Turning an Instrument Concept into Reality
CEOI Training Workshop
15 March 2010

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Space Science & Technology Department

Rutherford Appleton Laboratory

Science & Technology Facilities Council

Contents

Introduction

- Common sense!
- Good engineering practice
- The Broad Band Radiometer, BBR, is a good example of the process

Understanding Requirements

- Mission Requirements
  - Imperative that you understand, at least at the system level, the overall scientific aims of the mission
- Instrument Requirements and constraints
  - Imperative that you understand the detailed requirements on your instrument including

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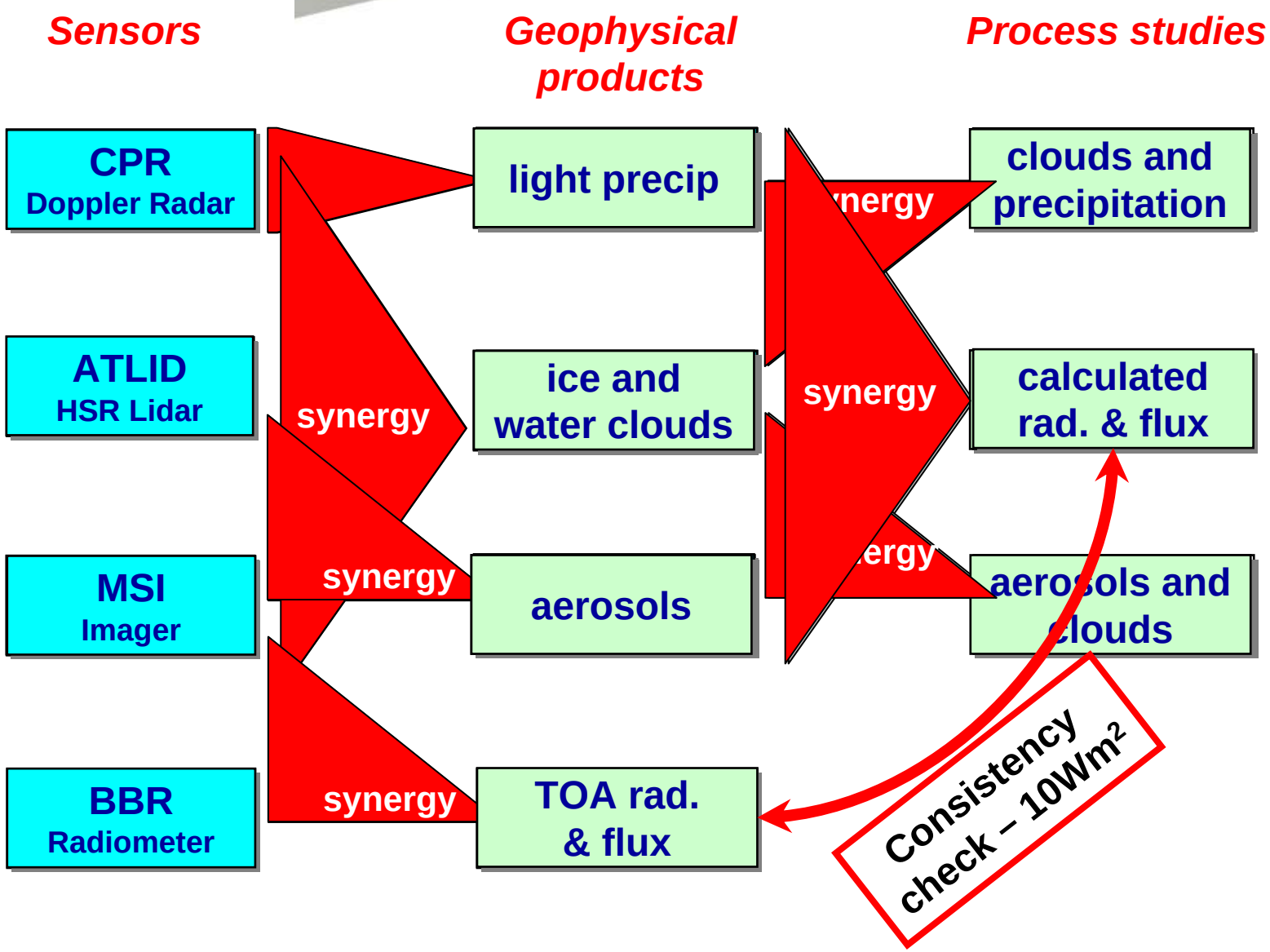

Sensors
Geophysical products
Process studies
CPR
Doppler Radar
ATLID
HSR Lidar
MSI
Imager
BBR
Radiometer
light precip
ice and water clouds
aerosols
TOA rad. & flux
clouds and precipitation
calculated rad. & flux
aerosols and clouds
synergy
synergy
synergy
synergy
synergy
synergy
Consistency check – 10Wm2

Science & Technology Facilities Council

The EarthCARE Joint Mission Advisory Group (Phase B)

TOR: User needs, science requirements, compatibility of system/instruments specs with science requirements, end-to-end performance, study & campaign needs, cal/val requirements/preparation, science data products & L2 algorithms.
Members: Personal invitation, independence from industry mandatory

Chairs: ***Anthony J. Illingworth,*** *U Reading* ***& Terry Nakajima,*** *U of Tokyo*

European/Canadian Members:

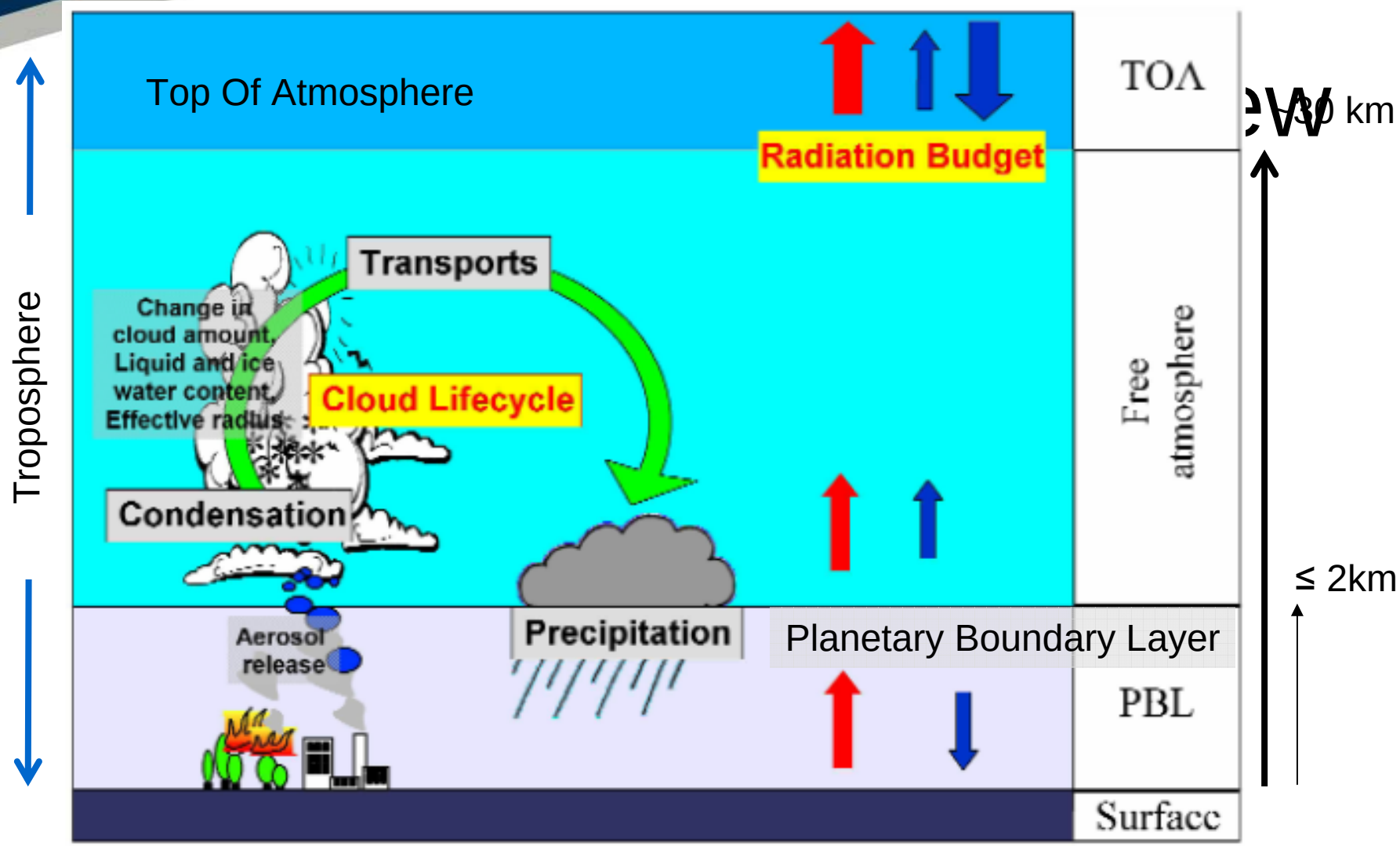
- **Howard Barker,** Environmt. Canada
- **Anton Beljaars,** ECMWF
- **Franz Berger,** DWD Obs. Lindenberg
- **Jean-Pierre Blanchet,** UQAMontreal
- **David Donovan,** KNMI
- **Martial Haeffelin,** IPSL
- **Gelsomina Pappalardo,** CNR IMAA
- **Jacques Pelon,** Serv. d'Aer. du CNRS
- **Anthony Slingo,** Univ of Reading
- **Ulla Wandinger,** Inst. Troposph. Res.
- ***Tobias Wehr,*** *ESA Mission Scientist*

Japanese Members:

- **Hiroshi Kumagai,** NICT
- **Takashi Nakajima,** Tokai University
- **Hajima Okamoto,** Tohoku University
- **Nobuo Sugimoto,** NIES
- **Yukari Takayabu,** Univ of Tokyo
- ***Toshiyoshi Kimura,*** *JAXA Mission Scientist*

Observers:

- **Graeme Stephens,** Col State Univ
- **Deborah Vane,** JPL
- **David Winker,** NASA Langley
- **Graham Feingold,** NOAA
- **John J. Bates,** NOAA


Top Of Atmosphere
Radiation Budget
TOA
Troposphere
Transports
Change in
cloud amount,
Liquid and ice
water content,
Effective radius
Cloud Lifecycle
Condensation
Free
atmosphere
Aerosol
release
Precipitation
Planetary Boundary Layer
PBL
Surface
≤ 2km

EarthCARE Mission Overview - Objectives

Scope: **To make Global (tropospheric) observations of**
Cloud-aerosol-radiation and
Cloud-aerosol-precipitation-convection processes:

With the objective of providing essential basic input data for numerical modelling and global studies of

The divergence of radiative energy

The aerosol-cloud-radiation interaction

The vertical distribution of water and ice and their transport by clouds

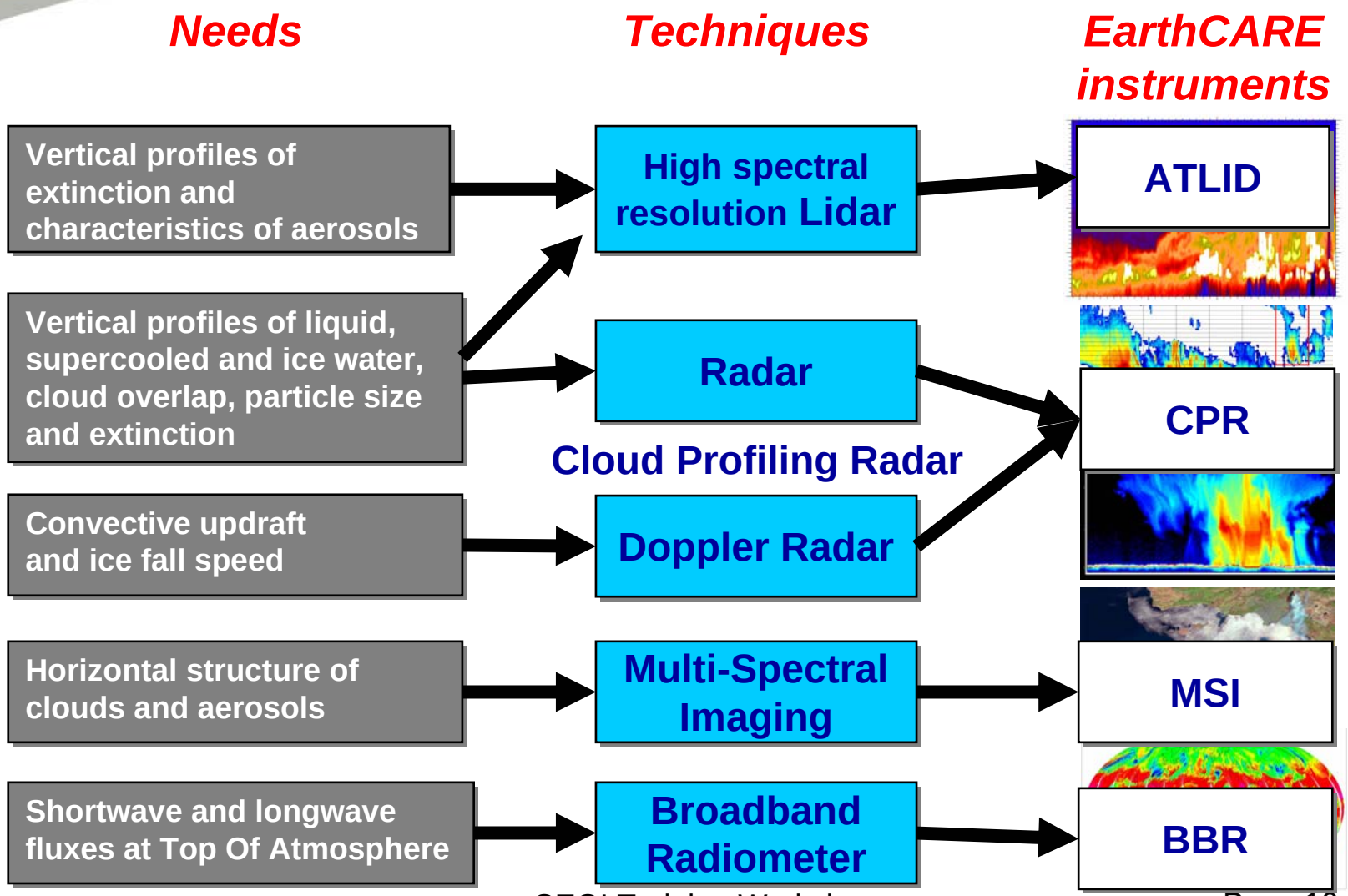
The vertical cloud field overlap and cloud precipitation interactions

To reach the Goal of :

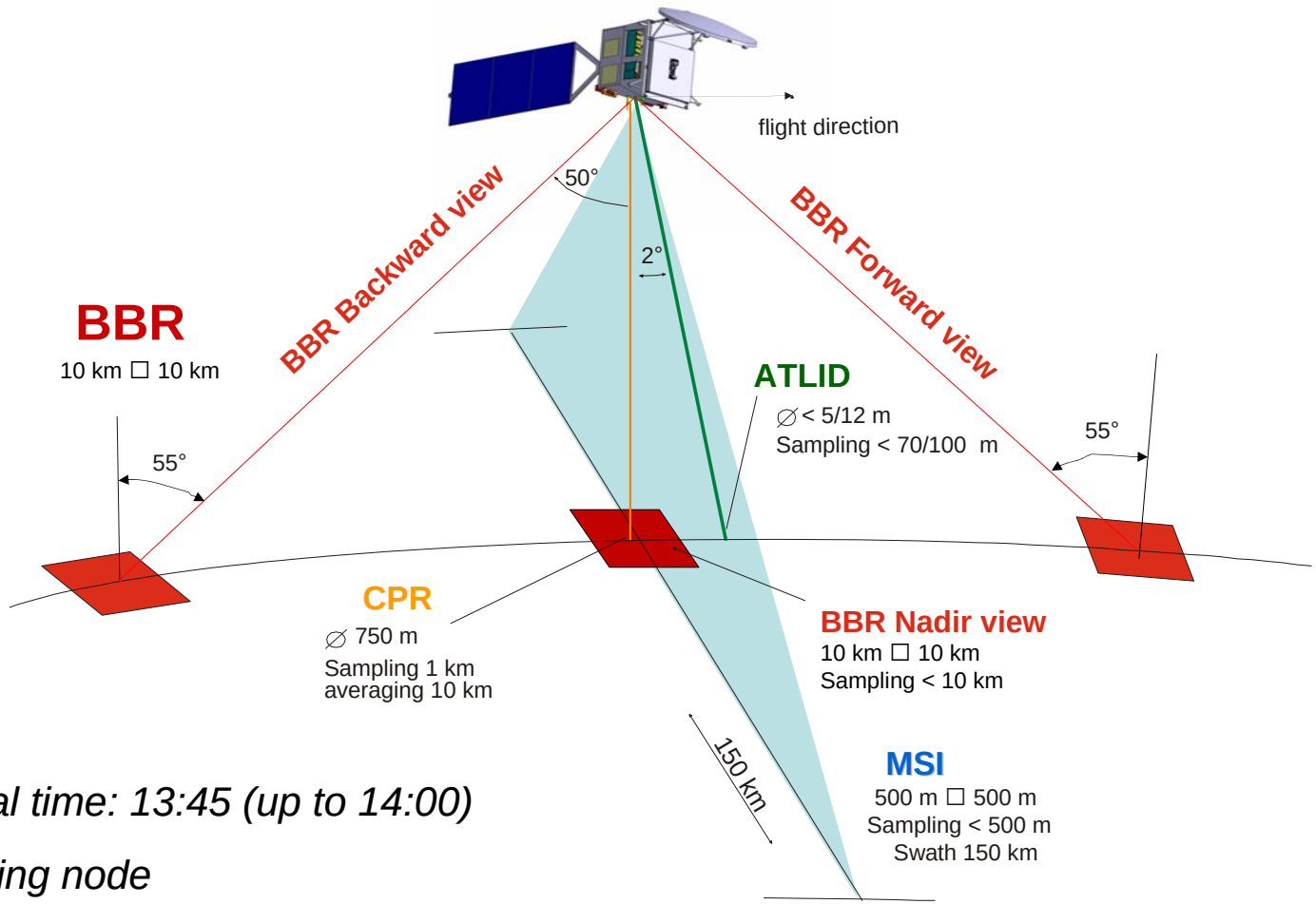
Reconstruction of vertical cloud/aerosol profiles to derive instantaneous radiative fluxes with an accuracy of 10 Wm^{-2}.

This is essential data for quantifying with sufficient accuracy the SW and LW forcing parameters needed in the Global Circulation Models used for the understanding and prediction of anthropogenic influenced climate change. Uncertainties at present are very large.

EarthCARE Mission Overview - Concept



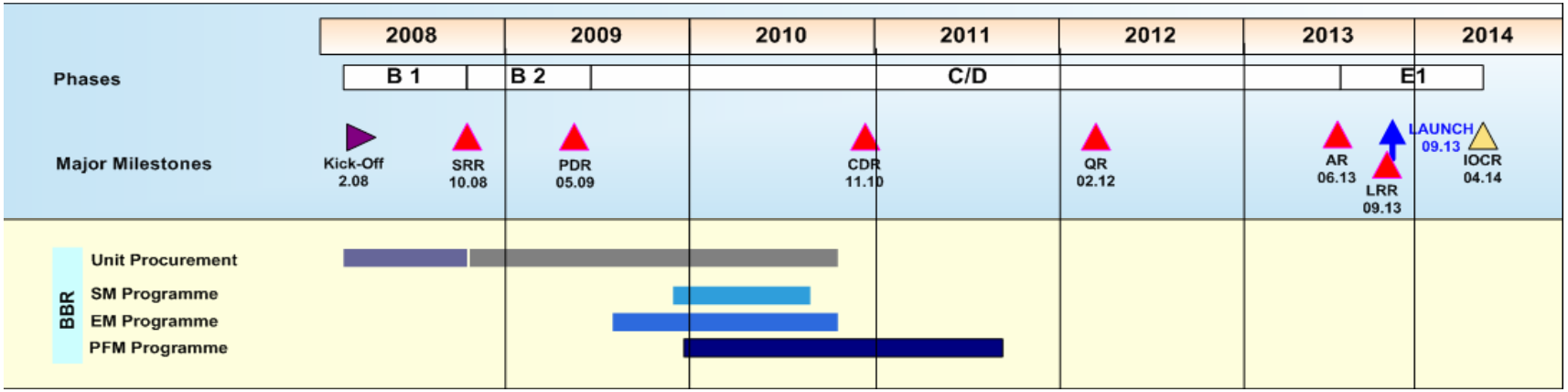
EarthCARE Mission Overview - Viewing geometry



Orbit local time: 13:45 (up to 14:00)

Descending node

BBR - Planning, development, industrial team



Incorporates heritage from Gerb, AATSR, ATSR-2 and mechanisms from missions such as RapidEye, Giotto

- Instrument Prime: Systems Engineering and Assessment (SEA) Ltd (UK)
- Optics Unit: Rutherford Appleton Laboratory (UK)
- Mechanisms: ESR (UK), Sula Systems Ltd. (UK)
- Software: SciSys (UK)
- Calibration consultancy: LMD (F)
- Detectors: INO (C)

BBR - Principal requirements

Measure Top of Atmosphere solar reflected and Earth emitted radiance

- In 3 simultaneously measured, 10 km scenes along the satellite track
- In Short Wave (SW) and Total Wave (TW) channels
- Measurements are unfiltered by correlating BBR radiances against MSI data to evaluate scene type and Long Wave flux is inferred from subtraction of BBR SW from TW unfiltered data

Fore, Nadir, Aft line of sight views	+50°, 0°, -50°	
Spectral Channels	Dynamic range	Absolute accuracy
Short Wave (<0.20 to 4 μm)	0-450 $Wm^{-2}sr^{-1}$	2.5 $Wm^{-2}sr^{-1}$
Total Wave (<0.20 to >50 μm)	0-550 $Wm^{-2}Sr^{-1}$	
Long Wave (inferred) (4 μm to >50 μm)	0-130 $Wm^{-2}Sr^{-1}$	1.5 $Wm^{-2}sr^{-1}$
Instrument linearity	Better than 0.005	
Spatial resolution, ΔX Spatial sampling distance	≤10 km Constant within ±1%, ≤1 km	
Integrated energy: - Scene centred around PSF barycentre of nadir view, at any altitude from 0-20 km - in SW with respect to TW channel - in nadir with respect to fore/aft views - Over any square target 1.5 x ΔX	Identical within 5% for the 3 directional views; Identical within 5% in the SW and TW channel; At least 99%.	
Polarisation sensitivity 0.2 μm to 4.0 μm Beyond 4 μm	<0.01 Minimised	
Geo-location of level 1B data	Better than 500 m RMS	

BBR Instrument Concept - Accommodation

Optics Unit (OU) position on spacecraft nadir facing panel

Instrument Control Unit (ICU) position internal to spacecraft

Mass:

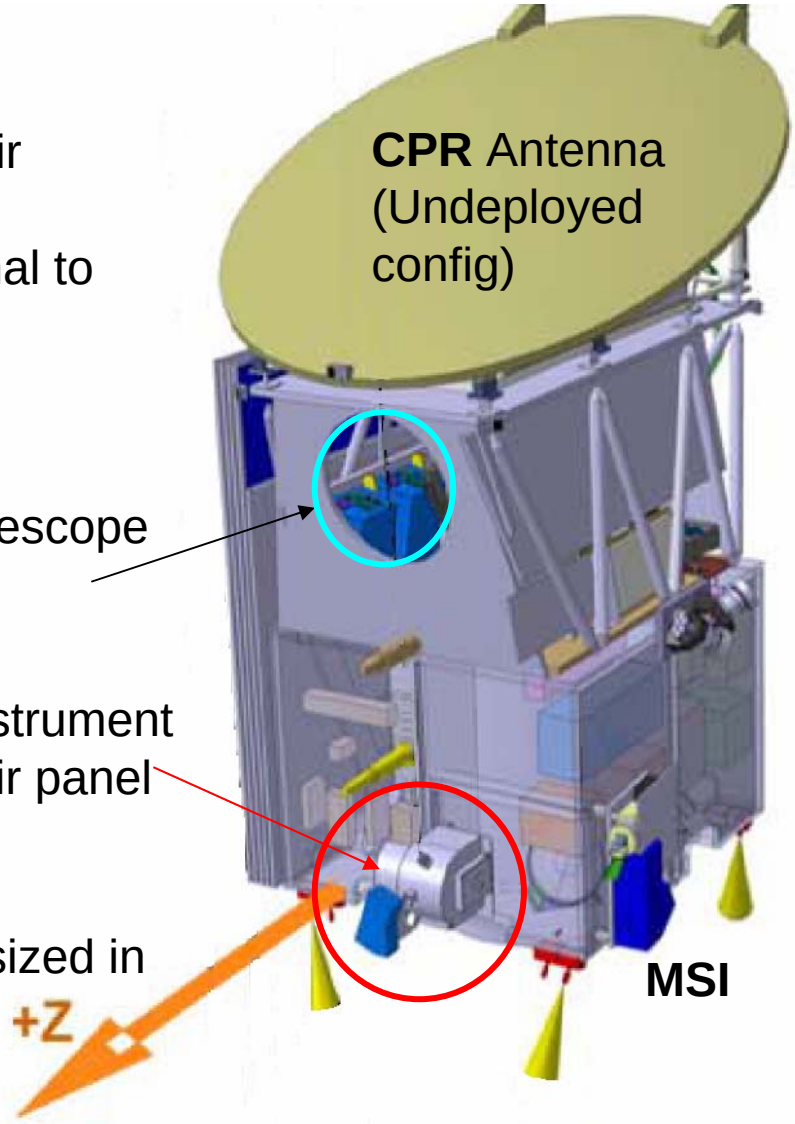
- ~ 23 kg OU
- ~ 8 kg ICU
- ~ 3 kg Harness

Power:

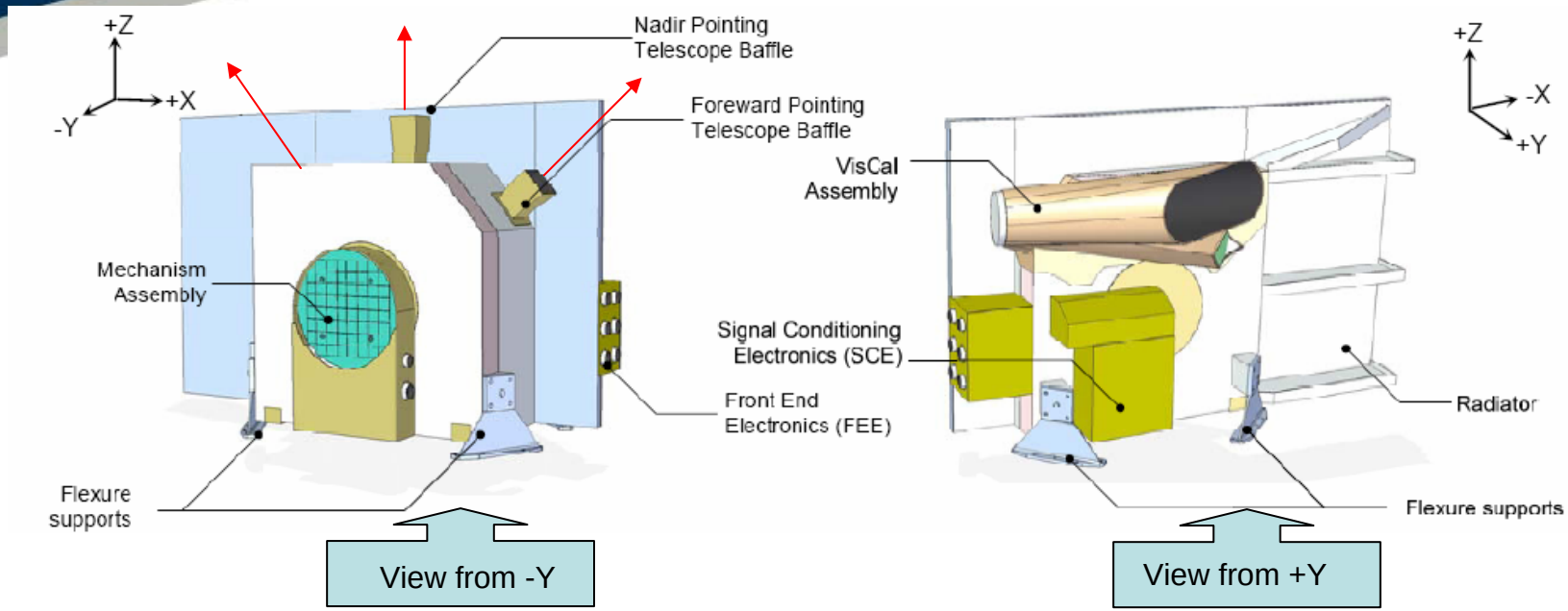
- ~ 33 W OU
- ~ 23 W ICU
- ~ 30 W survival

Data rate: 145 kbps av.

- – 32 pixels in each view sample (oversized in relation to scene)



BBR Instrument Concept - Optics Unit



Telescope Assembly

- Telescope Drum (telescopes x3)
- Focal plane assemblies and front end electronics
- Chopper Drum
- Calibration Drum
  - Blackbody References
  - View to VISCAL
- VISible CALibration system
  - Solar baffle, fold mirrors, diffuser

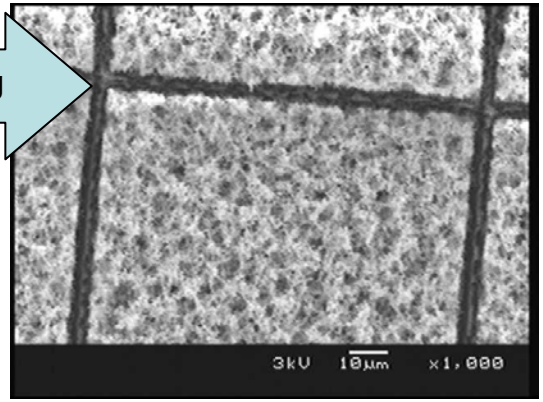
Mechanism Assembly

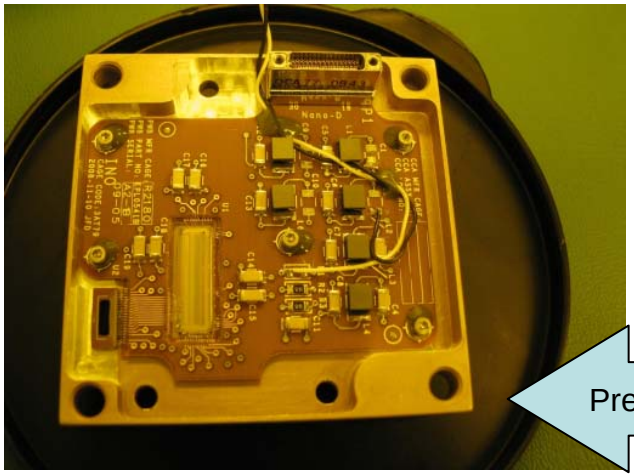
- Chopper Drive Mechanism
- Calibration Target Mechanism

Telescope Assembly - Detectors

- Au-black coating facility commissioned at INO
- Successful laser trimming of Au-black coating trials (3-12 µm spot size)
- Characterisation of INO Au-black coating demonstrates less than 4% reflectance in BBR spectral range
- Essentially flat spectral response across BW
- Trial detector (partially representative) delivered to RAL for spectral characterisation and proximity electronics testing

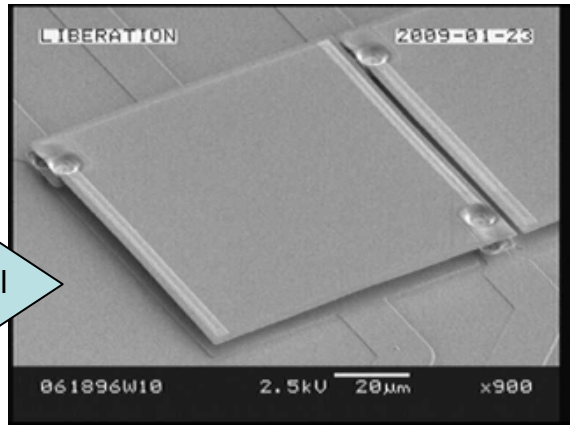
Laser Trimming





Pre-Blacking Trial Detector

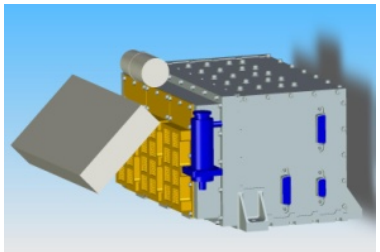
INO microbolometer pixel

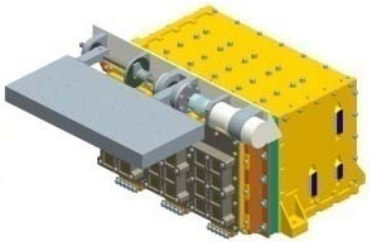


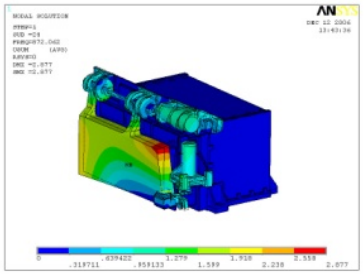
Mechanical Engineering

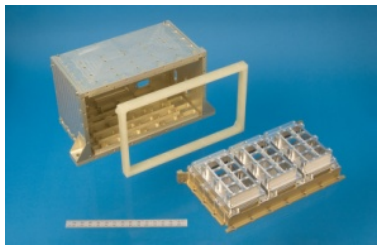
See a project through from concept to deliverable hardware

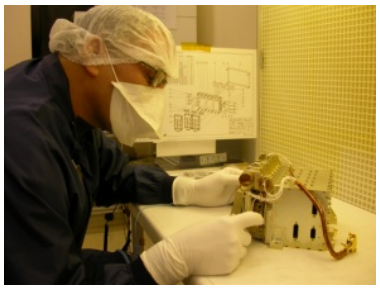
- Concept design
- Detail design
- Analysis
- Manufacturing
- Assembly
- Testing
- Delivery

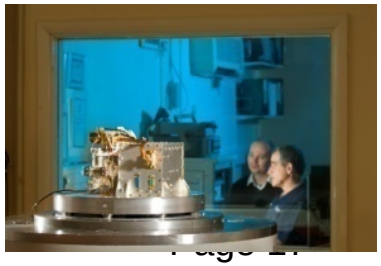




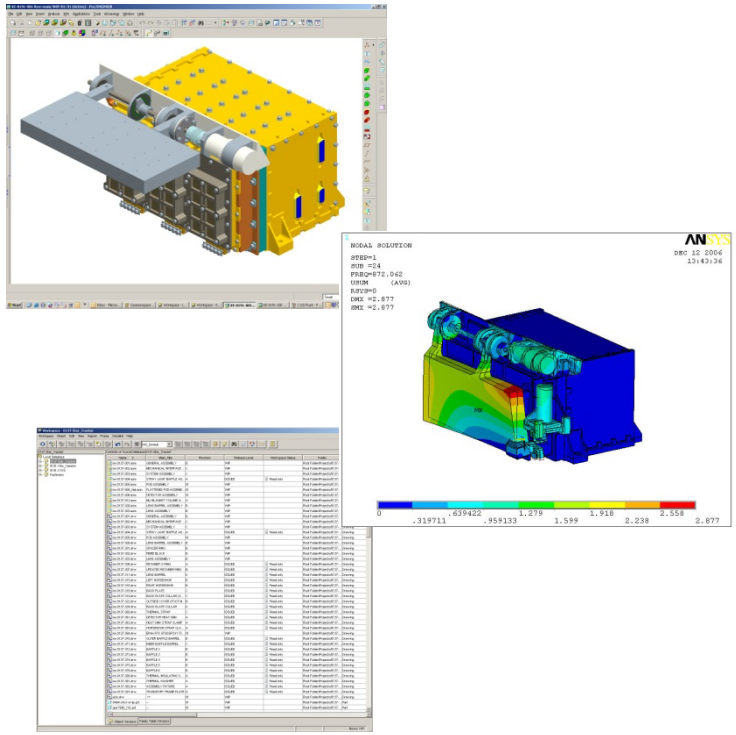






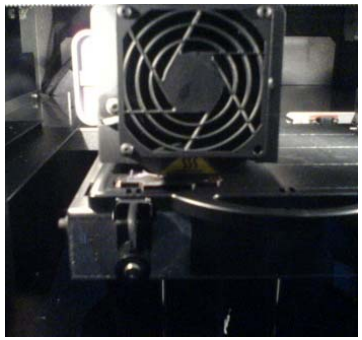


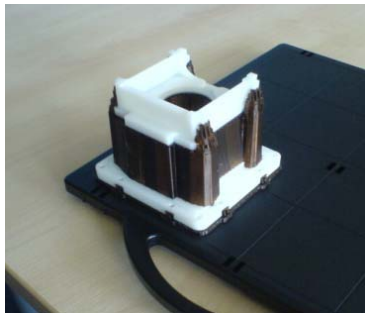
Design Tools



- 3D CAD
  - (PRO/Engineer, SolidEdge)
- Finite Element Analysis
  - (ANSYS)
- Data management
  - (PRO/Intralink, TeamCenter)

Rapid Prototyping

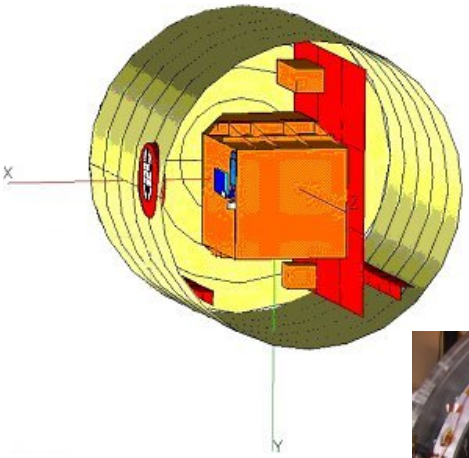


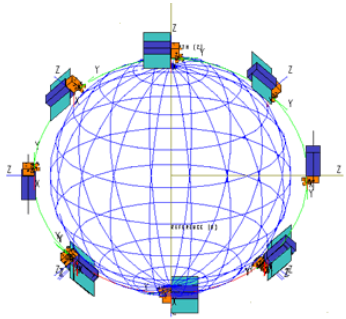


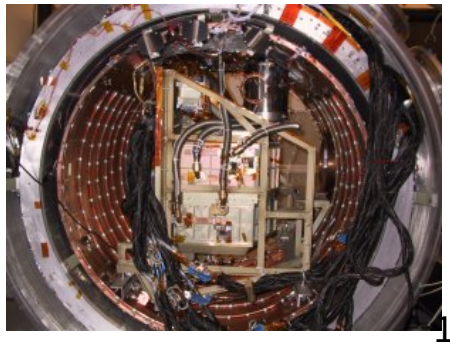
- On site capability to produce rapid prototype models
- “3D Printer”
- Direct from 3D CAD model

Thermal Engineering

- Conceptual studies
- Detailed design and analysis
- Design and procurement of thermal hardware
- Multi-Layer Insulation (MLI) design & manufacture
- Test specification and support







Tools

- ESATAN & ESARAD
- Spreadsheet based tools for mathematical modelling, e.g. cryocoolers
- In-house developed thermal properties database

Product Assurance

- Operates and maintains a quality management system certified to ISO9001:2000 and Tick-IT quality
- Provides PA support to all internal projects
- Operates systems for the control and tracking of NCRs, RFWs, ECRs, etc.
- Provides support to academia
- Qualified ESA inspectors

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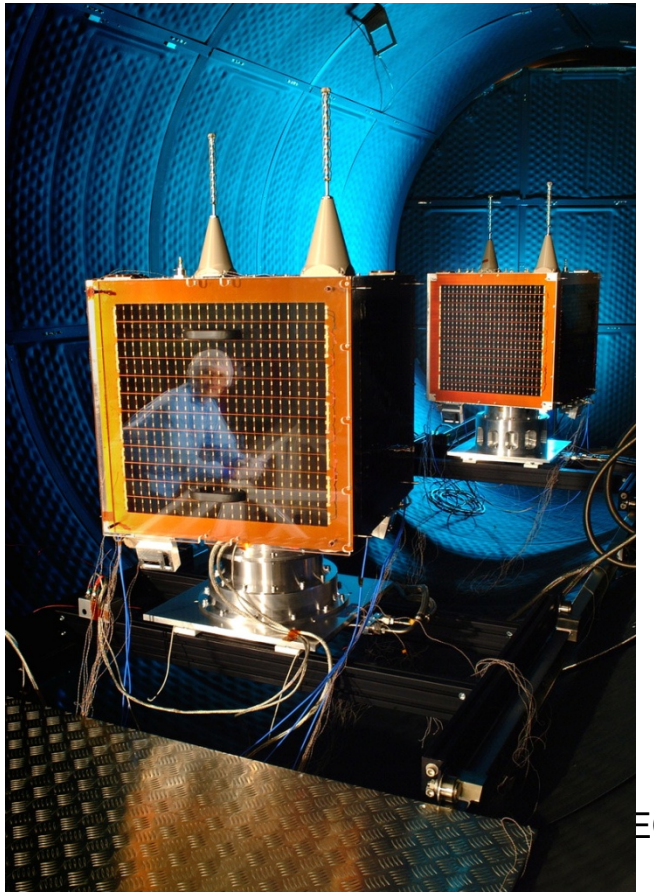
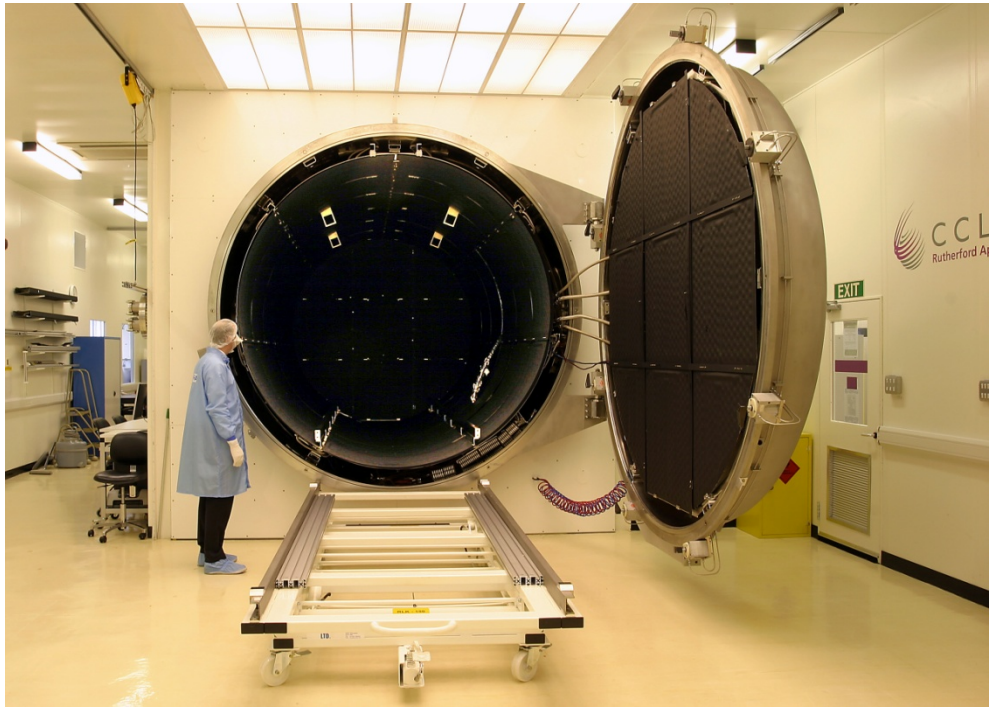
CLEAN ROOMS

SPACE TEST CHAMBER

Vessel size = 3m dia x 5.5m long

Ultimate pressure = < $1x10^{-6}$ mBar (payload and temperature dependent)





Dry pumped

Temp range = LN^2 to +150°C

200 monitoring channels

Multiple thermal plates

Mass Spectrometer & TQCM

Class 1,000 cleanroom conditions

VIBRATION & SHOCK TESTING

LDS V8-440

New shaker suitable for small-sats

Sine, Random and Shock

Max Force = 66 kN

Max Acceleration = 140g

Max Velocity = 1.78 m/s

Max Displacement = 63mm p-p

- Head Expander 1 -1200mm X 1200mm
- Head Expander 2 – 600mm dia
- Slip Table 1 - 1220mm x 1220mm
- Slip Table 2 – 750mm x 750mm
- 64 Channels standard, expandable to 128
- Force Limiting 6 Triaxes

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OTHER SERVICES

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MLI FACILITY

The MLI (Multilayer Insulation) Facility in conjunction with the Thermal Engineering group are specialists in the design, manufacture and installation of multilayer insulation blankets for spacecraft instruments.

Because cleanliness is of fundamental importance to the service provided, the Facility is located within a Class 6 (1,000) clean room environment.

- Specialists in design and manufacture for payloads and small spacecraft
- Experienced staff can recommend the proper combination of space qualified materials and processes
- Installed on or off site
- ISO9001 accredited

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Conclusions

- See – it really IS just common sense!
- Understand the requirements – hard and soft
- Get a good team together
- Understand the schedule and PLAN
- Get support from your senior management for resources
- Know your technical, programmatic, financial and resource limitations and live within them