Miniaturisation of instruments

Andy Vick,
Head of Disruptive Technology
STFC RAL Space

Why miniaturise

OK, let be honest: technologists don’t generally care about instrument size; most engineers are happier treating size as a free parameter.

Cost isn’t a reason, that scales more with complexity and complexity is often driven up by miniaturisation.

The main reason is to put more instruments on a platform, or instruments on (much) smaller platforms.

Flight opportunities

- Shared ride IOD programs
- Nanosats
- RPVs air, land or water
- High Altitude Platforms (HAPs)

Whilst the Global Hawk can lift >1000Kg there is a sweet spot for getting yourself a ride on any of these; 1-10Kg and 1-10W.

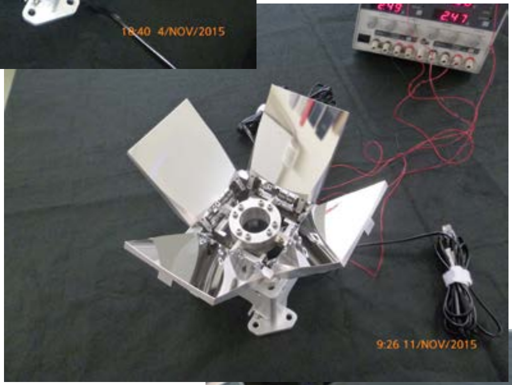
If you're clever about what measurements you take and how you take them there's a lot you can do (https://doi.org/10.17226/23503).

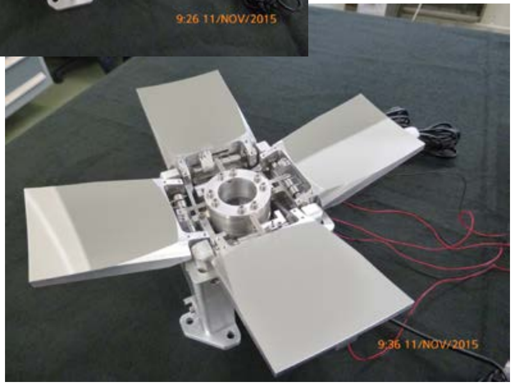
Spaceflight estimate a cost of $295K for a 3U Cubesat launch.

Size Drivers

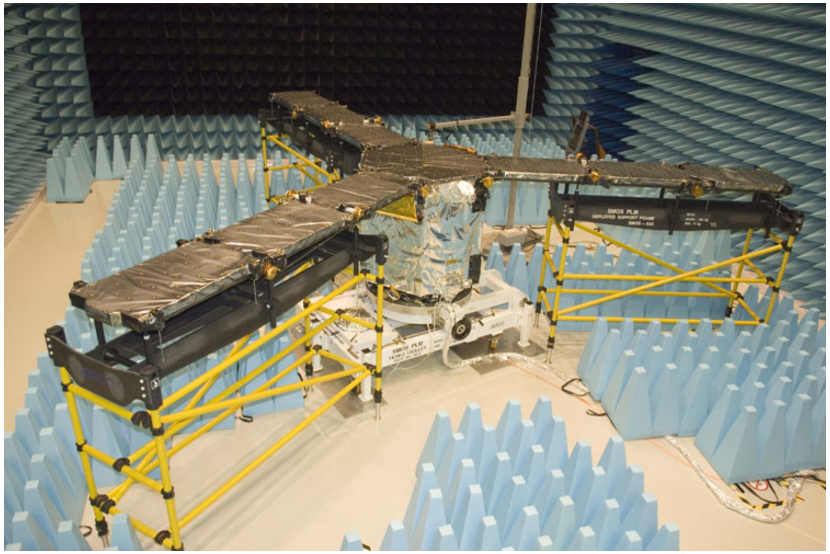
- Aperture (spatial resolution & signal gathering)
- Instrumental resolution (SNR & stability)
- Power (and cooling)
- Calibration

Spatial resolution Aperture

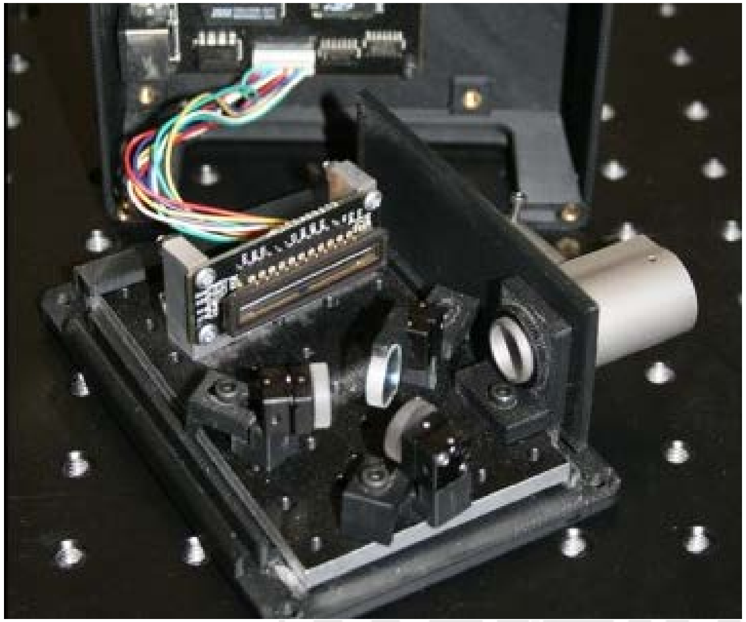


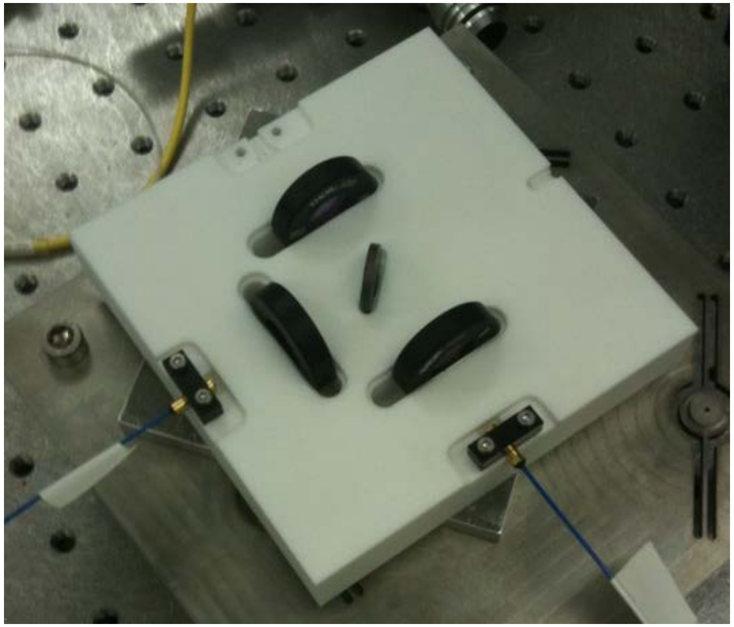


Spatial resolution: synthesis



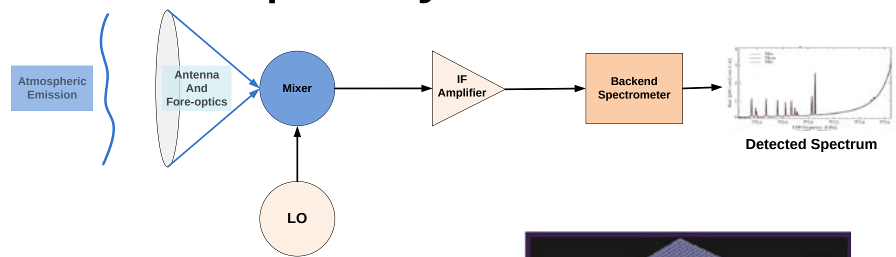
Instrumental resolutions





Miniaturisation by switch to new technologies

I.e. heterodyne detection at THz Frequency



Existing Technology (EOS MLS):

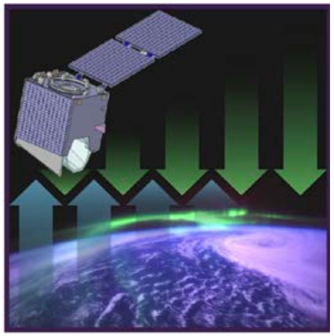
Gas laser Local Oscillator

- Large
- Heavy
- High-maintenance

Future Technology (LOCUS):

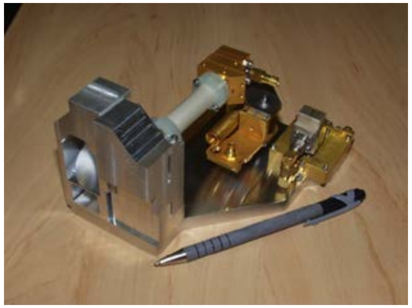
Quantum Cascade Laser Local Oscillator

- Small
- Light
- Reliable

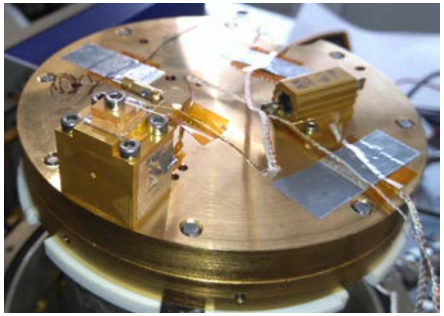


LOw-Cost Upper-atmosphere Sounder

EOS Aura MLS (2.5 THz radiometer)

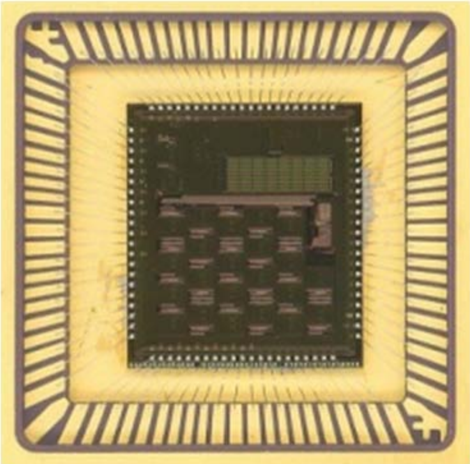


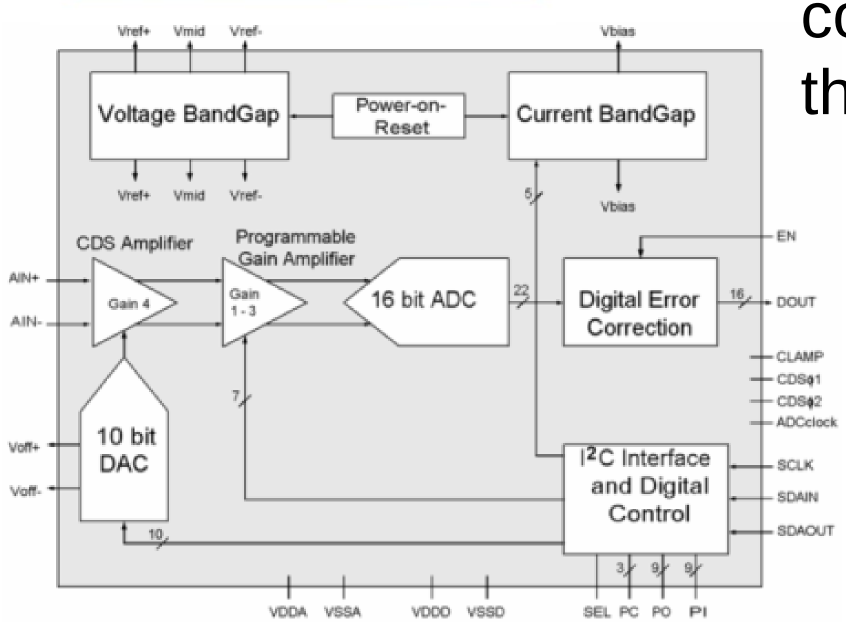
Example compact 0.5THz receiver



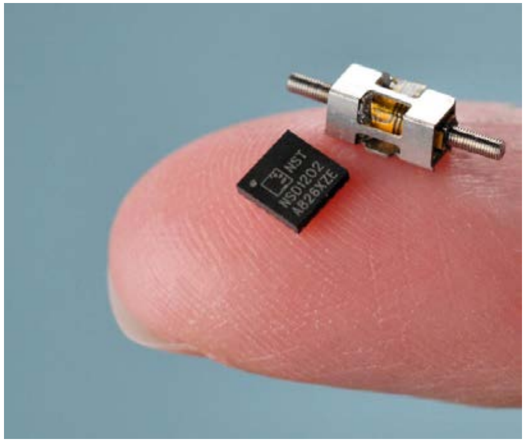
1THz QCL LO on Cold Finger

Power



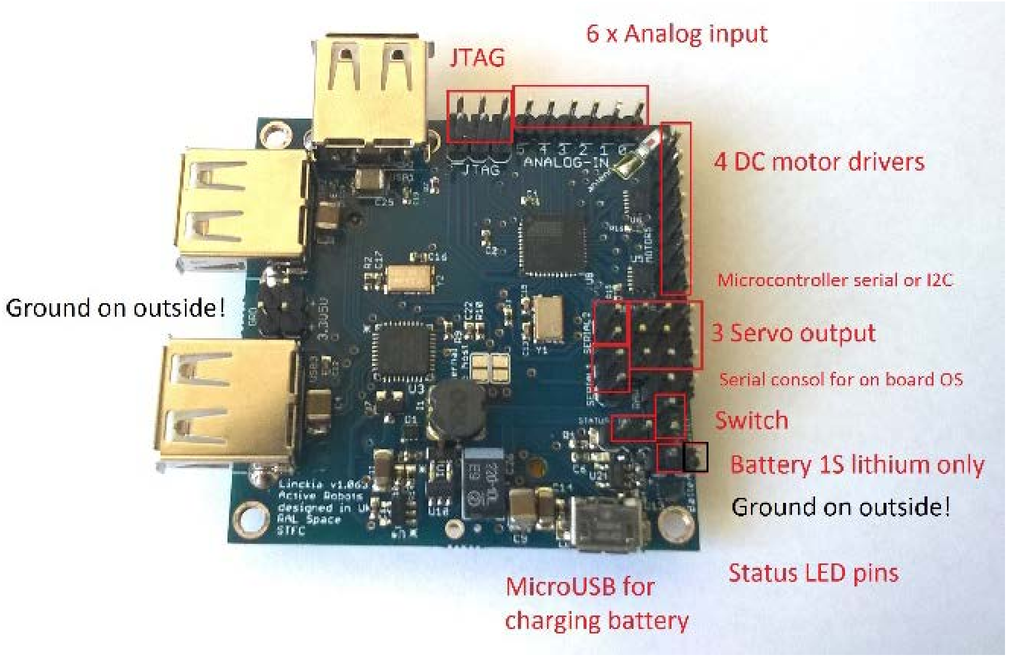


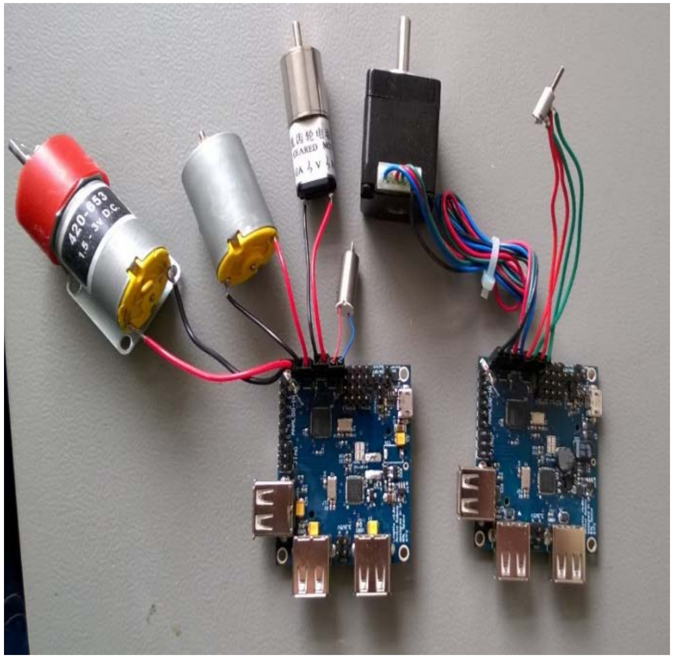
Electrical power really does scale with miniaturisation, or integration of functions, although the key here is space qualification of COTS components. We need to inherit from the automotive industry.



Power saving

There are also big savings to be made from modern control techniques (PWM, Switching amplifiers etc)





RAL Space

Cooling

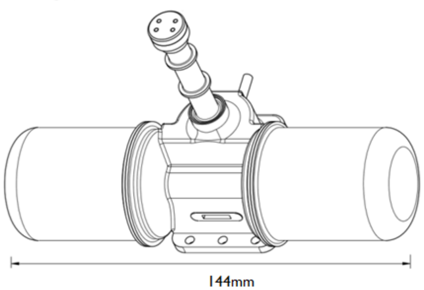
- RAL TD Miniature cooler technology
  - 580 g
  - 140 x 60 x 90 mm
  - < 20 W input power
  - 750 mW at 77 K

A Small Scale Cooler for use at 80K

ESA contract 4000102281/10/NL/SFe

T.W. Bradshaw, S.A. Brown, M.R. Crook, G. Gilley, S.Watson
STFC, Rutherford Appleton Laboratory, Chilton, Didcot, OX11 0QX, UK
T Tirolien
ESTEC

martin.crook@stfc.ac.uk
Space Cryogenics Workshop, ESTEC 2013



Next-Gen project aiming at 100g cooler with Additively manufactured JT or Pulse Tube.

Calibration

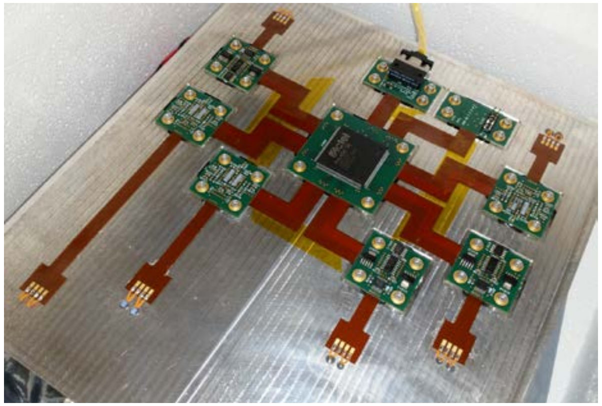
- Miniature fixed point Black-Body targets for IR calibration
  - correlate radiation thermometers
  - Cells contain 99.9999% pure metals
  - melt or freeze curve to within ±0.01° C.

Fixed-Point Cells for Blackbody Sources

NSTP-2 black body embedded electronics

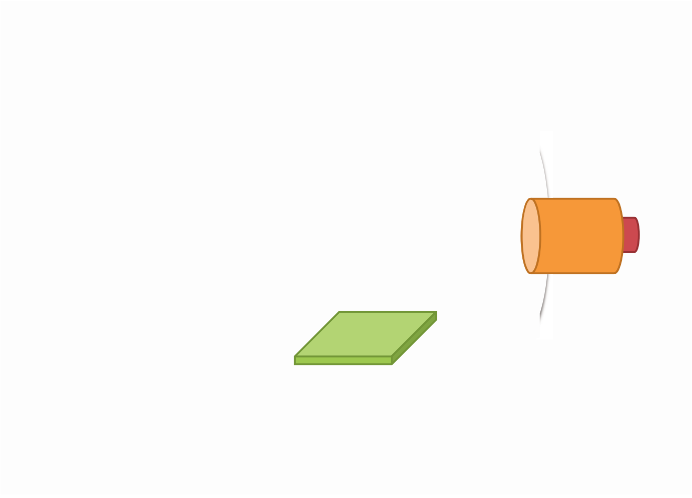
- Thermometer electronics embedded on black body structure
- All circuit elements (controller, thermometer conditioning, thermal breaks, wiring harness) on single semi-rigid PCB
- All-digital interface
- **High**: accuracy, resolution. **Low**: power, mass, EM susceptibility
- Demonstrated for Pt100 thermometers and 3 kΩ thermistors

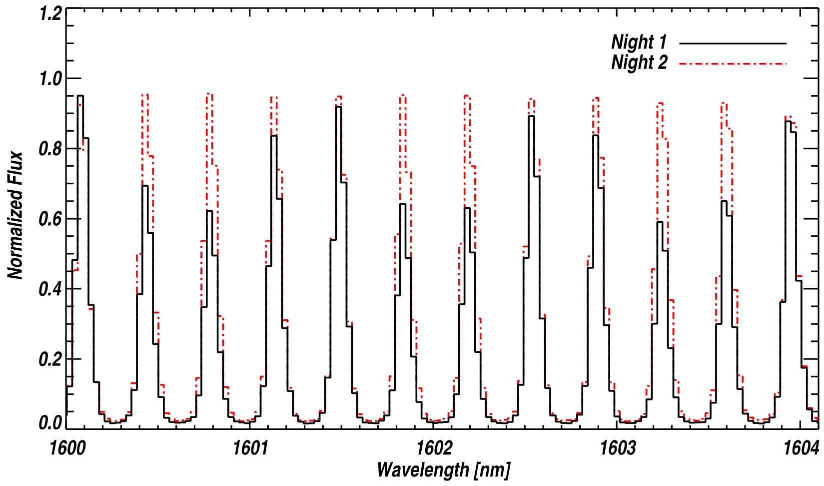
Parameter	**Current (SLSTR)**	**New**
Electronics		
Topology	12-bit SAR ADC Four switched ranges. Calibration depends on stability of entire circuit	24-bit ΔΣ ADC Single range. Calibration depends only on stability of reference resistor
Power consumption (excluding heaters)	4.2 W	300 mW
Readout accuracy	~ 15 mK	< 5 mK
Readout resolution	10 mK, preferred states	600 µK, Gaussian
Mass		
PCB and harness	1.2 kg	120 g
Electronics unit	1.6 kg	0 g

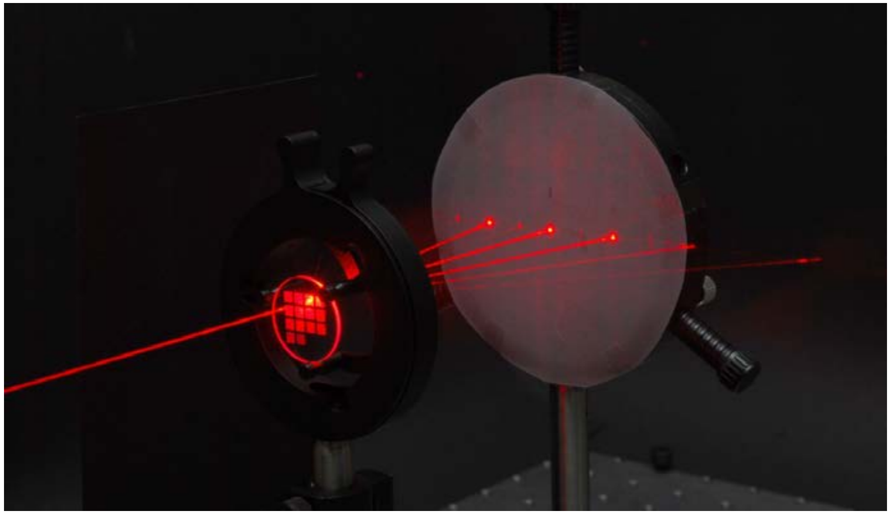


tim.nightingale@stfc.ac.uk

Calibration







Final remarks

- There's lots more that could be mentioned - integration of functions, non uniform geometries and manufacture
- All of these can benefit the large satellite program as much as the small
- But it’s the science goal that has to be the driving force, and that only gets worked out when you see what might be possible
- So I would urge you to interact, use CEOI and help us think outside of a (small) box