Changing the economics of space

LOw Cost Upper atmosphere Sounder LOCUS

Presented by

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On behalf

Motivation and Modelling

Mesosphere and Lower Thermosphere (MLT -~50 -150 km) is poorly sampled

MLT is cooling ~ten times faster than troposphere is warming → highly geared indicator of climate change

Major chemical species are atomic O, OH, H_2O and NO

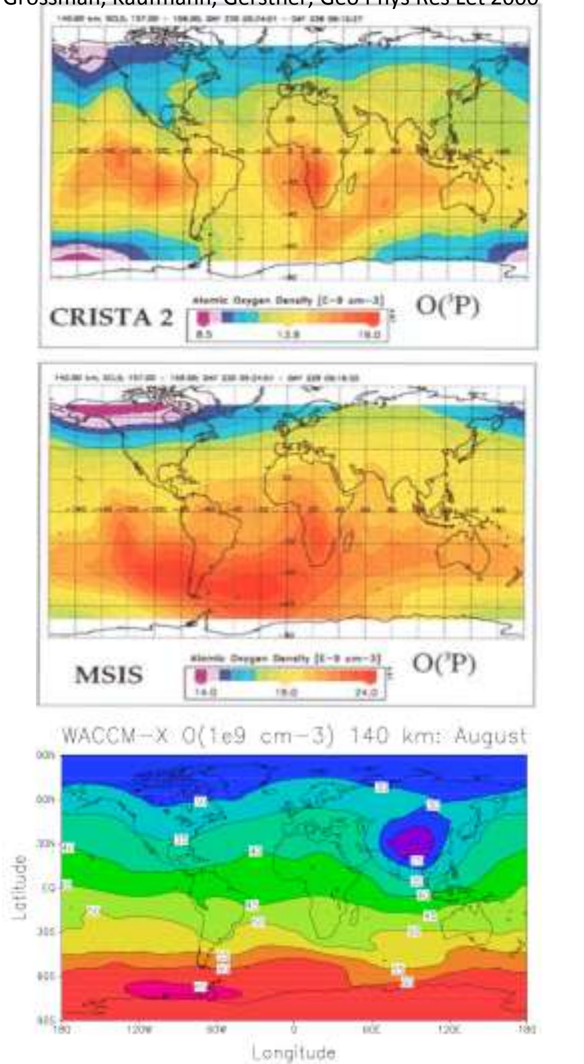
Complex physical phenomena and chemistry control the energy balance → all ultimately driven by atomic O

Sampling these species in the MLT can only be efficiently achieved in the THz range (0.8 – 5 THz)

Observational platforms for this are expensive and technically challenging

We wish to change the paradigm

Grossman, Kaufmann, Gerstner, Geo Phys Res Let 2000



Plane and Feng priv. comm. 2013

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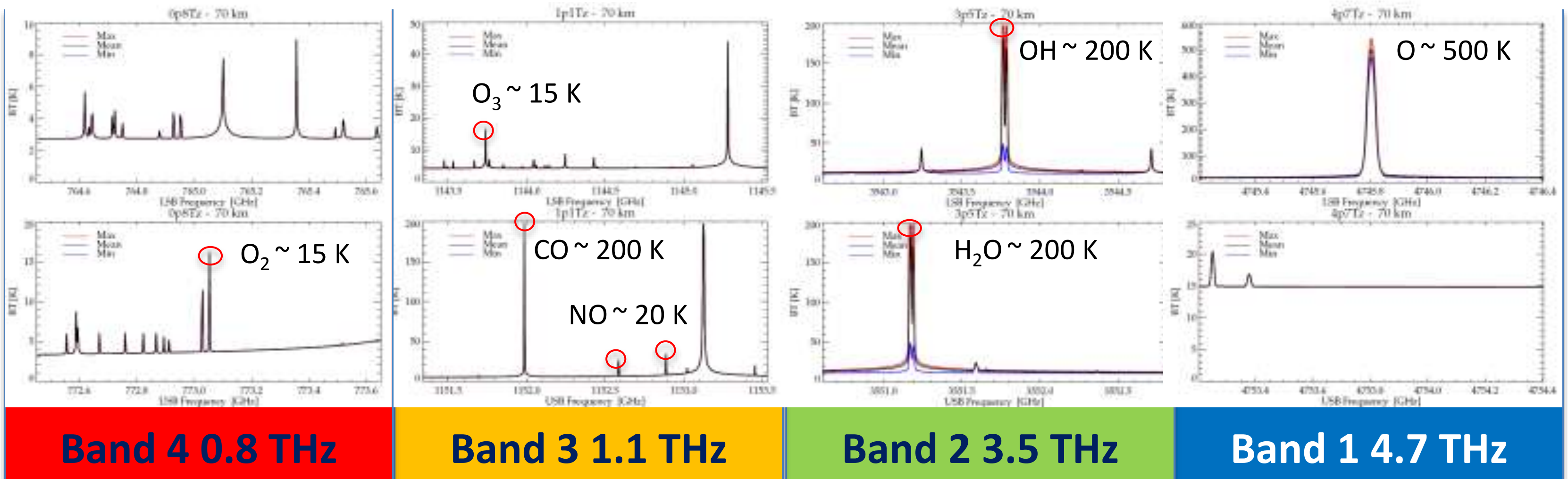
Line Selection

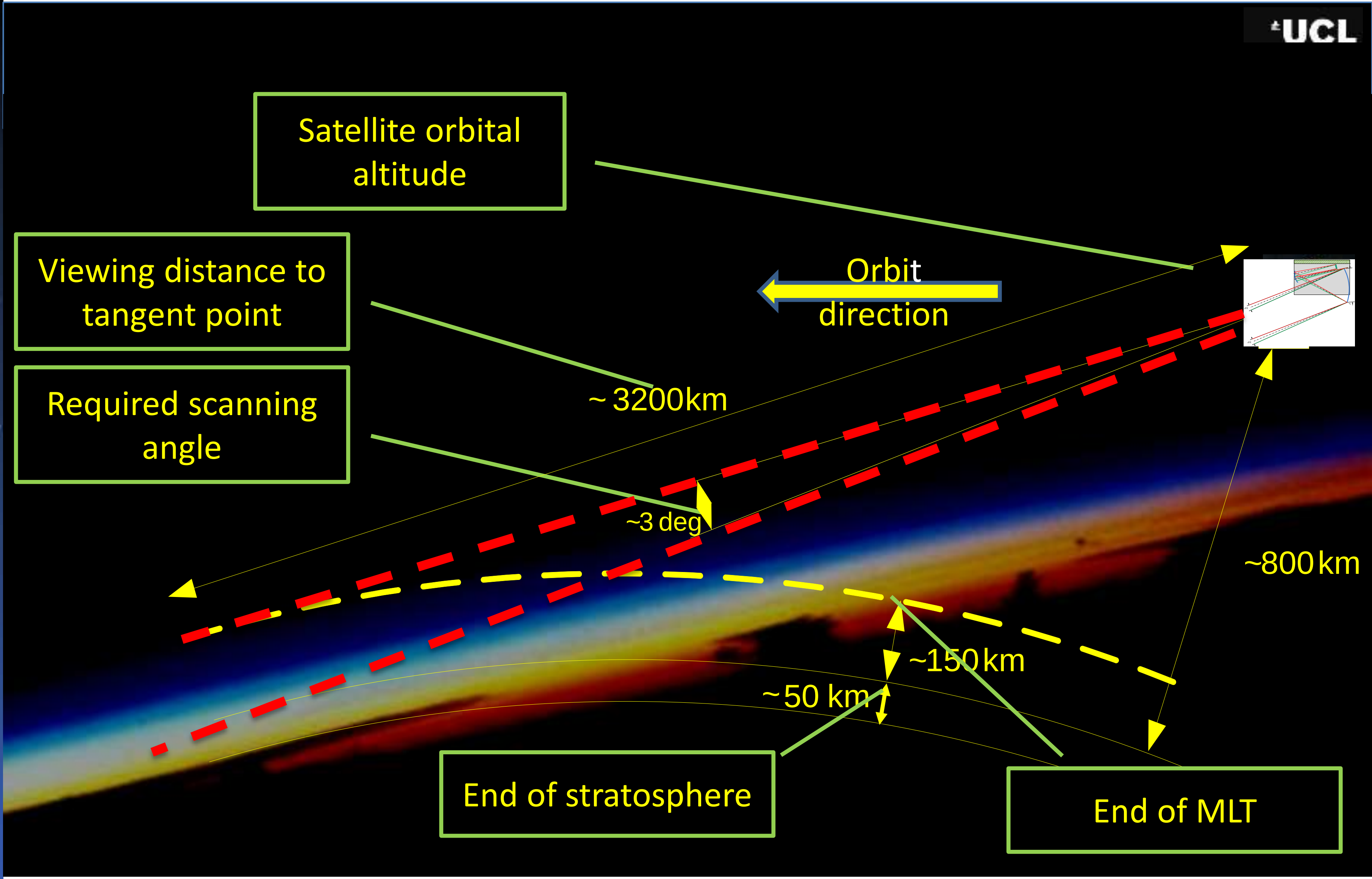
- A single frequency band heterodyne receiver covers ~few GHz
- Multiple receivers required to measure critical species
- Important to identify which frequency bands are required
- Extensive work at RAL on modelling spectral line frequencies and intensities based on output of Leeds WACCAM-X models



Species	Transition Frequency (GHz)	Band Delegation
O	47458039	1
OH	3543.7794	2
HO_2	3543.2439 3544.7130	2
NO	1152.5862 1152.8888	3
CO	1151.9854	3
O_2	773.05064	4

Gerber priv. comm. 2013

Mission Outline

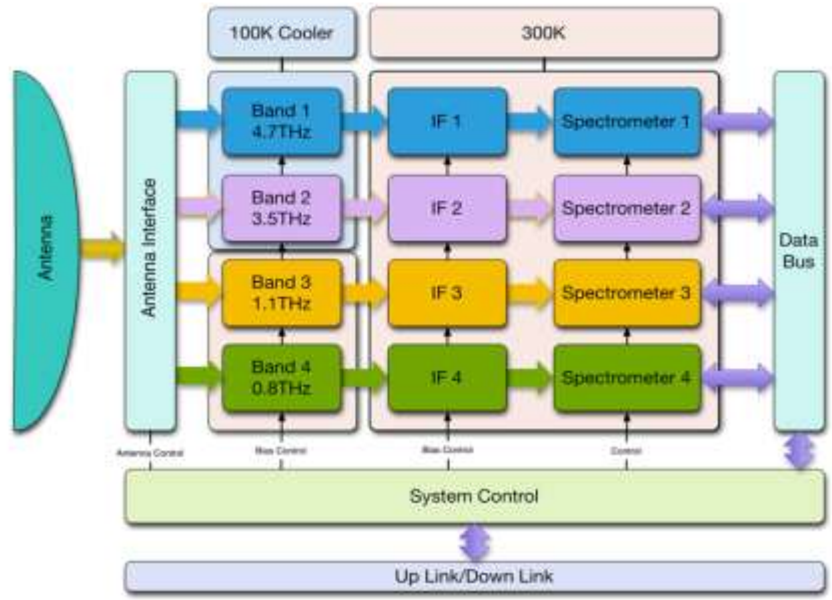


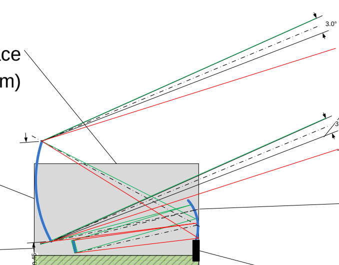
Payload Requirements and System Design

Terahertz Payload Parameter	Unit	Value/Description	Comments
Antenna Aperture Defined by lowest freq.	cm	55	Off-axis illumination providing a projected 55cm usable diameter. Steerable with on-board guidance.
Spatial Pixels	-	Single beam	Steering to required tangent heights
Spatial Resolution	km	3 (FWHM)	Limb view at 3,200km from satellite.
Spurious Sidelobes Level	dB	<-30	Defined as below main beam centre. Requires greater science definition.
Frequency Range	THz	~0.7 to 5	Achieved through use of four independent THz channels.
Instantaneous Bandwidth	GHz	6	Formed from 3x2GHz FFT spectrometer units.
Spectral Resolution	MHz	1	1MHz sufficient for spectral line characterisation.
Minimum Detectable Signal NEΔT (SSB assumed)		2, 4, 12, 46	…s 2,500, 3,500K, 10,000, 40,000K …B @ 0.8, 1.1, 3.5 & 5THz …pectively. 1MHz resolution and …c. integration time.
Observing Mode	-	Total Power	Intermittent calibration required.
Limb Min./Max. Tangent Height	km	50/150	
Vertical Sample Spacing at Limb	km	1.5	Dow we need to overlap channel beam to FWHM?
Calibration Target Monitor	K	±0.1K accuracy	Preliminary estimate. Thermal control may be required.
Physical			
Dimension Front-End	cm	30x20x10	
Dimension Back-End	cm	30x30x20	Includes IF plate and three independent 2GHz spectrometers.
Combined front and back end volume	cm^3	24,000	Includes THz Front- and Back-Ends and support plate. But not cooler or antenna.
Operational Temperature			
Active Cooling Temperature	K	100	<100K preferred for QCL
Passive Cooling Heat Lift	W	6	Includes conductive and radiation heat leaks. Likely to reduce with improved QCL efficiency.
Telemetry Requirements			
Monitor and Control	bit/s	22k (max.)	Rate non-critical and intermittent system status review required. Mostly autonomous operation
Data Transmission	bit/s	~48k tbc	For 1MHz and 8bit resolution across 3x2GHz bandwidth. Can store and perform high-speed burst rate.

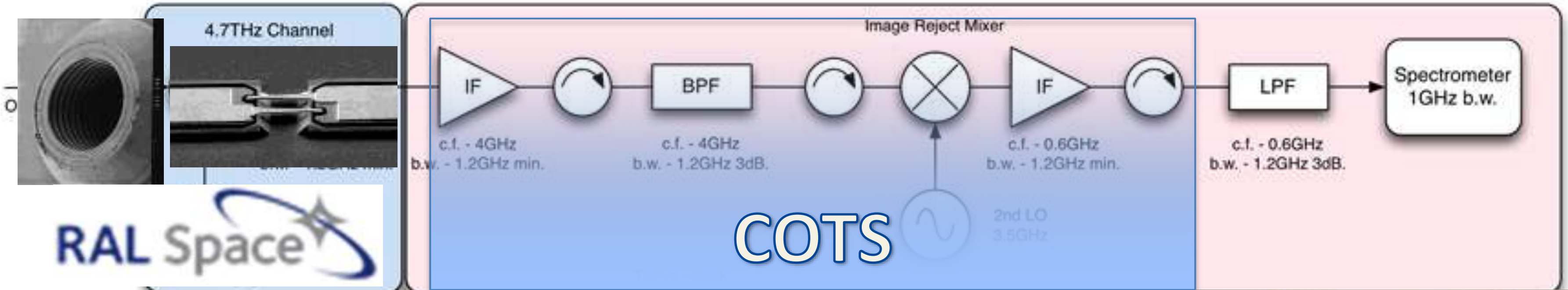
Ellison 2013

RAL Space

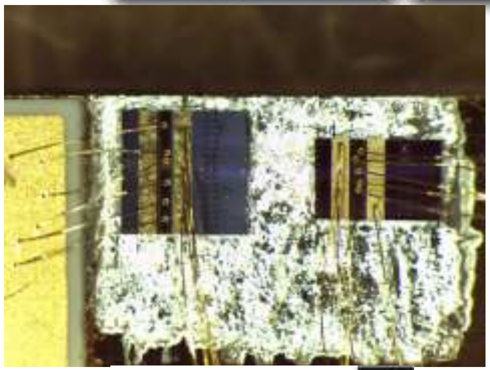




Payload Design and Development Needs



RAL Space



STAR-Dundee

Astrium

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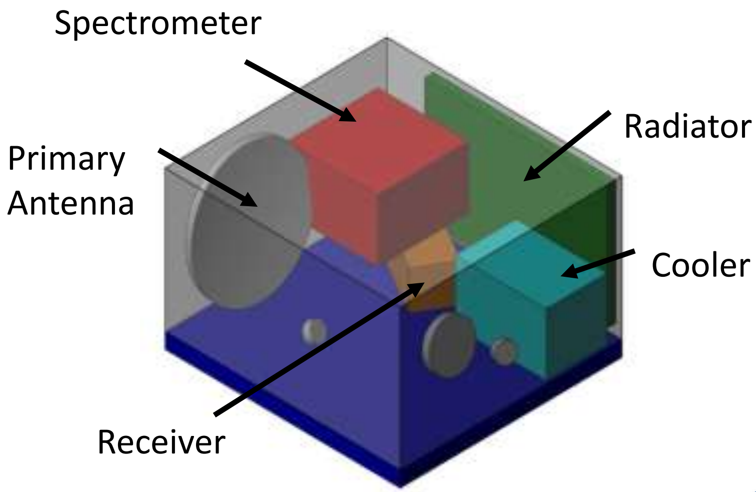
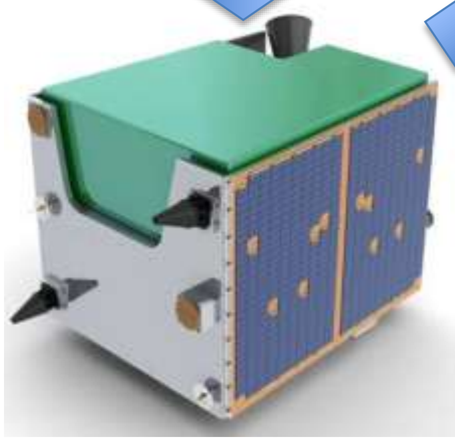
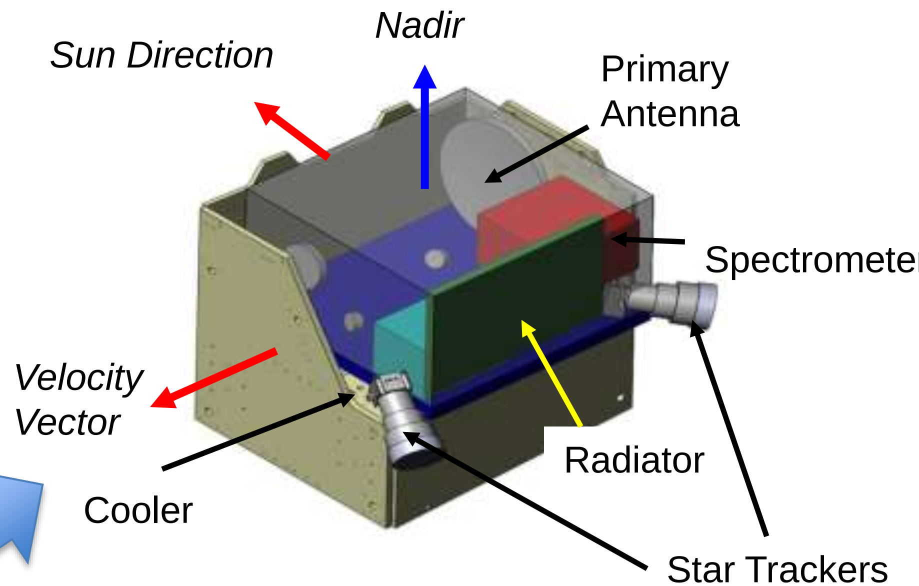
Mission Design Assumptions

- Dawn-Dusk sun synchronous orbit
- ~700 Km (around 98 degrees inclination)
- SSTL-150 spacecraft - Sapphire variant (launched on the 25th of February 2013) as baseline
- Payload bay includes: Receiver, Cooler, Spectrometer, Antenna Assembly and Radiator
  - Payload mass = 50 Kg (RAL)
  - Payload power consumption= 96 W (RAL)
  - Payload bay overall dimensions = 80 x 40 x 65 cm (SSTL)
  - Receiver = 12.5 x 20 x 20 cm (RAL)
  - Cooler = 20 x 30 x 30 cm (RAL)
  - Spectrometer Electronics = 30 x 30 x 20 cm (RAL)
  - Main Antenna Dish = 50 cm diameter x 5 cm thickness (RAL)
  - Secondary Dish = 15 cm diameter (RAL)
  - Tertiary Dishes = 6 cm diameter (RAL)
  - Radiator Size = 60 x 40 x 3 cm (SSTL)
  - Harness not included in mass budget

Satellite Critical Items Evaluation







Thermal Performance: (Radiator 600 x 400mm)
- Hot case temperature +15°C
- Orbital stability < ±2K
- Small seasonal variation
- Parasitic heat loads not included

Pointing Relative Stability:
- Achieves required relative stability during 30 sec,
- 2 min scan time requires further analysis

Pointing Absolute Stability Requirement :
- Performance over 1 hour and 1 day periods 0.01º (1σ)

Nocerino, Navarathinam and SSTL Team

Status and Future Opportunities

Outline payload and mission design completed

Identified critical areas for further study

- Deployable solar panels
  - → 84W heritage vs 96W needed
- Payload envelope/mass
  - →re-qualification of SSTL-150 spacecraft
- Deployable sunshield may be required
- Accommodation of electronics dissipation
  - → thermal control
- Second radiator for intermediate T intercept
- 2 min scan time
  - → Further analysis of AOCS needed
- QCL power output and integration into mixer

Submitted proposal for "In Orbit Demonstration" of the system to ESA

- → Successfully through to next round – full proposal required 25th April

Papers submitted to ESA "Living Planet" and SPIE "Remote Sensing"