Marco Polo ESA Cosmic Visions Candidate Mission
Near-Earth Object Sample Return Mission

Asteroid Thermal Mapping Spectrometer

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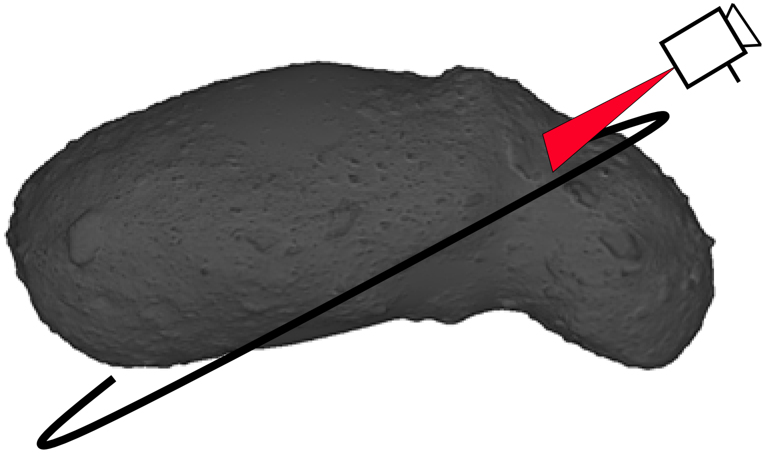
Why a Mid-IR Imaging Spectrometer?

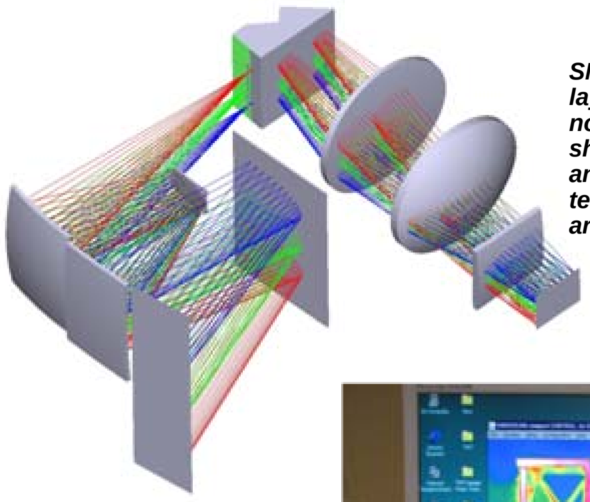
- **The focus of the Marco Polo mission is sample return.**
- **The remote sensing payload must:**
  - **Contribute directly to the success of the sample return element of the mission.**
  - **Be light weight to maximise the mass of the returned sample.**
- **An imaging thermal mid-infrared survey instrument fulfils these two key aims:**
  - **Measurement of the heating and cooling rates of the surface allow determination of the *thermal inertia* of the surface. This gives essential diagnostic information on the physical nature of the surface and near sub-surface – how rocky or dusty.**
  - **Spectroscopy also gives important information on regolith particle size, to help constrain further the thermal inertia.**
  - **Gives important compositional information on the surface allowing the returned samples to be placed in their correct geological context, even in shadow regions.**
- **Already a well established technique for Mars (e.g. Thermal Emission Spectrometer (TES), Mars Express OMEGA), coming soon to the Moon (Diviner Radiometer on LRO).**



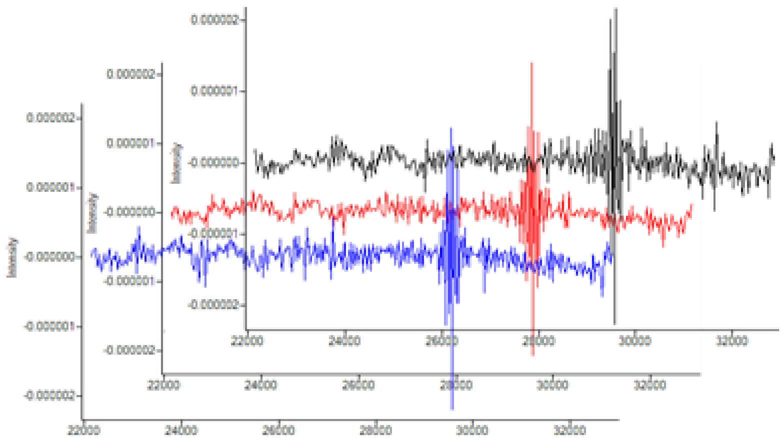
Hayabusa surface model (JAXA)

The Asteroid Thermal Mapping Spectrometer.
Heritage - Spatially Modulated Interferometer (SMI)

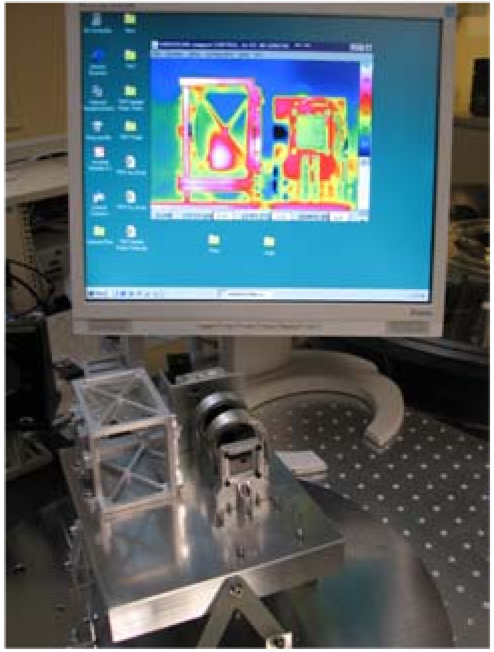
- **A novel mid-Infrared imaging spectrometer.**
- **Robust design, no moving parts.**
- **Extremely compact and low mass, ideal for the NEO-Mission:**
  - **E.g. PFS (Mars Express) = 30.8kg**
  - **E.g. TES (Mars Global Surveyor) = 14.4kg**
  - **Spatially Modulated Interferometer = 2.0kg**
- **Efficient light utilisation**
- **Instantaneous interferogram sampling**
- **Spectral resolution independent of slit width**
- **Based on previous designs with cooled linear detectors and Germanium lenses/prisms**



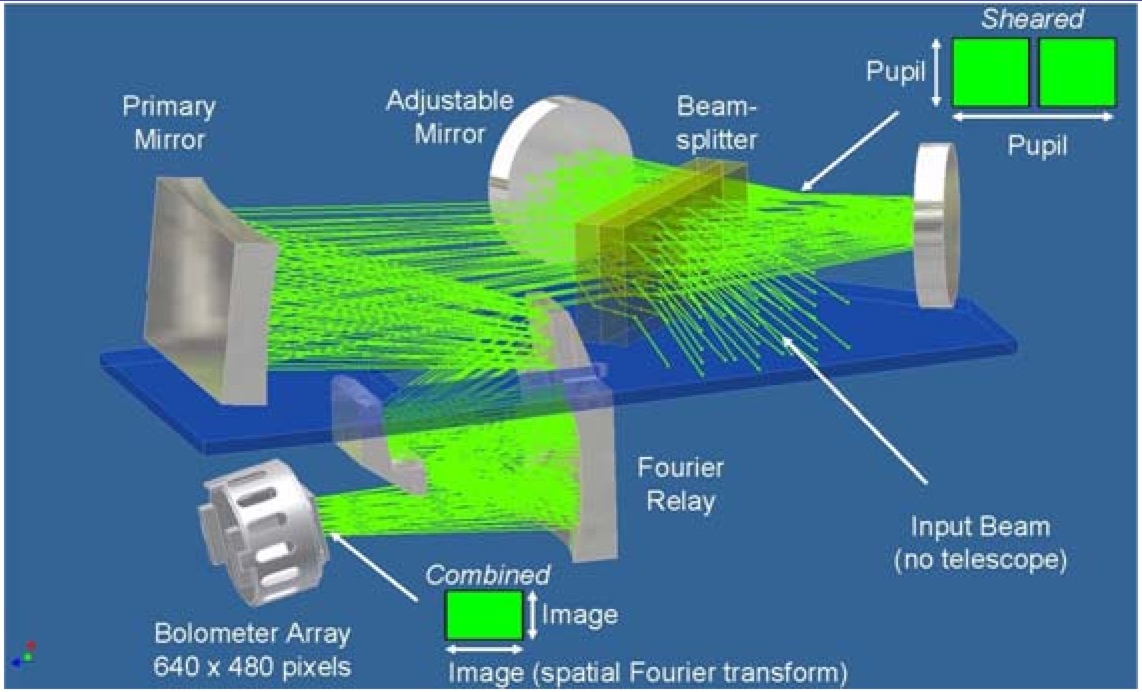
SMI Optical layout, showing novel beam shearing prisms and input telescope arrangement



SMI Breadboard under test (right). Interferogram generated from the cooled detector SMI breadboard instrument (left)



ATMS Breadboard Instrument



ATMS Breadboard design

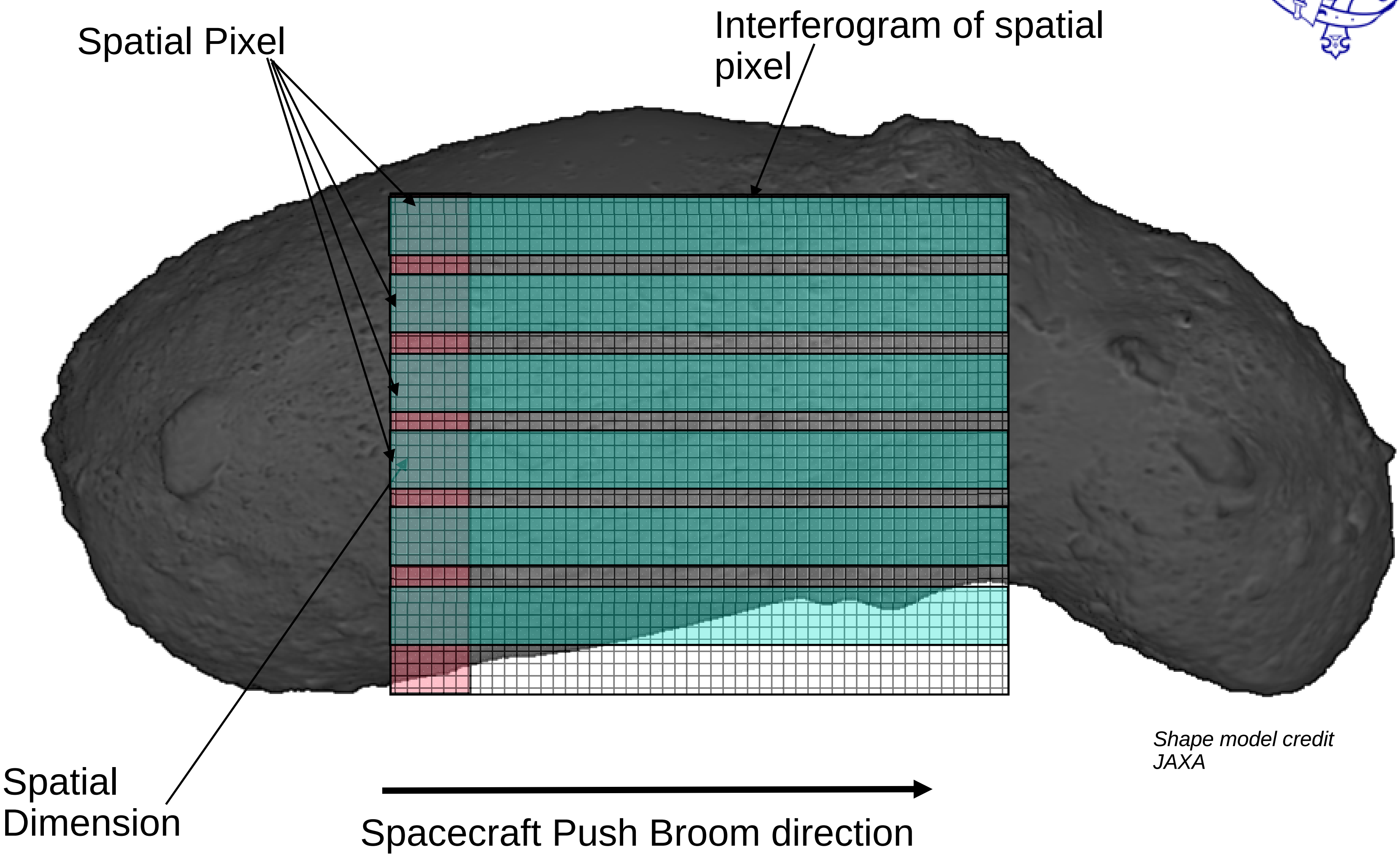
160 x 220 x 370

mm3 – but note the instrument is

not box shaped

- **For ATMS a new breadboard has been designed based on a ULIS 2D un-cooled bolometer detector array.**
- **Revised design optimised for surface science.**
  - **mineralogy (e.g. 10-20 cm^{-1} resolution)**
  - **Optimised for rapid push-broom operation**
- **High performance design**
  - **All reflecting optics for higher efficiency and wide wavelength coverage (limited by beam splitter and aliasing considerations)**
- **Mass still ≈1.3kg *before* light weighting.**
- **Only mechanism a scan/calibration assembly**

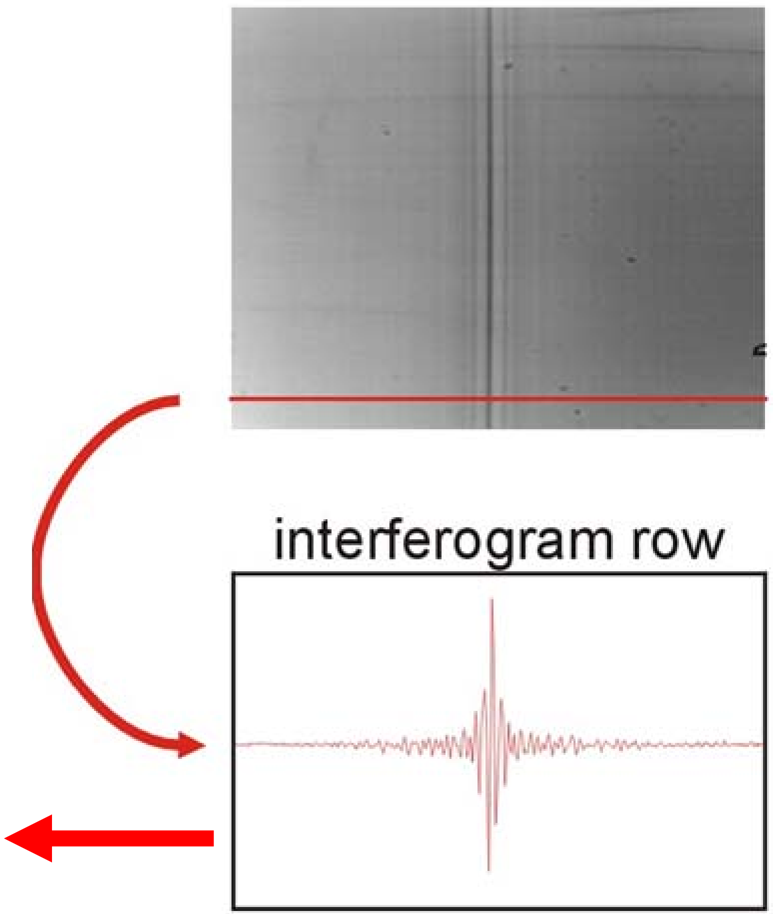
Example ATMS Observation mode with 2D Detector Array

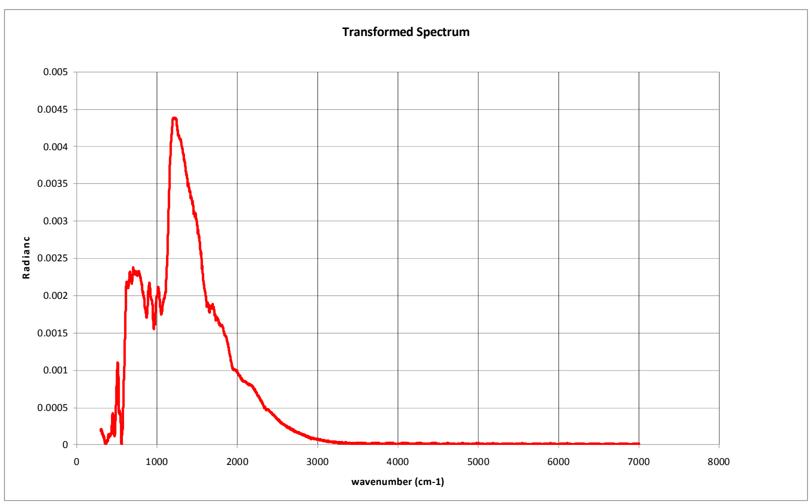


Shape model credit JAXA

Generating an image cube

- **Using a test ATMS setup with the zero path difference (ZPD) of the interferogram at the centre of the array shows the technique in use.**
- **The position of the ZPD in the spatial direction coincides with the spatial pixel (or macro pixel).**
- **The width of the returned interferogram (in pixels) determines the spectral resolution in the transformed spectrum.**

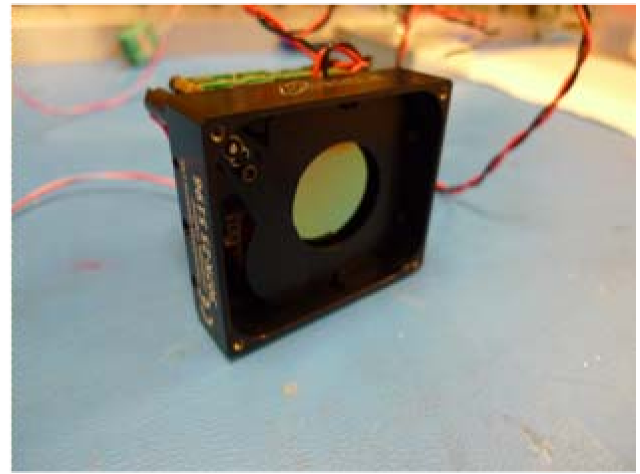


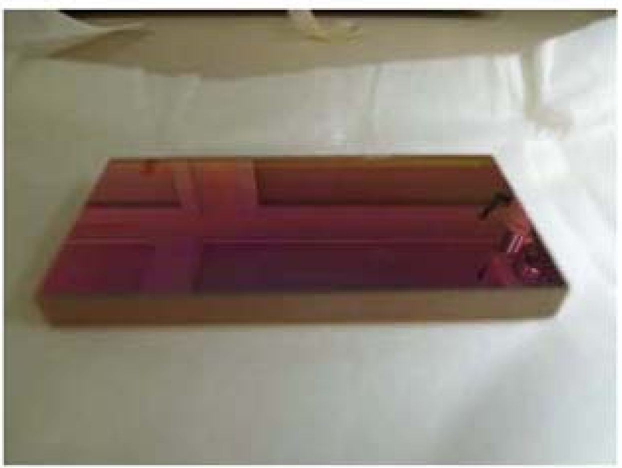


Current Breadboard Status

- **Major components for the ATMS instrument breadboard have been procured**
  - **ULIS 640x480 detector array currently under performance testing.**
  - **Mid-IR Beam splitters in hand and meet the necessary specifications.**
  - **Mirrors and mechanical mounts in manufacture.**

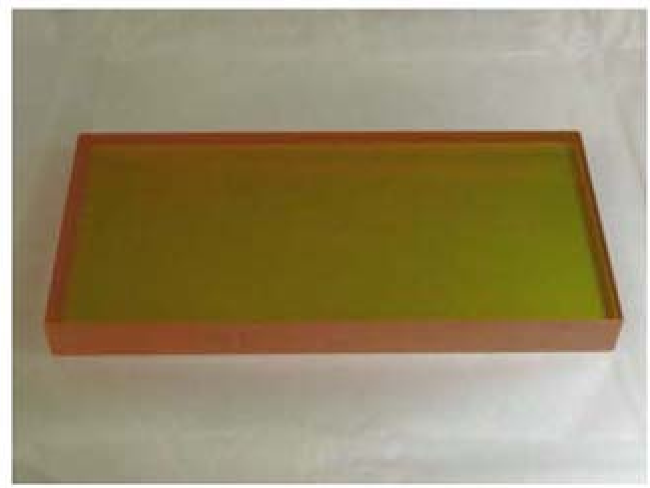
- **Expecting to have initial warm testing, concept demonstration by end of July 2009.**





ULIS 640x480 detector array for the ATMS breadboard (top right)

ATMS beam splitter (left) and compensator plate (right)



Summary

- **The Asteroid Thermal Mapping Spectrometer is a high performance imaging Spatially Modulated Interferometer (SMI).**
- **The design is based on previous SMI breadboard instruments, tested to the equivalent of ESA/NASA TRL 4/5.**
- **The ATMS design builds on these previous instruments and provides higher optical performance through the use of all-reflecting Fourier optics allowing the use of an un-cooled bolometer array.**
- **A breadboard instrument is currently in manufacture with key components already procured and tested (detector array, beam splitters).**
- **Bench level model testing anticipated by end of July 2009.**
- **Final breadboard will be subjected to a full calibration and test programme so as to demonstrate TRL 5 by March 2010.**