Embedded electronics for a flight black body

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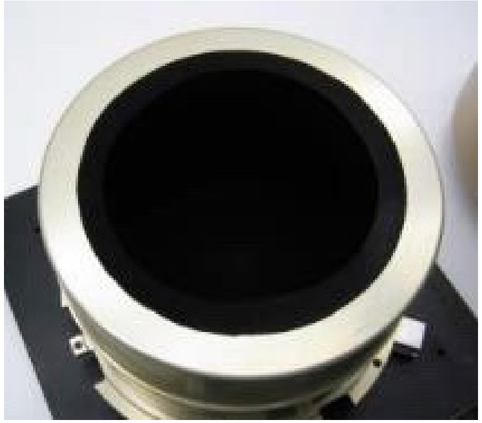
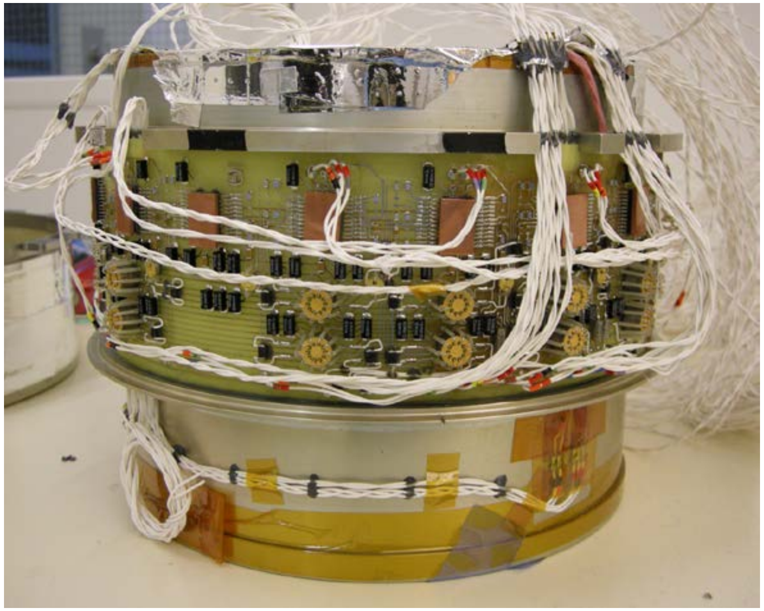
Why black bodies are important

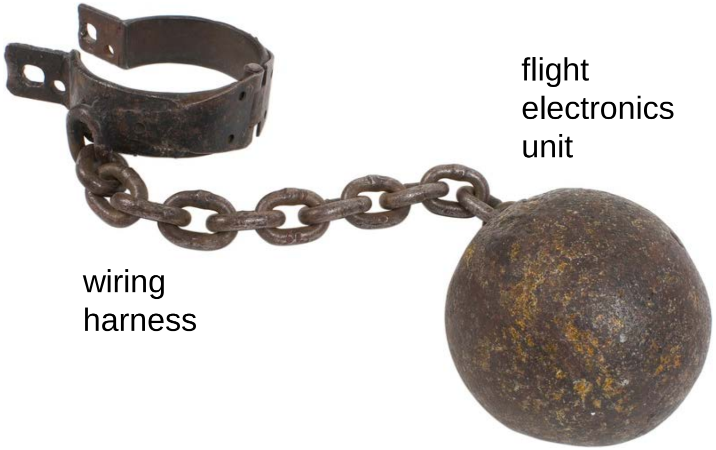
- The core instrument class for EO missions covering surface temperature, radiative balance, climate, atmospheric composition – anything requiring the measurement of thermal radiation – is the radiometer
- Black bodies are the primary source of calibration and traceability for all thermal infrared (and many microwave) radiometers. The basic performance of a radiometer is driven largely by the quality of its black body calibration targets
- Uncertainties in black body performance have a first order effect on calibrated radiances and, generally, a bigger effect still on retrieved geophysical quantities
- Black bodies can consume significant fractions of the mass, volume and power budgets of a satellite instrument. Any reductions you can make increase your chances of building a viable instrument





Why revisit BB electronics?

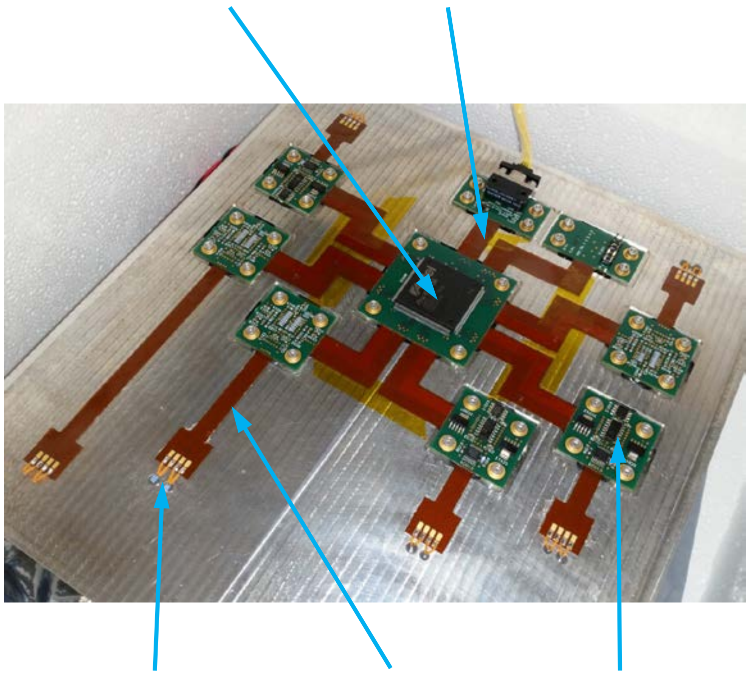
- A black body is a practical realisation of the Planck function
- Its performance is determined almost entirely by knowledge of two properties:
  - Temperature
  - Emissivity, or blackness (next talk)
- Temperature is measured with resistance thermometers (PRTs, RIRTs, thermistors)
- Readout electronics condition and digitise thermometers
- Design has barely changed in 25 years:
  - “Old-school” analogue-to-digital convertors: power hungry, poor resolution, so-so linearity, missing states, preferred states, ITAR
  - Bulky wiring harness carrying large number of analogue thermometer signals from BB
  - Separate flight electronics unit needed to process thermometer signals
  - Range switching needed
  - Hard to calibrate well



A new approach

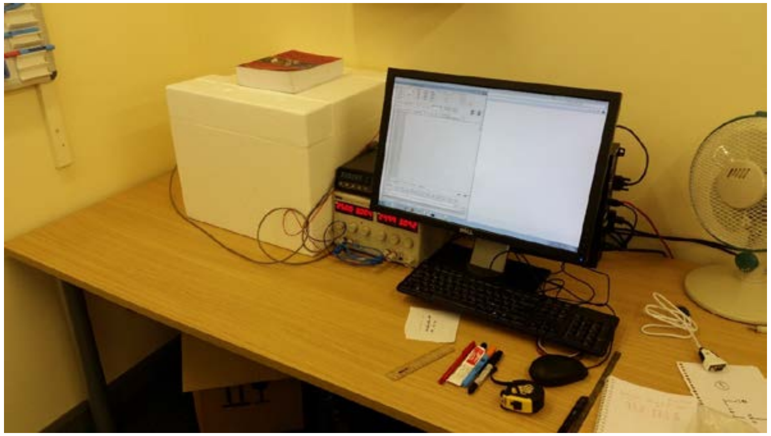
RAL Space

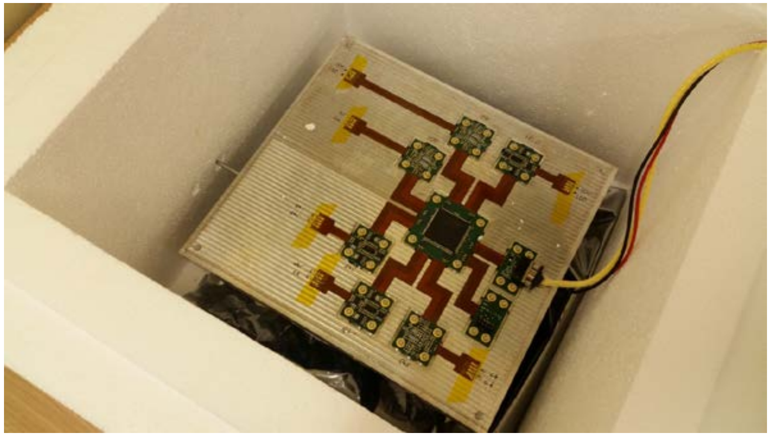
- Integrate everything onto a single semi-rigid PCB. Four main elements:
  - Readout nodes (miniaturised resistance bridge)
  - Data controller services readout nodes and consolidates information into a single serial data stream (currently SPI)
  - Integral thermal breaks
  - Integral wiring harness
- Use ΔΣ ADCs:
  - Low power, highly linear, high resolution, no preferred states
- Advantages:
  - High mechanical integrity
  - Low EM susceptibility
  - All-digital communications
  - External electronics infrastructure reduced or eliminated
  - Readout node temperatures follow thermometric temperatures



Testing

- Limited programme to fit within project constraints
- **Functional testing**
- Confirmed function of:
  - Readout nodes
  - Data controller state machine
  - Ground support equipment
- Measured:
  - Power consumption
- **Performance testing**
- Demonstrated:
  - Very low temperature sensitivity in readout nodes (fixed resistors)
  - Reproduction of thermometric temperatures to ~ 5 mK (Pt100 and 3 kΩ thermistors)
  - Very good equivalent noise performance





Summary

- 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 (NSTP-2)
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