Systems Engineering & Assessment Ltd: Improving Space Radar Instrument Performance Using Precision Transponders

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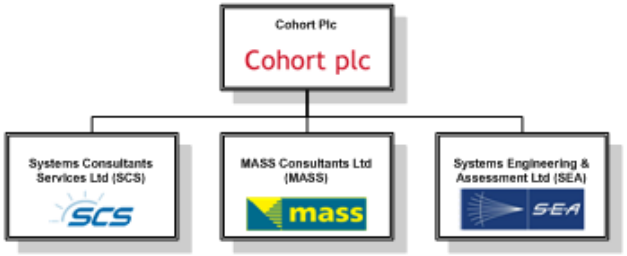
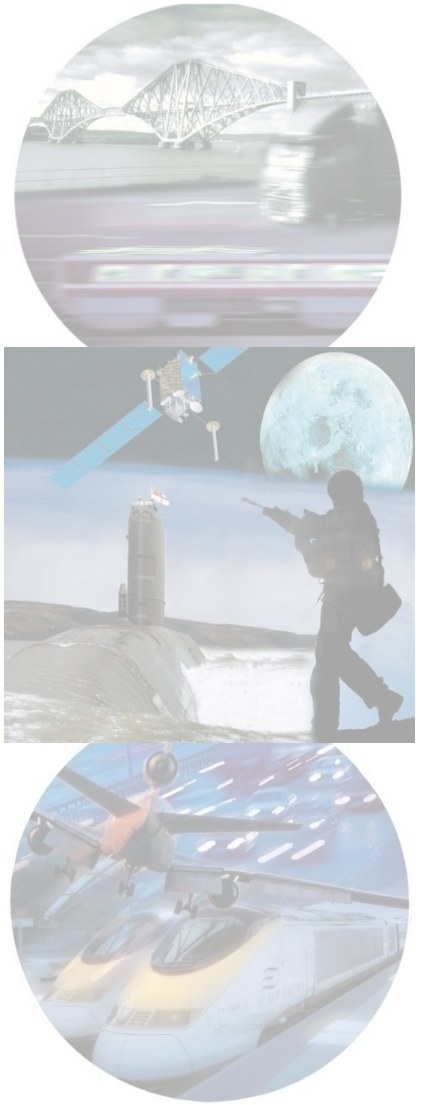


Topics for This Presentation

- **Systems Engineering and Assessment Ltd**
  - Who we are and what we do
  - Our preferred ways of collaborating
- **Transponder technologies**
  - Synthesised scattering targets to assure accurate radiometric calibration of space based radars
  - Underlying backend can also be used as test equipment as part of radar calibration before launch.
  - Much cheaper compact phase stable units as an alternative to corner reflectors to provide coherent targets for SAR Interferometry

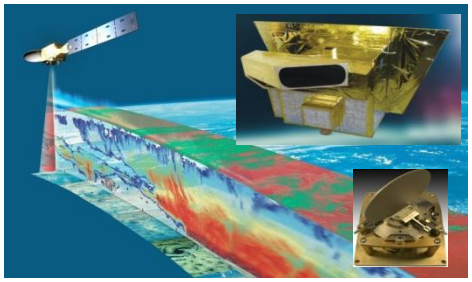
SEA Overview

- Provider of specialist electronic systems for the Defence, Space and Transport markets
- Approx 250 Staff - >80% professional engineers qualified to degree level or above
- Offices in Beckington and Bristol
- Six core areas of capability
  - High reliability systems for Space applications
  - Training, simulation and information systems
  - Communications
  - Research & Consultation
  - Managed Services
  - Sensor Processing Products



SEA From submarines to space

data recorders & wireless sensing for equipment monitoring

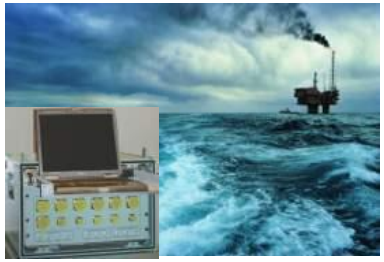


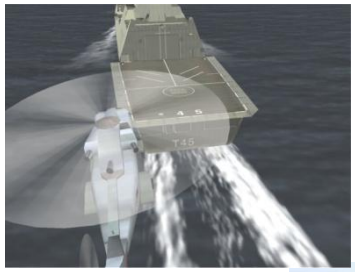
Space flight instruments and electronics

digital traffic enforcement

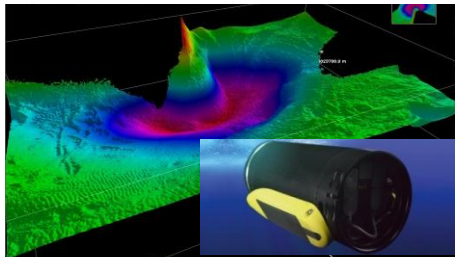
Test and Calibration equipment

novel sensor networks





Simulation & visualisation of complex systems



Sonar systems for sub-sea survey

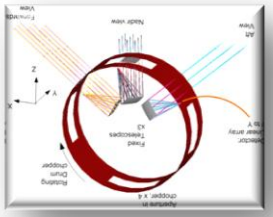
Sensor data capture, & communications

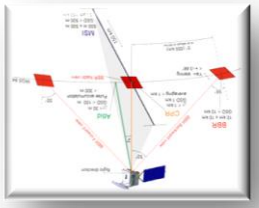
Space flight Capability

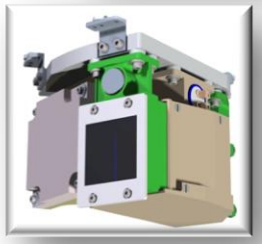
High reliability systems for space applications

Space Instruments

- BroadBand Radiometer

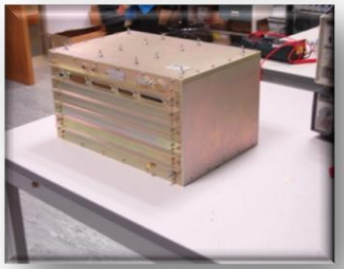






Interface units for use on satellites and satellite instruments, including flight verified SpaceWire implementation

- Bepi Colombo
- Earthcare



Technology Development

- MEMS rate sensors / accelerometer
- RF Wireless
- Space nuclear (thermal) power sources
- Contactless power and data transfer
- Bio-containment technologies

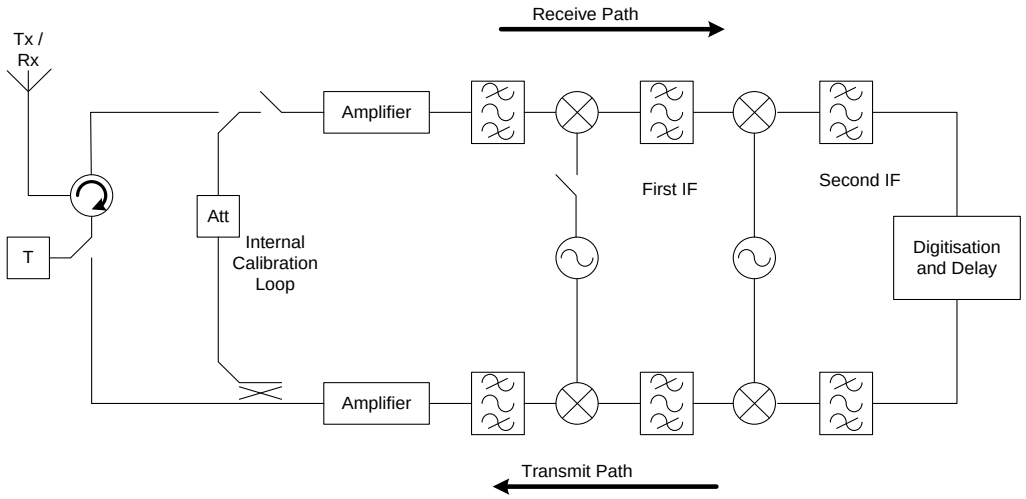
Collaboration to Mutual Benefit

- **Assembling the right team to deliver a custom solution**
  - EarthCARE Broadband Radiometer with Rutherford Appleton Laboratories, Scisys, ESTL & Sula,
  - MEMS Rate Sensor with Atlantic Inertial systems & Selex Galileo
  - RF Wireless with Astrium SAS, Swedish Space Corporation University of Bristol and Agusta Westland
  - Space Nuclear Power with National Nuclear Labs, Dalton Institute, University of Leicester, University of Oxford and RAL
  - MSR Sample Receiving Facility and PP Research with Health Protection Agency, Bovis Lendlease, Natural History Museum, Open University and Imperial College London
  - Passive microwave radiometer elements with Astrium UK, JRC Systems, RAL, RPG
- **We are open to working together for a common interest**
  - Perhaps we could be working with you?

Radar Calibration Transponders

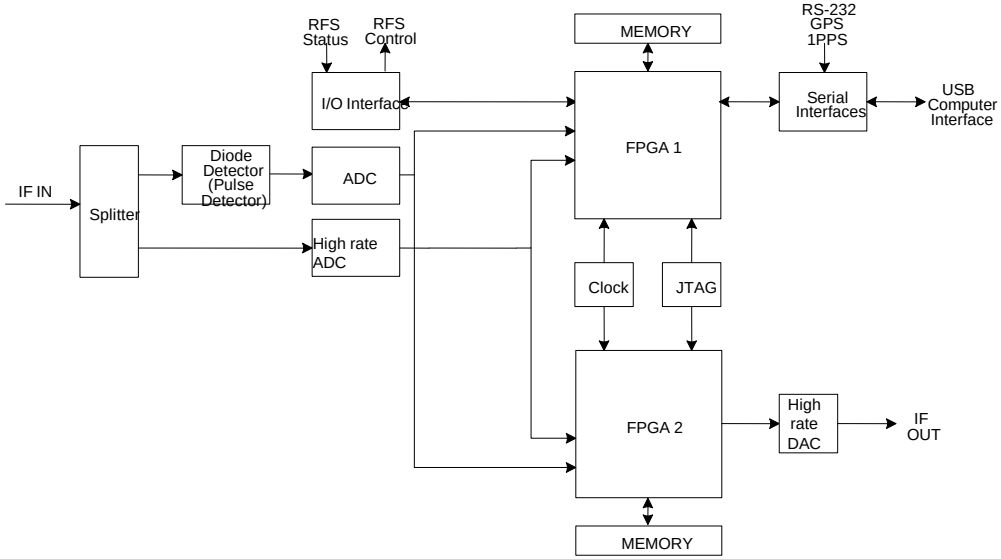
- **Provide a simulated target for use in calibrating radar instruments**
  - Capable of providing radar cross section of >100dBm^2
  - Capture and record received chirp
  - Potential to delay, modify or substitute with test signals
- **Very powerful tool to characterise**
  - Radar electronics degradation
  - Antenna pattern changes
  - Atmospheric effects
- **Relatively cheap infrastructure on the ground to improve radar performance**
- **Complimentary to ground test equipment**

Architecture Principles



- **Instrument specific front end**
  - receiving antenna,
  - receiver & down converter
  - transmitter & up converter
  - transmitting antenna

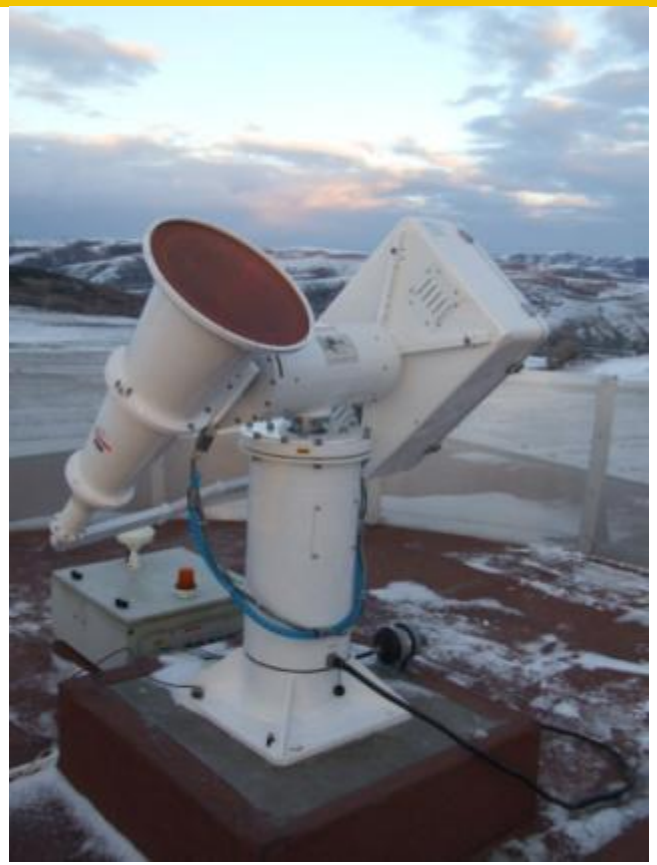
- **Digital back end**
  - Time synchronisation
  - Pulse detection & capture
  - Pulse chracterisation, manipulation & retransmission
  - Generation of test signals
  - Monitoring and Control

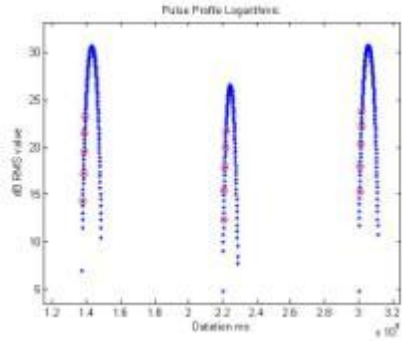


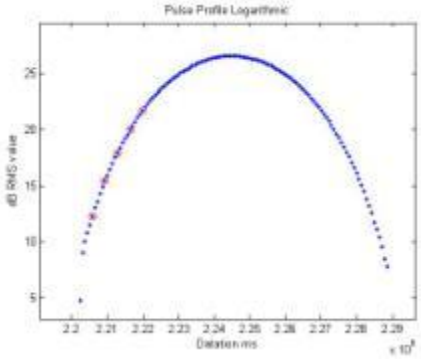
Met*Op* advanced scatterometer: calibration transponders

Operational Calibration Transponders

- three ground stations deployed across Turkey
- operational since April 2007
- autonomous operations; remote diagnostics via internet
- **Achieved Amplitude stability is 98.10±0.05dBm^2**
  - Four times better than specification
  - Orders of magnitude better than ground targets
- **Met product quality/fidelity exceed those of US equivalent satellites.**
- Post Delivery Support to EumetSat for life of MetOp satellites

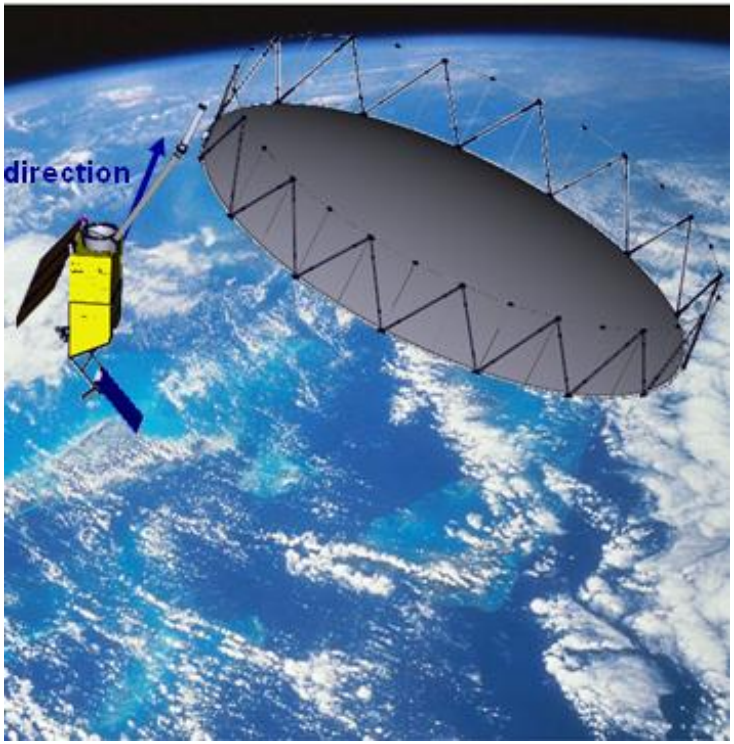






BIOMASS & COREH$_2$O Calibration

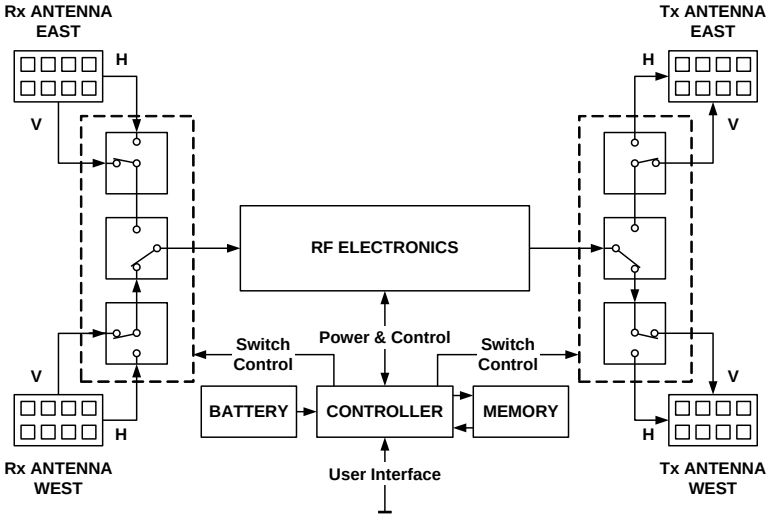
- **SEA are developing both external calibration concepts**
- **BIOMASS (P Band for vegetation)**
  - Very large antenna will offer calibration challenge for characterisation
  - Specific approach required to solve Ionospheric disturbance problems
    - Dual frequency approach (similar to GPS) being studied
    - Direct measurement using top side sounder would exceed mass budget
  - Approach potentially applicable for L band
- **COREH$_2$O (Ku & X for snow & ice)**
  - Antenna sizes much more manageable
  - Site selection to optimise performance (atmospheric humidity & precipitation)



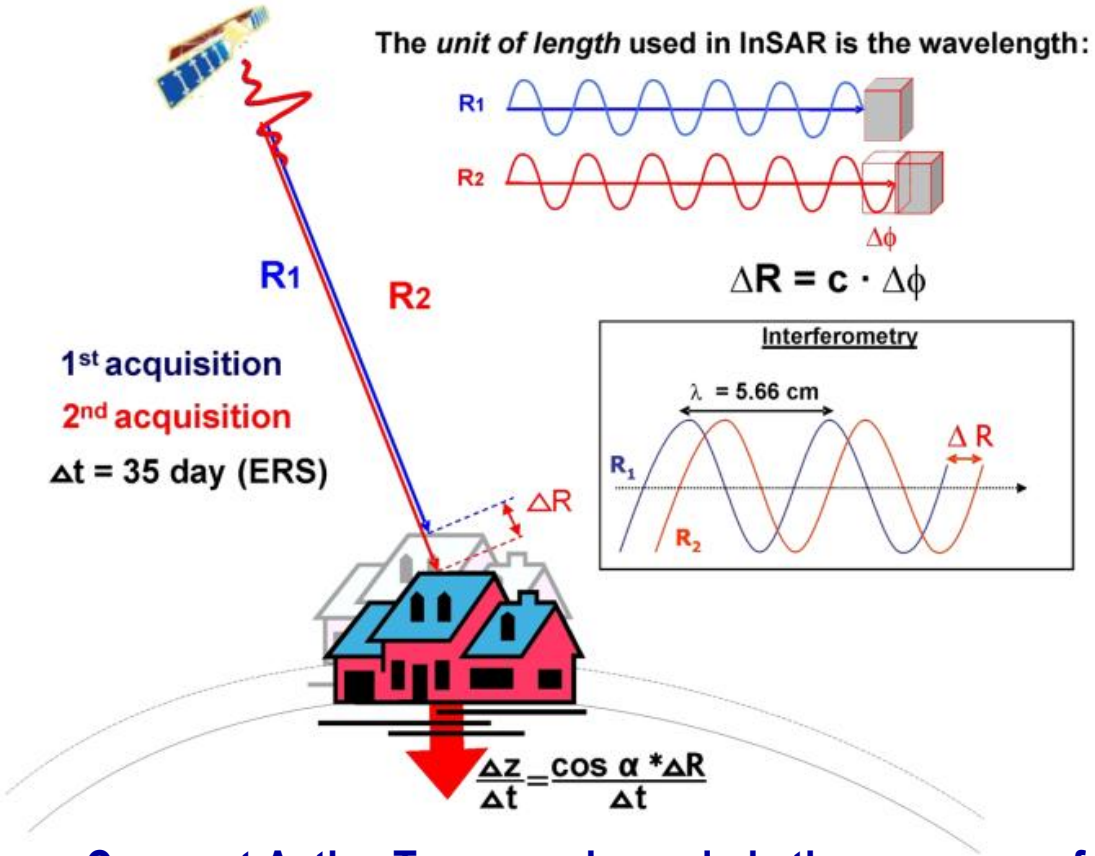
Artists impression of BIOMASS: Some change in antenna pattern might reasonably be anticipated through in-orbit lifetime!

ReflecX Compact Active transponder

- **Low cost, smaller alternative to corner reflectors for use in Synthetic Aperture Radar Interferometry (InSAR) at C-band**
  - 45cm long and 1/10th of the weight of an equivalent corner reflector (32dBm2)
- **Used for landslide monitoring, highway & reservoir subsidence, pipelines etc**
- **Several field trials have confirmed phase stability, and robust for >18months**
- **I²GPS EU-FP7 project has integrated a CAT with a GPS receiver**
  - Targeting pre-cursors to mass debris flows in Slovenian Alps
  - Technology permits simultaneous measurements, phase centres referred to a common geodetic reference



Persistent Scatterer Interferometry & Compact Active Transponders



- SAR interferometry identifies radar line of sight displacements of <5mm
- Between radar satellite overpasses
- Needs reliable persistent scatterers

- Compact Active Transponders mimic the response of a much larger target
- Have easily identifiable phase centre as a reference for a common baseline with other surveys

Example From Previous Trial

- **Units need to be installed in the zone of interest.**
  - With clear line of sight to satellite (30-70º, East-West)
  - Mounted securely to “the target”
  - One reference device off the area of instability
- **Typical duration 6-12 months**
  - Periodic visits to reprogramme CATS and clear vegetation
  - Aperiodic visits within 24day window if anomalies seen
- **Potential issues/ hazards**
  - Radio interference at 5.4GHz
  - Trip hazard can be protected by non-conductive fence if needed
  - Power supply is 6V battery, so no shock risk

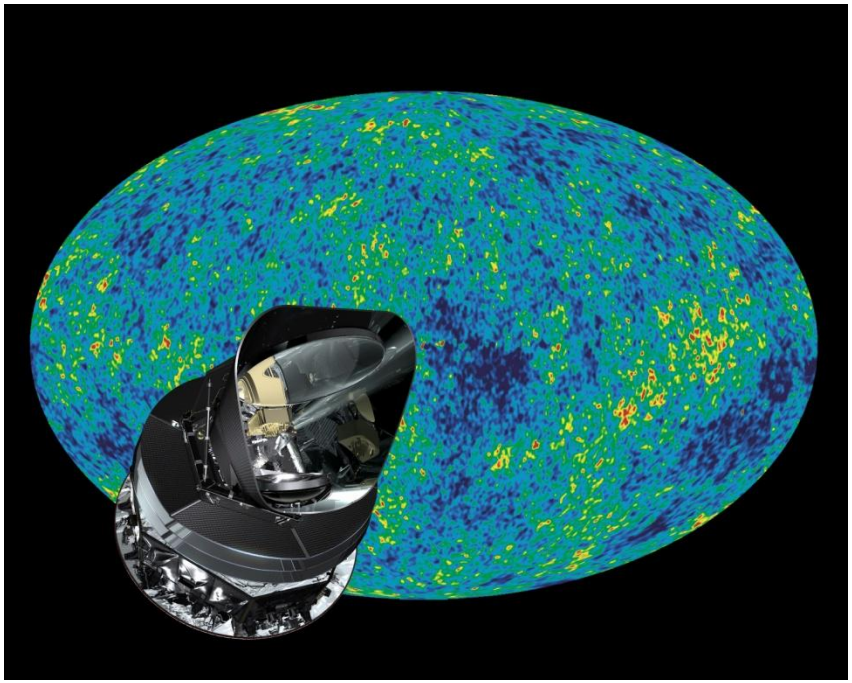
Corner Reflectors versus Compact Active Transponders

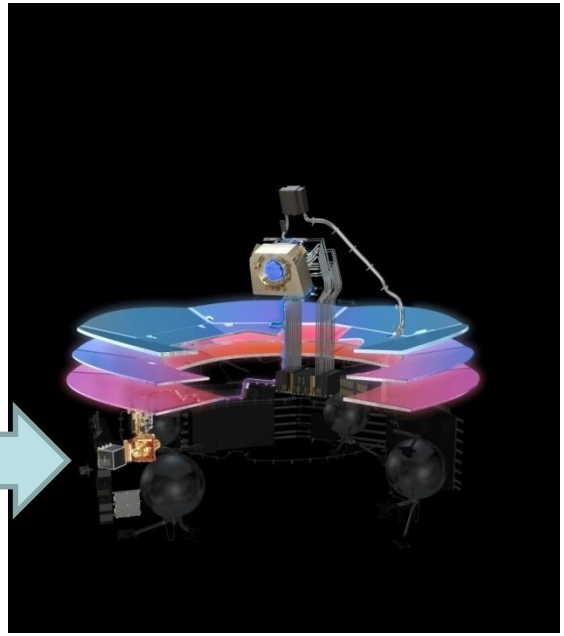
- **Corner Reflectors**
  - Typically large metal tri-hedrals
  - Need to be tightly aligned (thermal distortions, birds nests and theft present a problem)
  - Inherently phase stable
- **Compact Active Transponders**
  - Much smaller than their effective radar cross-section
  - Have to include clever electronics to stay phase stable
  - Electronics currently only available at C-band (Envisat, Radarsat, Sentinel1)

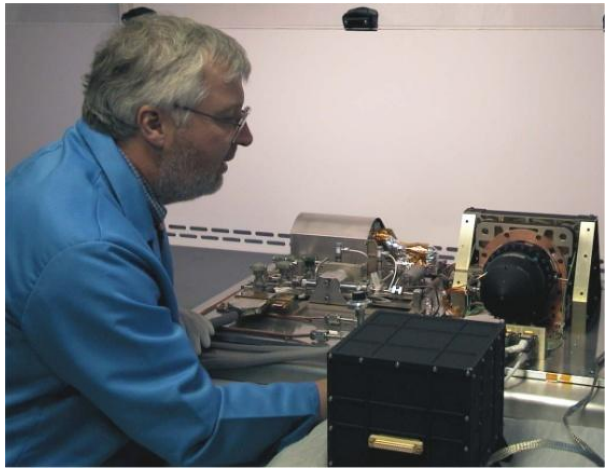
Thank you for your attention

Example : Planck 4K cooler drive electronics

- Critical Equipment (SPF) on €600M space mission
- Operational in orbit since May 2009 and performing a factor of x2 better than specification on vibration cancellation.
- SEA developed hardware, software, system analysis and build

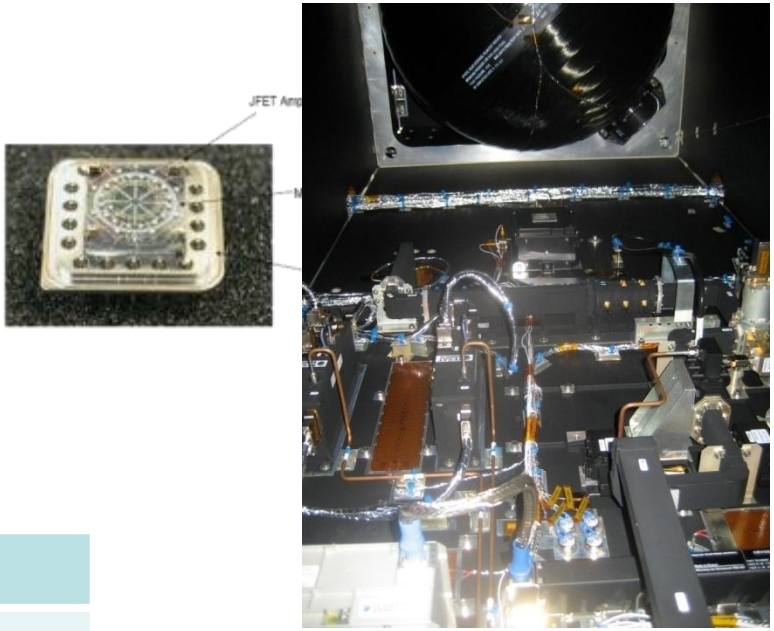






‘SiREUS’ MEMS rate sensor

- **Specialised ‘gyro’ for satellites used to point antennas/ instruments at target areas. Historically have been expensive and heavy ring-laser units.**
- **Improvements in star-reference systems provide scope for new technology based on well-proven “MEMS” technology.**
- **SEA-led development programme funded by ESA (€4M) special sensor technology > x10 better than ‘best available’ Now a Selex ‘standard product’**
- **Currently flying on CryoSat 2 strong interest Worldwide**



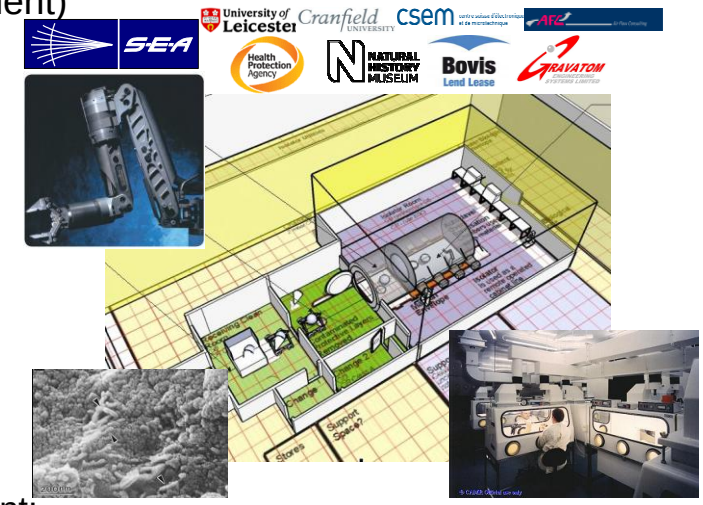
	MEMS	Ring laser
Mass	700g	3-4Kgs
Power	5W	35W
Exportability	No restriction	US ITAR
Cost	€200k	€500k

SELEX GALILEO

AIS Atlantic Inertial Systems

MSR Sample Receiving Facility

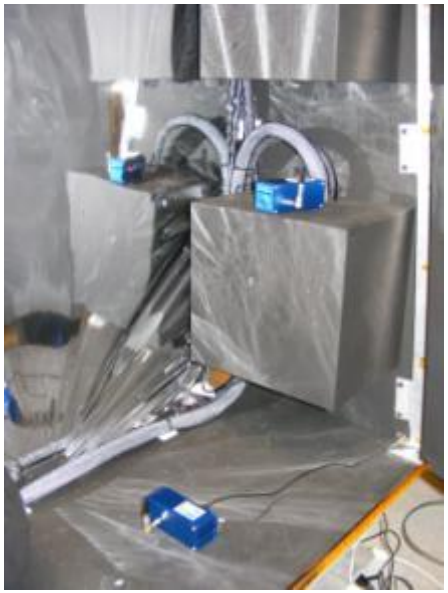
- **Objectives**
  - Prove samples offer minimal Biohazard prior to transfer to Scientific Curation Facility(ies) (COSPAR requirement) **and**
  - Protect scientific integrity of samples (scientific requirement)
- **Teaming**
  - Health Protection Agency
  - Universities
  - Natural History Museum
  - Specialist architects for sterile/secure facilities
  - Robotics and remote manipulations experts
- **Summary**
  - Requirements and preliminary design
  - Ran a very successful workshop at ESTEC
    - Space (PP) Scientific & Biocontainment communities;
    - Addressed opening, curation and biohazard assessment;
    - Critically assessed requirements & identified key issues.
  - Robotic handling preferred to suited laboratories for sample level manipulation
  - For cost-effectiveness should be co-located with (or enclosed within) a BSL4 facility
  - Sample opening requirements should be placed on the MSR biocontainer sealing system



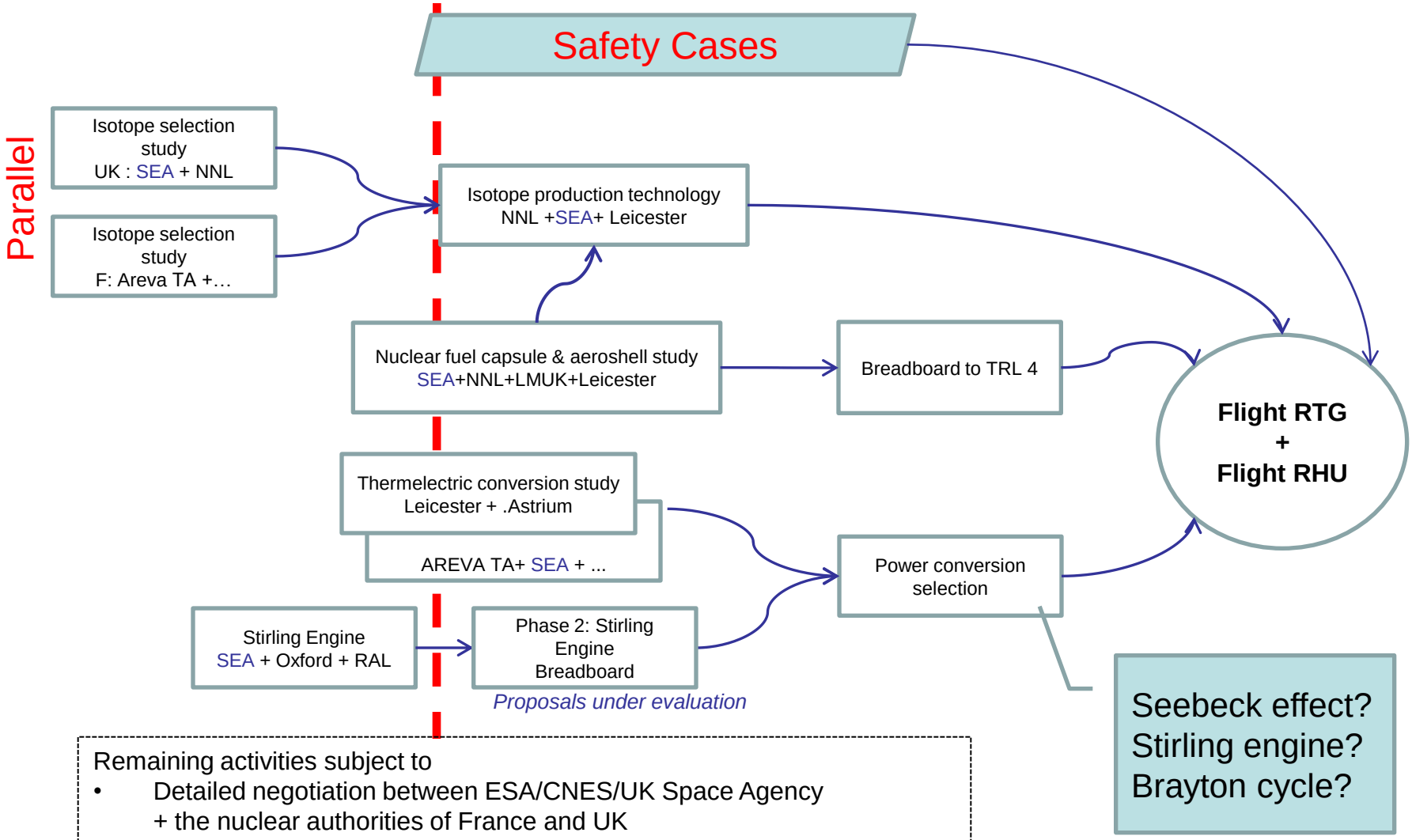
- **Participation in EU workshop/ESA-UK Space Agency workshop etc**

RF wireless: summary

- **Benefit/ Proposition**
  - high integrity wireless sensors for difficult environments
  - very low power sensor networks, connectivity to standards
  - ITAR free and radiation tolerant
  - not ‘COTS’ - high integrity and power reduced
- **Innovations/ Technology**
  - network architectures, topology and standards implementation
  - hardening and validation of wireless available IP cores
- **Financing**
  - ESA (>£1M) fully funded contract with ‘hard’ deliverables,
- **Exploitation**
  - high integrity integration, test and flight environments
  - medical and nuclear applications
- **Parallel/ complementary developments**
  - wireless usage monitoring (for landing gear fatigue)
  - wireless fuel gauging (wing tanks)
  - high performance, low power MEMS sensors



Space Nuclear Power - Roadmap

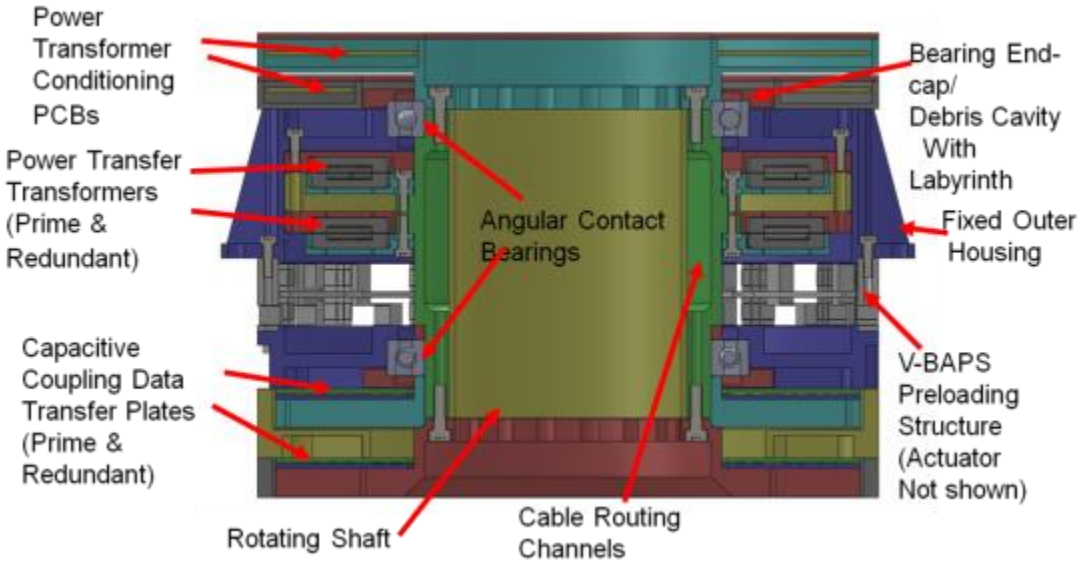


Remaining activities subject to

- Detailed negotiation between ESA/CNES/UK Space Agency + the nuclear authorities of France and UK
- Competition for the contracts

Contactless Power and Data Transfer

- **Key requirements**
  - Transfer 200W power with >95% efficiency
  - Full duplex data transfer at 5Mbits/s with a BER of 10-9
  - Mass, 8kg maximum
  - Envelope:
    - External diameter Ø250mm max
    - Central clearance through hole Ø50mm min
    - Height 250mm max
- **Application**
  - Rotating instruments such as MWI/ICI for MetOp 2G



- DevelopmentTeam
  SEA, ESR, Sula Systems