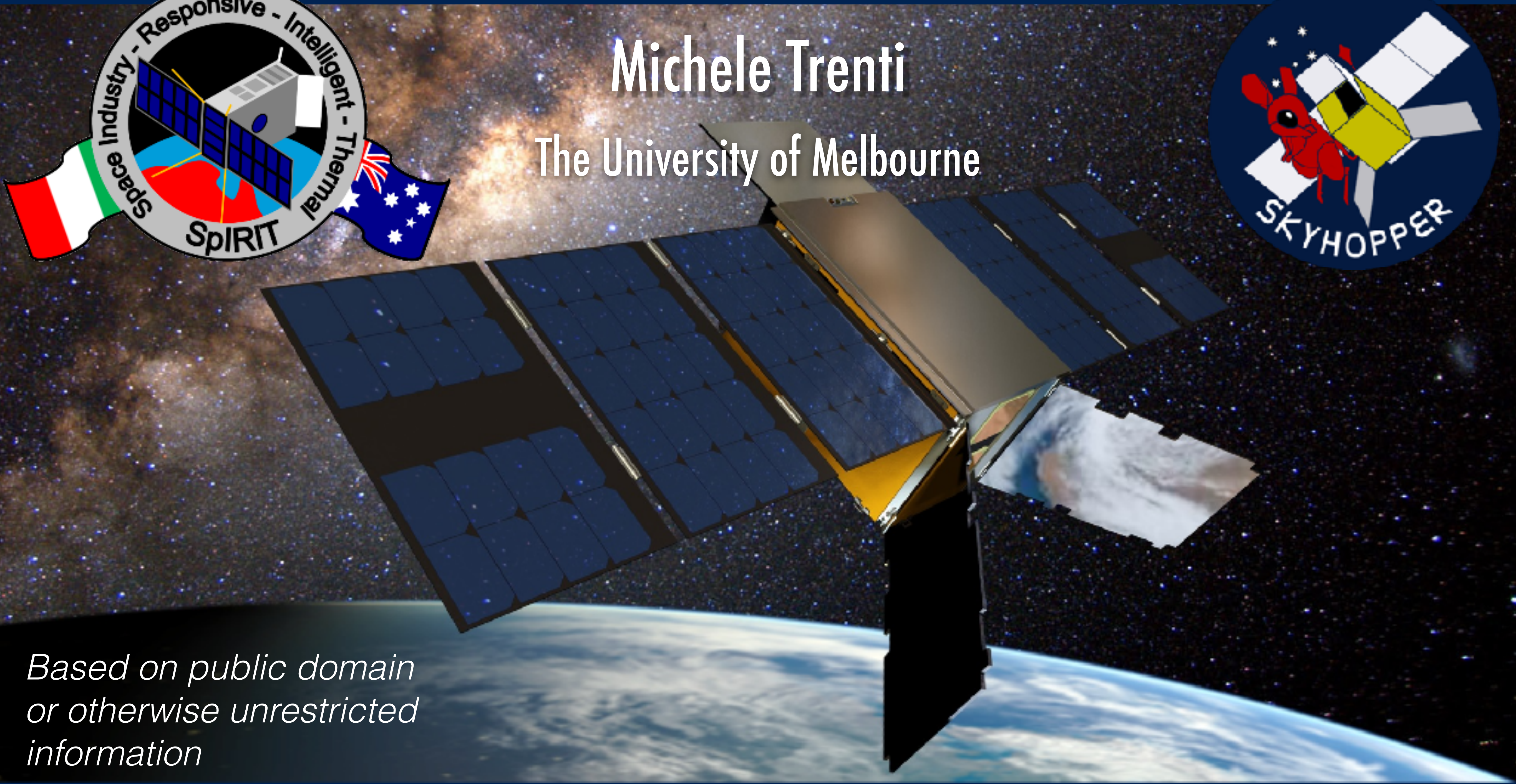
Astrophysics with CubeSats

Michele Trenti

The University of Melbourne



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HERMES-SP/TP 1st Scientific Workshop - 19/11/2020

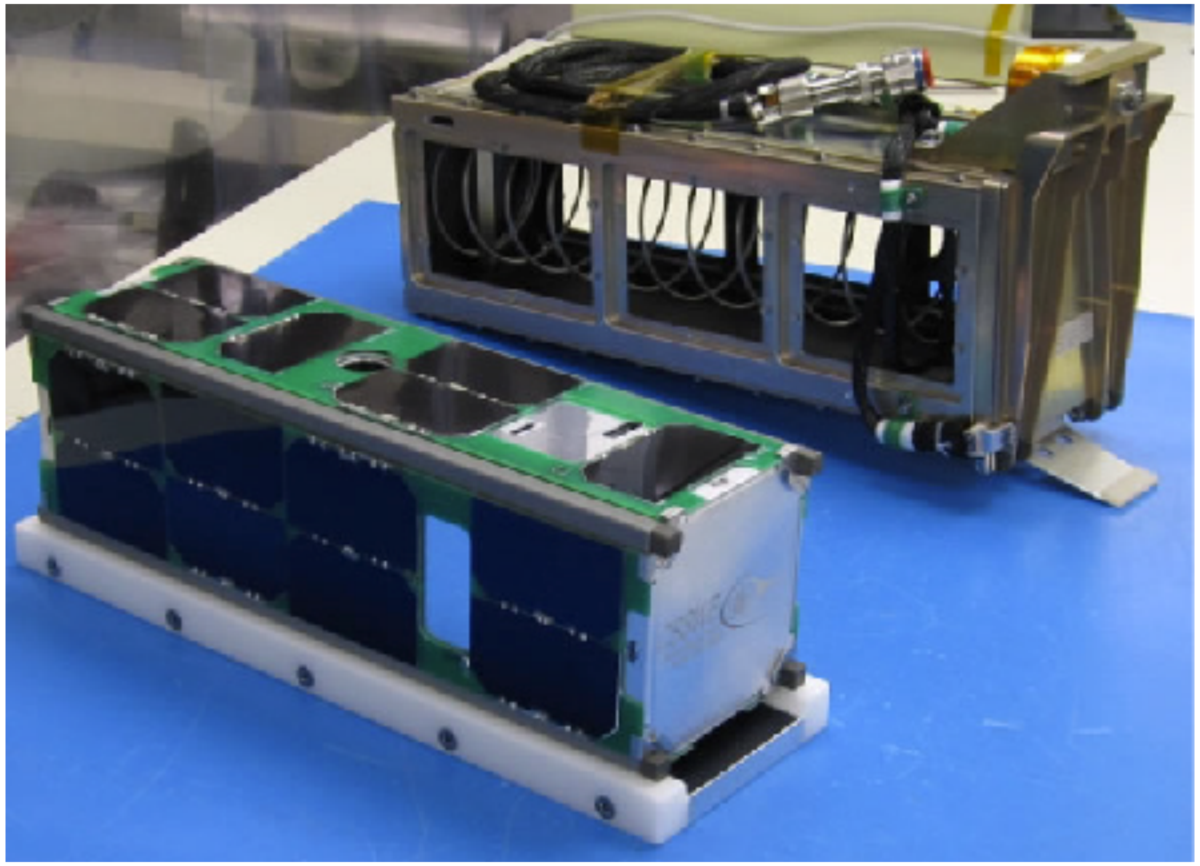
Why astrophysics from space?

Credit: NASA

New opportunities: CubeSats

- **In-principle advantages for tiny focussed missions**
  - Cost, rapid development, advanced tech
    - Research applications pioneered in 2008
    - Growing number of research CubeSats today

CSSWE 3U (2012)

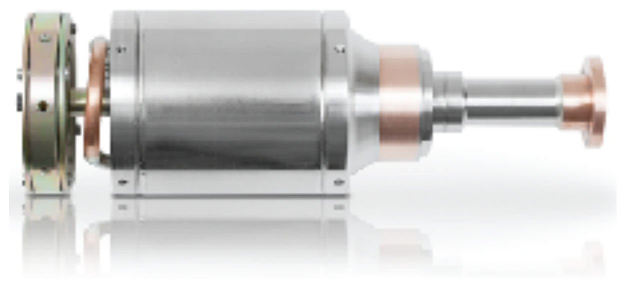


Credit: CU Boulder

CubeSats for astronomy

- **Challenges:**
  - **Accurate attitude control**
  - **Data downlink (+prompt target uplink)**
  - **Thermal management**

- **Enabling technology:**

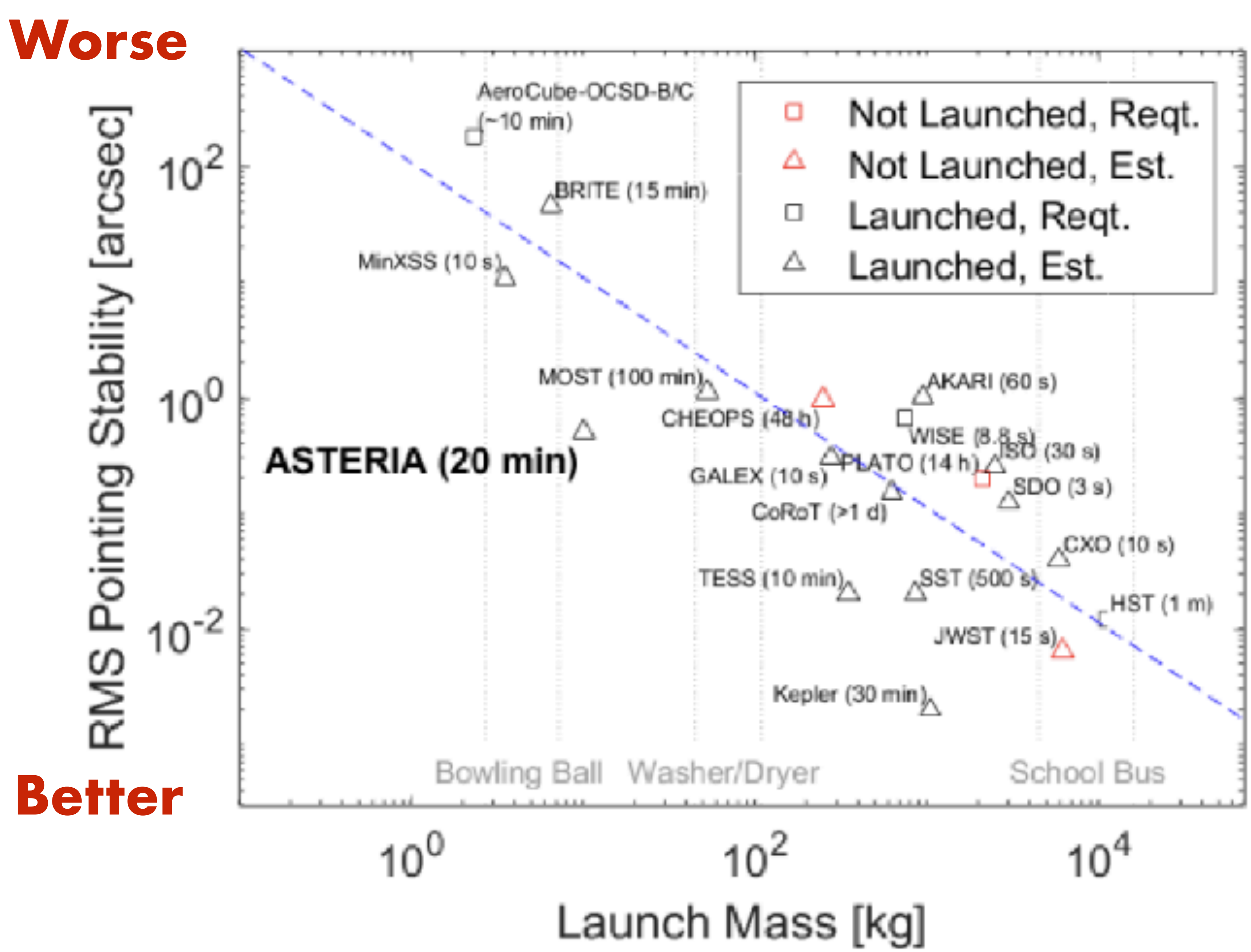


Astronomy demonstration in orbit

Credit: MIT/JPL

- **Asteria (6U, 2017 launch): optical imaging**

<1″ pointing stability & high-precision photometry



Smith+ 2018

Astronomy demonstration in orbit


Credit: MIT/JPL

- **Asteria (6U, 2017 launch): high data throughput**

Downlink of images is enabled by S-band!

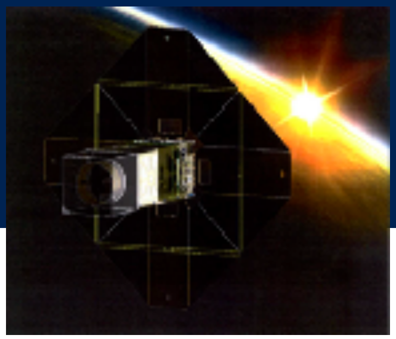
Table 2: Summary of the ASTERIA spacecraft.

Parameter	Value
Mass	10.165 kg
Stowed dimensions	239 mm x 116 mm x 366 mm
Power generation	48 W (beginning of life)
Energy storage	52.7 Wh (beginning of life)
Telecom frequency	S-band
Data rates	32 kbit/s uplink 1 Mbit/s downlink
Processor	Xilinx Virtex 4FX / PowerPC405
Onboard storage	14.5 GB

Smith+ 2018

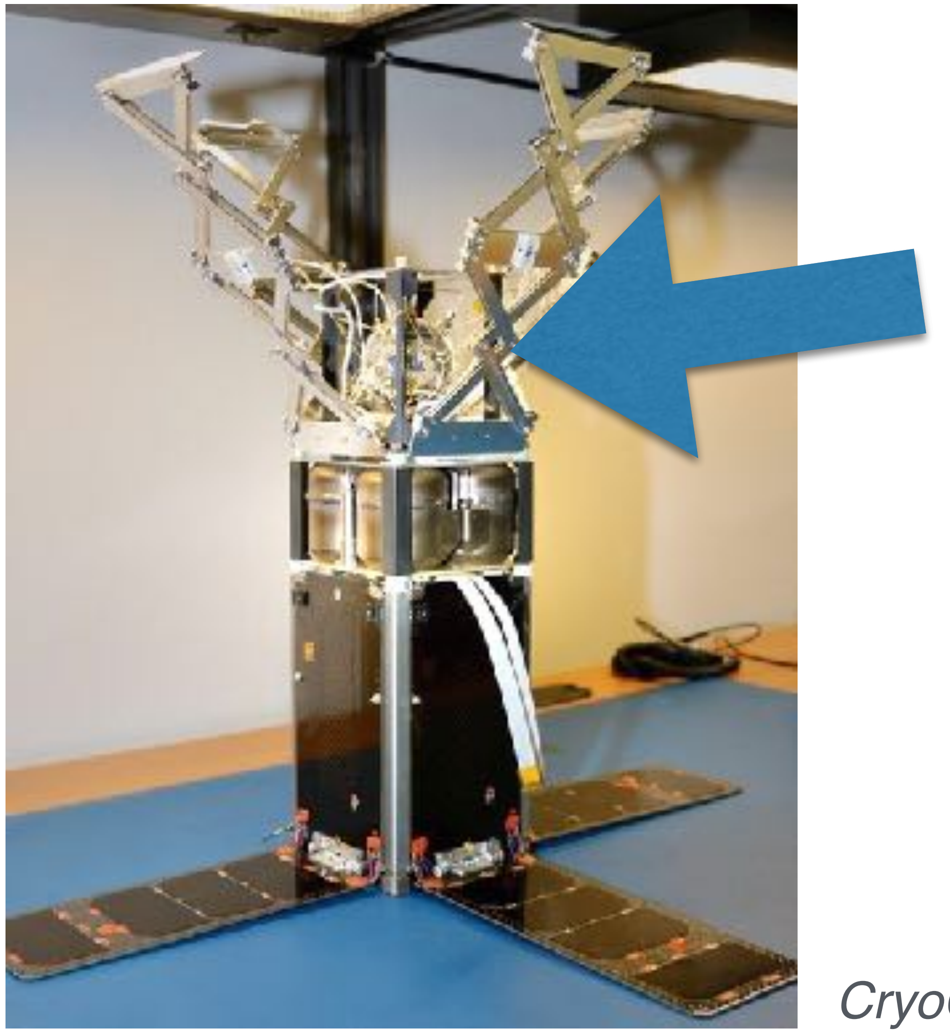
Future: Ka/Ku band comms also being developed

Cryogenic thermal management



- **CryoCube (2020; 3U) aims to demonstrate T=100K**

Deployable SunShield around a (small) payload

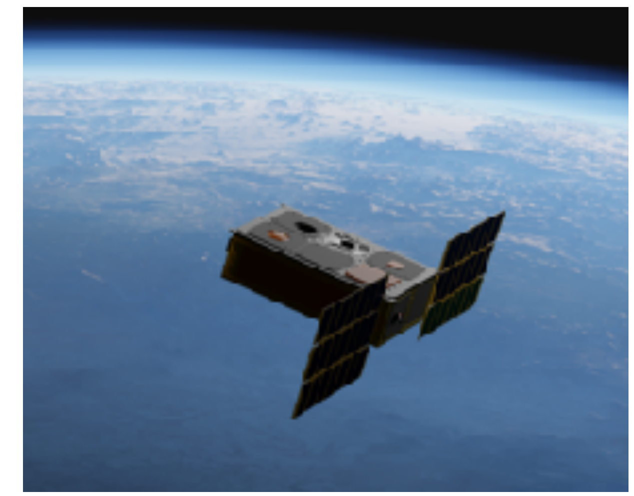


CryoCube website

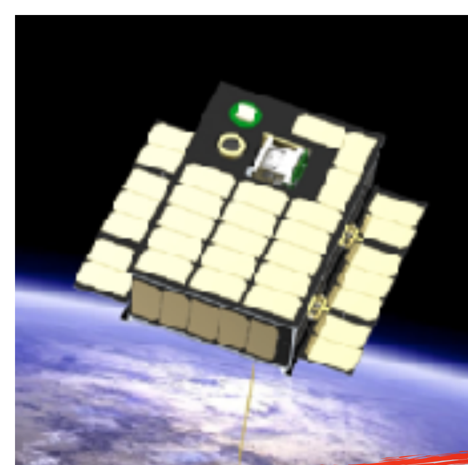
Tech demo for active cooling (microcoolers) ongoing

Next on the launch pad (selected list)

- **2021+: UV spectroscopy/imaging [exoplanets]**
  - **CUTE (6U)**
  - **SPARCS (6U)**



- **2022+: High-energy constellations [GRBs, GWs]**
  - **BurstCube (6U)**
  - **HERMES (6x3U+)**
  - **Camelot (9x3U)**



10x increase (n=233) "CubeSat" in ADS from 2011 to 2018!

An innovative IR space telescope?

An innovative IR space telescope?

Yes, thanks to CubeSat tech!

SkyHopper

Hubble

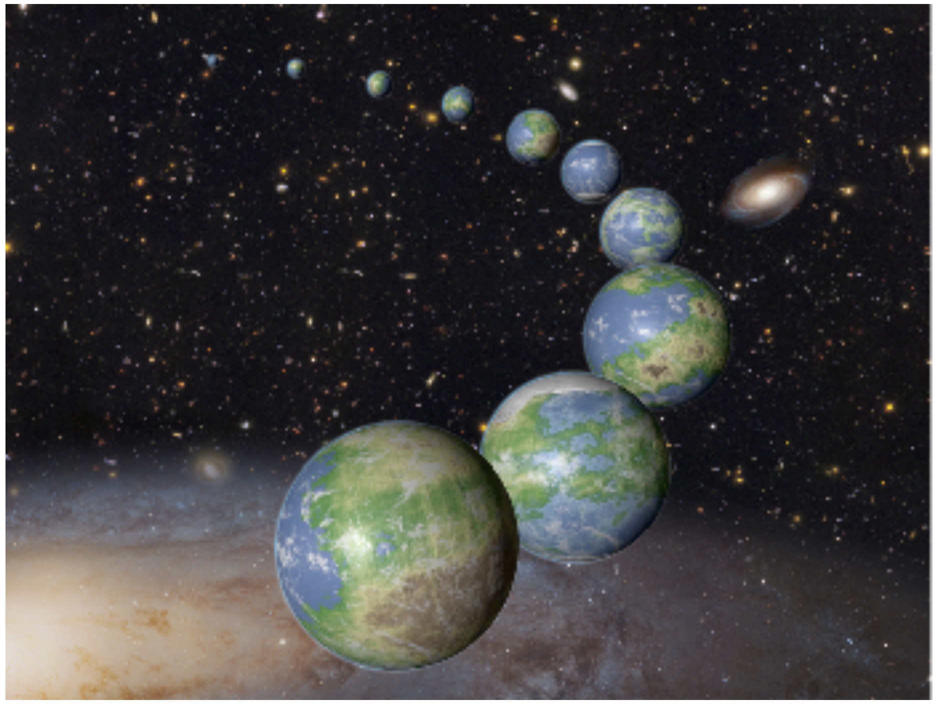
The idea: An IR "shoe-box" telescope

- **12U CubeSat [~22kg,~50W]**
  - 15cm imager [4(+2) bands, 0.8-1.7 µm]
  - 1.5deg^2 FoV, 4M pixel
  - Highly stable spacecraft [~3″ RMS]
  - Rapid slew [~2deg/s] & 24/7 comms
  - 2yr primary mission

What motivates this?

Science case: Frontier problems

- **Are we alone?**
  - Search for other Earths

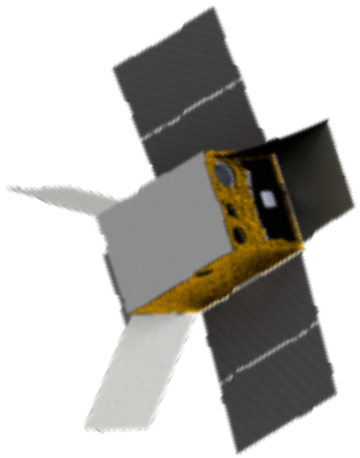


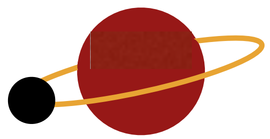
- **Where are we coming from?**
  - First stars and galaxies

Artist's concepts, NASA

HERMES-focussed science: Transients

- Hop to observe Gamma Ray Bursts in the near infrared
    - Identify stellar explosions 13 billion light years away (within the first galaxies)





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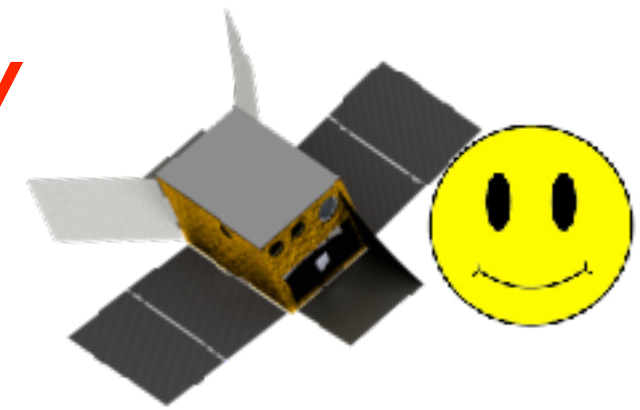
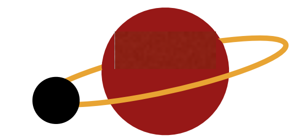
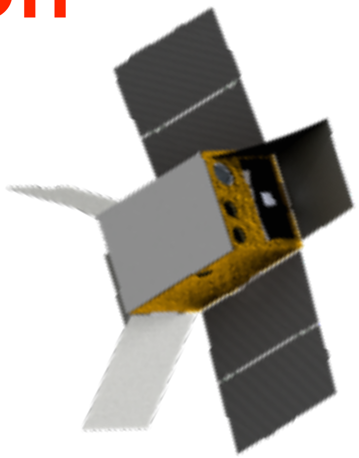




Hopping 1000 times faster than Hubble to double GRBs at z>5 (first Gyr)!

GRB afterglow requirements

- Rapid photometric redshift determination of z>5 GRB afterglows during reionization

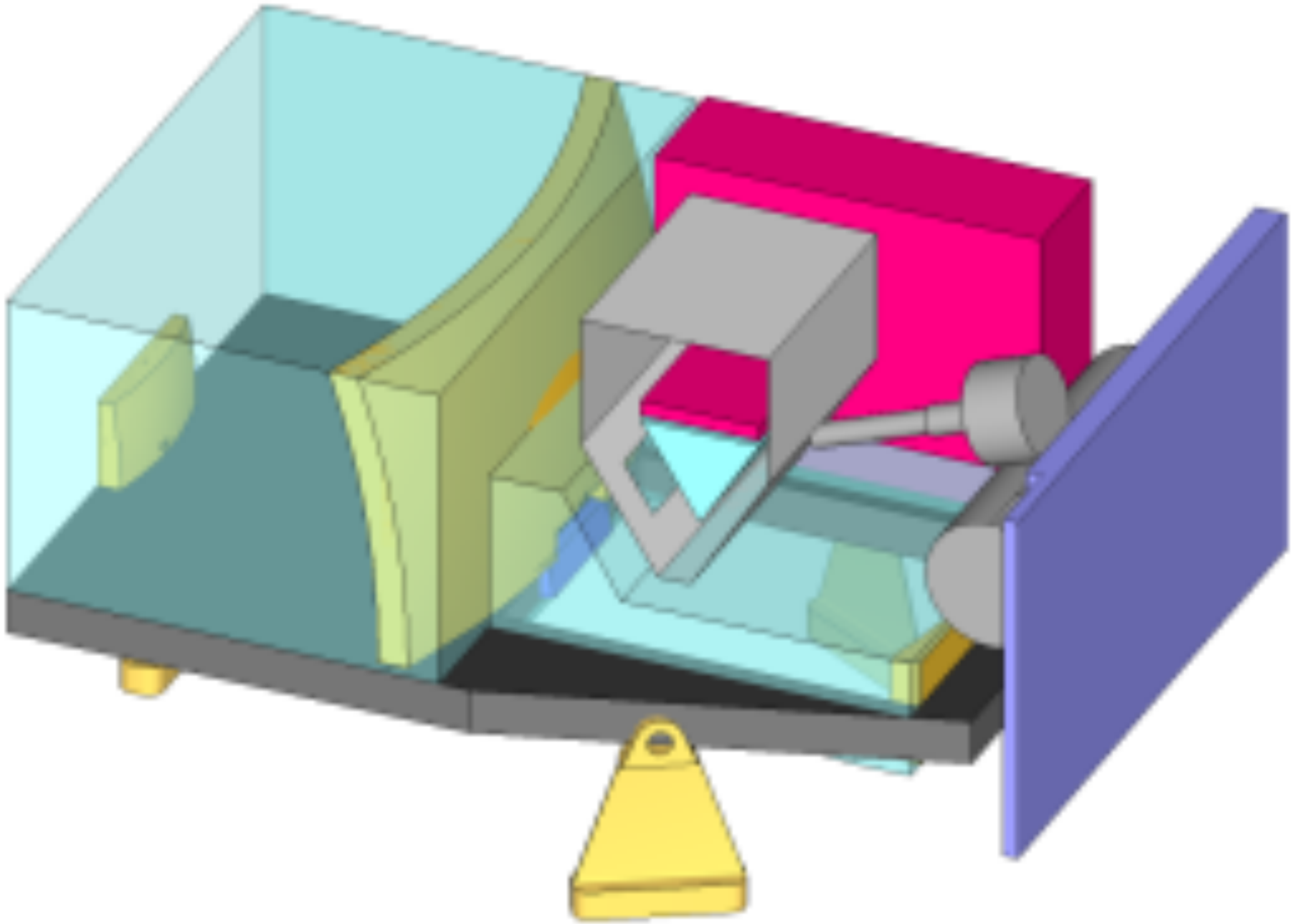


  - High point-source sensitivity
    - m_{AB}=19.5 in t=600s
  - Simultaneous imaging in 4 bands (0.8-1.7 μm)
  - On target in <180s from trigger (if visible)

- Key challenges:
  - IR detector thermal management
  - Near-real time uplink/downlink of targets/photometry

Hardware: 10x20cm IR telescope

- **Ambition: First IR imager (HgCdTe) actively cooled to 140±0.1 on a CubeSat**



SkyHopper is technologically challenging: risk mitigation?

HERMES-SkyHopper connection: SpIRIT

- **SpIRIT: first mission funded by Australian Space Agency**
  - 6U (10kg) CubeSat to launch in 2022
  - Australian-made spacecraft, Italian x-ray instrument

- **Key goals:**
  - Showcase maturity of Australian space industry
  - Augment HERMS SP/TP capabilities
  - SkyHopper risk mitigation
    (thermal management, real-time comms)

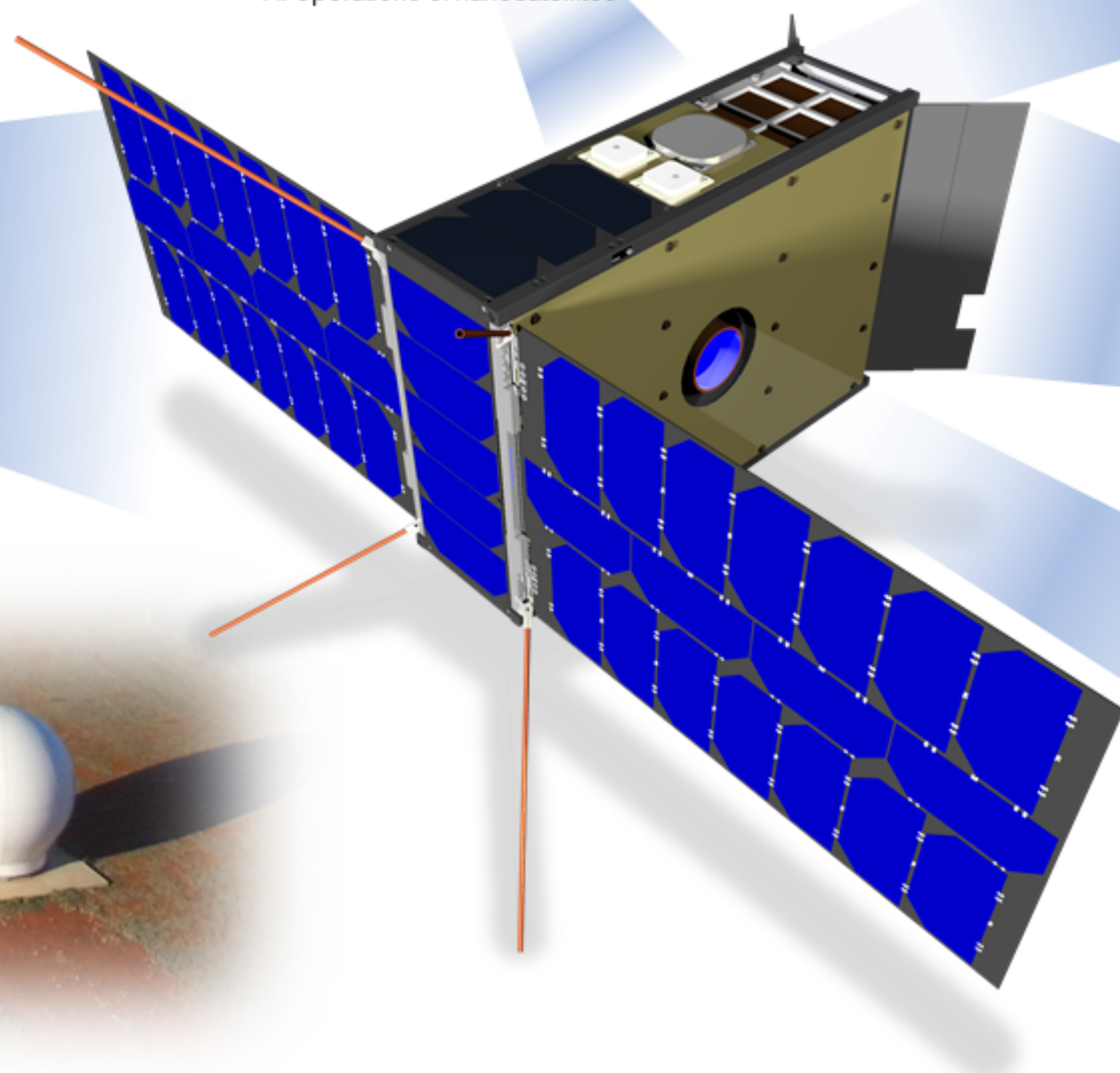
SpIRIT at a glance

THE UNIVERSITY OF MELBOURNE
Mission lead

THE UNIVERSITY OF MELBOURNE
Mercury payload
AI operations of nanosatellites

HERMES
HERMES payload
X-ray remote sensing instrument

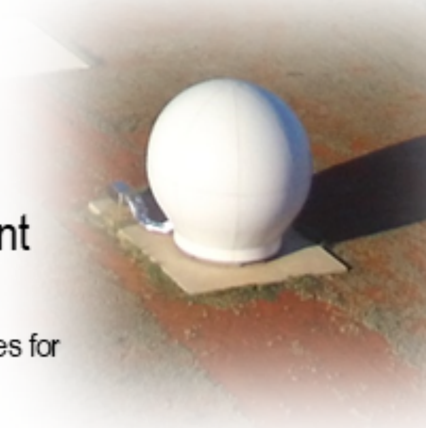
INOVOR TECHNOLOGIES
Apogee bus
Australian made nanosatellite platform



THE UNIVERSITY OF MELBOURNE
TheMIS payload
for cooling of advanced sensors

SITAEL AUSTRALIA
System engineering

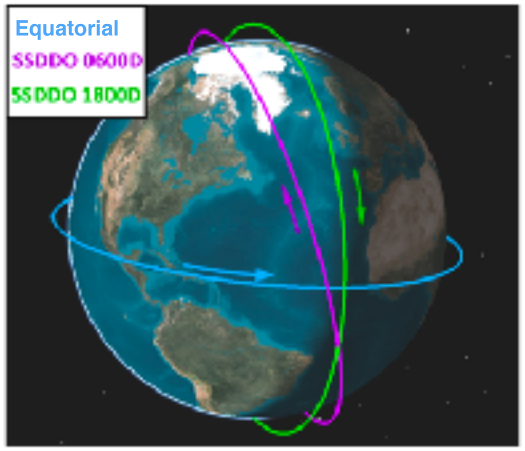
Nova Systems
Autonomous intelligent ground segment
Autonomous integrated capabilities for ground segment operations



NEUMANN SPACE
Thruster payload
Australian electric propulsion technology

SpIRIT-HERMES complementarity

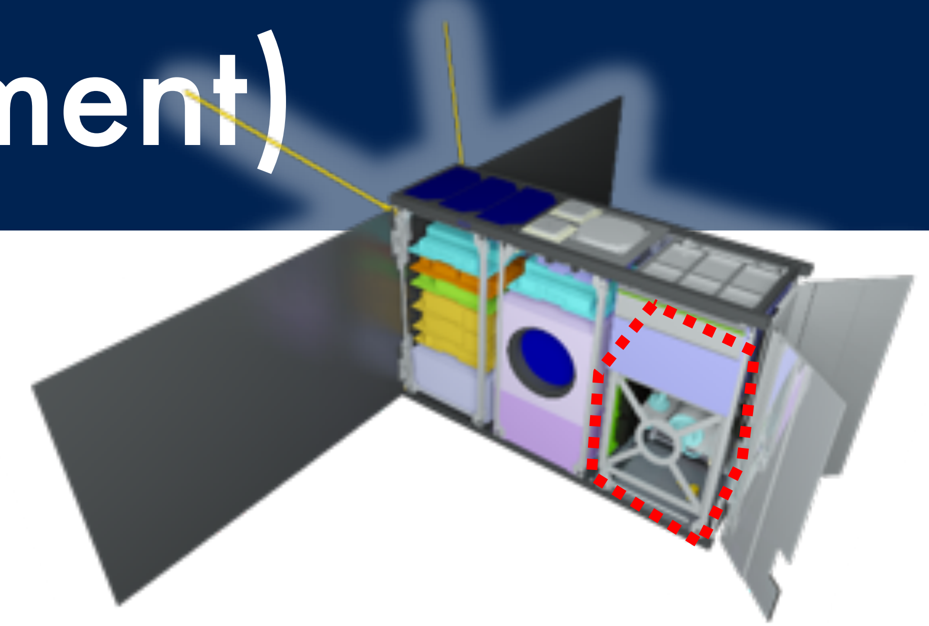
- SpIRIT orbit improves HERMES event localisation (near orthogonal plane)



- SpIRIT's cooling improves HERMES performance (10x reduction in leakage current)

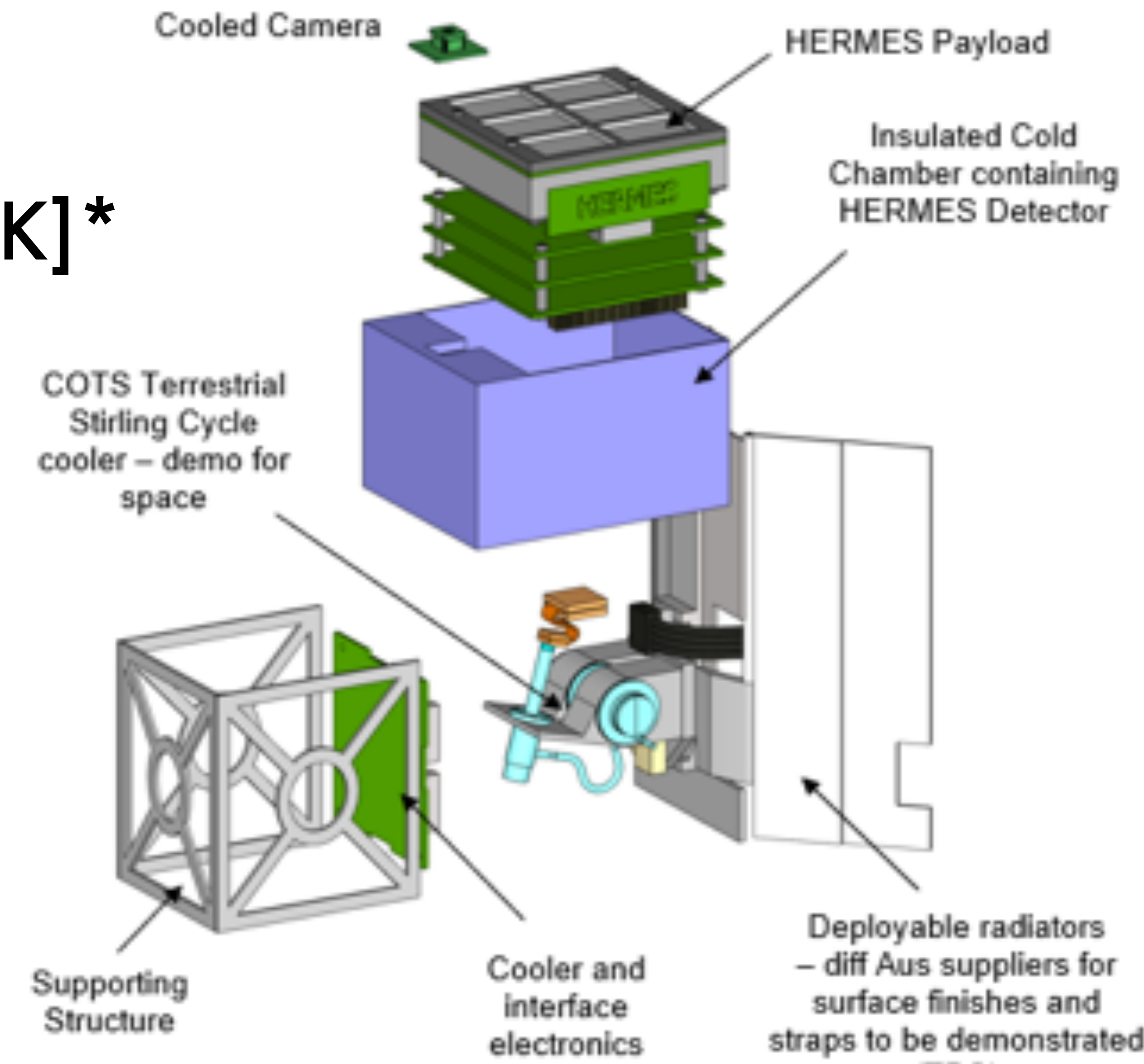
- Ground segment cooperation opportunities

TheMIS (Thermal management)

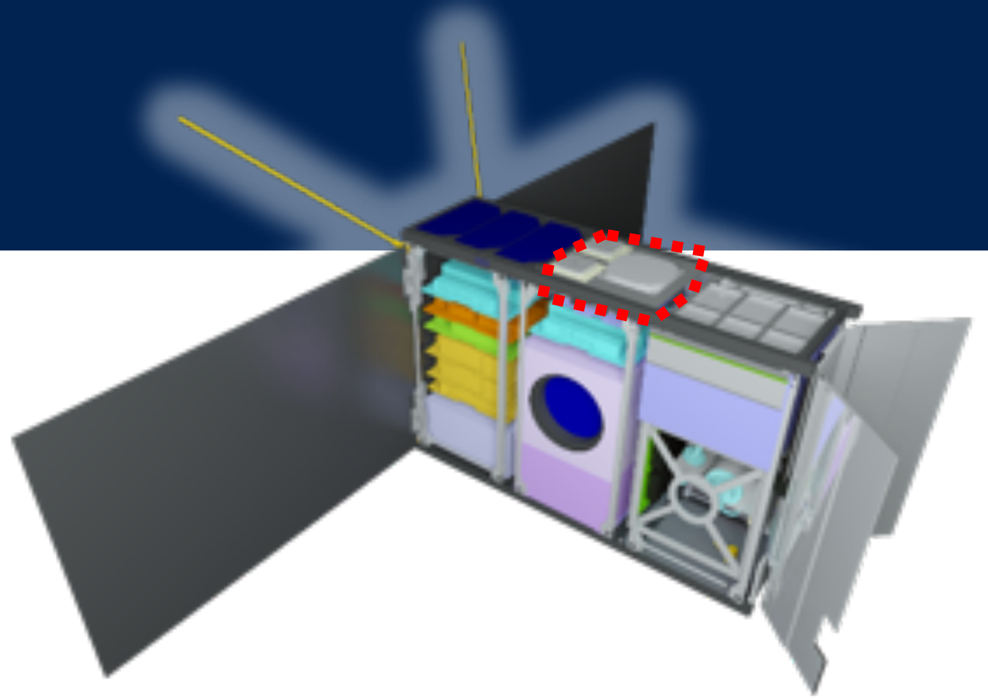


- **Subsystem for payload active thermal management:**
  - Efficient (Stirling cycle)
  - Payload T∈ [243K;273K]*
  - Stability to <0.5K
  - Explore active vibration cancellation
  - Deployable radiators

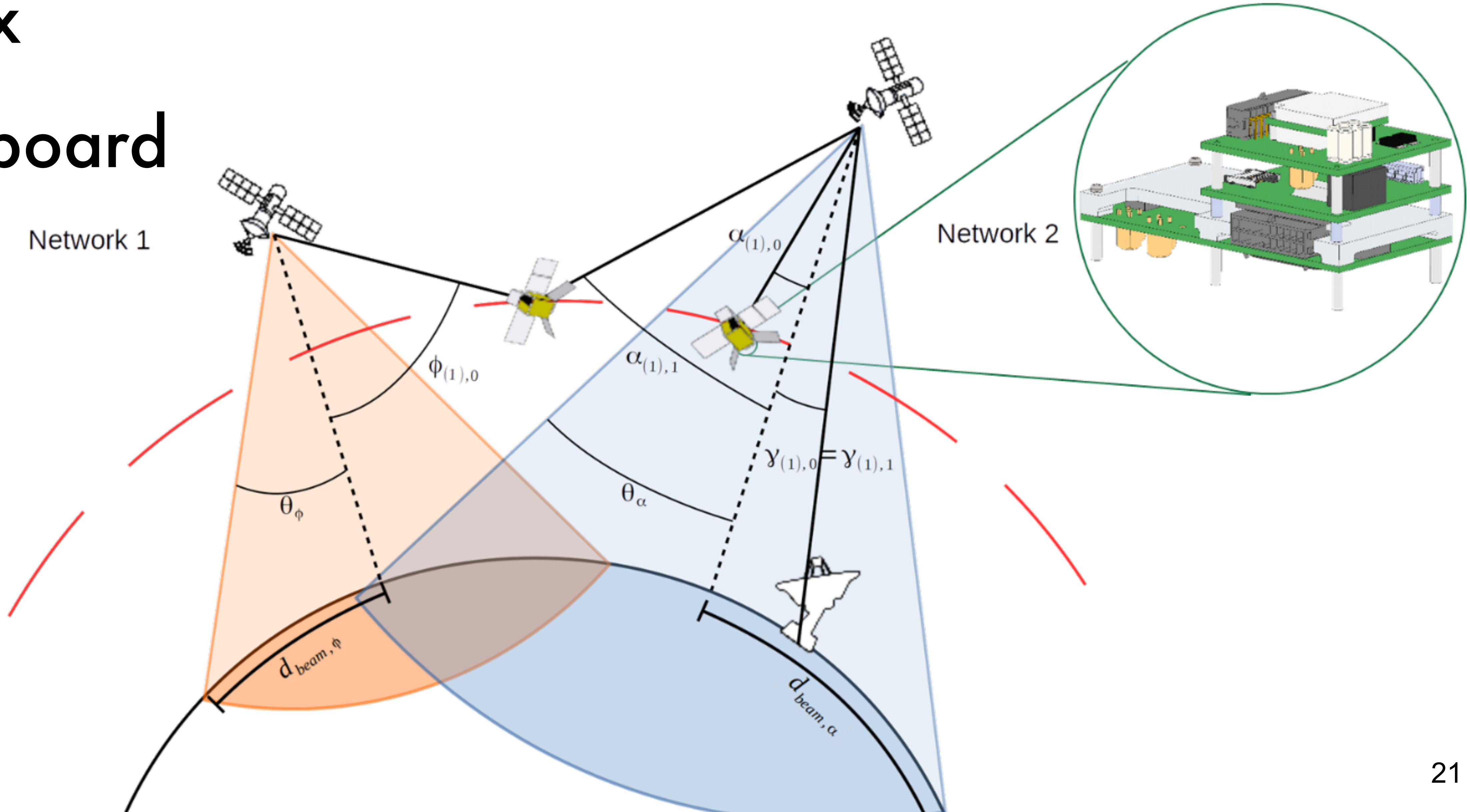
*[*Cooler tip capable to T<100K]*



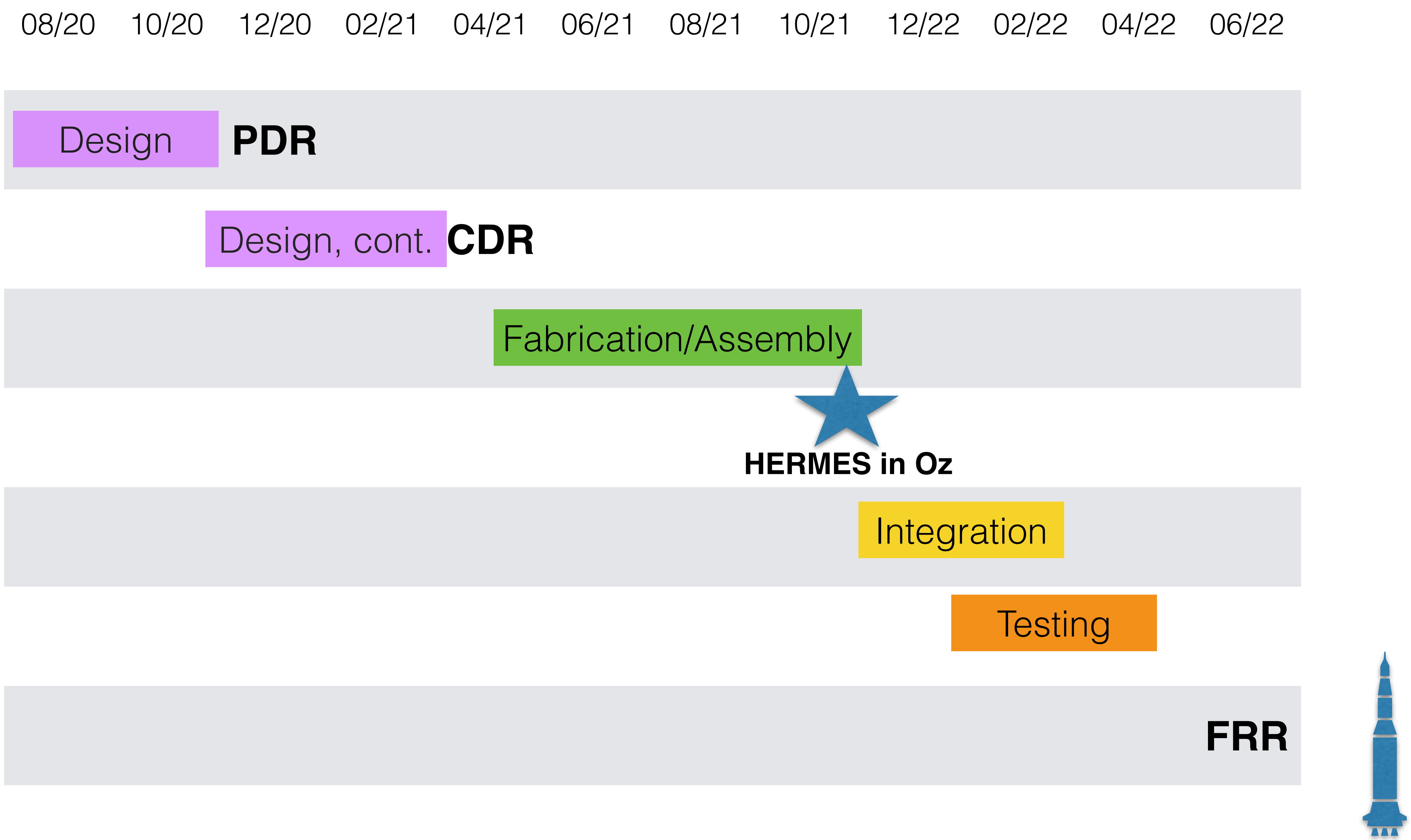
Mercury (Rapid comms)



- **Subsystem for near-real-time communications**
  - Iridium duplex+Globalstar simplex
  - AI on-board

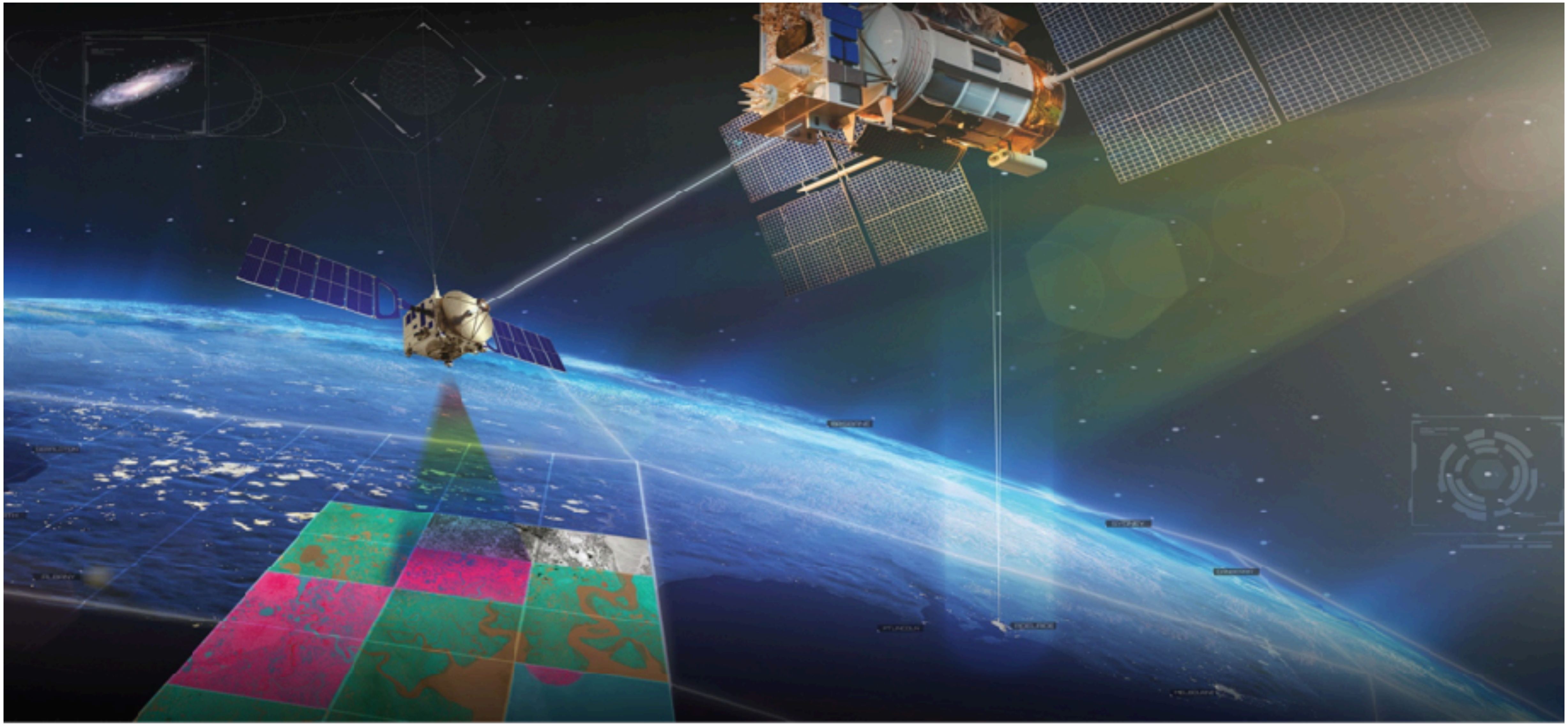


SpIRIT: Timeline



The future

- **Nanosats have growing role in astrophysics**
  - **Complement rather than compete with flagships**
- **Distributed-aperture space observatories**



Summary: Emerging capabilities

- Nano-satellites enable cutting-edge low-cost space telescopes
    - Complement flagships
- CubeSat advantages:
    - Innovation, agility, dedication
- Australia's contribution (in cooperation w/Italy): SpIRIT, SkyHopper
- Bright future, limited by imagination