THE MODULAR INFRARED MOLECULES AND ICES SENSOR (MIRMIS) FOR ESA'S COMET INTERCEPTOR F-CLASS MISSION. N. E. Bowles1 (neil.bowles@physics.ox.ac.uk), A. Näsilä2, T. Kohout3, G. L. Villanueva4, C. Howe5, G. H. Jones6, C. Snodgrass7, K. L. Donaldson Hanna8,9, B. T. Greenhagen9, P. G. J. Irwin1, S. B. Calcutt1, R. Evans1, K. Shirley1, T. Warren1, T. Hewagama4,10, S. Aslam4, D. E. Jennings4, A. Akujärvi2, A. Penttilä11 and the Comet Interceptor team. 1Department of Physics, University of Oxford, UK, 2VTT Technical Research Centre of Finland Ltd., Espoo, Finland, 3Department of Geosciences and Geography, University of Helsinki, Finland, 4NASA Goddard Spaceflight Center, Greenbelt, MD, USA, 5STFC RAL Space, Didcot, UK, 6MSSL, University College London, UK, 7Institute for Astronomy, University of Edinburgh, Royal Observatory, Edinburgh, UK, 8Department of Physics, University of Central Florida, Orlando, FL, US, 9Johns Hopkins Applied Physics Laboratory, Laurel, MD, US, 10Department of Astronomy, University of Maryland, College Park, MD, US, 11Department of Physics, University of Helsinki, Finland

Introduction: The Comet Interceptor mission [1,2] concept was selected by ESA as the first of its new “F” class of missions in June 2019. Comet Interceptor (CI) aims to be the first mission to visit a long period comet, preferably, a Dynamically New Comet (DNC), a subset of long-period comets that originate in the Oort cloud and may preserve some of the most primitive material from early in our Solar System’s history. CI is scheduled to launch to the Earth-Sun L2 point with ESA’s ARIEL [3] mission in ~2028 where it will wait for a suitable DNC target. This novel approach to mission target selection is now possible because large sky surveys are now providing increased detection rates for comets and new survey capabilities such as the Large Synoptic Survey Telescope (LSST [4]) can be expected to allow ~5 years between discovery of a target and interception by CI.

The CI mission is comprised of three spacecraft. Spacecraft A is the main spacecraft that will pass by the target nucleus at a distance of ~1000 km to mitigate against hazards caused by dust due to the wide range of possible encounter velocities (e.g. 10 ~ 80 km/s). As well as acting as a science platform, Spacecraft A will deploy and provide a communications hub for two smaller spacecraft, B1 (supplied by the Japanese space agency JAXA) and B2 that will perform closer approaches to the nucleus. Spacecraft B1 and B2 will make higher risk/higher return measurements but with the increased probability that they will not survive the whole encounter.

This presentation will provide details of the Modular InfraRed Molecular and Ices sensor (MIRMIS) instrument that is currently baselined as part of the CI Spacecraft A scientific payload. The MIRMIS consortium includes hardware contributions from the UK (University of Oxford, STFC RAL Space) and Finland (VTT Finland).

Instrument Science Background: Measurements of the spatial distribution of ices, minerals, gases (e.g., H2O, CO2, CH4 etc.) and surface temperature are essential to constrain the formation and evolution of the CI target’s nucleus and coma. Mapping of the compositional diversity and thermal physical variation (via the thermal inertia) could indicate whether the nucleus is a rubble pile object with different evolutionary histories, or a uniform body formed as a single process.

MIRMIS covers the spectral range 0.9 to ~25 μm and will map the ice, mineral, and gas composition of the target’s nucleus and coma (Figure 1) and the distribution of surface temperatures on the nucleus.

Figure 1. Spectral range and main example compositional species covered by the MIRMIS. Example spectral data from [5] and [6].

Figure 2. Layout of the MIRMIS instrument showing the Near-IR (NIR), Mid-IR (MIR1/2) and Thermal IR (TIRI) modules.
MIRMIS Instrument Measurement Principle:
MIRMIS comprises four integrated modules (NIR, MIR1/2 and TIRI, Figure 2) to provide near-IR and mid-IR spectroscopy of the coma and thermal-IR multispectral mapping of the nucleus. For measurements of the coma’s volatile inventory MIRMIS (NIR and MIR) will target the bright molecular fluorescence emission from 2.5 to 5 µm (Error! Reference source not found.), including spectral regions that are sensitive to e.g., CO₂ that are unobservable from the ground. Spatially resolved mapping of coma fluorescence with MIRMIS (NIR) and point measurements (MIR) will measure the spatial distribution of the primary volatile molecules, identify trace gas species, characterize coma chemistry inhomogeneities, and determine chemical abundance variations that can be traced to nucleus regions that are indicative of bursts. MIRMIS will also be able to measure nuclear ice and mineral compositions by targeting silicate mineral features (e.g., 1 and 2 µm), water ice absorption features (e.g., 2.7 – 3.0 µm), organics (3.0 – 3.6 µm), CO₂-ice (4.3 µm), and CO-ice (4.7 µm). MIRMIS’ thermal infrared module (TIRI) will provide unique information on the temperature distribution on the nucleus and surface composition (Error! Reference source not found.). By measuring the nucleus’ limb to disc centre response at multiple >6 µm wavelengths, MIRMIS will provide key information on the surface and near sub-surface thermal physical properties (e.g., cold traps, boulders/powdered regolith). MIRMIS-TIRI uses multiple infrared spectral channels to determine the nucleus’ composition and a broadband imaging capability to measure its temperature. Spatially resolved temperature maps provide information on potential volatile source regions.

MIRMIS will be co-aligned with CI’s CoCa (Comet Camera) camera [2], also mounted on Spacecraft A, to provide time resolved global scale context to the measurements of spacecraft B1 and B2.

MIRMIS instrument overview: MIRMIS’ four integrated modules are contained in a single compact (252.5 x 170 x 212.5 mm³) high heritage instrument. The four modules are (Figure 2):

(a) A Near Infrared (NIR) – Fabry-Perot (FP) hyperspectral camera covering the wavelength range 0.9 to 1.7 µm with spectral resolution of ca 30-40 nm. The field of view is 6.7 x 5.4° and the Instantaneous Field of View (IFoV) is 0.18 mrad with a programmable number of spectral bands; (b) Two FP Mid-Infrared point spectrometers (MIR1+2) covering the spectral range ca. 2.5 -4 and 4-7.0 µm with spectral resolution of ca. 30-40 nm with a programmable number of spectral bands. Field of View (FoV) is 1° circular; (c) A multispectral thermal infrared imaging radiometer (TIRI) that combines thermal imaging with filter radiometry to map surface temperature and composition of the nucleus. TIRI covers the wavelength range from ~6 to 25 µm with a 9 x 7° FoV and an IFoV of 0.26 mrad. TIRI includes an on-board calibration target for radiometric accuracy with a requirement to map the surface temperature of the nucleus to ±5 K (±1 K goal) and estimate surface emissivity to ±1% (0.5% goal) in the thermal infrared.

The four modules share a common mechanical, thermal, and electrical interface to the spacecraft. The combined MIRMIS instrument command and data handling unit (CDHU) is designed to allow independent operation (via a preloaded command table and on-board data storage) during the encounter with the Comet Interceptor target body (Figure 3).

![Figure 3. MIRMIS top-level sub-system diagram.](Image)

Current Status: The MIRMIS instrument is currently part of the Spacecraft A baseline payload under study at ESA. Study and breadboarding activities are underway at VTT Finland (filter development, NIR/MIR module breadboard testing), and University of Oxford/RAL Space (TIRI module breadboard assembly and microbolometer detector performance).

Acknowledgements: UK contributions to the MIRMIS instrument are supported by the UK Space Agency National Space Technology Programme and the University of Oxford’s John Fell Fund.