# A multispectral camera solution for guidance and navigation on space servicing vehicles

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**Clean Space Industry Days** |

**ESTEC**

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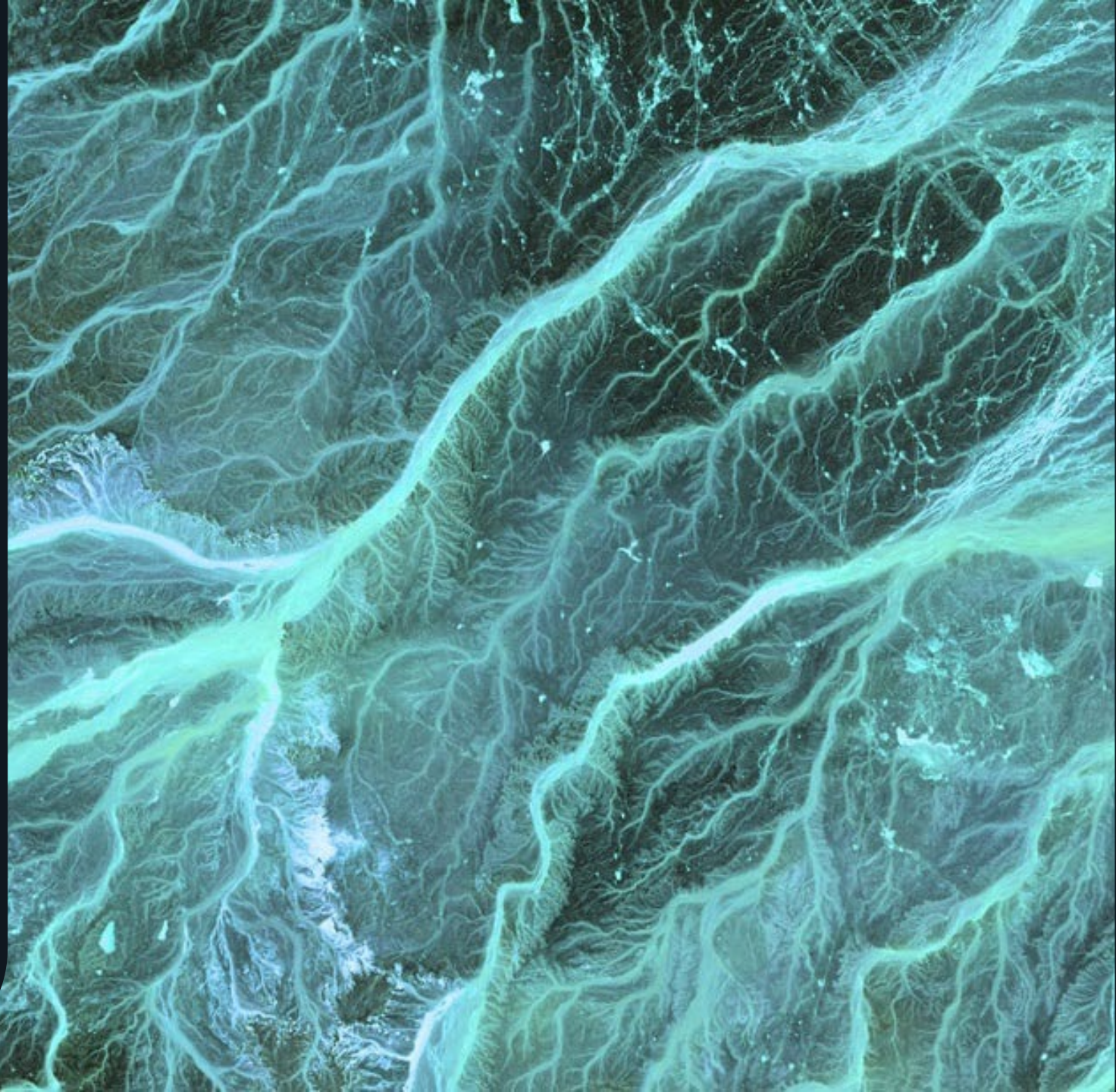


# MuLaN GSTP Project Overview

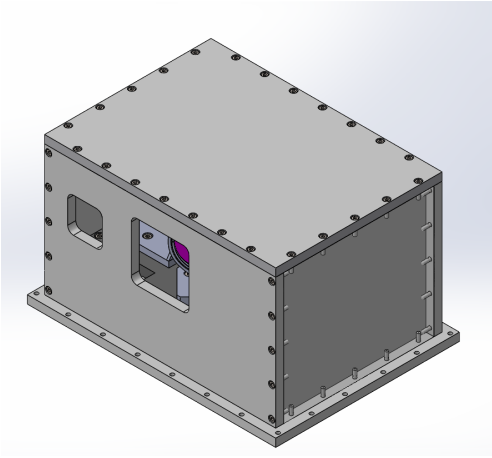
## Objectives

- Develop a **Multispectral camera Engineering Model** for use on Space Servicing Vehicles, as an autonomous navigation solution for rendezvous missions
- Simulation development of multispectral modality space **mission scenarios**
- **Data fusion** algorithms for multispectral data in space relative navigation task
- Robust **relative navigation pose estimation** algorithms for multispectral data
- **Integration** of novel multispectral camera and relative pose estimation algorithms

## Goal

Reach **TRL 6**

Demonstrating critical functions verification of the element in relevant environment



# MuLaN Project Consortium

MDA International Space Mission Partner

- ✓ **Space Sensors** – Our space cameras, range finders, and Lidars provide the eyes and ears to our partner's missions to accurately control spacecraft and payloads.
- ✓ **Communications**- MDA UK provided the ColKa antenna for the International Space Station which has successfully completed commissioning. We are now working on the evolution of this product for future space missions.
- ✓ **Space Robotics** - With 40+ years of Canadarm expertise, and over three million hours of engineering support to on-orbit robotic operations, we are proud to enable the space ambitions of our partners. MDA UK are working with our Canadian colleagues to develop the UK expertise in commercial space robotics.

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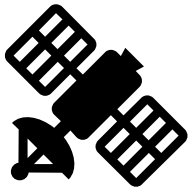
Robotics, Autonomy and Machine Intelligence Group (RAMI)

- ✓ Research excellence in robotics and autonomous system, in particular guidance and navigation, recognition, and target tracking algorithms development.
- ✓ Areas of expertise include:
  - ✓ visual simultaneous localisation and mapping (VSLAM)/visual (and lidar) odometry for navigation
  - ✓ guidance, path planning and control
  - ✓ autonomous platforms cooperation
  - ✓ artificial intelligence (AI) based object detection, recognition and tracking
  - ✓ AI based decision-making for autonomous systems

# Problem and Opportunity

Space **transportation logistics ecosystem** will require flight ready rendezvous and in-orbit servicing capability to satisfy evolving institutional and commercial transportation needs.



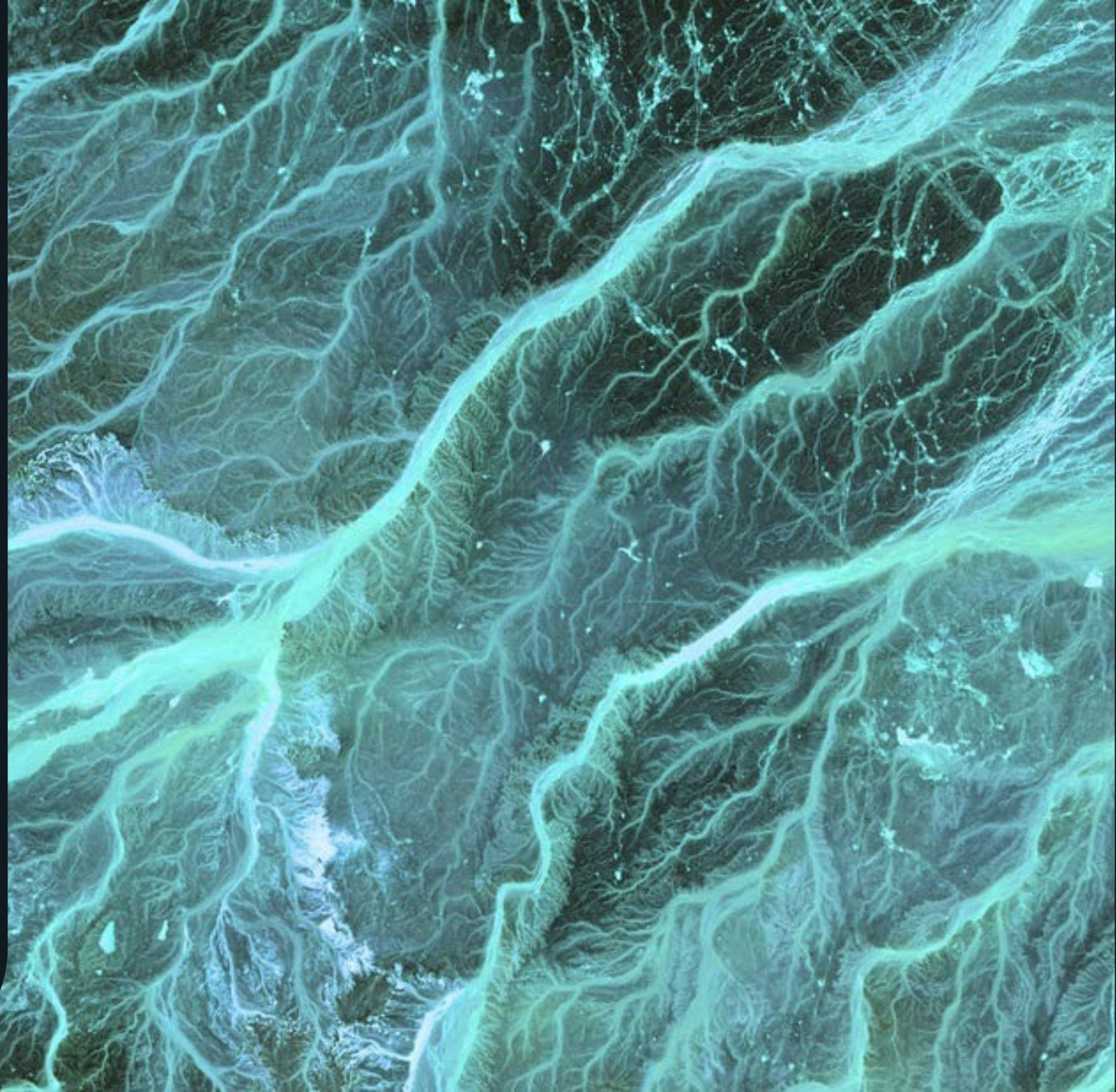
Estimate of **245** GEO satellites are approaching **EOL** by 2035 → they would require servicing, life extension or removal to achieve net-zero strategy aimed to be reached in 2030.

*ESA In-Orbiting Servicing industrial workshop (2022)*

Critical technology development for **imaging and navigation** sensitive to both VIS and IR wavebands, allowing operation in a multitude of lighting conditions.

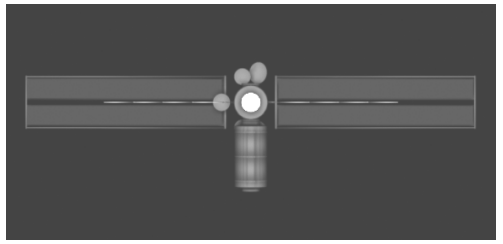
Bespoke **pose-estimation** algorithm with **data fusion** to provide regular updates regarding position and attitude of target spacecraft to allow safe guidance of chaser spacecraft

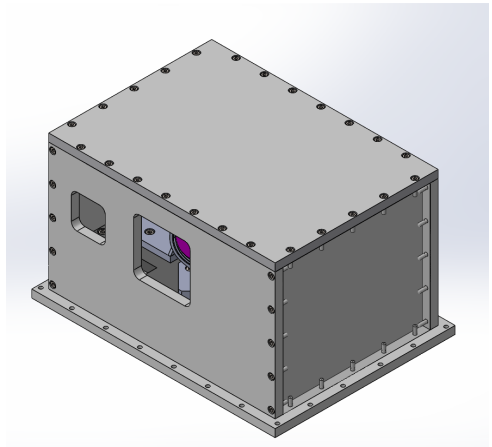
# VIRGO Capabilities



# VIRGO – Technical Overview

- **V**isible **I**nfra**R**ed **G**uidance **O**ptics.
  - Multispectral capabilities in Thermal Infrared (TIR) and Visible (VIS) bands make VIRGO robust to various lighting conditions (e.g., solar occlusion, casted shadows).
  - Provides positional and attitude states of a target spacecraft using machine learning algorithms and sensor fusion.
  - Modularity options available to cover long (>250 m) and very short (<5 m) ranges.
  - Current baseline provides multispectral capabilities between 15 m and 250 m. Visible band with wider FOV covered down to 5 m.
  - EM (TRL6 demonstrator) approaching Test Readiness.

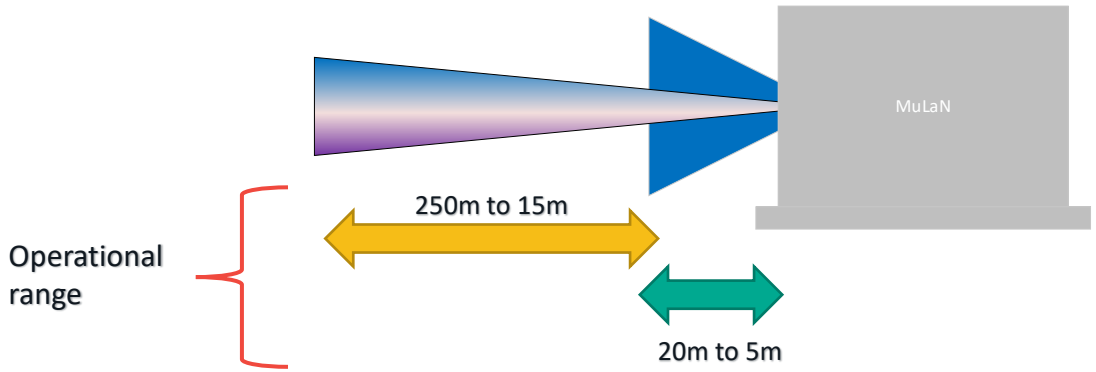


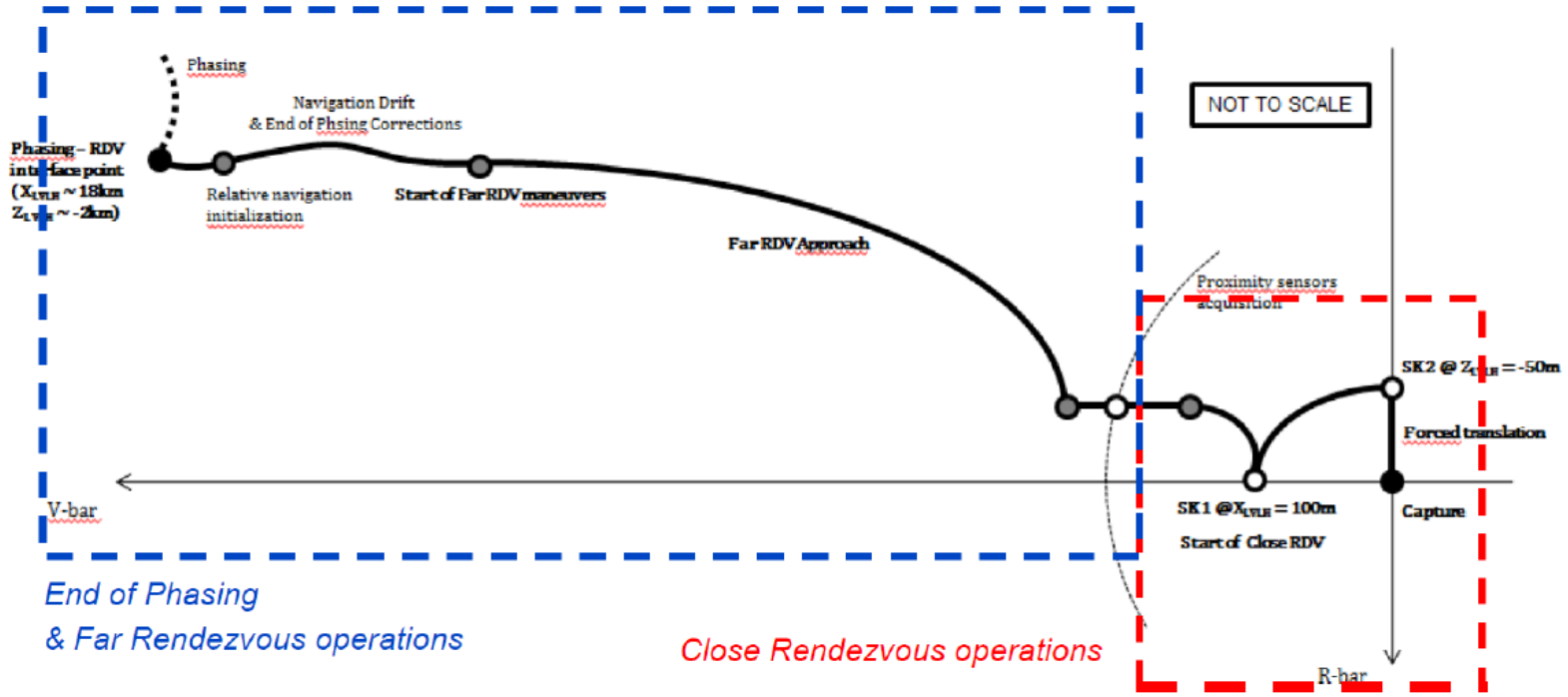


| DATASHEET | |
|---|---|
| **Parameter** | Value |
| **Spectral Response** | 400 – 800 nm (VIS)<br>8 – 14 µm (IR) |
| **Pixel Format** | 2046x2046 (VIS)<br>660x660 (IR) |
| **Bit depth** | 12 bit (VIS)<br>14 bit (IR) |
| **Frame rate** | 1 Hz |
| **Field of View** | 26 degrees (VIS, IR) |
| **Mass (3 lenses)** | < 4 kg |
| **Envelope (3 lenses)** | < 200 x 200 x 180 mm |
| **Power** | 40W max (TBC)<br>25W nominal (TBC)<br>Regulated 28V DC supply |
| **Radiation** | 10krad TID |
| **Operating temperature** | [-10°C, +50°C] (TBC) |
| **Range** | 250 m – 15 m (mid range)<br>20 m – 5 m (short range) |
| **TM/TC/Data Interface** | SpaceWire |

# VIRGO – CONOPS for EM

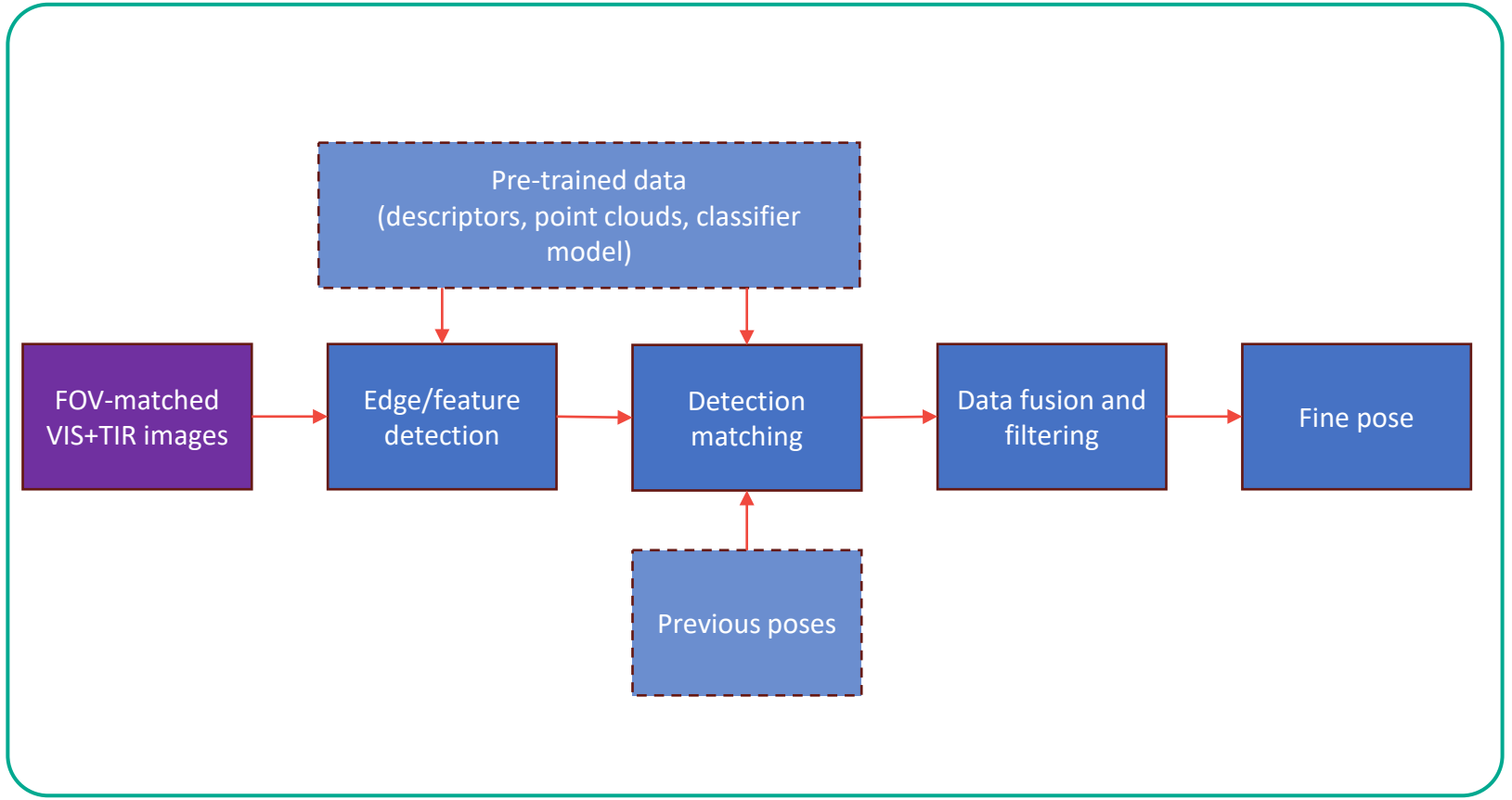
- VIRGO to provide rotational and positional pose-estimates of cooperative rendezvous targets. Currently considered:
  - On-orbit servicing in GEO
  - Lunar Gateway (deep space)
  - Simple chaser dynamics
- Scope will increase with further TRLs to include complex, non-cooperative rendezvous, and a wider range of scenarios.



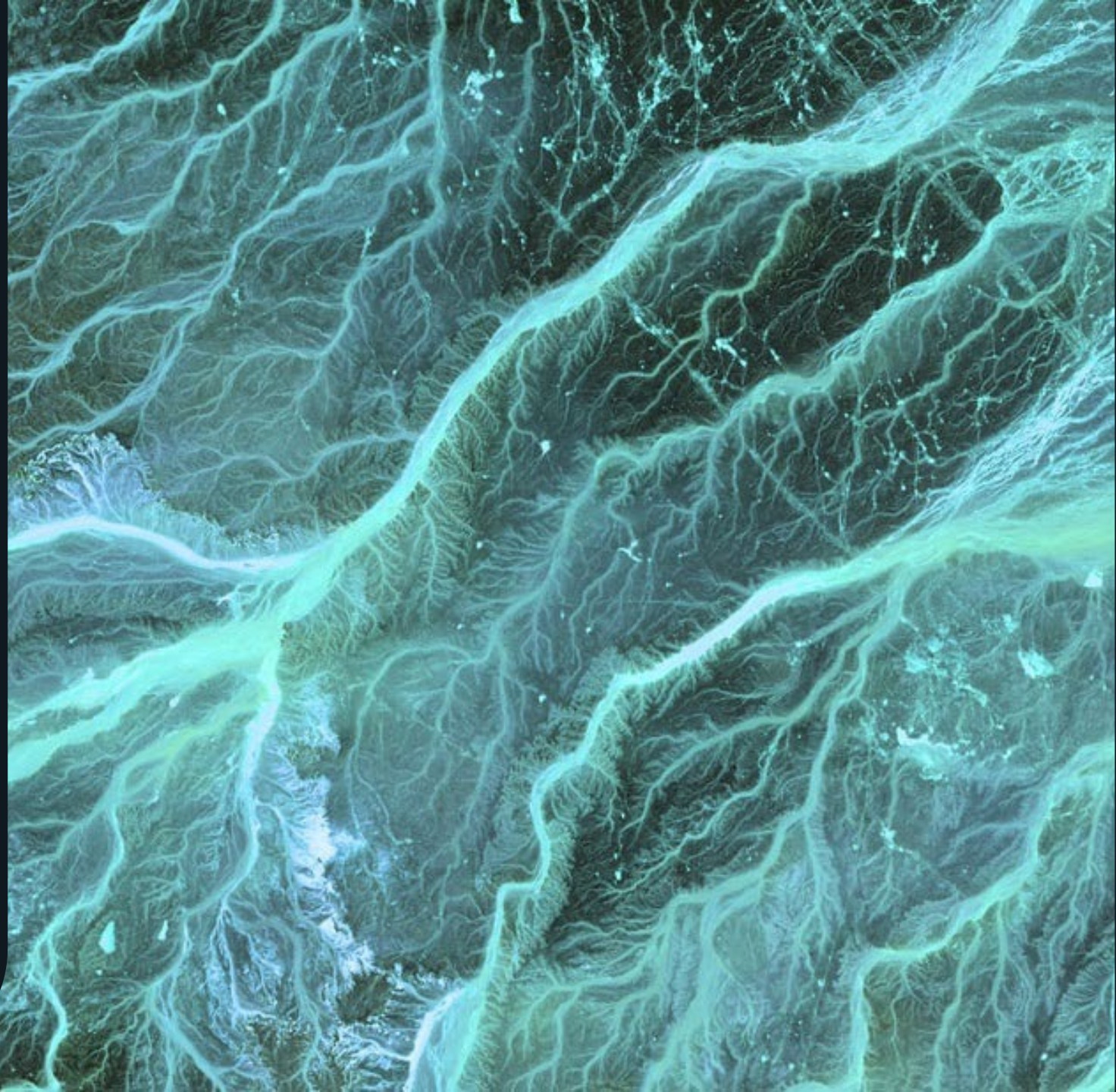



# VIRGO – Pose-Estimation Algorithm

- Training data generated on the ground and flashed onto VIRGO
- Can be reconfigured for different targets
- TIR and VIS streams handled in parallel, and then fused
- Edge detection for TIR, feature detection for VIS
- Methods used include PnP-Ransac, SVM, EHD, BRISK, FAST and ORB.

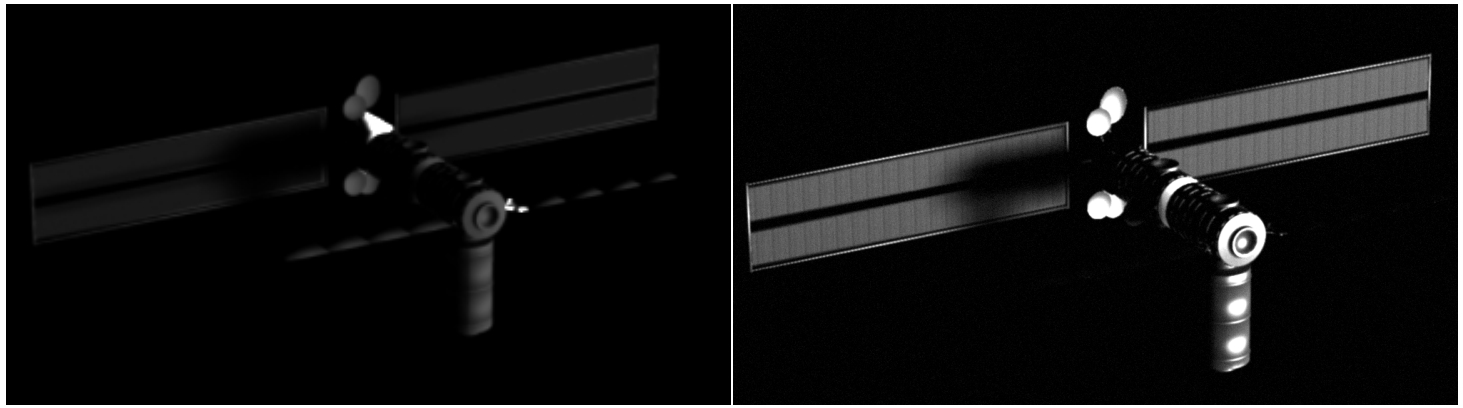


# Simulations & Breadboarding



# Simulation Scenarios

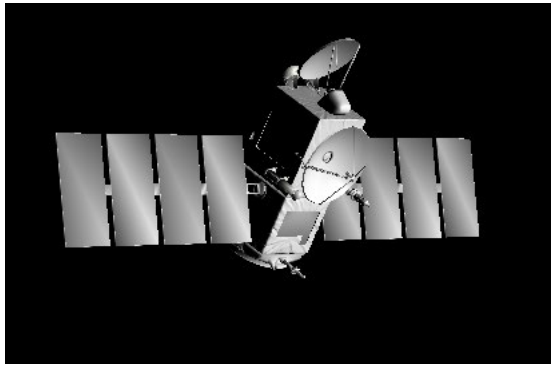
- Simulation of target scenarios performed in line with CONOPS
- Simulation performed in PANGU
- Focus primarily on RV scenarios with:
  - Lunar Gateway
  - GEO with Jason-1



*Simulation of VIRGO system in PANGU observing Gateway in the Thermal (Left) and Visible (Right)*

- PANGU is used to render satellites, sun, and other astronomical bodies
- PANGU allows accurate simulation of optical effects including:
  - Camera limitations (i.e., distortion and blur)
  - Material properties (i.e., reflectivity, and emissivity)
  - Thermal modelling (i.e., thermal emission)

- Simulated data provided to CUoL for initial development and testing of Pose Estimation Algorithm



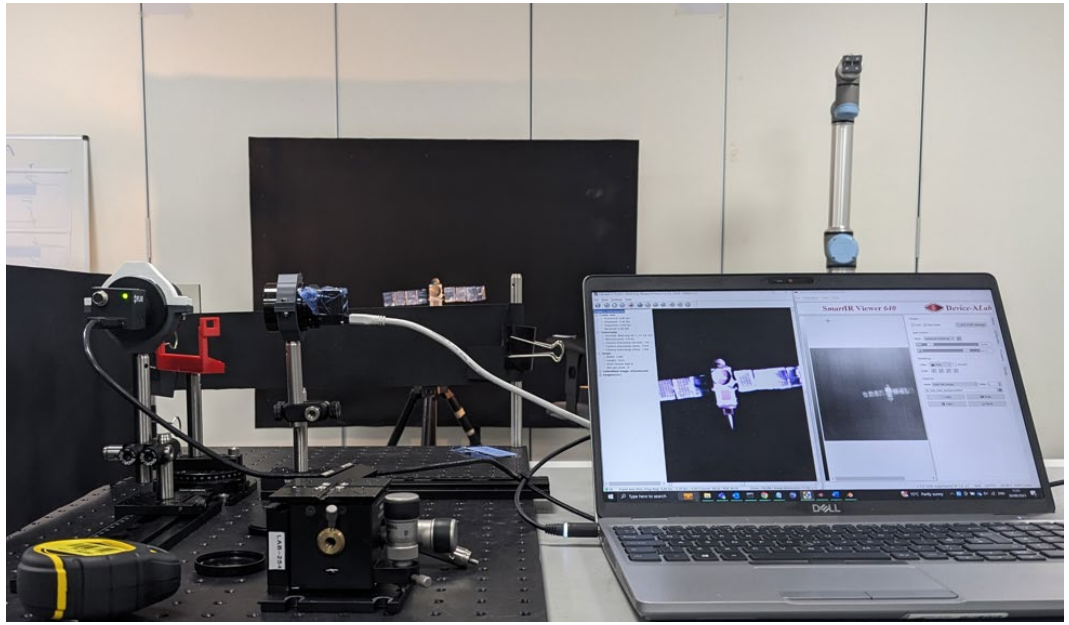
*Simulation of VIRGO system in PANGU observing Jason-1 in the Visible*

# Breadboard Testing

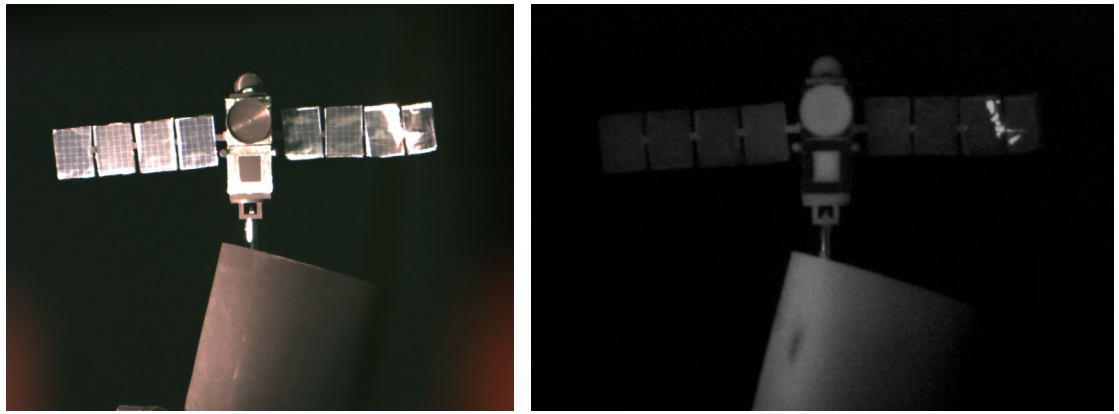
- Data captured in IR and Visible wavelengths
  - Backdrop used to provide 'empty' space background
  - Shroud used in attempt to hide tripod
  - IR Lamp (off camera to image left) used to provide visible and IR light

- Visible data left RAW
- IR data processed and adjusted to compensate for offsets

- Data provided to CUoL for testing of the algorithm
  - Provides insight regarding algorithm performance (allowing for errors with 3D printed model)
  - Can highlight any potential bugs or faults within the algorithm
  - Confirms which functions are necessary within the VIRGO camera
  - Confirms if the test set-up and models used for testing are sufficient for testing the camera

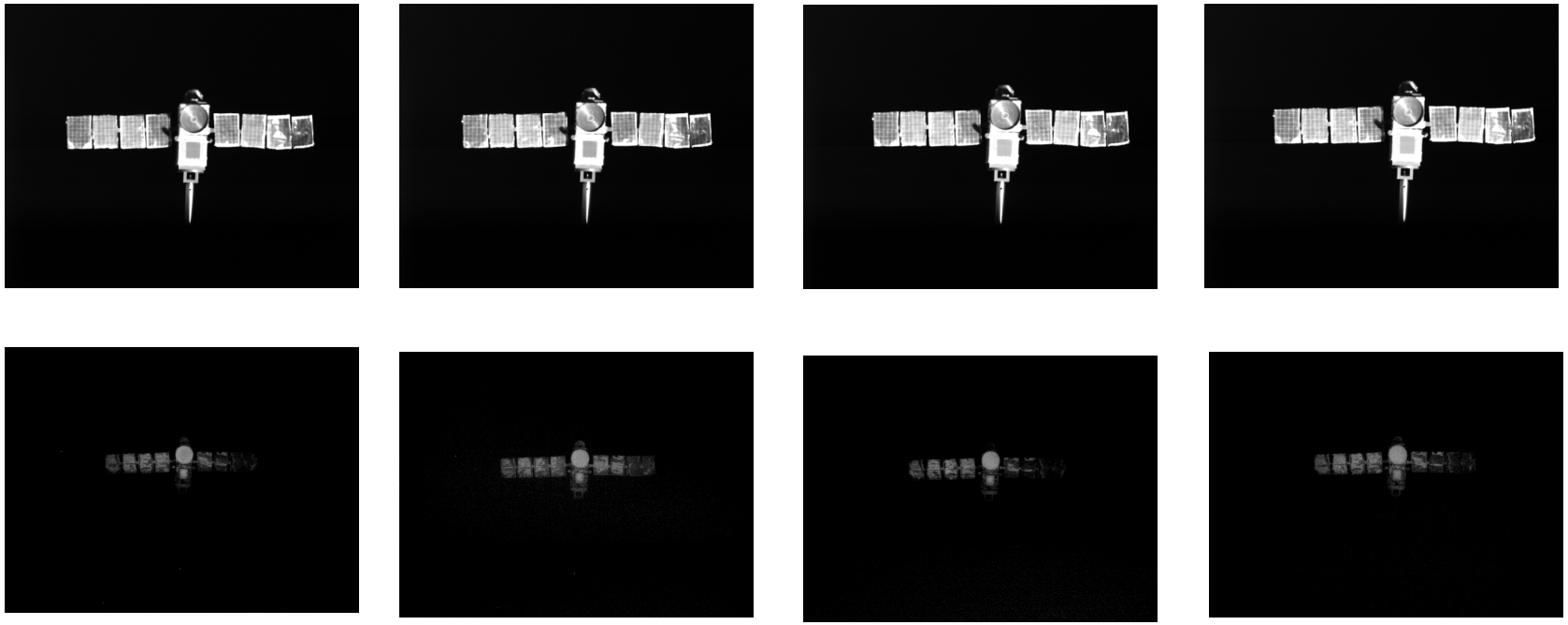


*Overview of breadboard*



*Example images of satellite model*

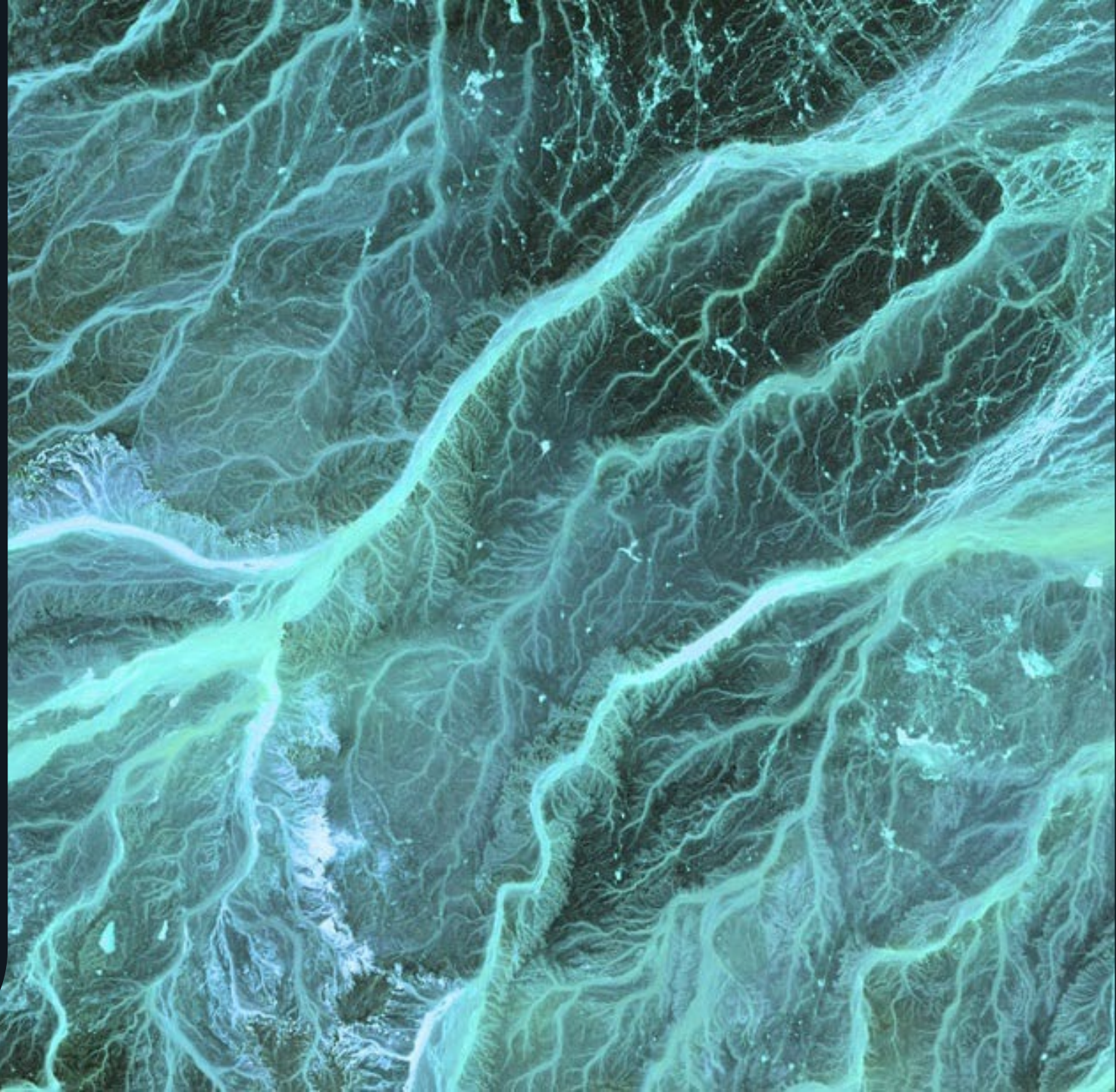
# Breadboard Testing



*Satellite Model images (VIS, IR) with steady motion towards camera*

*Satellite model mounted on tripod*

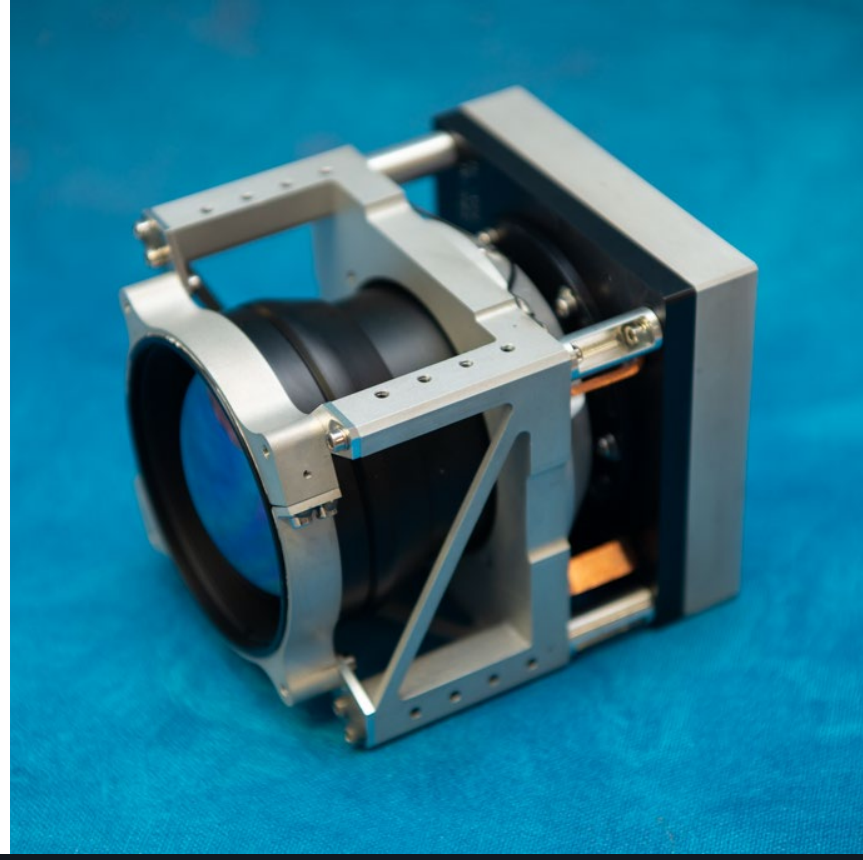
# Conclusions



# Conclusions and next steps

- Development of **VIRGO** multispectral camera **solution** by MDA UK and City University of London under MuLaN GSTP programme
- **Rendezvous scenarios** simulation for camera application: GEO on-orbit servicing, Lunar Gateway
- **Breadboard** activities to de-risk EM design and algorithm development

- **Next activities**: manufacturing VIRGO EM, verification of critical functions in relevant environment (TRL6)
- **Final goal**: VIRGO camera in MDA flight products offering



## FLARE

<1.7 kg
RS-422
50 km max range
12 W

Full Wave Laser Rangefinder

## LEIA

<7 kg
SpaceWire
2 km max range
85 W scanning

Scanning LIDAR

## SIRC

<1.2 kg
Camera Link with RS-422 or SpaceWire
40 m GSD at 450 km
8W peak

Space Infra Red Camera

# Thanks for your attention

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