot Interferometer (FPI) technology, which is combined with an InGaAs image sensor (640×512 pixels) to create the spectral imager. The NIR spectral imager concept has been successfully demonstrated in Low Earth Orbit (LEO) onboard the Reaktor Hello World CubeSat. The same design is considered as the baseline for Comet Interceptor, but the FPI technology is compatible with any image sensor, so it is possible to modify the design if necessary. The spectral imager will include an internal calibration source for wavelength calibration, so it will be possible to re-calibrate the instrument during the commissioning.

The design of the visual spectrum camera is based on a space-qualified 3D-Plus' FPA 4Mpx CMOS 3DCM73x. It features the CMV4000 sensor (2048×2048 pixels) from AMS (formerly CMOSIS). The same sensor has been used in the VTT's visual range hyperspectral camera on the Aalto-1 nanosatellite with good results. University of Tartu is also developing a high-sensitivity Earth observation imager using Gpixel's GSENSE series scientific CMOS sensor. If the sensor and readout electronics will be approved within ESA's Industry Incentive Scheme, it can be considered for OPIC.

In order to maximize the science return of OPIC, a DPU is used to automatically prioritize the images for transfer during the flyby (e.g., to transfer images with the most useful signal and the least smear). This is needed because the high probability of dust impacts that could harm the instrument and the spacecraft during the approach and flyby. Image compression will also be used for the high priority data in order to maximise the link throughput. The DPU also controls imaging parameters in case all images are too dark, saturated or smeared. The DPU can be based on the space-qualified Q7 system-on-chip by Xiphos Technologies which integrates dual ARM Cortex^{TM}-A9 MPCore processor together with an FPGA. This board has been tested in space on-board Reaktor Hello World nanosatellite together with VTT's hyperspectral imager, and it is also being implemented and tested for ESA's PICASSO and APEX cubesats.

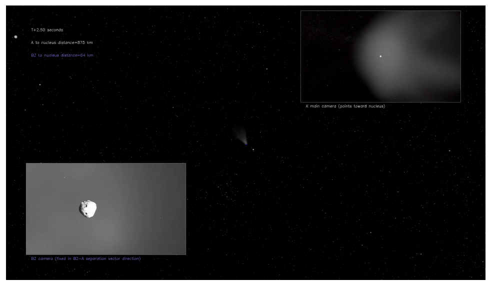

Figure 4: A simulated view from the OPIC onboard the B2 spacecraft travelling at 65 km/s with respect to the comet. Full animation: https://vimeo.com/321107967/bca114809a

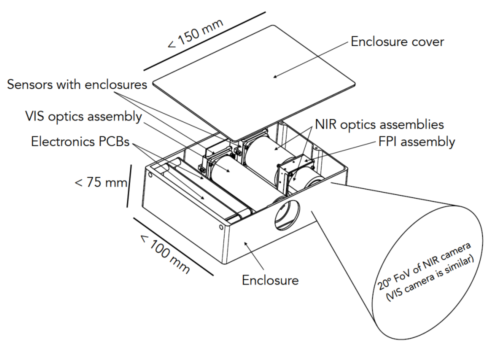

Figure 5: OPIC sketch.