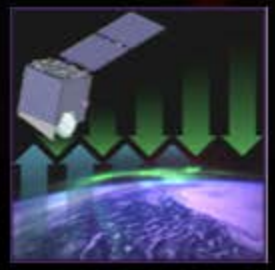
LINKING OBSERVATIONS OF CLIMATE, THE UPPER ATMOSPHERE AND SPACE WEATHER

LOCUS



The LOCUS consortium(s)

LOCUS Elegant Breadboard (8th CEOI)

University of HUDDERSFIELD

The Open University

JCR SYSTEMS

Durham University

UNIVERSITY OF LEEDS

STAR-Dundee

STFC

SURREY SATELLITE TECHNOLOGY LTD

RAL Space

UCL

Centre for EO Instrumentation & Space Technology

UK SPACE AGENCY

The LOCUS Satellite (EE9 proposal)

AVANCEZ 1829 CHALMERS UNIVERSITY OF TECHNOLOGY

INSTITUTO de ASTROFISICA de ANDALUCIA CSIC IAA

NTNU – Trondheim Norwegian University of Science and Technology

LEIBNIZ-INSTITUT FÜR ATMOSPHÄREN PHYSIK IAP

UNIVERSITY OF OXFORD

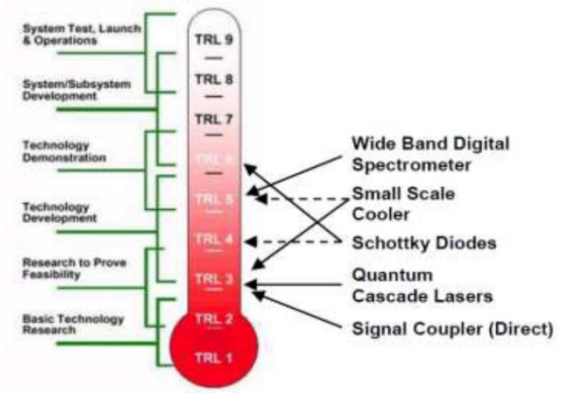
Met Office

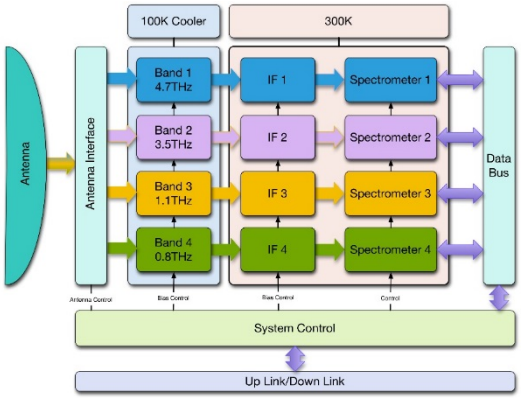
National Centre for Earth Observation NATURAL ENVIRONMENT RESEARCH COUNCIL

LOCUS payload development

RAL Space / UCL / Uni. of Leeds / STAR Dundee / Uni. of Huddersfield / Durham Uni. / JCR Systems

- **LOCUS:** *A new THz remote sounder for global mapping of the mesosphere/lower thermosphere (MLT). Original concept supported by CEOI*
- **CEOI objective:** Raise payload TRL
- **7th call: Receiver TRL advancement**
  - 1.1-THz Schottky diode receiver
  - 3.5 & 4.7-THz Quantum-cascade lasers (QCLs)
  - Wide-band spectrometer enhancement
  - Space compact cryocooler
- **8th call: System elegant breadboading**
  - Off-axis Cassegrain antenna development
  - Optical bench integration & test
  - Thermal vacuum tests of the integrated antenna





The LOCUS Elegant Breadboard

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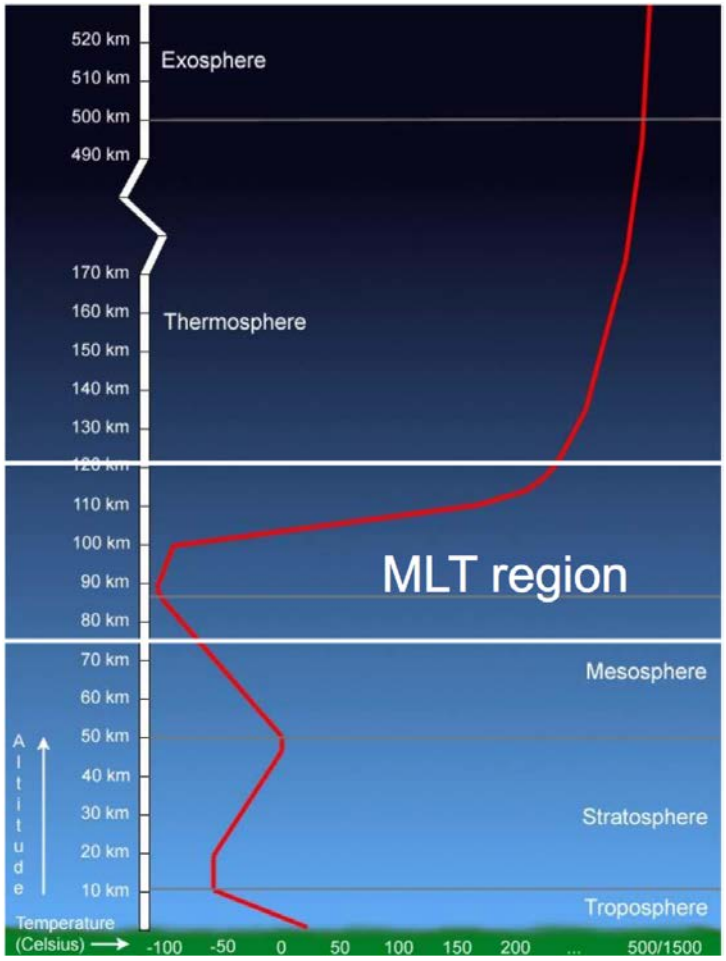
SURREY SATELLITE TECHNOLOGY LTD

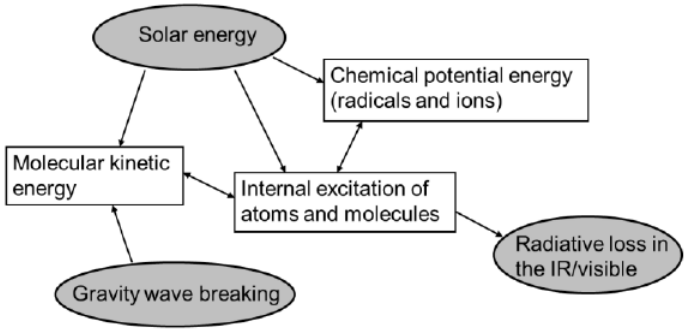
LOCUS Science

- The MLT (Mesosphere, lower Thermosphere) is a “gateway” between Earth’s atmosphere and near space environment
- Indicative of climate change through:
  - Increased cooling rates
    Beig et al., JGR, 2011
  - Increase of mesospheric clouds
    DeLand et al., JGR, 2015
- Not well explored, because it is:
  - Too high for balloons; too low for orbiters
  - Many key species only detectable at THz frequencies



LOCUS Science

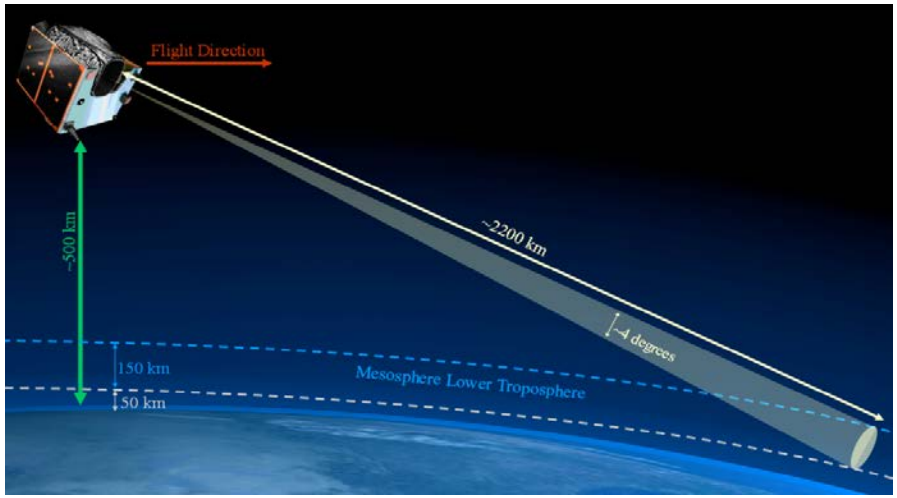
- Key MLT observables are:
  - O: Understanding thermal balance and chemistry of Upper Atmosphere (O not globally measured; drives cooling actively & through quenching rates)
  - NO (formed in the MLT) is believed to be transported down, impacting on O_3 chemistry. (relevant to Climate Change)
  - OH, HO_2, CO: Understanding Upper Atmospheric chemistry and dynamics
  - Formation of noctilucent clouds (correlation with atomic Oxygen depletion)



The LOCUS concept

A breakthrough THz remote sounder: www.locussatellite.com

- A limb scanning observatory with THz and IR channels to identify the relevant species.
  - The IR radiative fluxes (which have already been “accessed” in the past allows us to better understand the thermal equilibrium of the MLT but not its chemical composition
  - Simultaneous measurements of IR emission from vibrationally excited CO2, NO, O3 and OH will provide complementary information on thermal structure, polar mesospheric clouds (PMC), energetics and chemical processes.



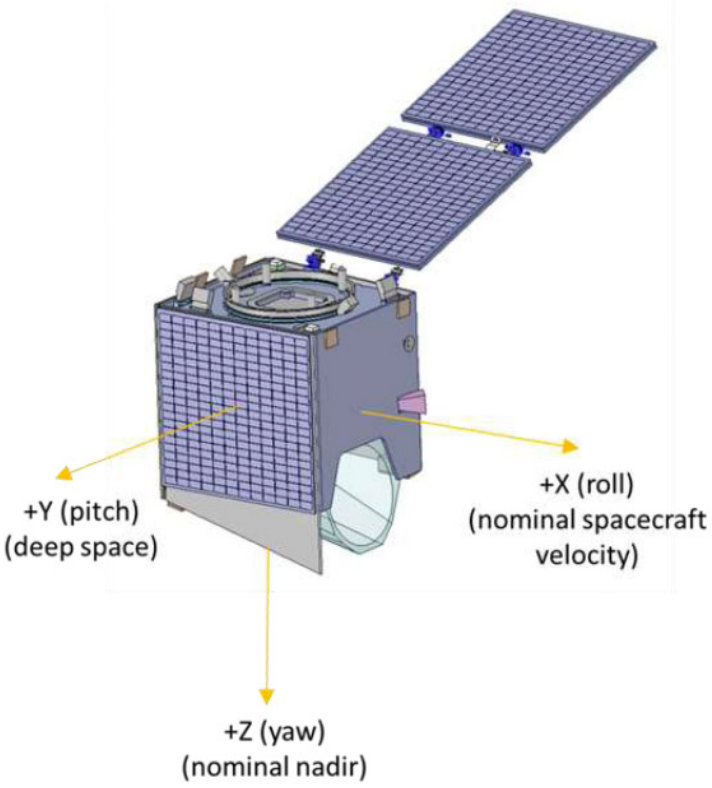
Band	Centre ν (THz)	Species Covered	Predicted Performance (NETD K)
1	4.7	O, O_3	46
2	3.5	OH, CO, HO_2	12
3	1.15	NO, O_3	4
4	0.8	O_2, O_3	3

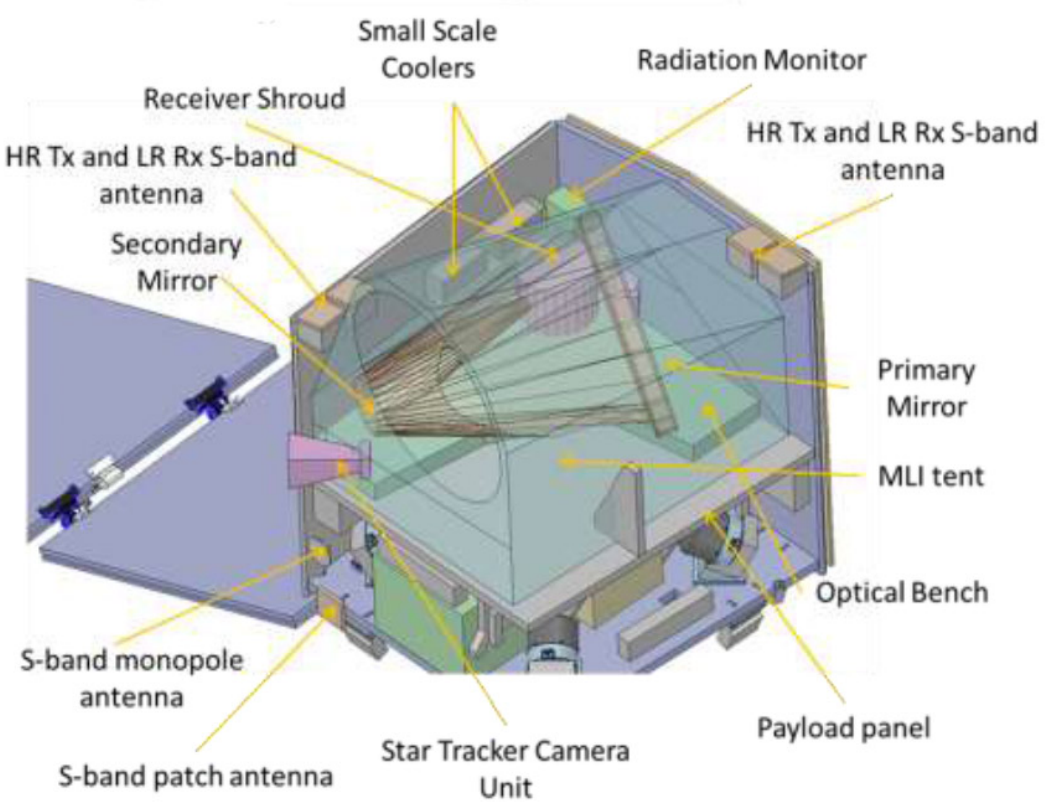
TABLE I. THz Receiver Band designation

Centre λ (μm)	Bandwidth (μm)	Species Covered	Required Detectabililty ($W m^{-2} sr^{-1}$)
15	5.2	CO_2	$1x10^{-3}$
9.3	1.74	O_3	$3x10^{-4}$
5.3	0.41	NO	$1x10^{-5}$
2.07	0.54	OH	$1x10^{-5}$

TABLE II. IR Receiver Band designation

LOCUS Satellite & Payload

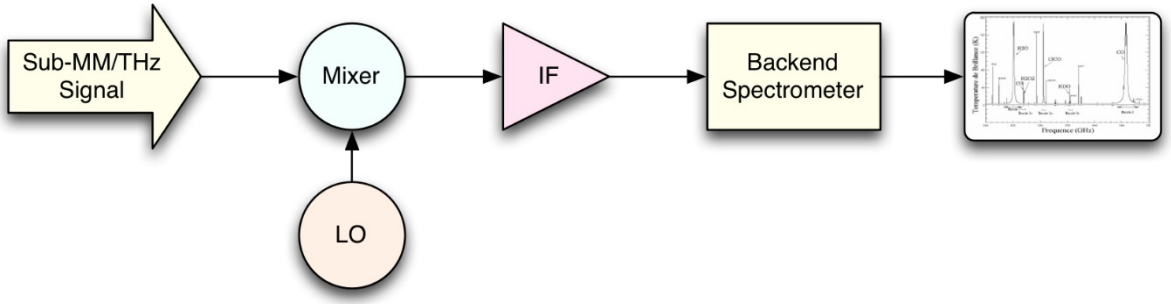




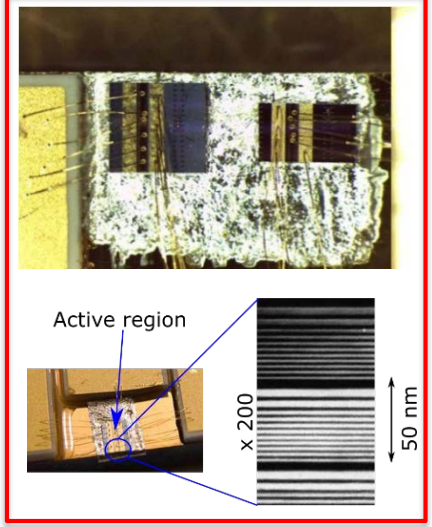
SSTL150 satellite and payload concept from SSTL led ESA IOD.

Basic heterodyne system concept

- LOCUS uses heterodyne frequency down-conversion technology (mixers).
- Quantum cascade laser (QCL) provides local oscillator (LO).
- Small active coolers required to cool QCLs.
- Achieves ~1MHz spectral resolution via high-speed digital sampling.

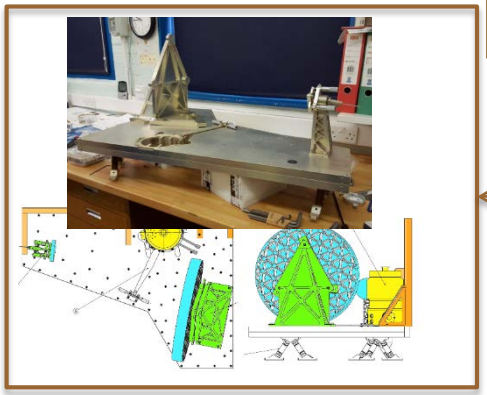


LOCUS Critical Technologies

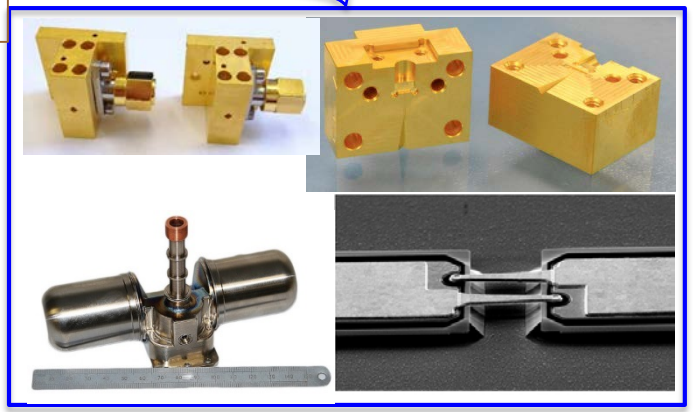


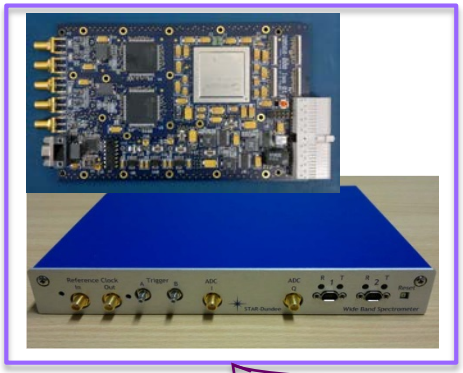
3.5 & 4.7 THz QCL Local Oscillators
University of Leeds

Optical Bench, telescope mounts, thermal model (UCL-MSSL)

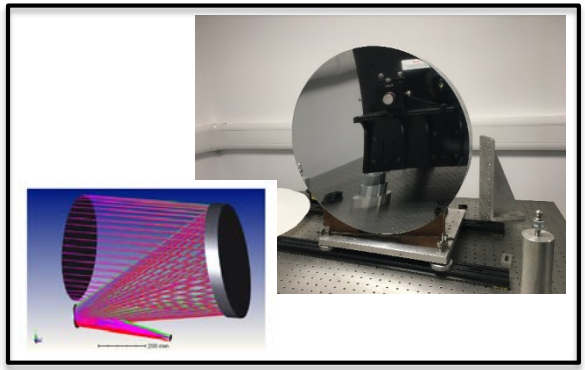


Schottky Barrier Diode & Space Coolers RAL

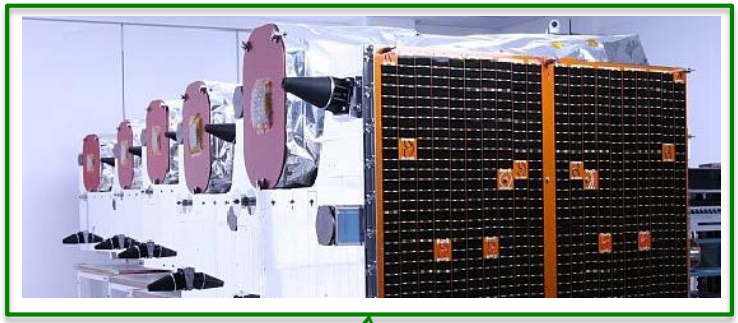




Wide-band Spectrometer
STAR-Dundee



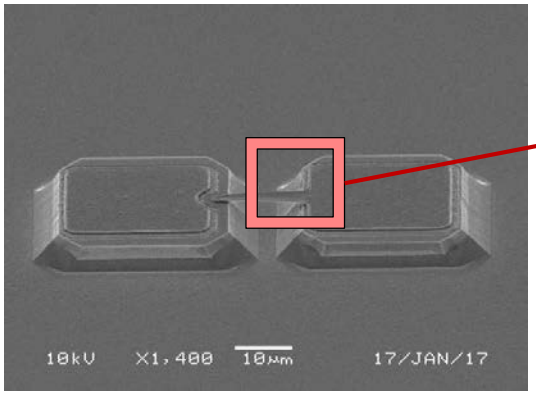
All-Aluminium compact Cassegrain telescope, IR pixel
(UCL, Glyndwr Uni., Huddersfield Uni., Durham Uni,)



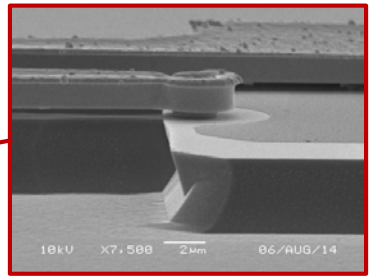
Small Satellite
Surrey Satellites Ltd

Critical TRL: Supra-THz Mixers and LOs

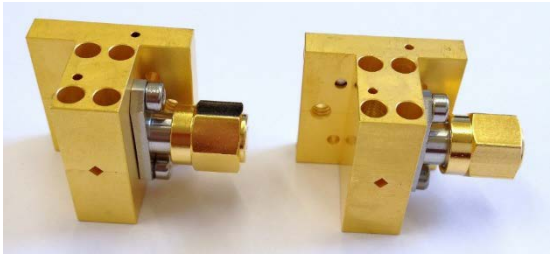
- Developing core mixer technology at 1.15THz (to 4.7THz via GSTP).
- Use electron beam lithography to define GaAs Schottky diode – reduce shunt capacitance to improve responsivity at THz frequencies
- Move to low bias InGaAs devices to reduce LO power.
- For 1.15THz & below, use harmonic LO chain.



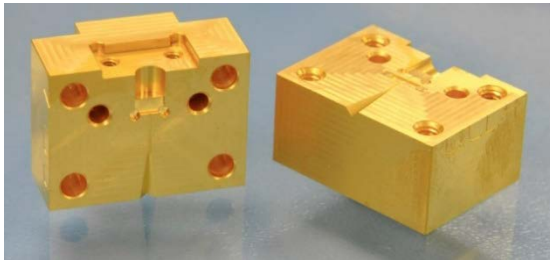
Flip-chip diode



Under-cut walls
near
Schottky Contact



7th Call 1.15THz mixers



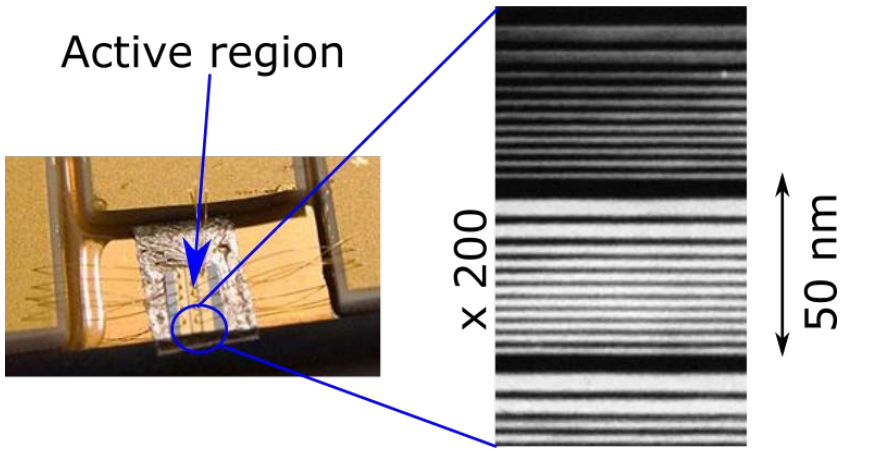
Split block receiver with horn

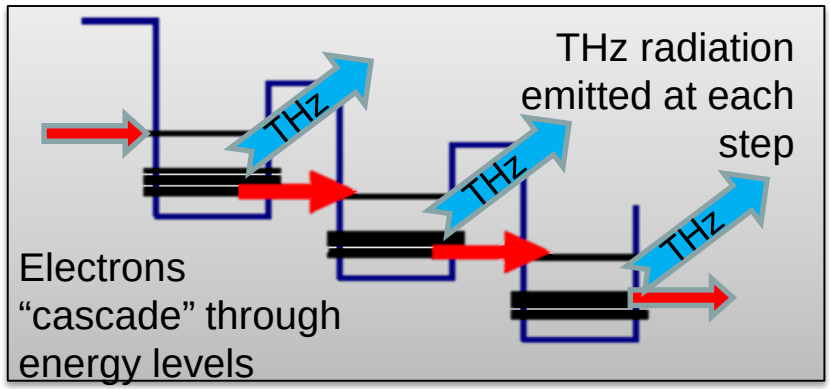
- For 3.5THz / 4.7THz, integrate with QCL in single waveguide block.

Critical TRL: Quantum cascade lasers

Powerful and compact continuous-wave THz source for LO:

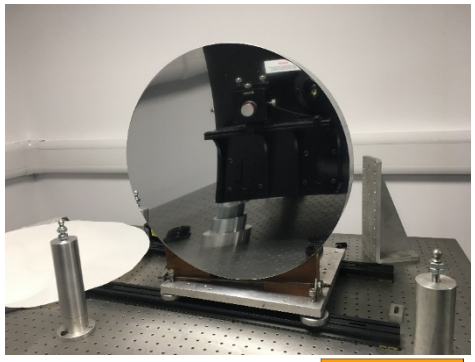
- “Electron-recycling” → efficient THz generation.
- Fabricated using molecular-beam epitaxy.
- Provided mW output at key LOCUS frequencies – 3.5/4.7THz.
- Waveguide integration successfully achieved.
- Operation demonstrated in an active space-cooler environment (~60K).

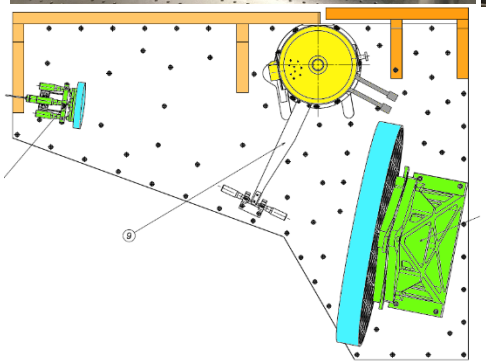


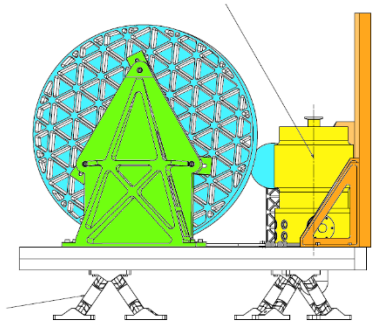


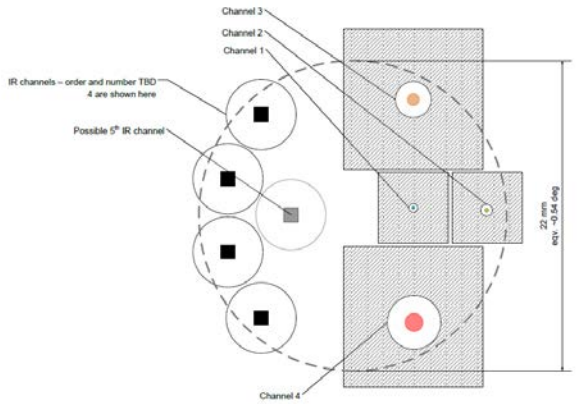
LOCUS breadboard and optics

- Off-axis Cassegrain antenna design.
- Optics & receiver mounted onto an aluminium optical bench.
- Compact cryocooler provides 50 K stage for QCL operation.
- IR observation capability.
- Activity will raise to TRL 4/5.



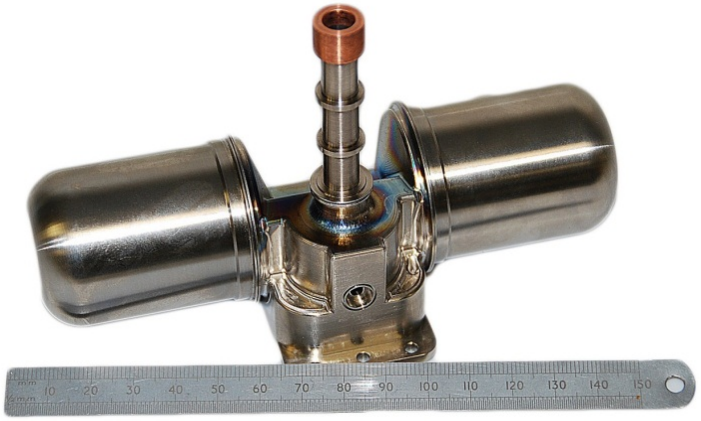


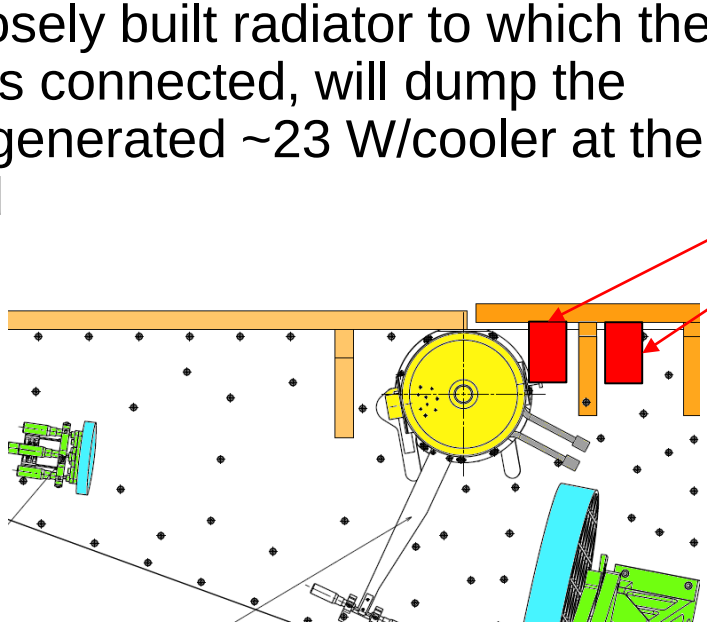


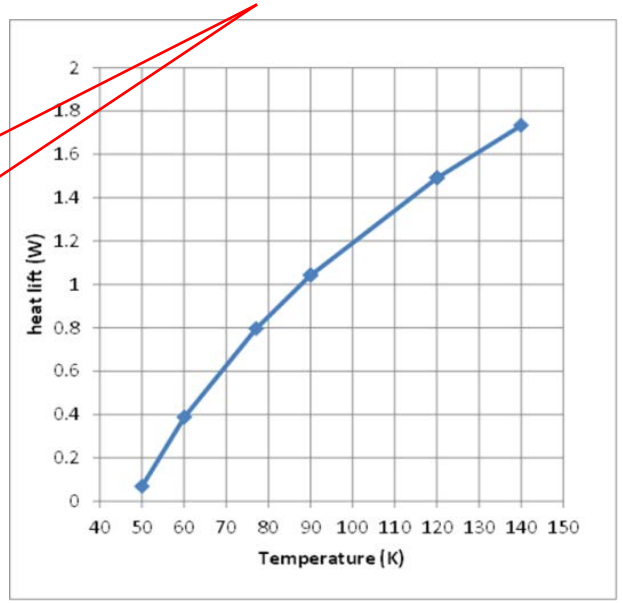


Tactical Space Coolers

- The RAL tactical mini-cooler provides 1W of cooling at 100K
- LOCUS would be the first Small-class satellite in Low-Earth Orbit (to our knowledge) with an active cooler
- A purposely built radiator to which the cooler is connected, will dump the power generated ~23 W/cooler at the hot end

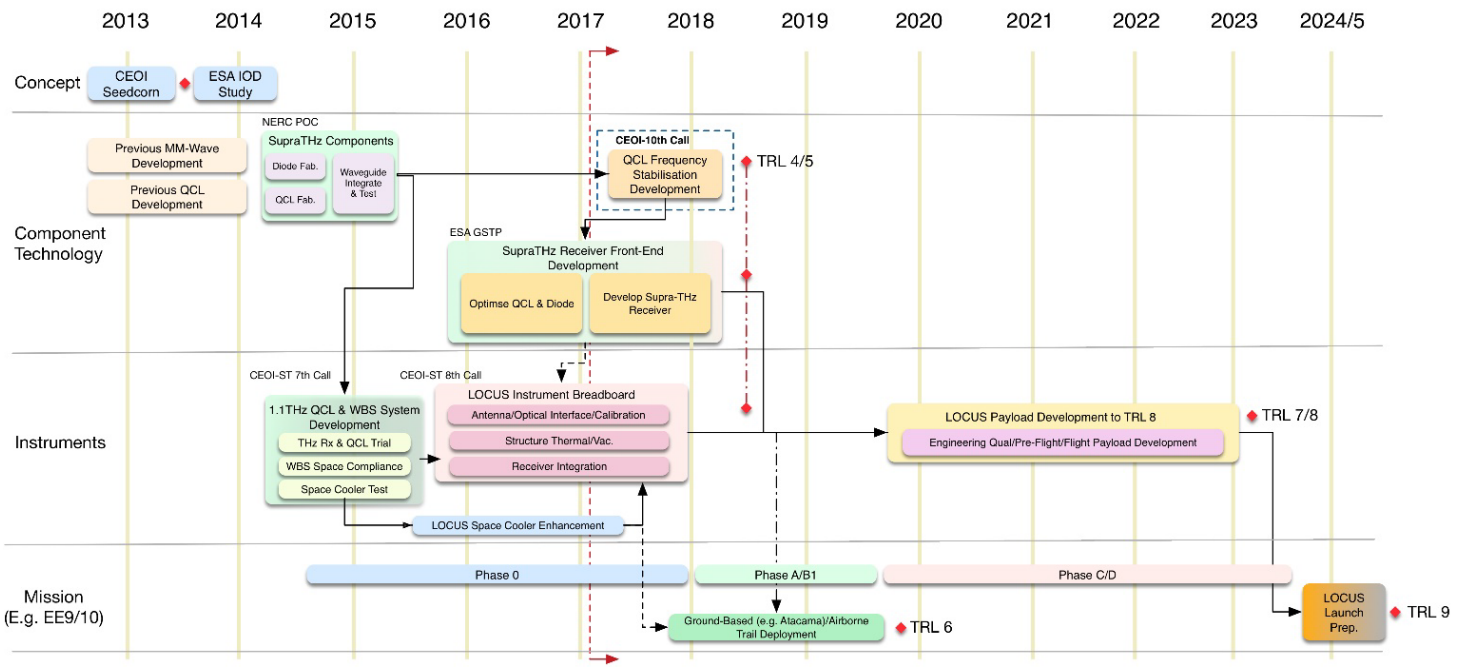






LOCUS roadmap

- CEOI 7/8th call advances receiver/system to TRL 4/5
- IOD concept study completed for ESA.
- Airborne demonstration proposed for CEOI 10th Call (unsuccessful)
- Future candidate for EE10 mission



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Thanks for listening

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