Optimising Thermal Mapping Instrument Filters to Unveil Enceladus' Subsurface Secrets

Sharing is encouraged

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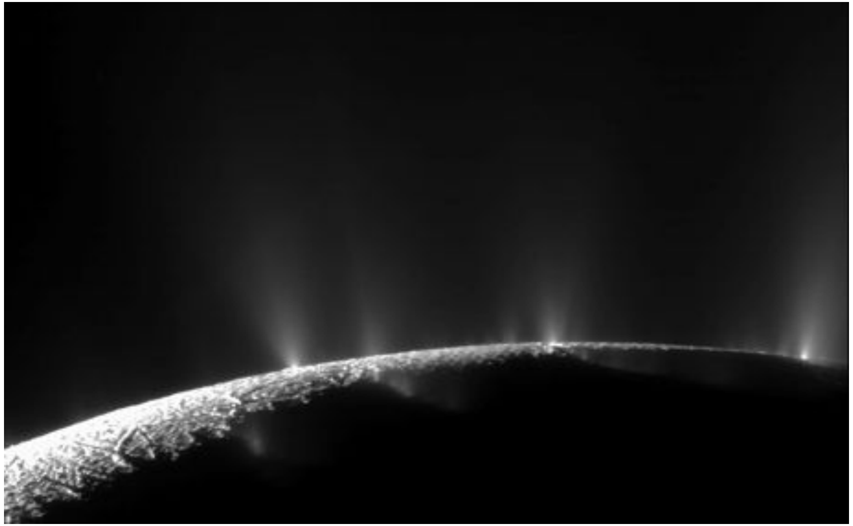
EGU Abstract

Background and Importance - Enceladus

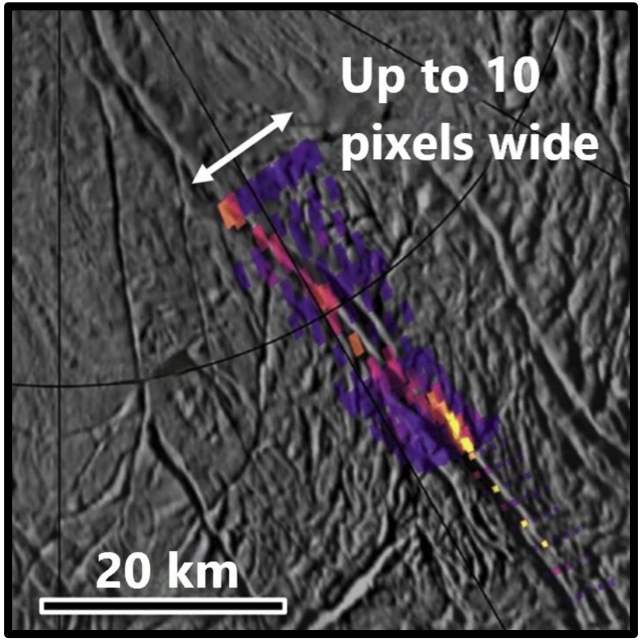
- Small (252 km radius) moon of Saturn, with a global ocean beneath its icy crust
- The South Pole 'tiger stripes': fractures erupting water vapour and organic compounds
- Astrobiology potential – could Enceladus host life?



Plumes erupting from Enceladus
[NASA/JPL-Caltech/Space Science Institute]

Previous Mapping Work & Its Limitations

- Thermal data from Cassini's Infrared Spectrometer (CIRS)
  - Few high-spatial resolution observations
  - Sparse south polar coverage
- Results showed:
  - Fractures vary in temperature



Cassini Thermal Map [NASA/JPL/GSFC/SWRI/SSI (2010)]

The Enceladus Thermal Mapper (ETM)

- Multi-band radiometric instrument
- High TRL (LTM and MIRMIS/TIRI)
- Now need to consider a very cold target (30K)
    - Longer wavelengths necessitate different filter profiles

The Enceladus Thermal Mapper

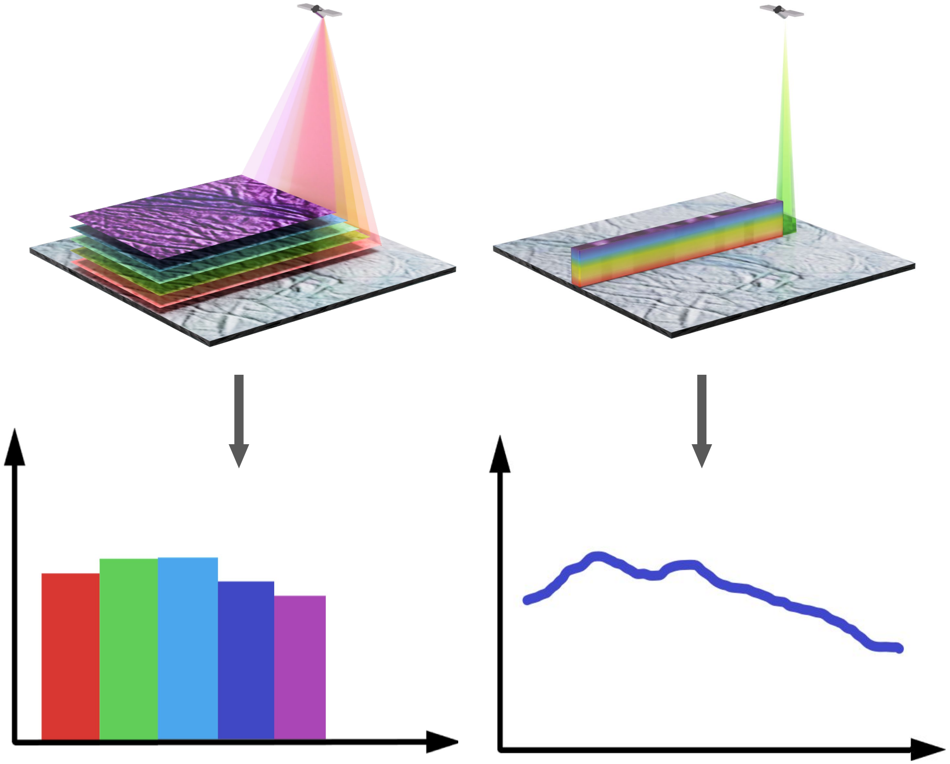
Radiometric Thermal Mapping vs. Spectroscopy

- **Multispectral mapping:**

  High spatial resolution

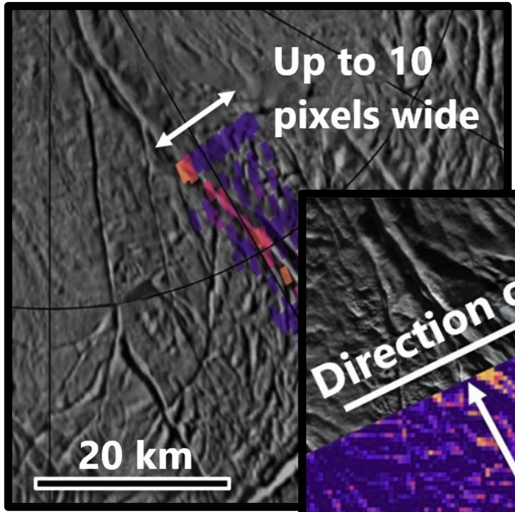
- Spectroscopy:

  High spectral resolution

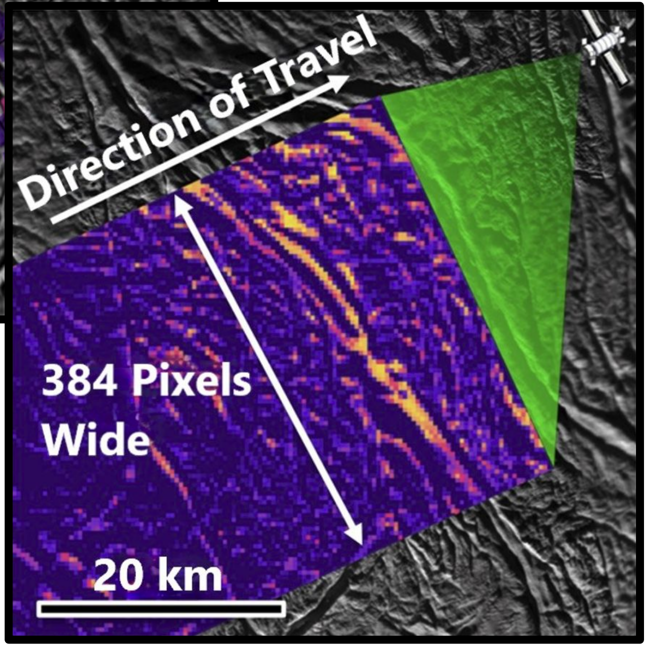


ETM’s Technical Adaptations

- A follow-on from Cassini CIRS to map Enceladus’ thermal properties.
- Performance depends on orbit, but at 150 km:
  - 80 m per pixel
  - 31 km wide track.



Cassini Thermal Map [NASA/JPL/GSFC/SWRI /SSI (2010)]

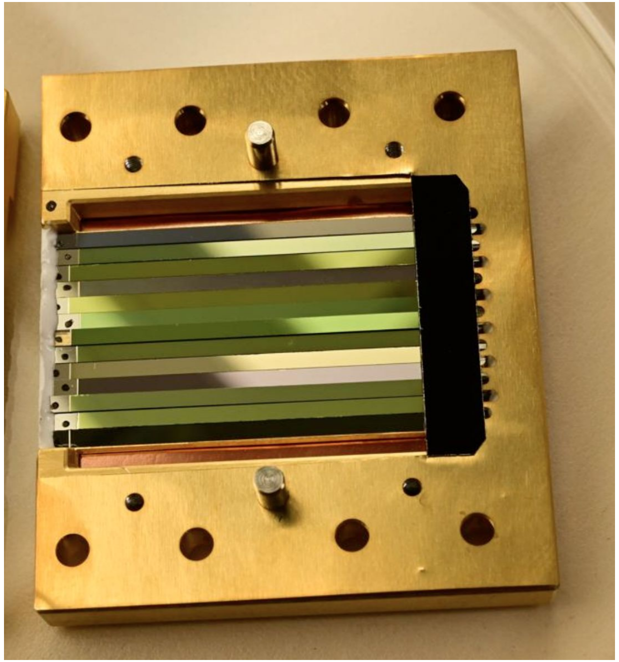


ETM Thermal Map (Visualization)

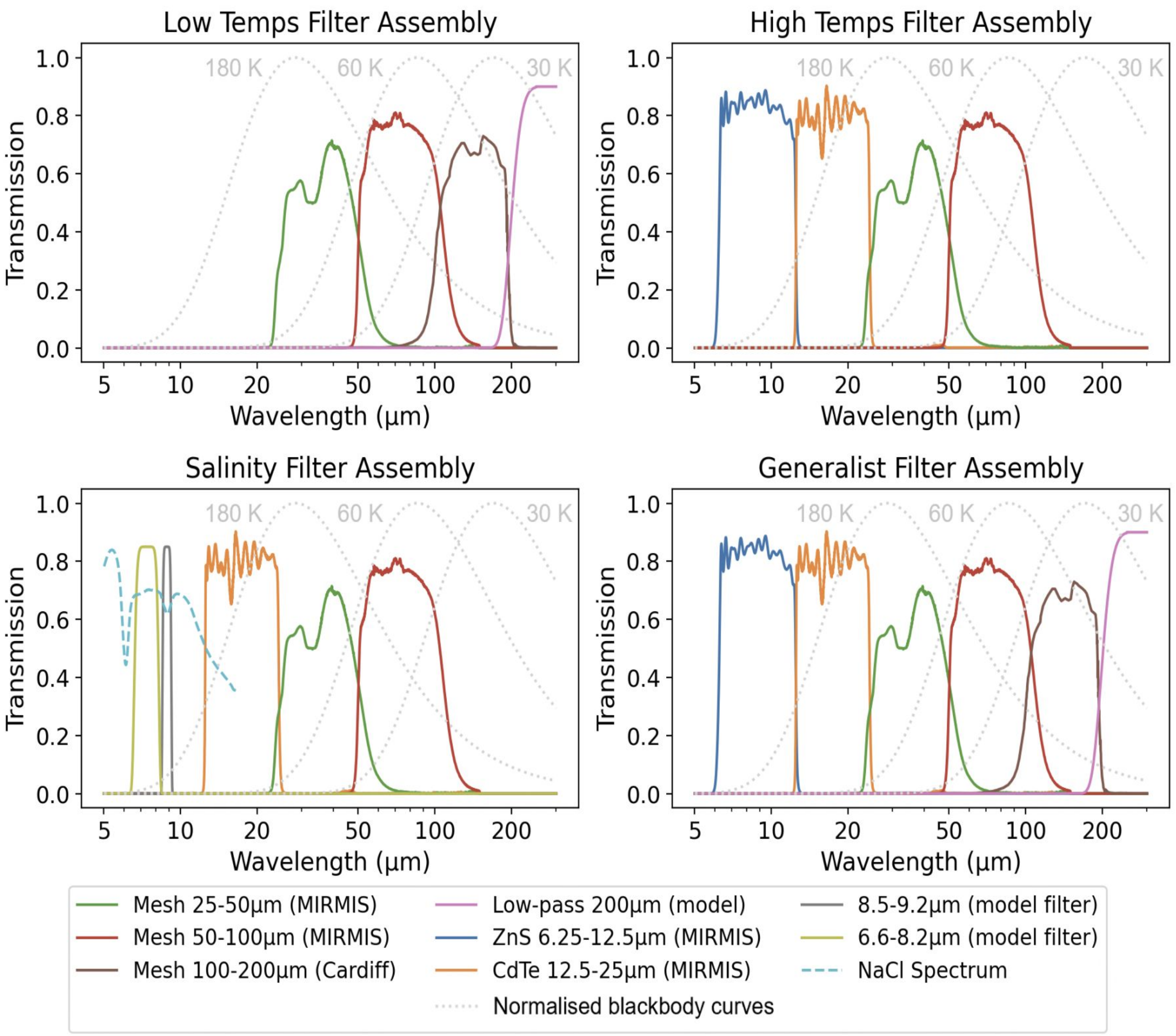
Instrument Modelling and Filter Selection

- Optimise filter performance to be sensitive to a range of target temperatures

- Trade-offs & limitations



The Filter Assembly from Lunar Thermal Mapper



Signal to Noise Ratios

Low Temps

Filter	Description	Width (px)	30K	60K	180K	200K
3	Mesh 25-50μm	92	0.1	10	637	820
4	Mesh 50-100μm	92	3.5	66	837	994
5	Mesh 100-200μm	92	12	76	466	536
6	Low-pass 200μm	92	15	56	244	276

High Temps

Filter	Description	Width (px)	30K	60K	180K	200K
1	ZnS 6.25-12.5μm	92	0.0	0.0	24	51
2	CdTe 12.5-25μm	92	0.0	0.4	302	466
3	Mesh 25-50μm	92	0.1	10	637	820
4	Mesh 50-100μm	92	3.5	66	837	994

Salinity

Filter	Description	Width (px)	30K	60K	180K	200K
2	CdTe 12.5-25μm	60	0.0	0.4	244	376
3	Mesh 25-50μm	60	0.1	8.2	515	662
4	Mesh 50-100μm	60	2.8	54	676	803
7	8.5-9.2μm	60	0.0	0.0	1.3	3.1
8	6.6-8.2μm	120	0.0	0.0	1.3	3.7

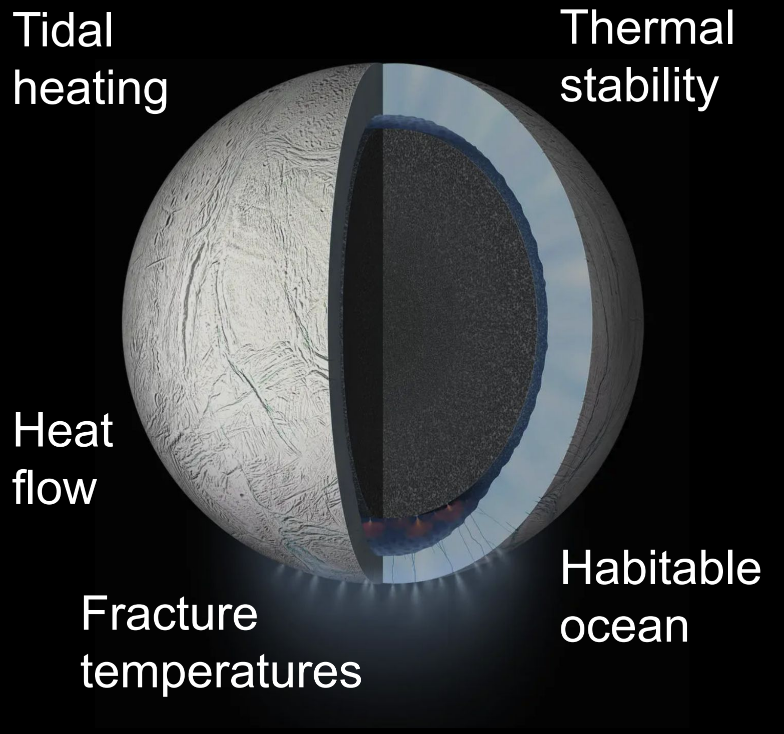
Generalist

Filter	Description	Width (px)	30K	60K	180K	200K
1	ZnS 6.25-12.5μm	60	0.0	0.0	19	41
2	CdTe 12.5-25μm	60	0.0	0.4	244	376
3	Mesh 25-50μm	60	0.1	8	515	662
4	Mesh 50-100μm	60	2.8	54	676	803
5	Mesh 100-200μm	60	9.4	61	376	432
6	Low-pass 200μm	60	12	45	197	223

Project Aims and Relevance to Science Goals

- Enceladus’ geothermal activity
- Global surface properties through precise temperature measurements.
- Constrain global conductive heat flow: consistent with long-term solutions? (required for habitability)

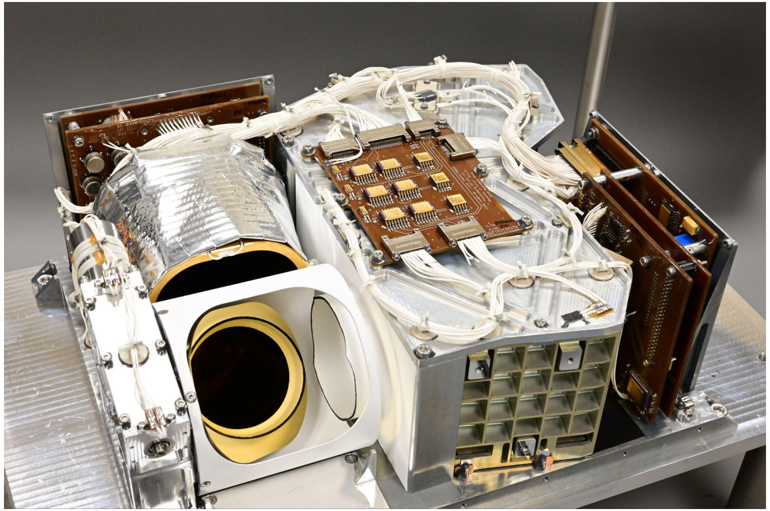
Aspects we aim to contribute towards understanding better



[Modified from NASA/JPL-Caltech]

Conclusions and Future Work

- Multi-band radiometric instrument to map day, night, polar winter, and fracture temperatures.
- Instrument model: Simulating ETM observations to optimise filter selection for mission goals.



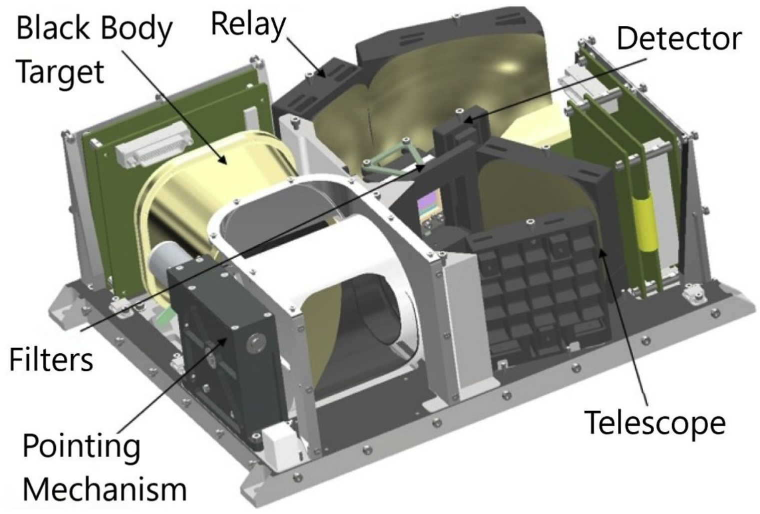
The Lunar Thermal Mapper

Filters Model

Thermal Model

Instrument specs

- IFOV with 35 µm pitch INO detector is ~540 µrad per pixel
- Mass = 4.5 kg with margin (actual pFM mass 3.8kg)
- Power = 6 W average, ~12 W peak
- Volume 262.5 x 214 x 100mm excluding MLI blankets
- Internal 1 GB storage
- RS422 power connector
- Internal calibration target and space view for radiometric calibration
- 28V nominal voltage



The Enceladus Thermal Mapper

$$SNR = \frac{D^* \sqrt{A_d} \Omega_d \int \tau \epsilon_s B_\lambda(T_s) \, d\lambda}{\sqrt{f}}$$