

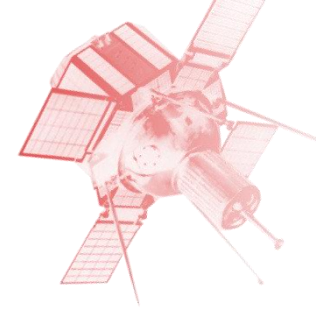


**CRAFT
PROSPECT**

a space engineering practice

Challenges in Quantum Devices for Space

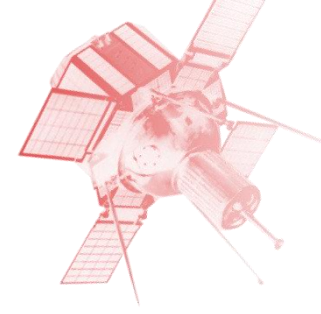
Craig Colquhoun
Monday, 13th February 2023



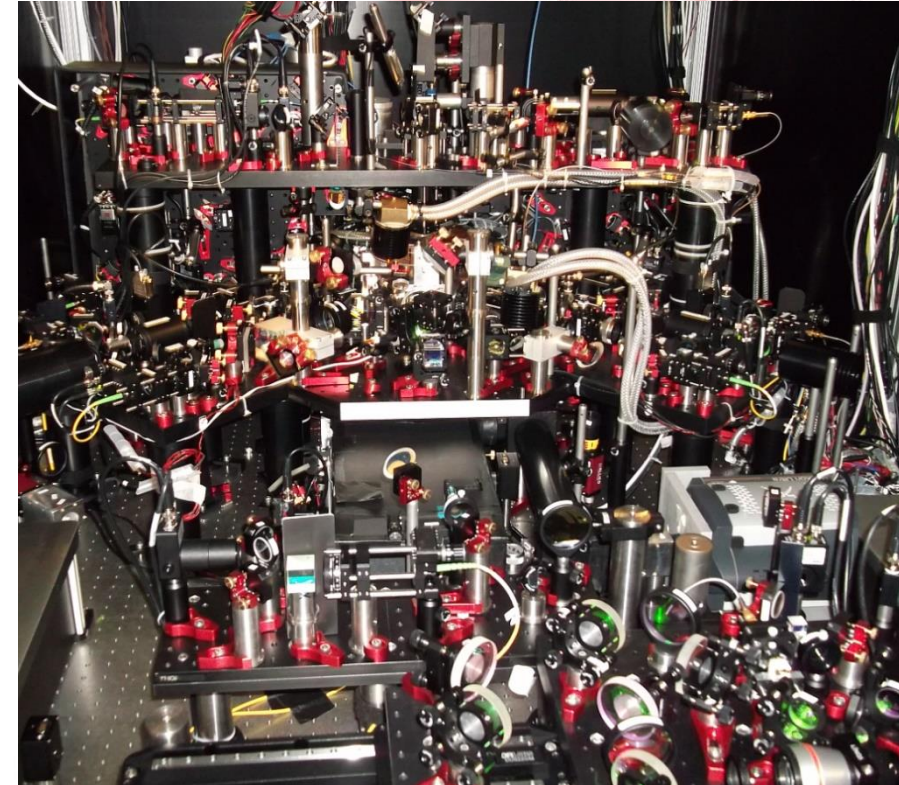
- Background
 - Miniaturisation efforts
 - Integration initiatives
 - CubeSats
- Space Challenges
 - SWAP-C (still)
 - Launch
 - Thermal
 - Vacuum
 - Radiation
- Case Study: ROKS



* Optical Labs

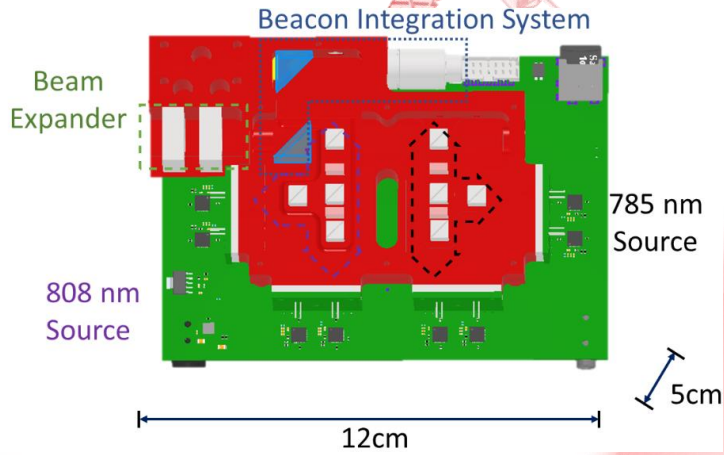
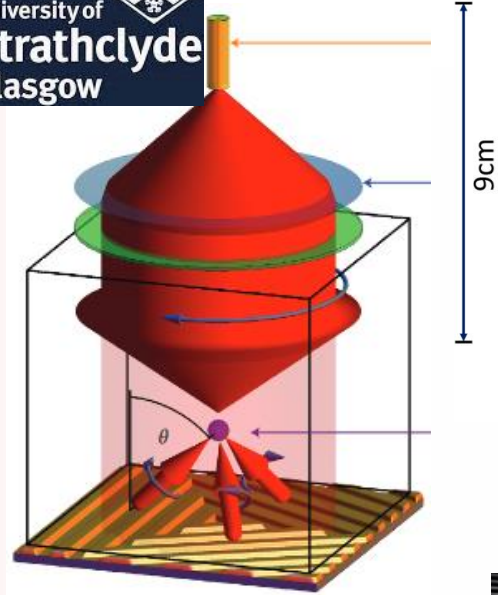
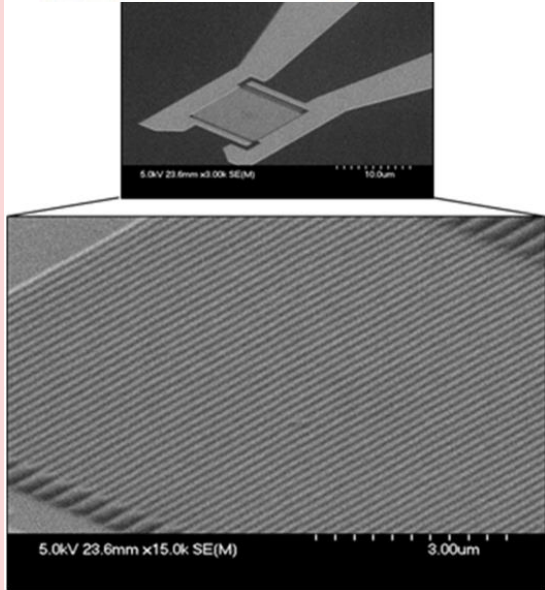


- High SWAP-C
- Sensitive to environmental changes
 - Thermally / humidity controlled
 - Vibrationally dampened
- Environment stabilised for experiment
- Focus on miniaturisation and integration

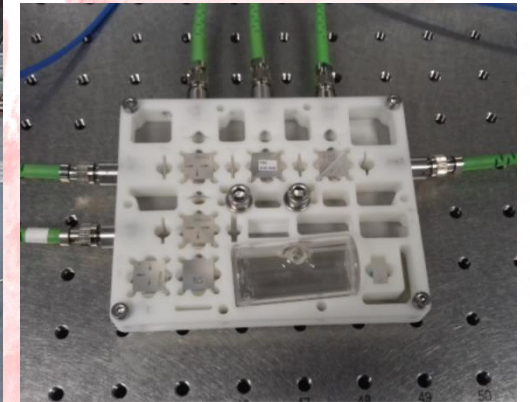
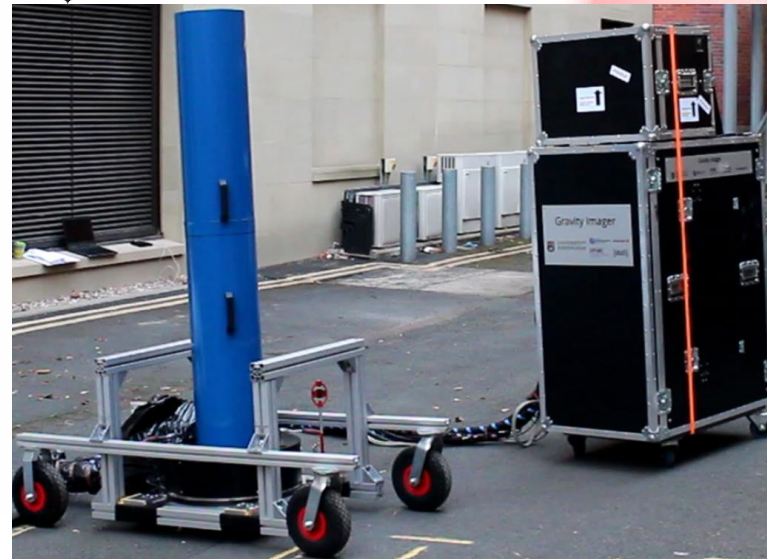
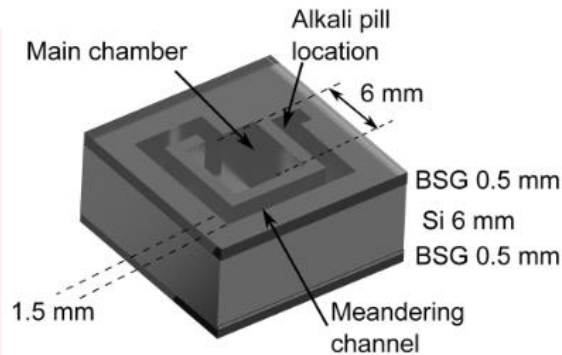
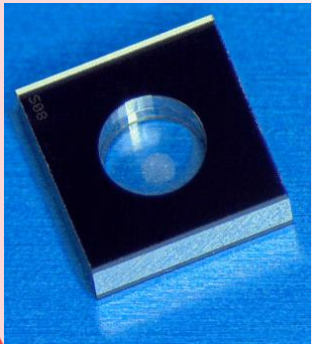
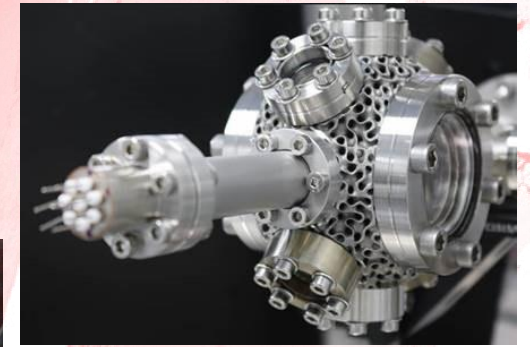
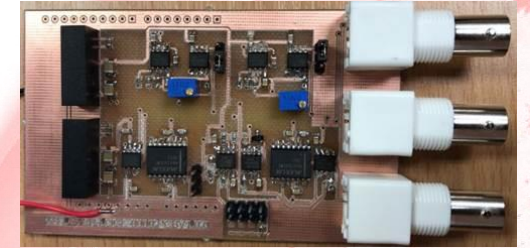




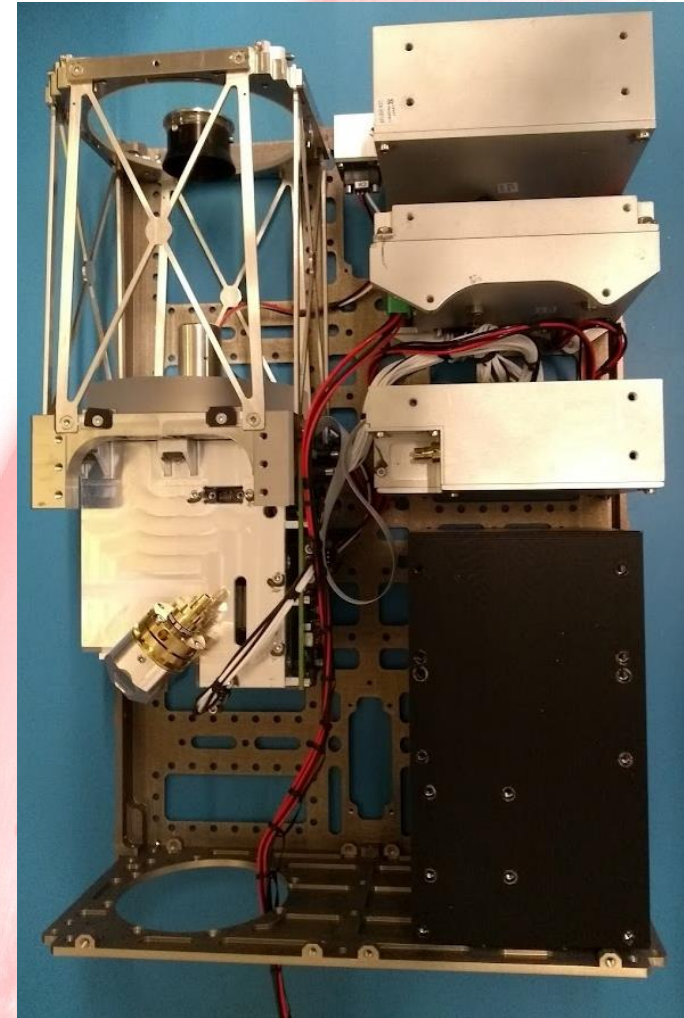
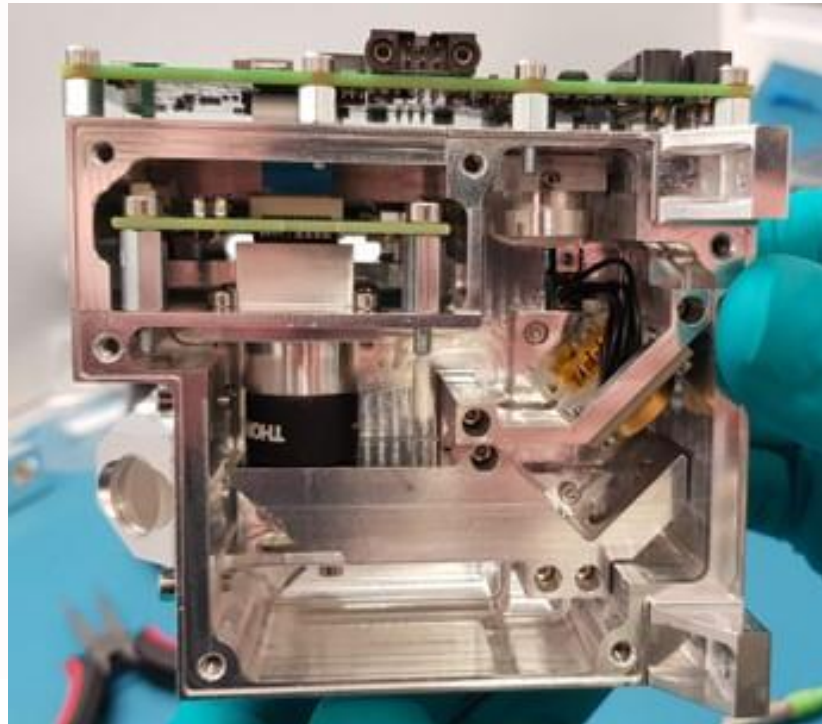
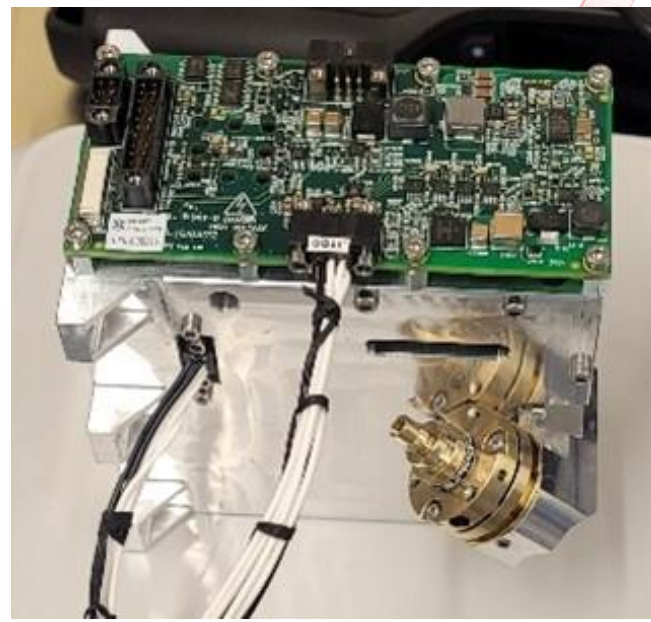
Miniaturisation / Integration



UNIVERSITY OF BIRMINGHAM



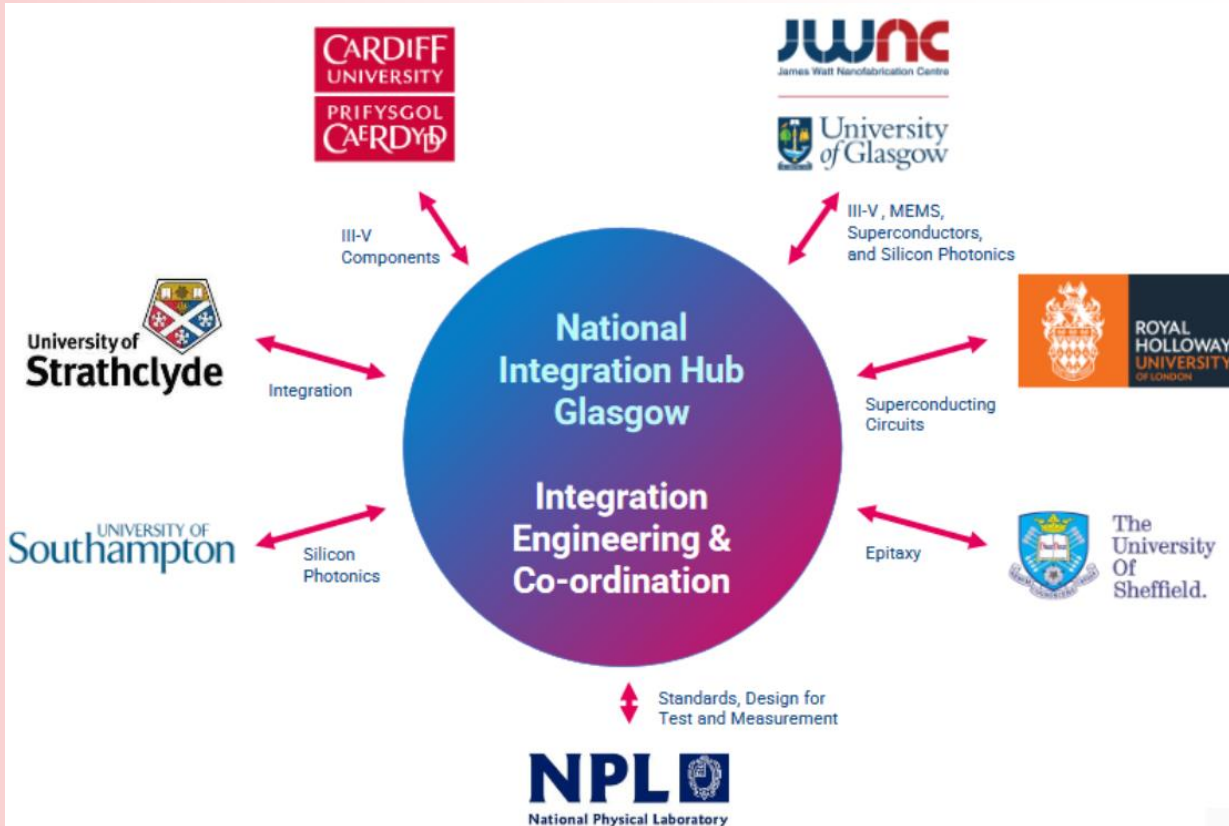
* CubeSat Modules



* Further Quantum Developments for Industry



CRAFT PROSPECT



NMIS
National Manufacturing Institute Scotland

Let's make it happen

NPL
CAMPAIGNS

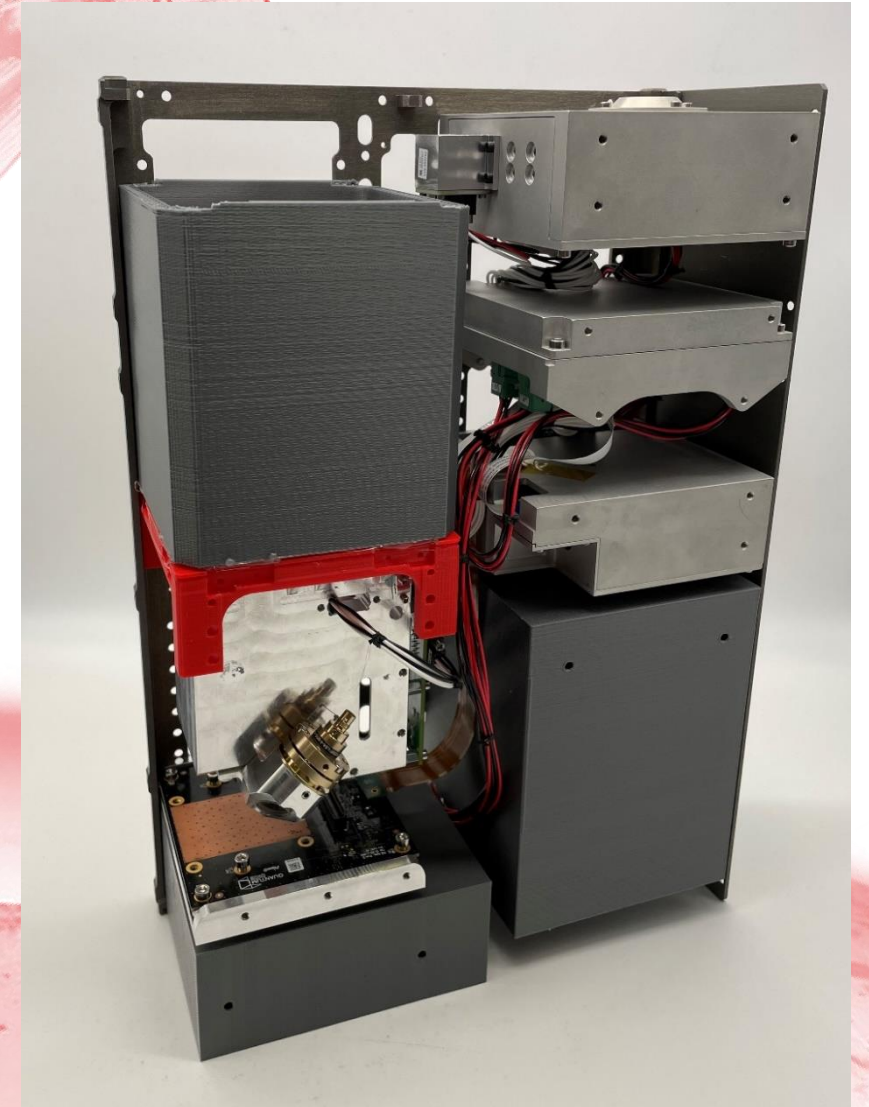
Measurement for Quantum

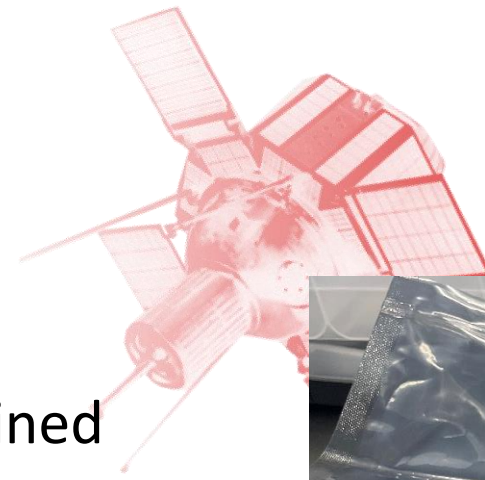
Removing barriers to innovation



* Space Challenges

- SWAP-C (still)
- Launch environment
 - Vibrations
- Radiation
- Space environment
 - Extreme thermal conditions
 - Large temperature fluctuations
 - Vacuum pressures
 - Reduced cooling mechanisms
 - Component / material outgassing





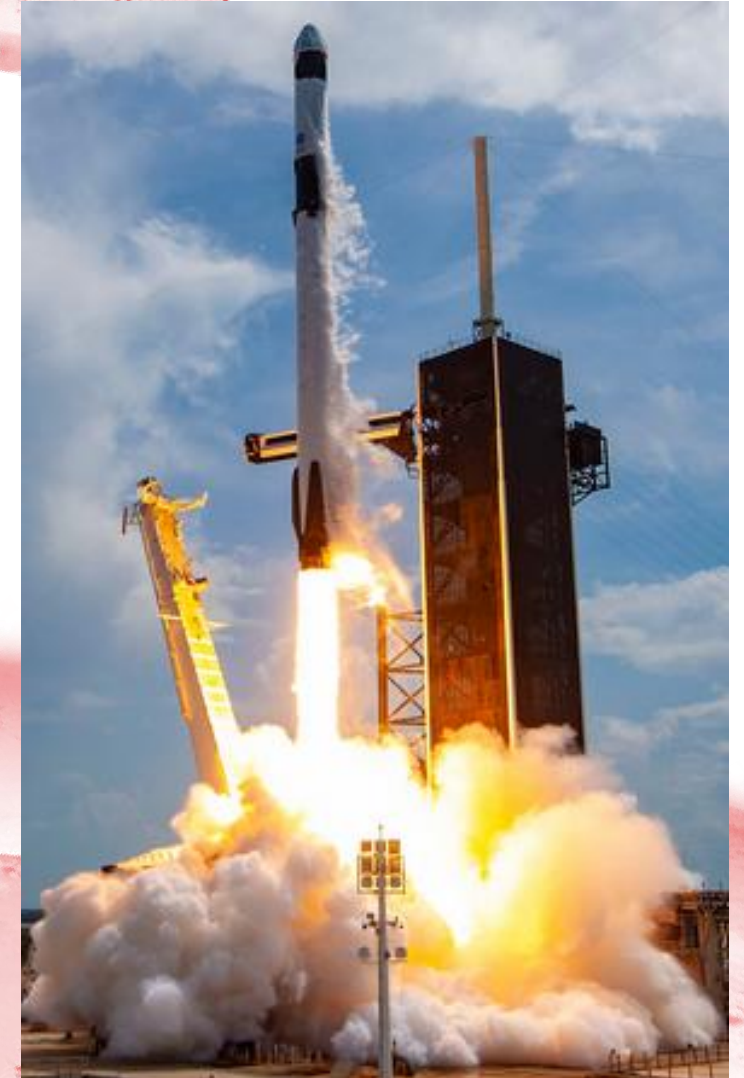
- Size
 - Cubesats - size standards, relatively constrained
 - Reiterative design / manufacture cycle
- Weight
 - +Weight -> ++Launch cost
- Power
 - Constrained by battery and solar capabilities
- Cost
 - New space – not limited to ‘space / military spec’
 - CubeSats – launch £100,000s rather than £10,000,000’s



* Launch Environment

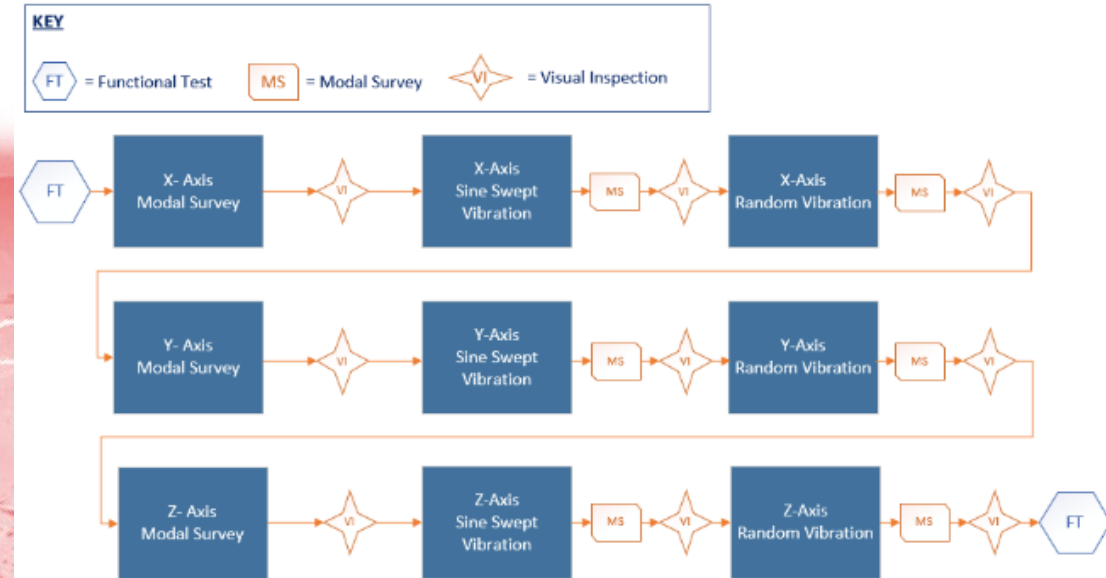
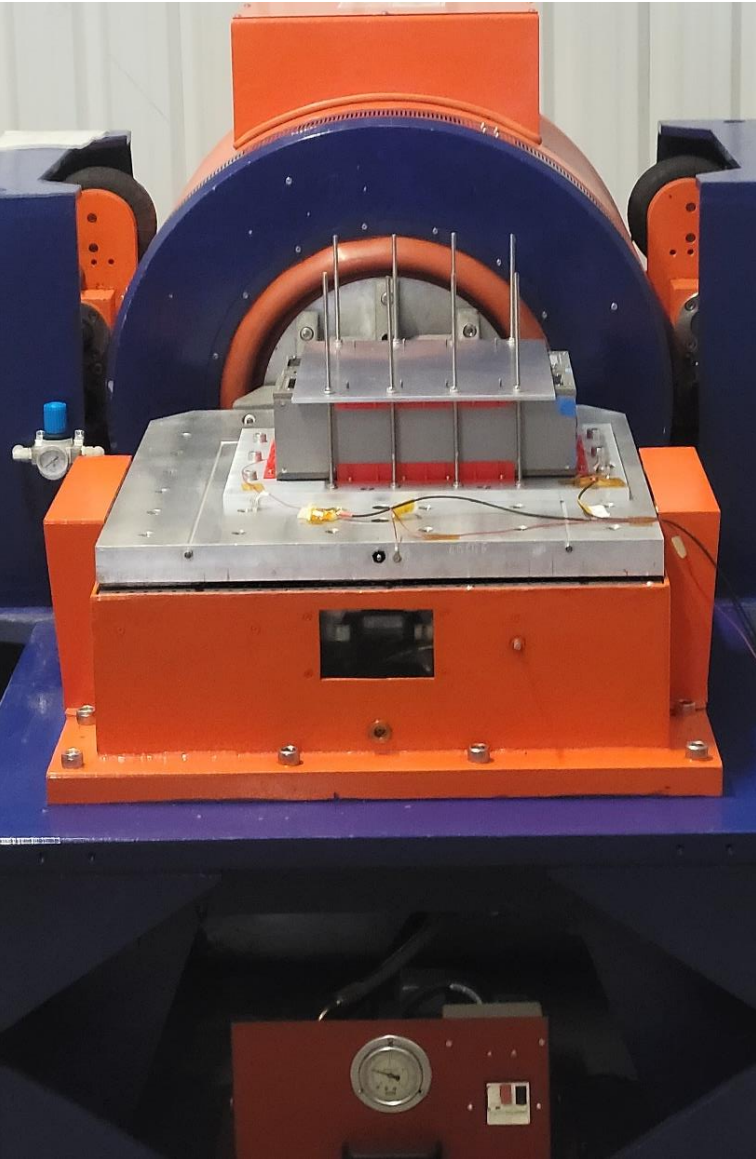
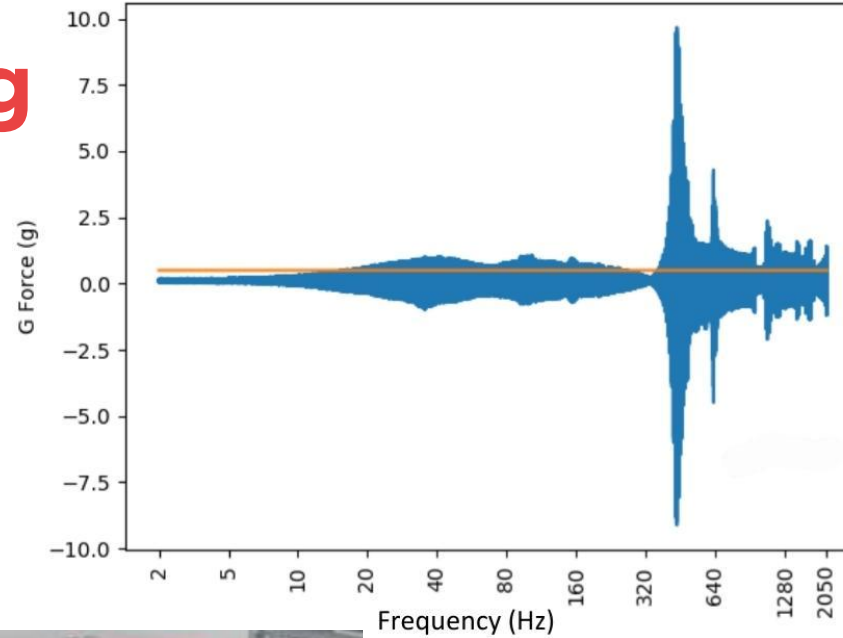


- Intense vibrations
 - Lots of different frequencies
 - Mechanical resonances
- Mitigations
 - Component selection
 - Design to prevent destructive cascades
 - Design for resilience
 - Staking
 - Testing

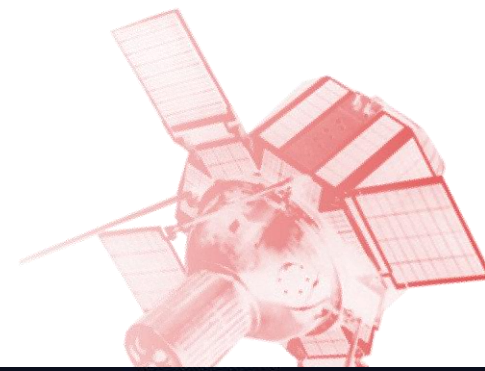


* Vibrational Testing

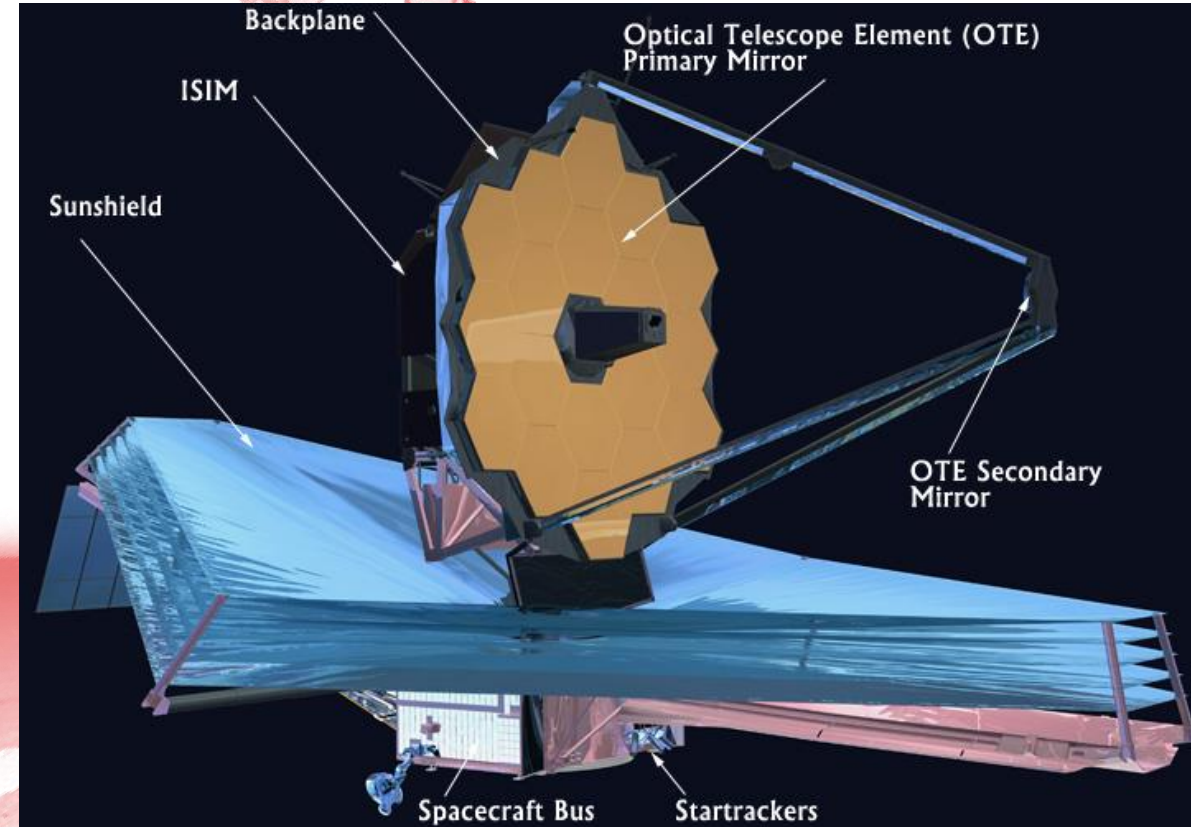
modal Survey, Resonance Sweep
G Force: 2Hz to 2050Hz



* Thermal

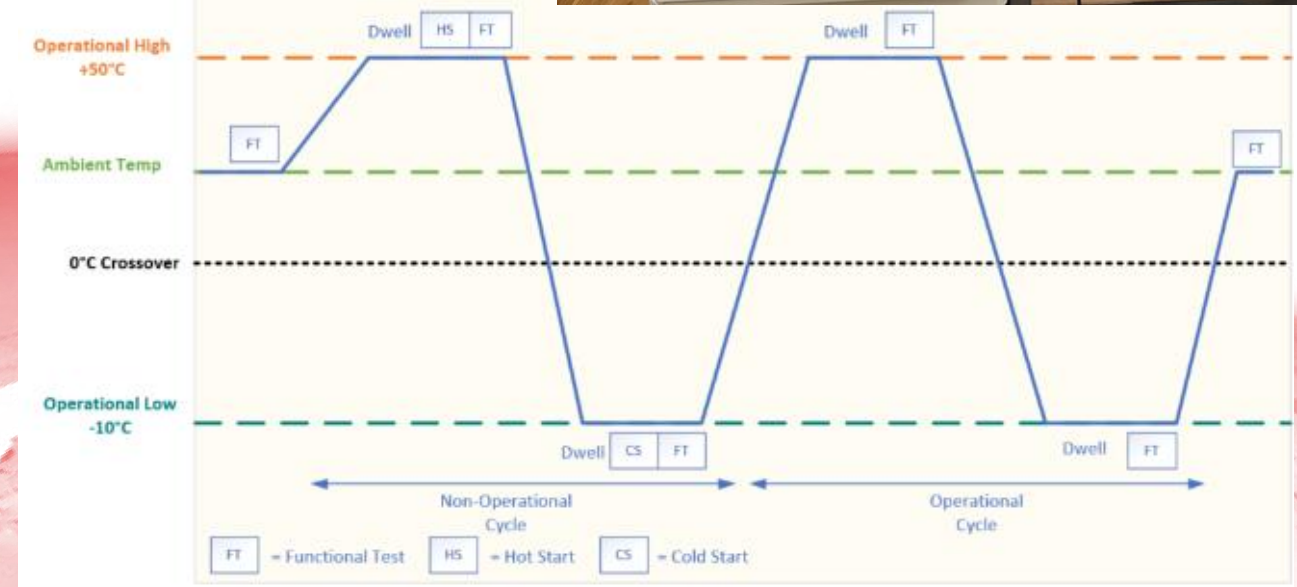
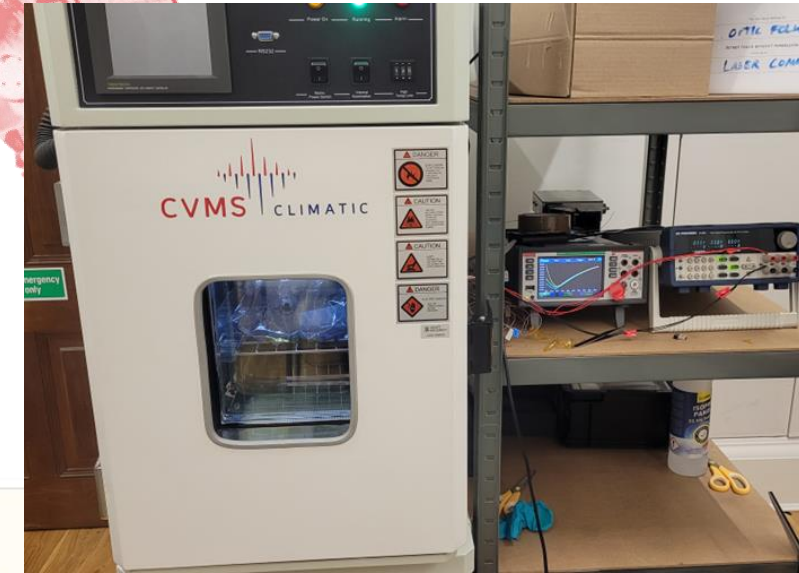


- Extreme thermal conditions
 - Large temperature fluctuations
- Mitigations
 - Component selection
 - Thermal bulk where required
 - Heat strapping where required
 - Design to minimise misalignment
 - Testing



* Thermal Testing

- Thermal Chamber
 - Thermal cycling
 - Throughout operating temperatures
 - To qualification, and survival extremes
 - Hot / cold starts
 - Many cycles



* Vacuum

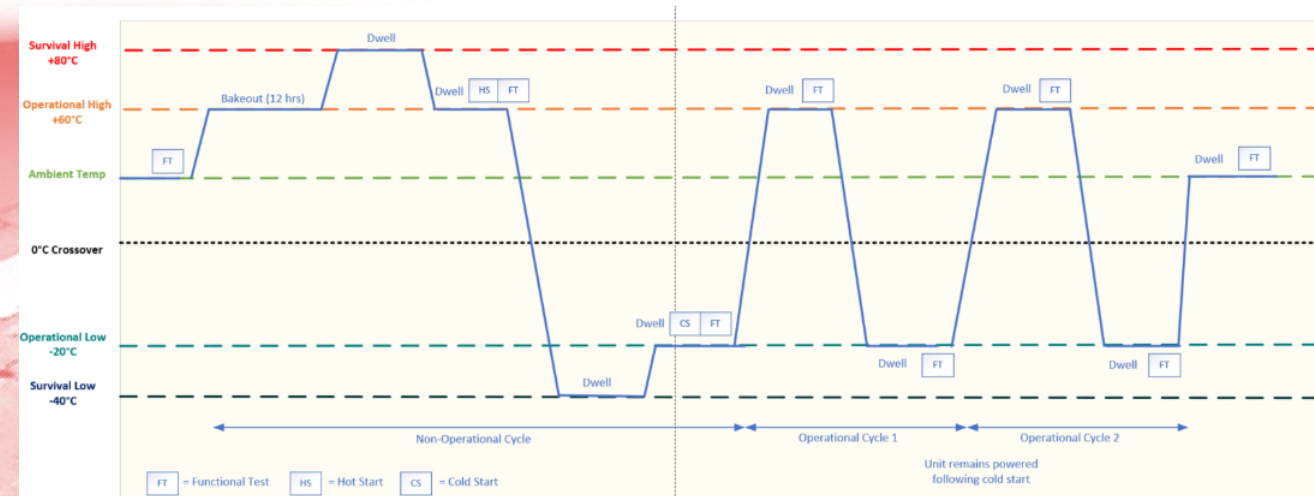
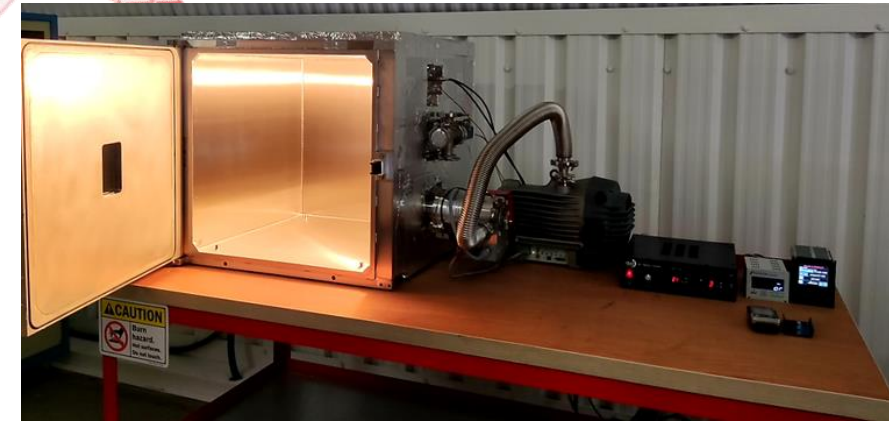
- Vacuum pressures
 - Reduced cooling capability
 - Component / material outgassing
- Mitigations
 - Compartmentalisation
 - Heat straps (conduction cooling)
 - Bakeout
 - Testing



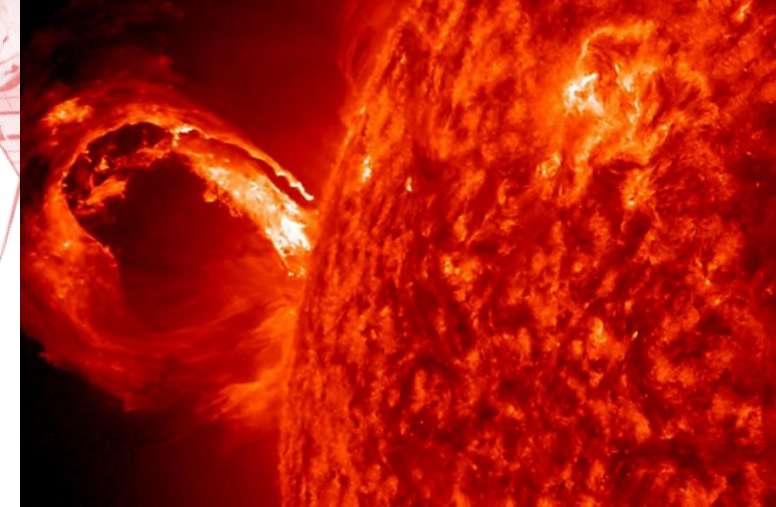
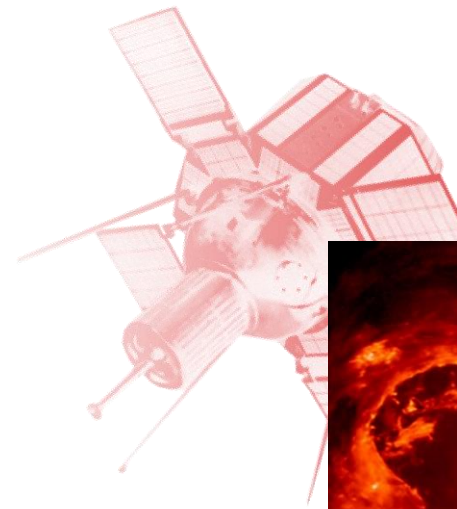
* Vacuum Testing



- Vacuum
 - More closely resembles space environment
 - Allows to test active thermal control
- T-Vac
 - Can assess outgassing effects
 - Can be used for bakeout



* Radiation



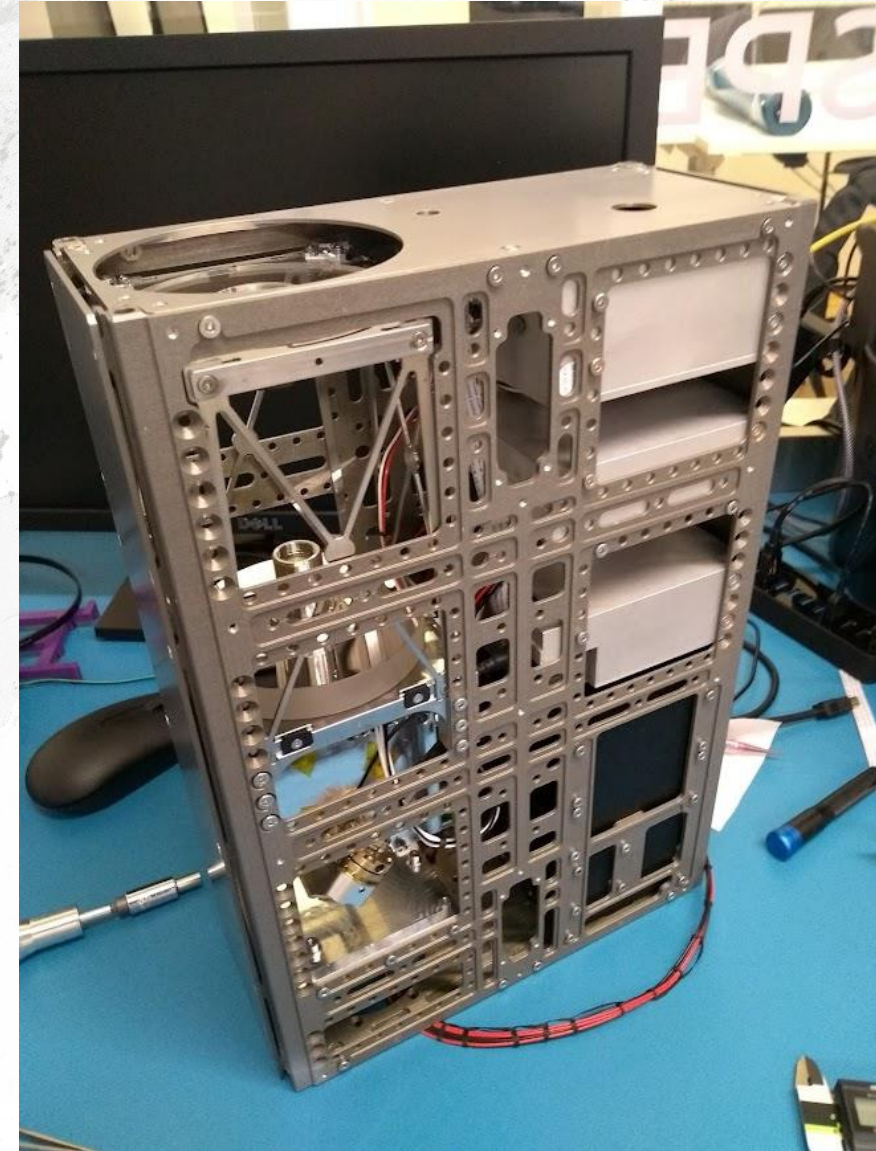
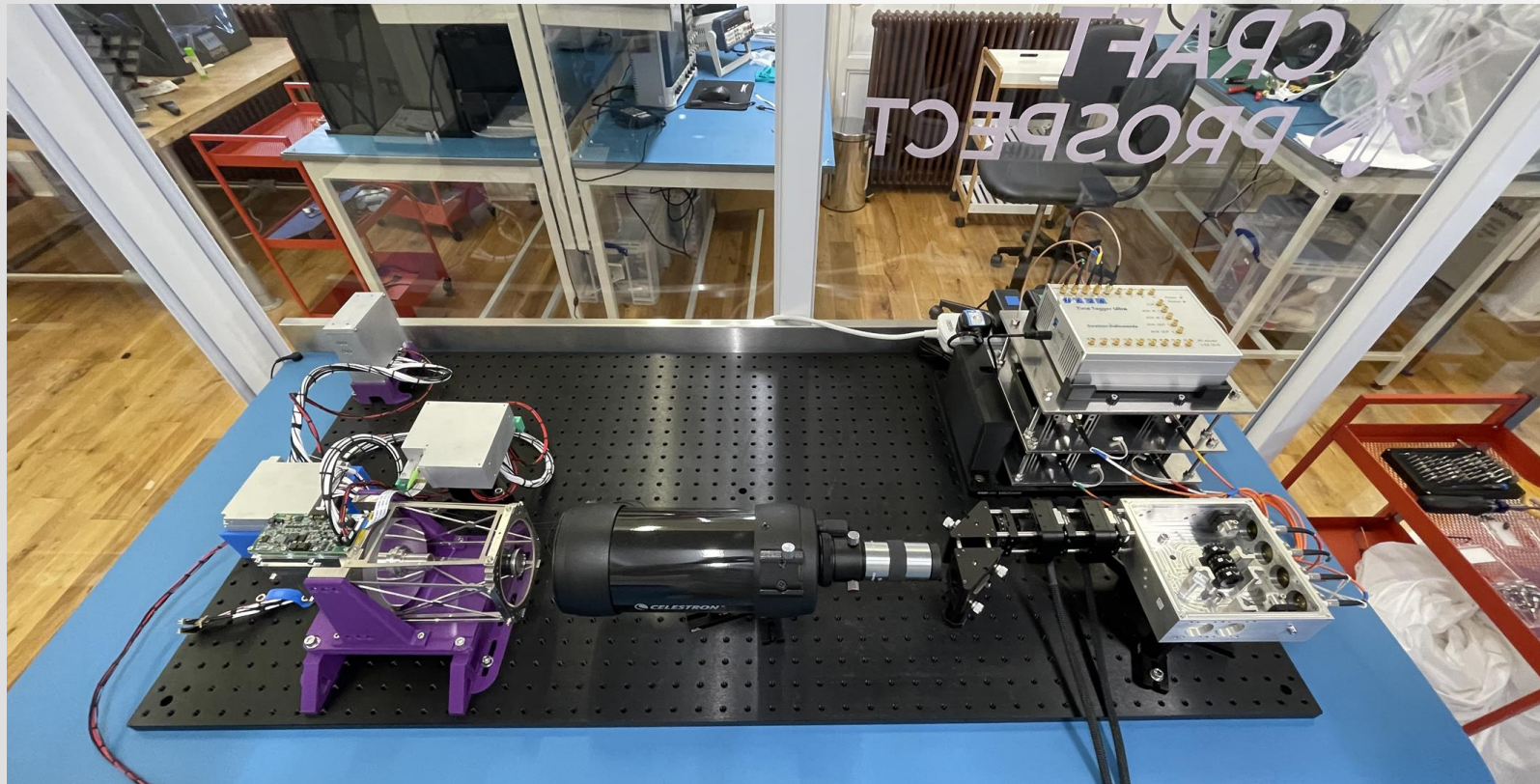
- Effects
 - Data corruption
 - Component degradation
 - Radiation induced attenuation / discolouration
- Mitigations
 - Component / material selection
 - Shielding of sensitive items
 - Redundancy
 - Testing



* Case Study: ROKS



- 6U BB84 QKD Satellite
- LEO (500 km altitude)



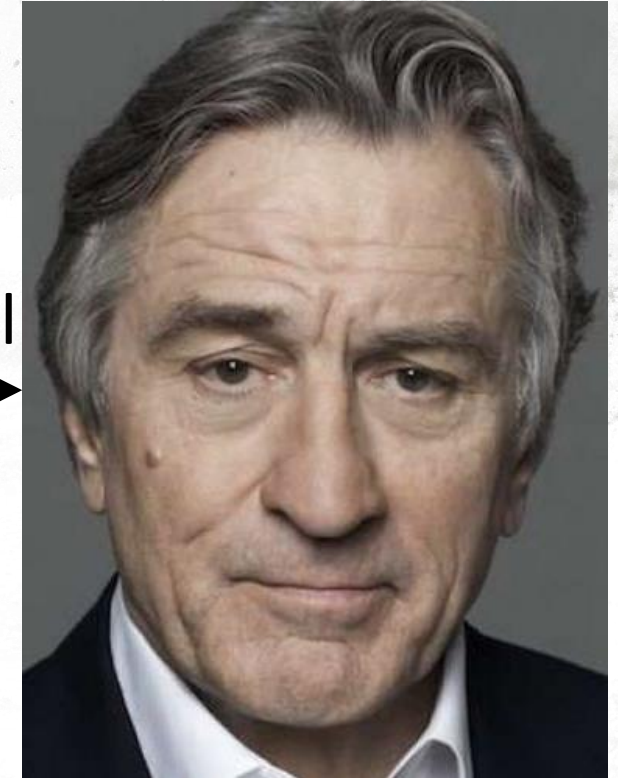
* Case Study: ROKS

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+	+	x	x	+	x	+	x	x	+	↖	↔	↗	↔	↗		↕	↕	↖	↗
↕	↔	↗	↖	↔	↖	↕	↗	↖	↔	0	1	1	1	1		0	0	0	1



Alice

Basis information over classical channel

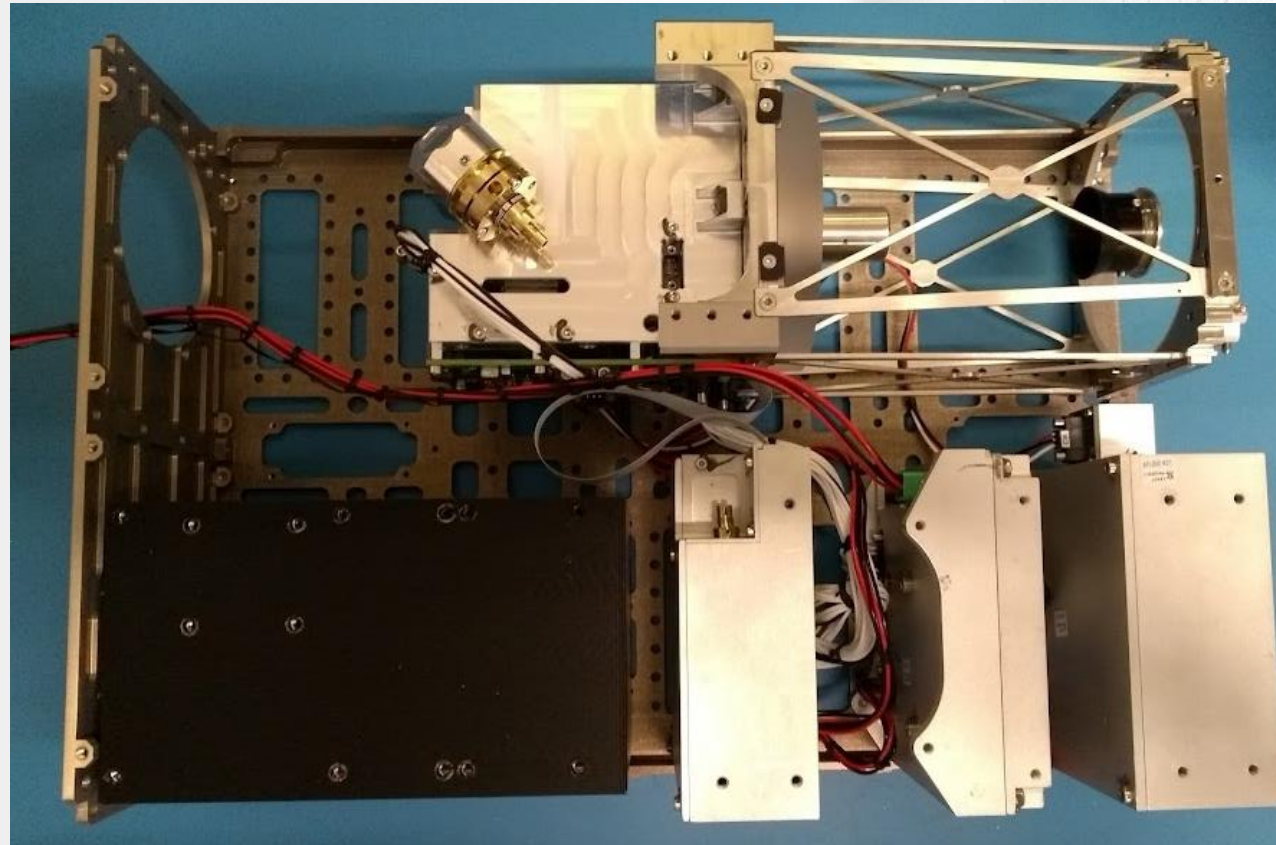


Bob



* Case Study: ROKS

Beam Steering Module



Optical
Telescope

Forwards
Looking Imager

Quantum
Source

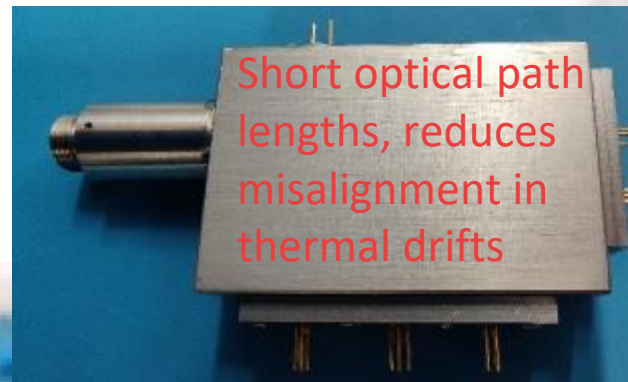
Payload
Computer



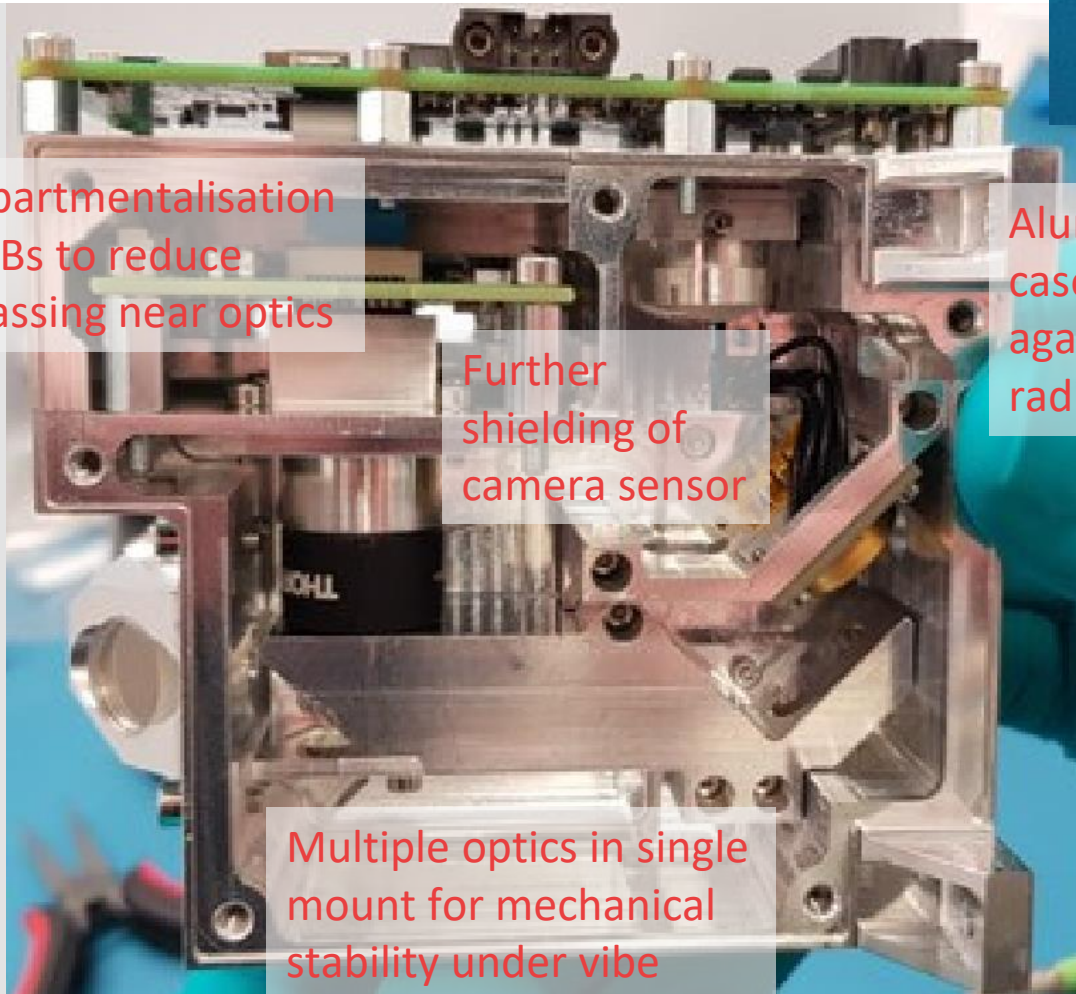
* Case Study: ROKS



Curved corners,
resilient under vibrate



Short optical path
lengths, reduces
misalignment in
thermal drifts

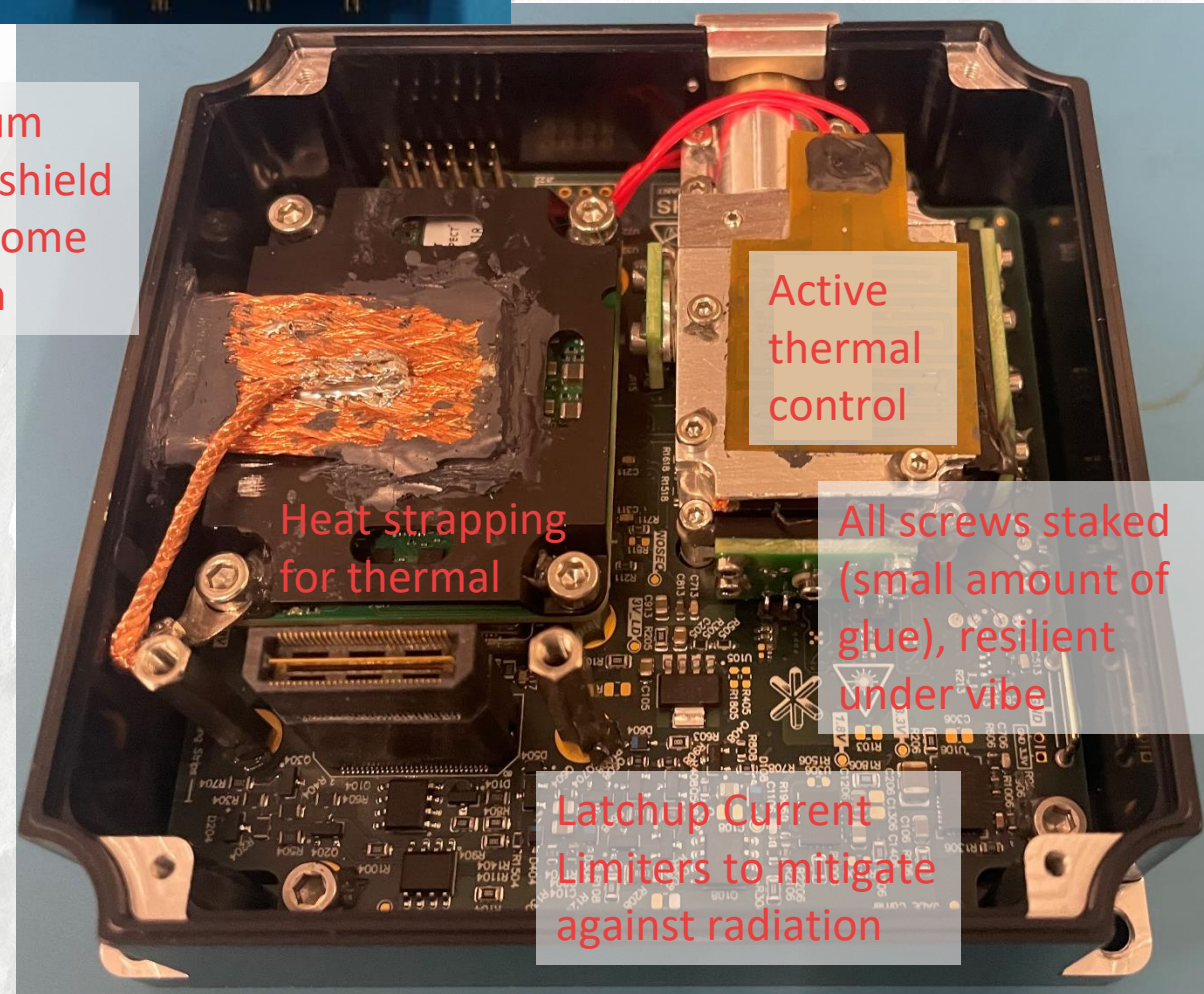


Compartmentalisation
of PCBs to reduce
outgassing near optics

Further
shielding of
camera sensor

Aluminium
cases to shield
against some
radiation

Multiple optics in single
mount for mechanical
stability under vibrate



Active
thermal
control

Heat strapping
for thermal

All screws staked
(small amount of
glue), resilient
under vibrate

Latchup Current
Limiters to mitigate
against radiation

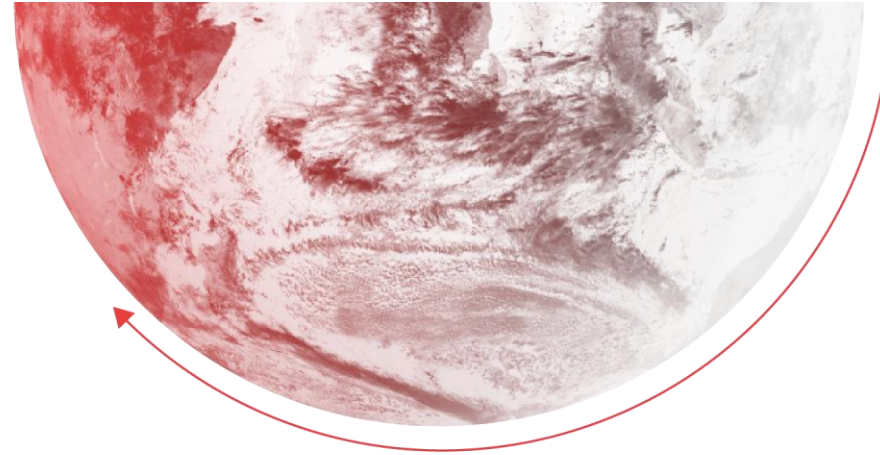


* Conclusions



- Space is difficult
- We are making strides towards space QT
- Component selection is critical, certification isn't
- Design for resilience
- Design to reduce misalignment
- Test everything
- Try to break modules before launch, not after





THANK YOU



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