UK Cold Atom Sensors: a Fast Track Demonstrator

Trevor Cross, Andy Vick (RAL Space), Steve Maddox

14th *Appleton Space Conference, 6th December 2018*

Outline

1 | Quantum Technologies & the UK National Programme

2 | Teledyne e2v & Cold Atom Sensors

3 | RAL Space & Quantum Technologies

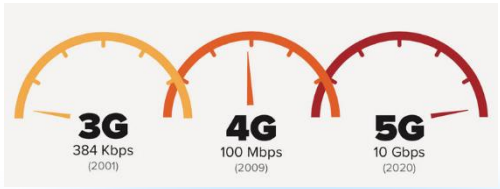
4 | Cold Atom Space Payload (‘CASPA’)

5 | Conclusion (AV)

Quantum Technologies

What is Quantum Technology?

- Utilising the properties and subtle effects of single or small groups of atoms or photons



5G networks

Quantum Computing

Master clock in space

Geodesy & Gravity science

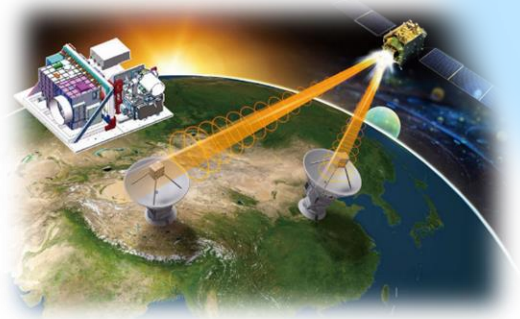
Secure comms QKD

Imaging with few photons

Precision sensing

Network synchronisation

Future GNSS



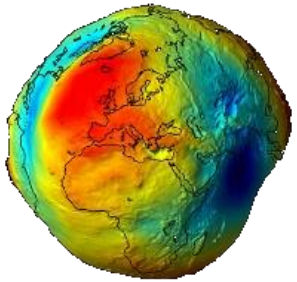
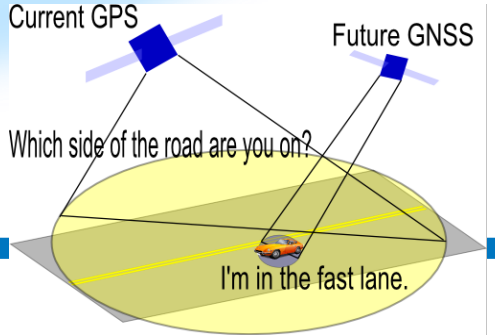
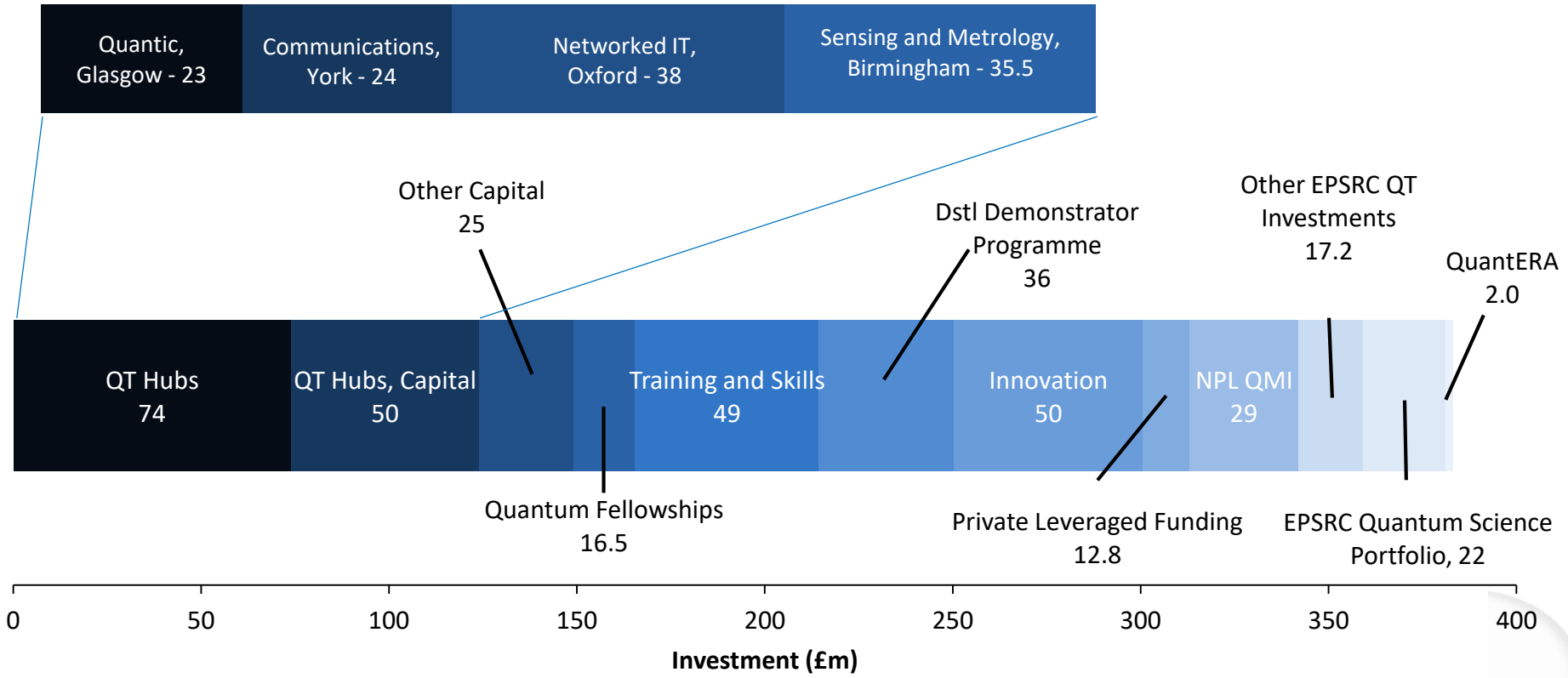


Photo: ESA/GOCE



Government Office for Science

Quantum Research in the UK



Initial UK £270M investment over 5 years in 2013; grown now to £385m; phase 2 for a further 5 years being planned at similar scale: £80m hub renewal already announced 9/2018 by Chancellor

TELEDYNE e2v Everywhereyoulook™

UK Quantum technology investment plan

pilot projects: Precision Navigation and Timing 2013

Chicheley quantum landscape document 2013

Demonstrator projects (2015-2019)

Quantum landscape document updated Chicheley (2016)

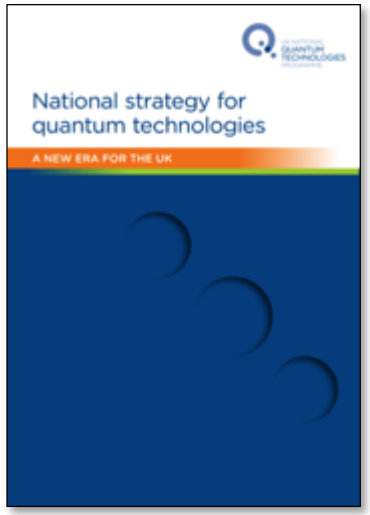
Timing and GPS vulnerability

National programme Phase 1 ~£405M (2015-2019)

Blackett report (2016)

Funding route for commercialisation

ISCF wave 2 "Pioneer" £20m (2018-2021)



National programme phase2 (2019-2024)

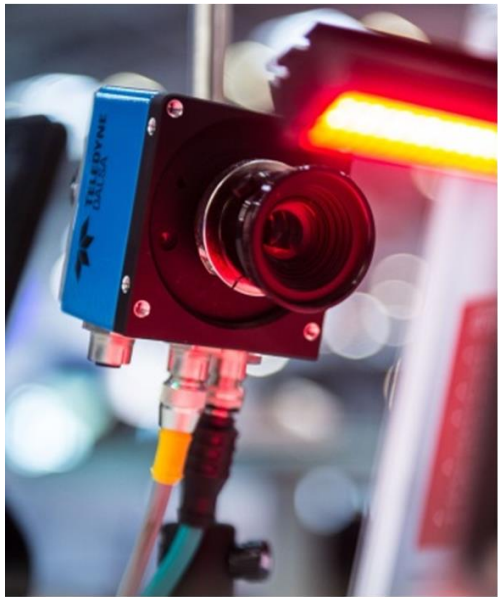
October 2018 Budget £315m

Initial UK £270M investment over 5 years in 2013; grown now to £405m; phase 2 for a further 5 years at similar scale: announced 11/2018 by Chancellor

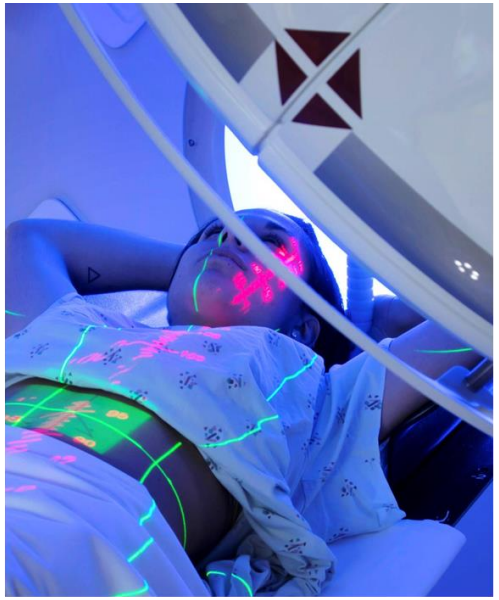
This is Teledyne e2v

Teledyne e2v - part of Teledyne Imaging

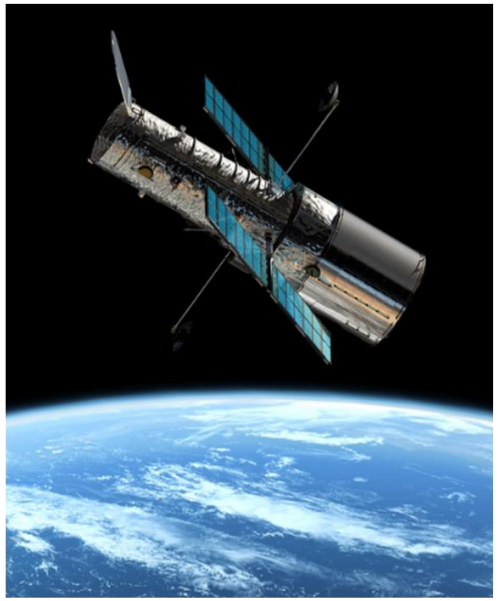
Part of the $3bn p.a. Teledyne group



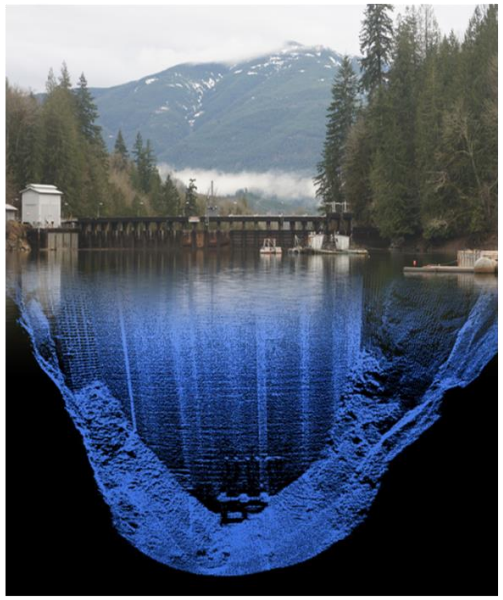
Machine Vision
DALSA | e2v | TS&I | ICM
Image sensors, cameras, processing hardware and software
Infrared, Visible, UV, X-Ray



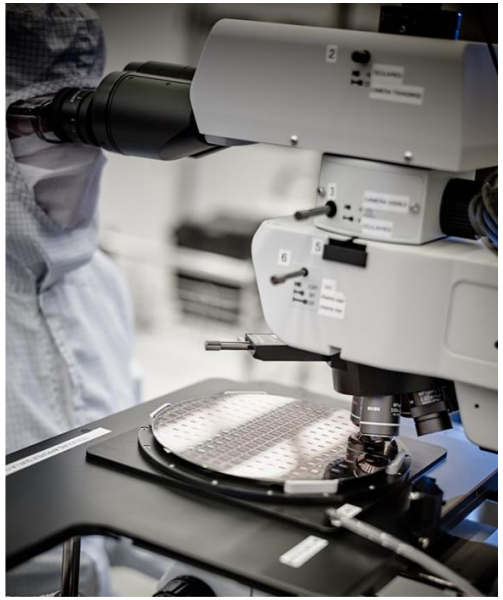
Medical and Life Sciences
DALSA | e2v
Radiography detectors, Radiotherapy generators



Aerospace & Defense
e2v | TS&I | DALSA
Sensors and systems for astronomy, earth science, and defense
High reliability chipsets & subsystems



Geospatial
Optech | CARIS
Lidar & Sonar 3D Surveying, Geographic Information Systems Software



Semiconductors
DALSA | e2v
MEMS foundry
CCD foundries
Packaging services

A remarkable portfolio of specialist components & systems in sensing, signal generation and processing

Teledyne e2v and Quantum

Quantum Technology at Teledyne e2v

Gravity

Using gravity to detect objects beneath the ground for the construction sector and defence.

Space

Gravity sensing from space for future science missions.

Timing from space for navigation and synchronisation.

Timing

Synchronisation of large networks in telecoms, navigation and synthetic aperture radar for defence.

Scale: Projects, Partners, Team

Projects

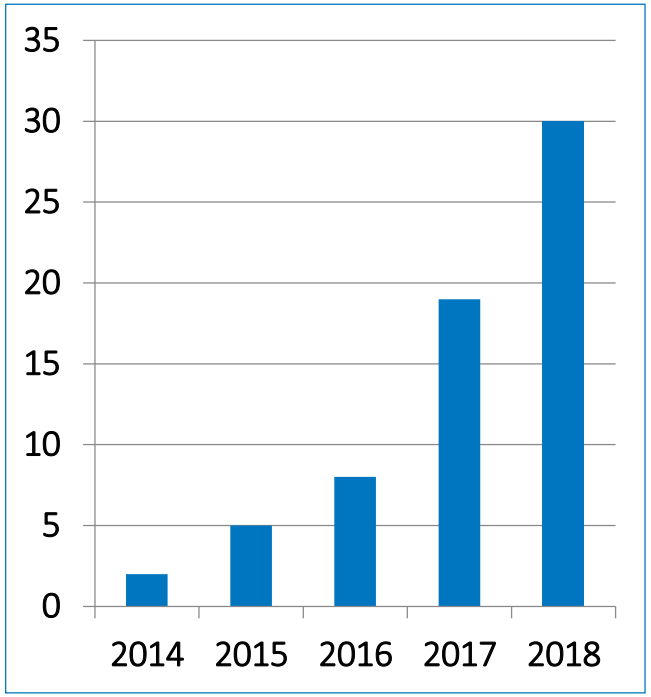
A growing portfolio….

- FREEZERAY (Cold atom preparation)
- Gravity Imager [Dstl]
- REVEAL (commercial gravity sensor)
- Gravity Platform (ruggedization)
- MinAC (miniature atomic clock)
- CASPA (cold atom space payload)
- NSTP-2 (atomic clock for space)
- Sub-Orbital (space payload study)
- SYNCHRONICITY (atomic clocks)
- QUANTIFY (Earth observation)
- GRAM (Gravity new applications)
- Ixon Science camera (with Andor)
- *KAIROS (Pioneer)*
- *Gravity Applications (Pioneer)*
- *QKD via satellite (ARQIT - Pioneer)*

Partners(*)

University of Birmingham
NPL National Physical Laboratory | QMI Quantum Metrology Institute
University of Southampton
RSK
XCAM
Clyde Space
Magnetic Shields Electromagnetic Engineering
Fraunhofer UK
optocap
ANDOR an Oxford Instruments company
AIRBUS DEFENCE & SPACE
ICS
LEONARDO
covesion
Geomatrix Earth Science Ltd
HCD
CATAPULT Satellite Applications
University of York
UNIKLASERS
NetworkRail
Cardiff University
QinetiQ
aLTRan
hs2
UK SPACE AGENCY
EPSRC
ATKINS
[dstl]
Innovate UK

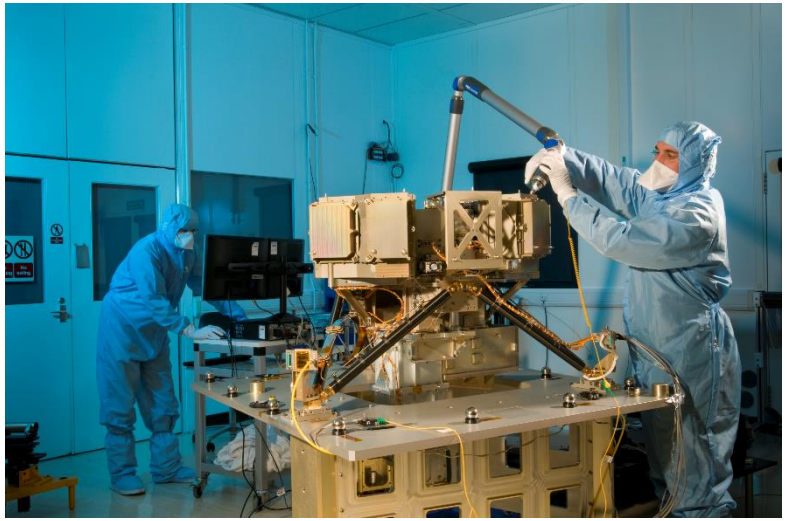
Team

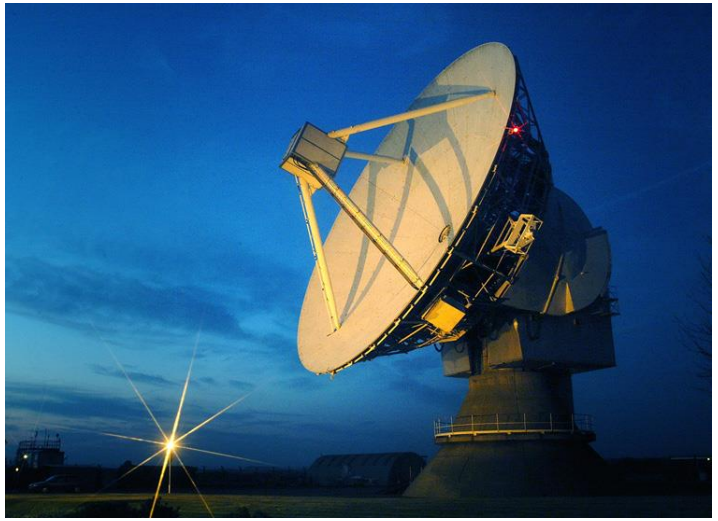


Full time equivalent staff at Te2v

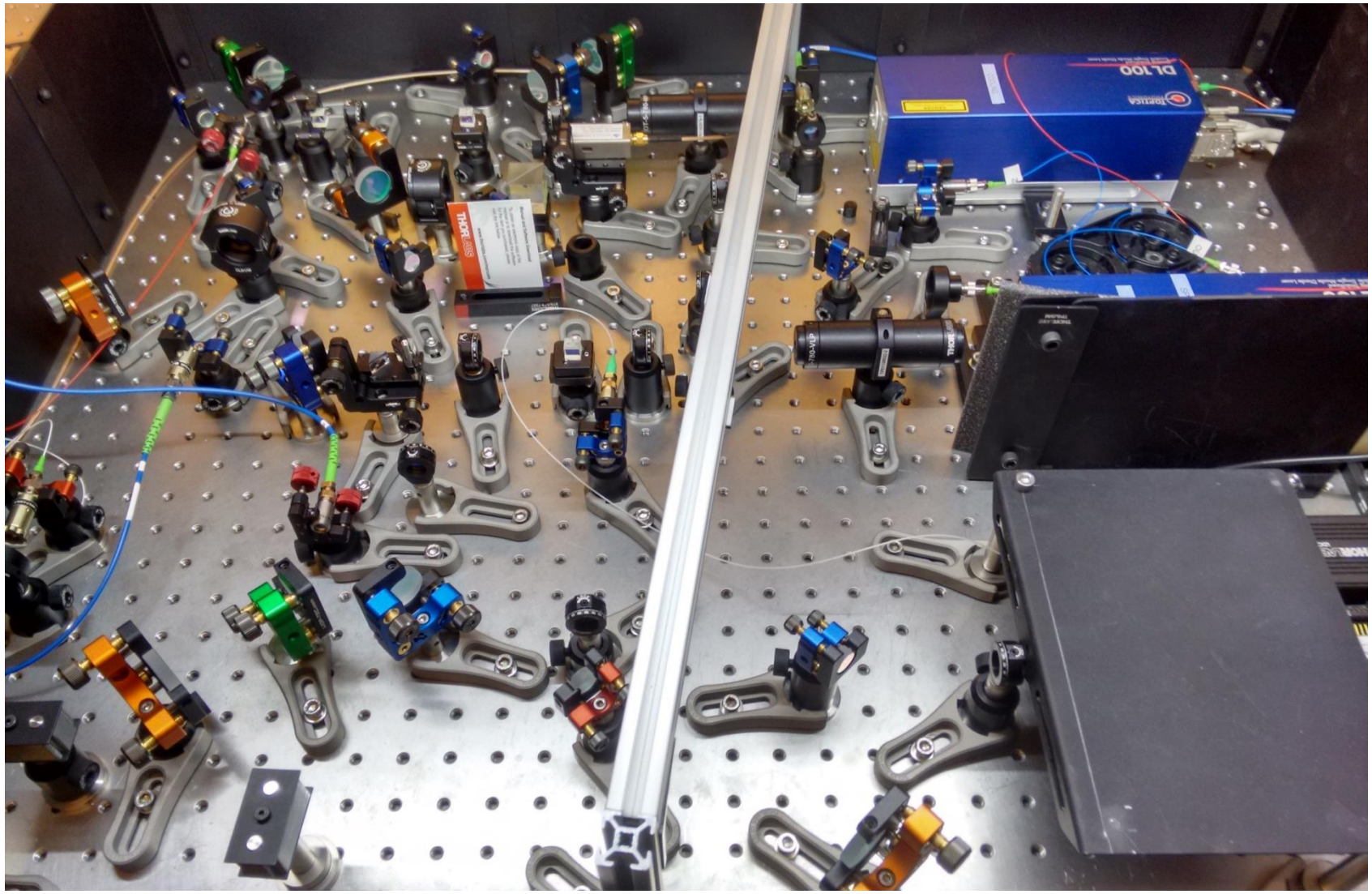
(*) CR&D partners in Innovate UK projects

RAL Space and Quantum

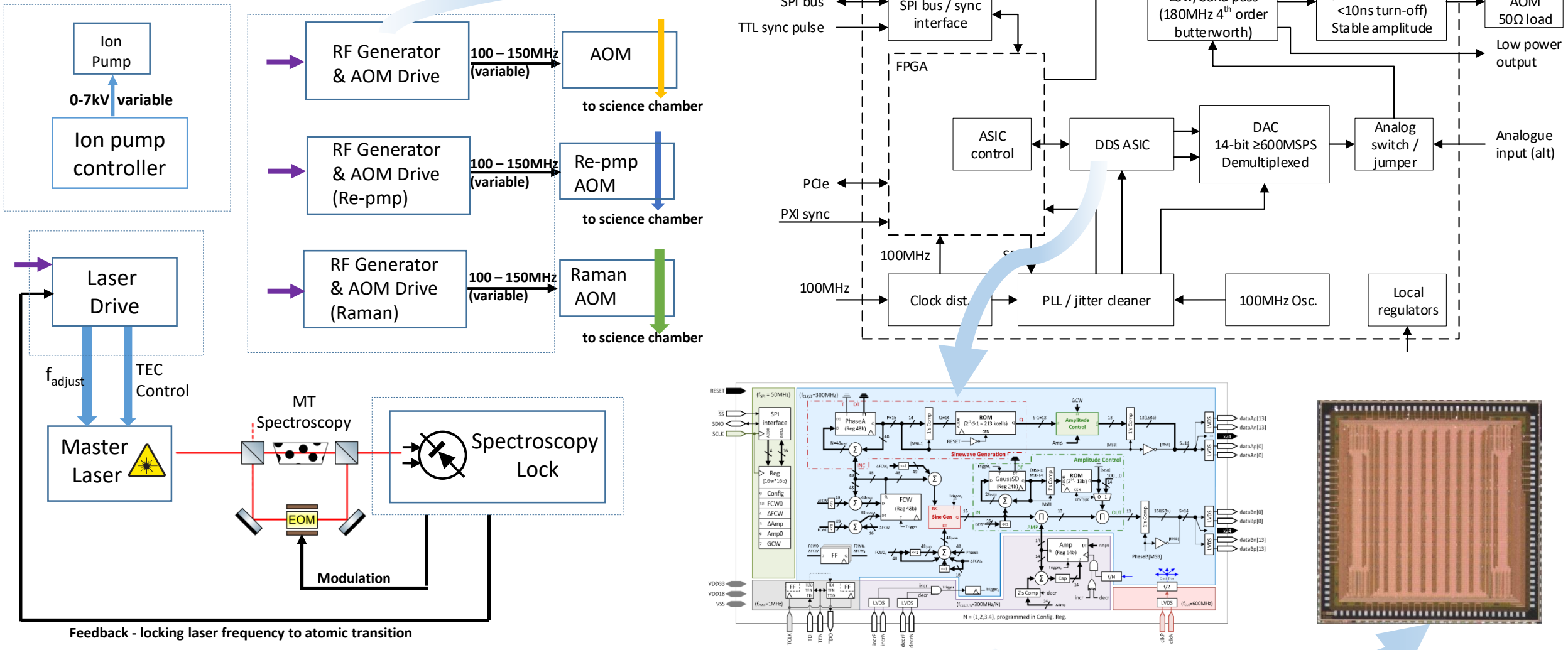




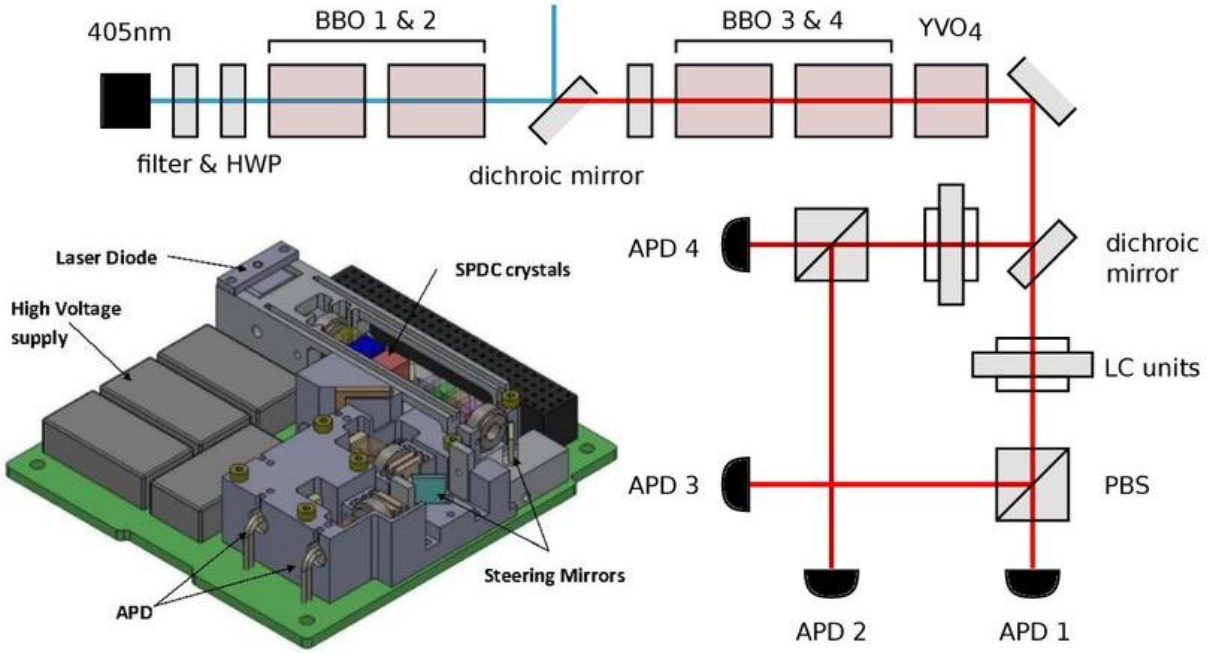
RAL Space Quantum Technology



McLaren: Space CA Electronics



Quantum Space Laboratory



QKD QUBESAT

RAL Space

Centre for Quantum Technologies

National University of Singapore

QUANTUM COMMUNICATIONS HUB

The Fast Track Demonstrator

Cold Atom Space Payload
(CASPA)

CASPA: Cold Atom Space PAyload

Project Lead: Teledyne e2v

Mission

Build a 6U CubeSat capable of autonomously producing a cold atom cloud in the space environment.

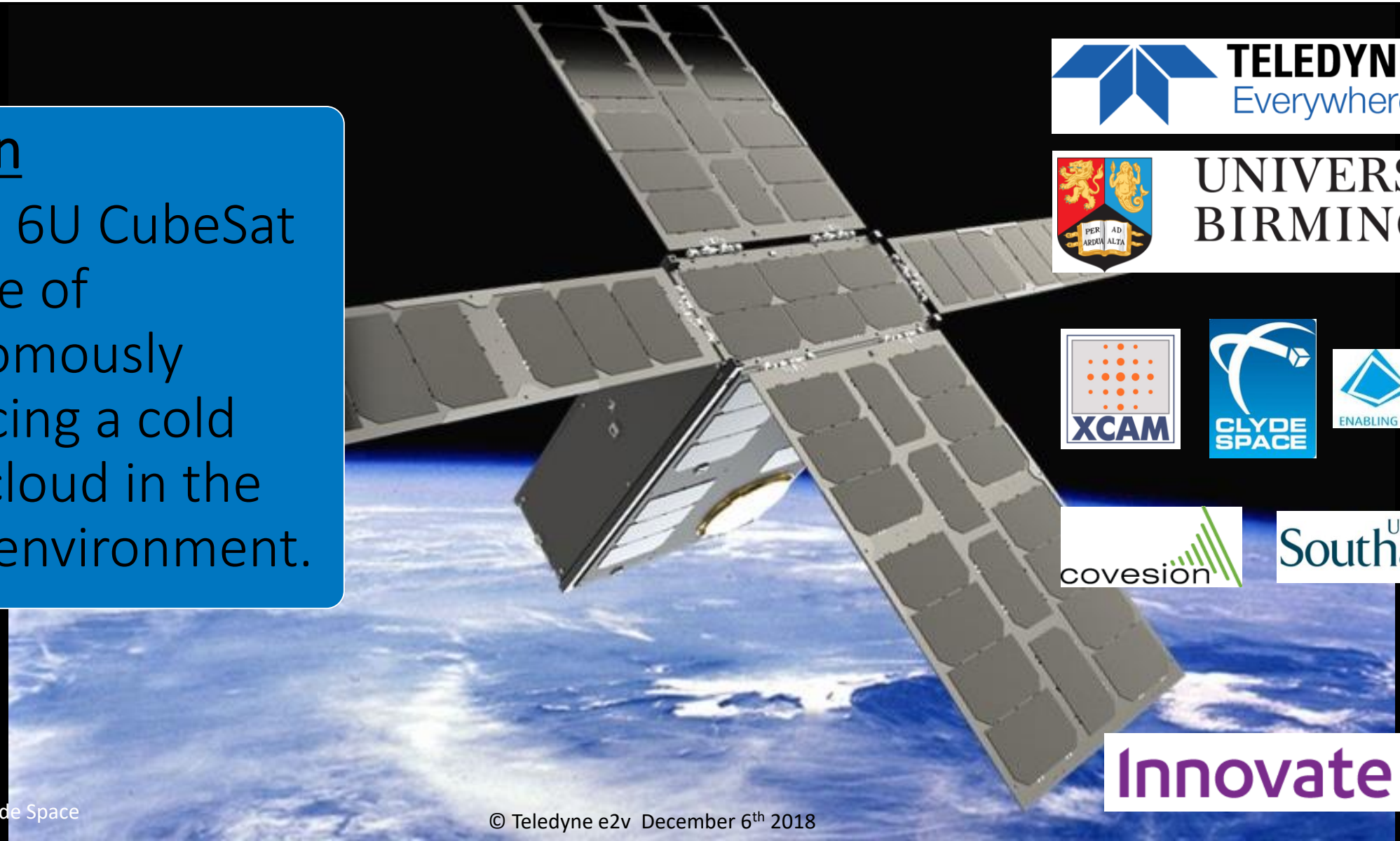
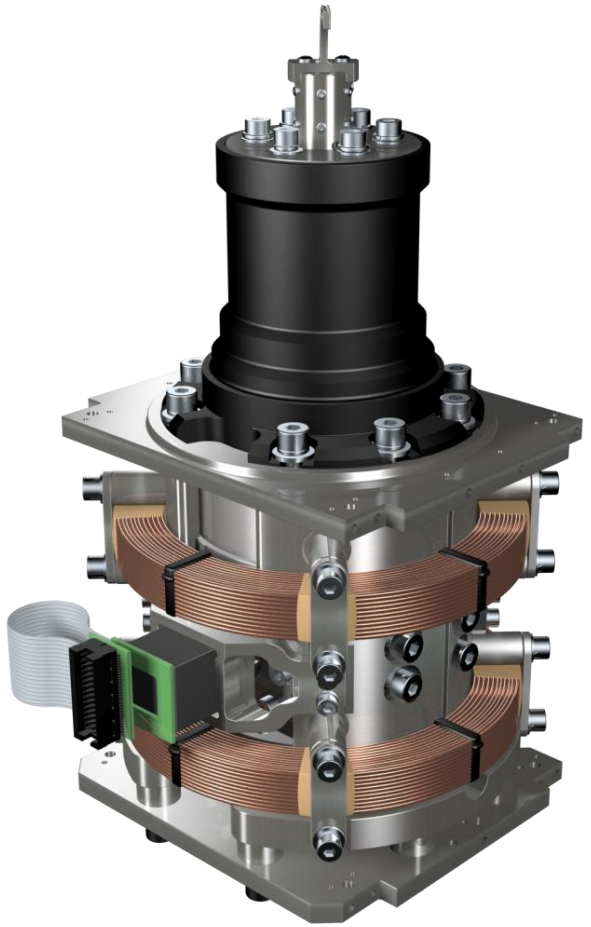


Image courtesy of Clyde Space

Why CASPA?

- Strategic technology for ESA and NASA with additional commercial applications
- Hindered by high complexity and low TRL
- CASPA first step to address complexity, increase robustness, build TRL, develop supply chain
- UK capability and supply chain for future cold atom space instruments (building on e2v heritage in vacuum and space instrumentation)
- CubeSat constraints provide useful focus for setting clear but challenging engineering challenge



CASPA Spacecraft

- **6U** CubeSat
- **4U** payload
- **40W** peak power
- Payload mass <**4kg**

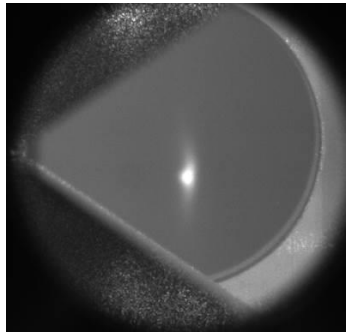
Breadboard Integration

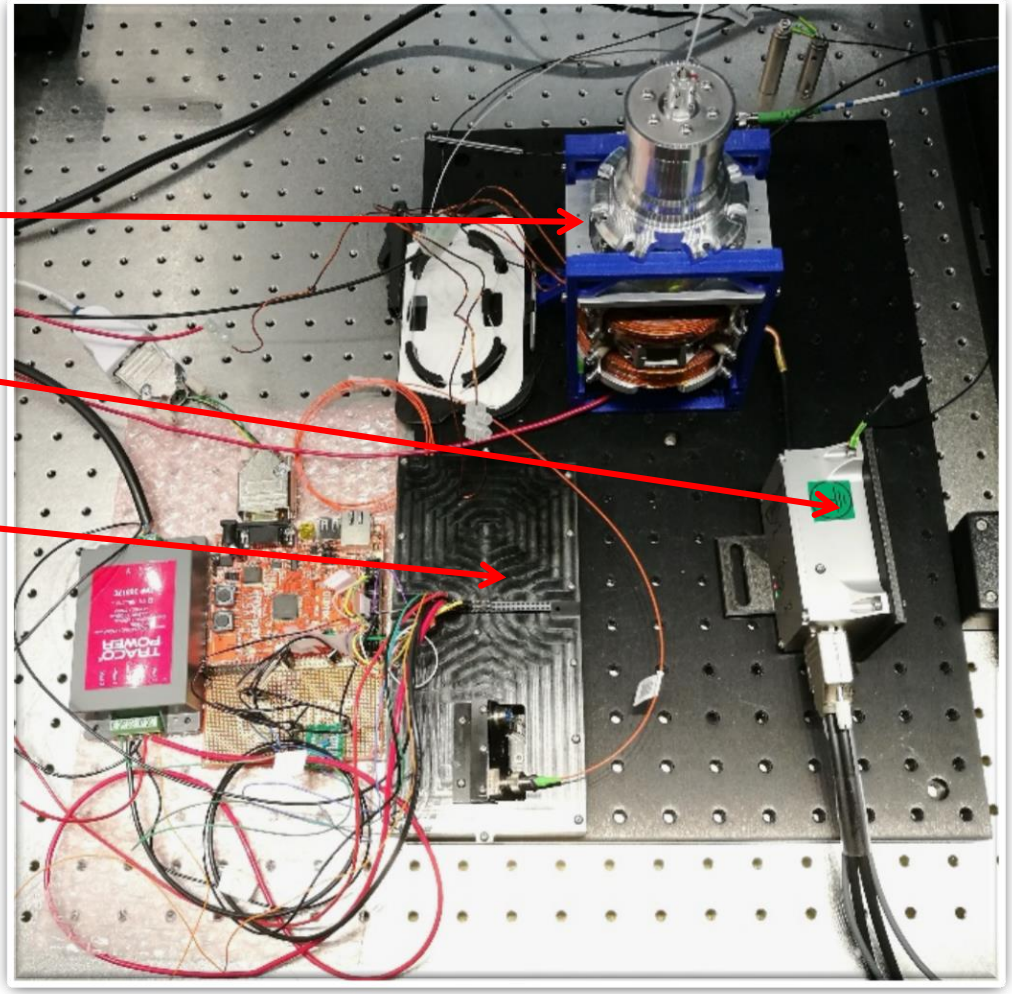
The University of Birmingham

Physics package – Vacuum Assembly and Telescope

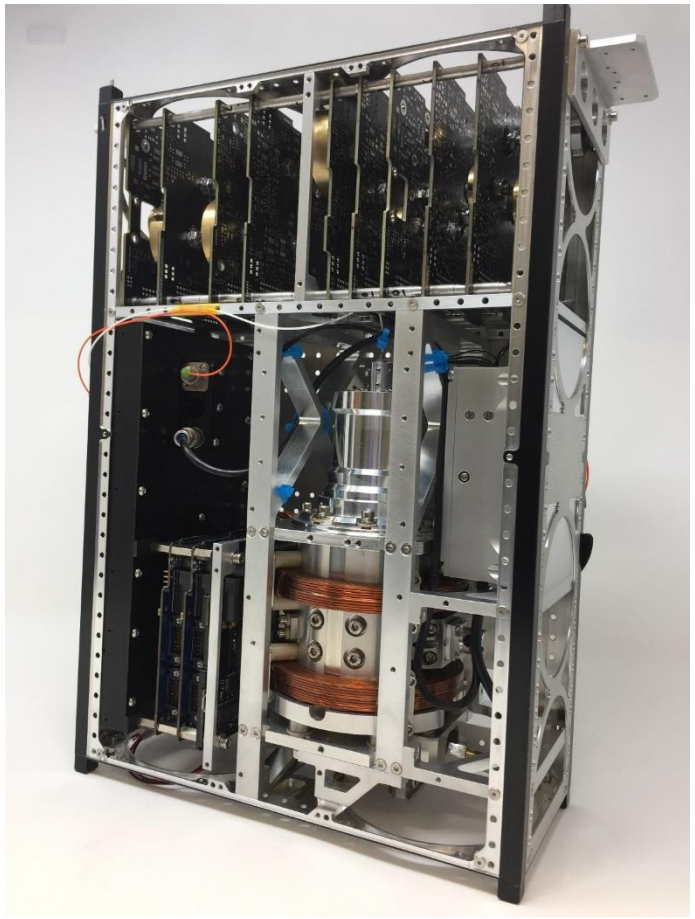
High Voltage Power Supply

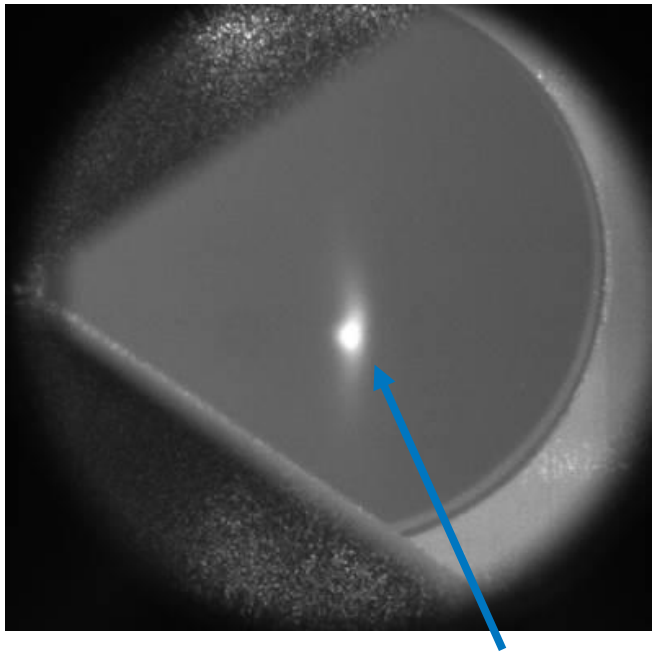
Integrated laser system





Engineering Model Integrated

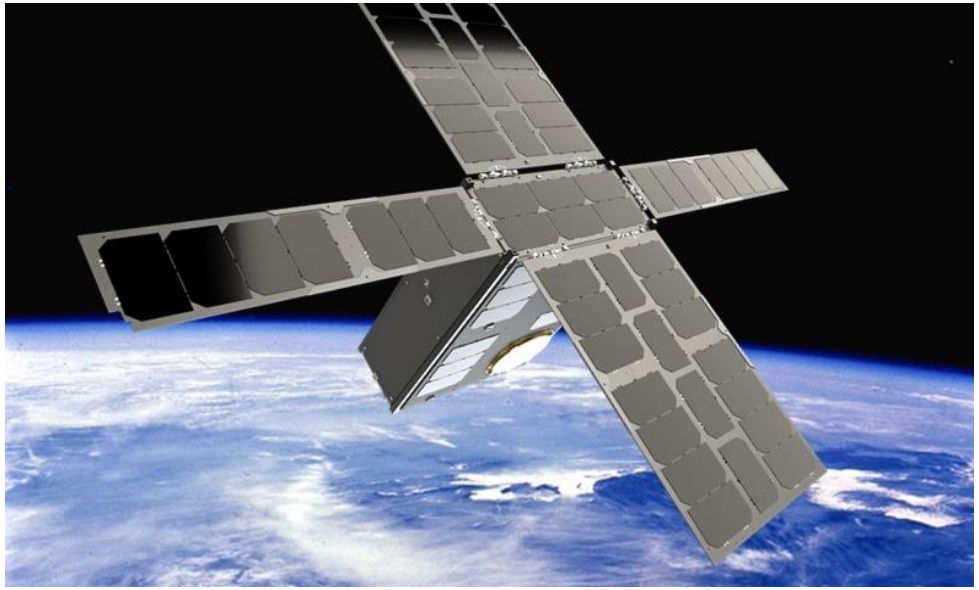




10^7 atoms at microkelvin temperatures

Next Phase

- CASPA project has developed much of necessary hardware / capability
- In parallel, RAL Space has developed complimentary electronics capability and other UK organisations have developed leading technology in this area
- The UK now has the capability to lead in this area
- Now is the time for the UK community to pool resources and take a leadership position by rapidly moving to an in-orbit demonstration.



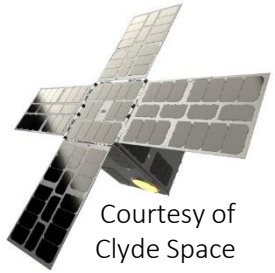
Options for scale up

Time and cost to launch

Cold atoms (tech demo)
e.g. 6U CASPA CubeSat

Courtesy of Clyde Space

Low sensitivity sensor (tech demo)
e.g. 12U+ CubeSat



Courtesy of Clyde Space

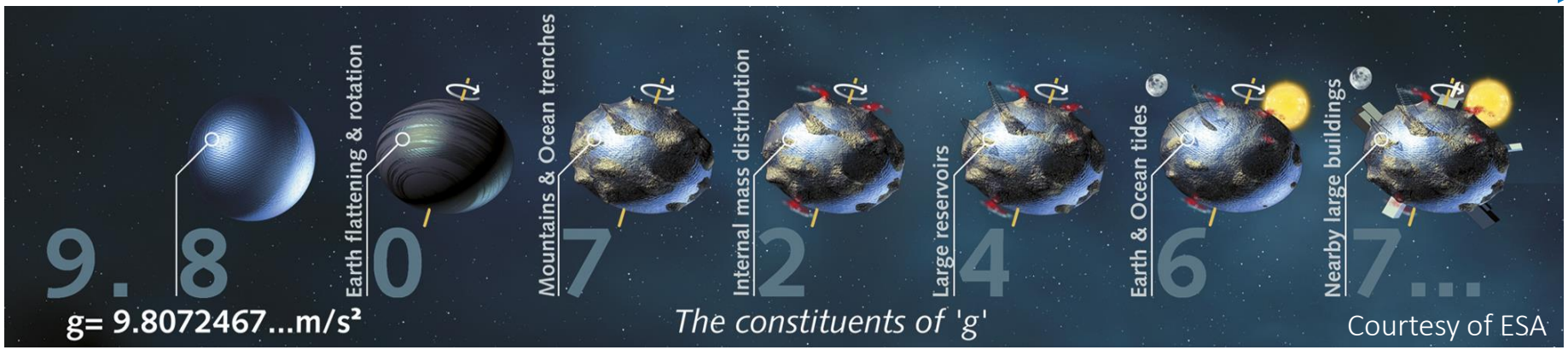
Mid sensitivity sensor (science / commercial applications)
e.g. SSTL 42 platform

Courtesy of SSTL

Courtesy of ESA

High sensitivity sensor (science mission)
e.g. GOCE

Functionality/Sensitivity



TELEDYNE e2v
Everywhereyoulook™

Benefits

- Leveraging the significant investments in the current and future UK National Quantum Technology programme
- Combines best offerings from UK Quantum Sensors for Space community (industry, SME's, academia, RTO)
  - Develops UK capability in a strategic future sensor technology
  - Lots of non-Space spin off applications
  - Big supply chain opportunities
- Builds on UK strength in cost effective, small satellite technology
- Potential to use the planned UK's Scottish small sat launch facility
- Potential to use the National Space Test Facility at Harwell

Conclusions

Where to next

Develop the mission specifications;

- Systems, Gradiometer hardware : Teledyne E2V
- Electronics, optics : RAL Space

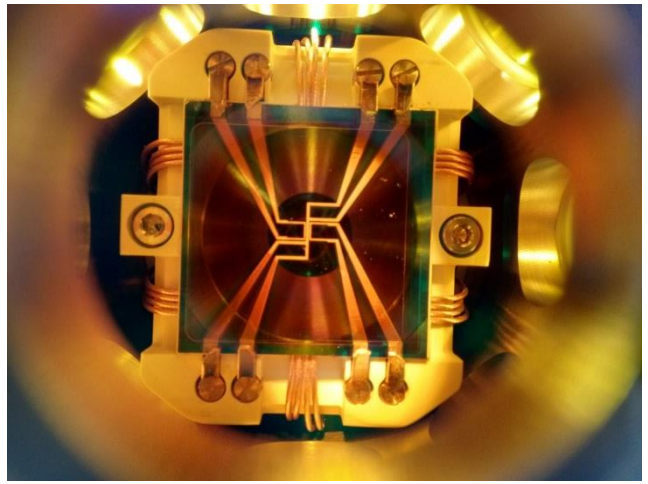
Accelerate developments in key areas;

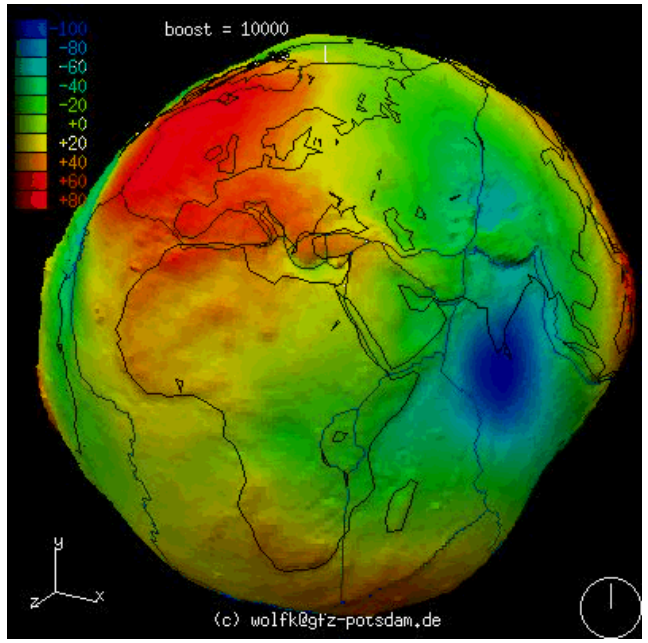
- Lasers and laser control systems
- System level control, data handling

Build support and a business case

- Users (hydro, civil-eng, minerals)
- Science community

Makes the UK the World leader across science and commercial QT applications





Conclusion

- With thanks to the CASPA team:

- With thanks to RAL Space and STFC

Thank you