EarthCARE

The Earth Cloud, Aerosol and Radiation Profiling Satellite Mission

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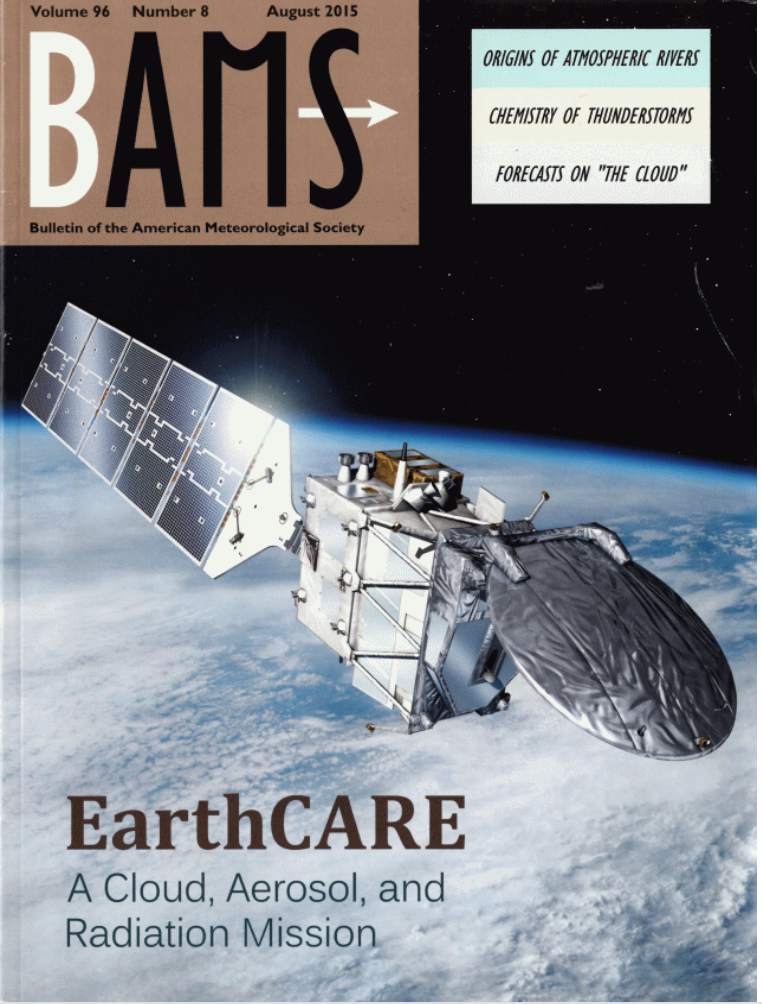
European Space Agency



ESA's 6th Explorer mission

implemented in cooperation with JAXA

Mission objective:
Understanding of cloud-aerosol-radiation interactions so as to include them correctly and reliably in climate and NWP models

A. J. Illingworth *et al.*

The EarthCARE satellite: The next step forward in global measurements of clouds, aerosols, precipitation and radiation

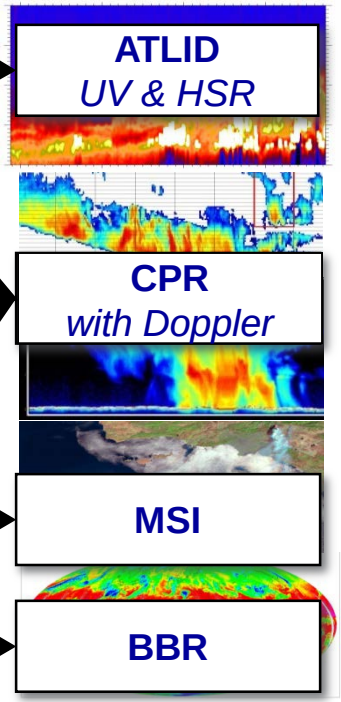
http://journals.ametsoc.org/doi/pdf/10.1175/BAMS-D-12-00227.1

Required Global Observations:

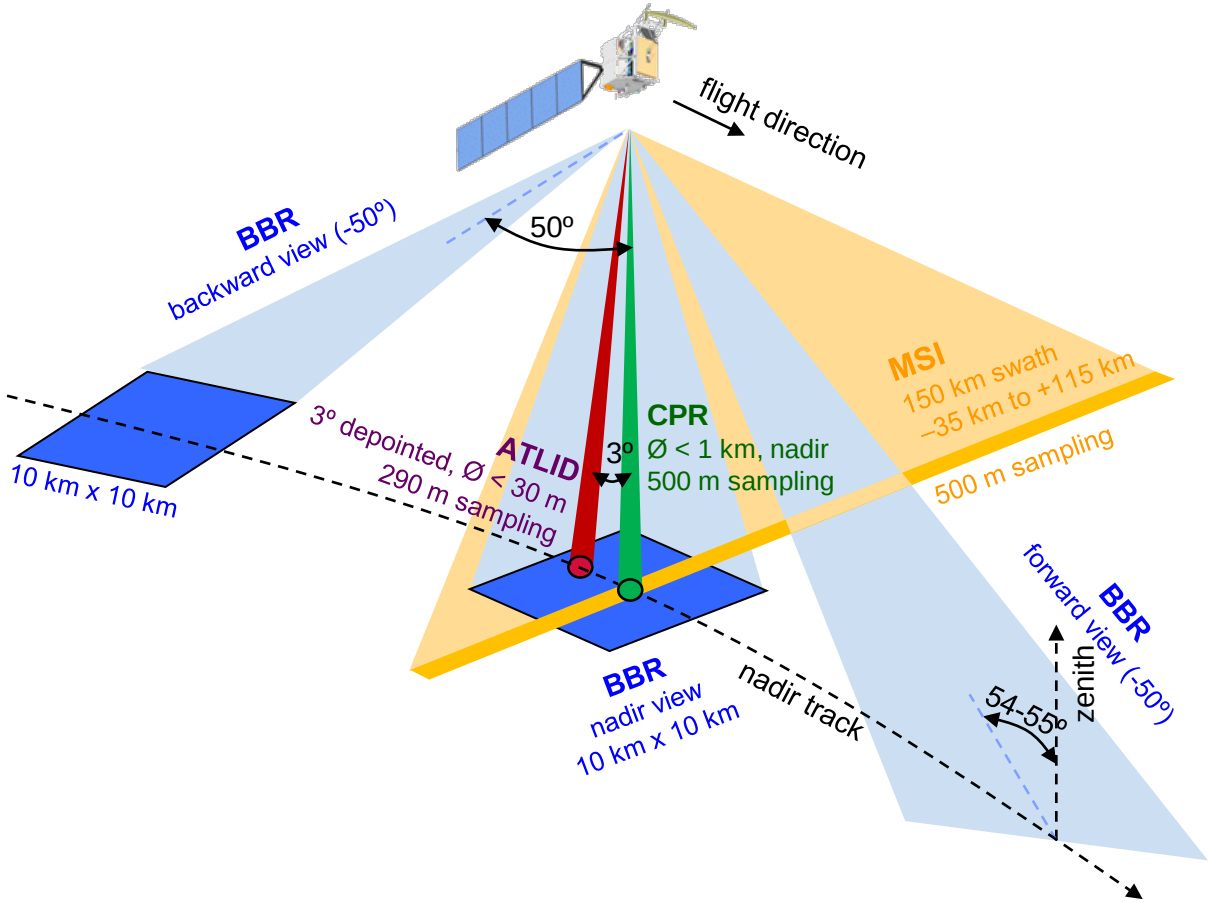
- Vertical profiles of natural and anthropogenic aerosols, their radiative properties and interaction with clouds
- Vertical distributions of atmospheric liquid water and ice, their transport by clouds and their radiative impact
- Cloud distribution (‘cloud overlap’), cloud-precipitation interactions and characteristics of vertical motions within clouds
- Estimates of radiative heating profiles and fluxes
- Calculated TOA radiance and flux* ↔ observed TOA radiance and flux

**from retrieved 3-dim cloud-aerosol profiles*

Needs	Techniques	EarthCARE instruments
Aerosols: Vertical profiles of extinction and characteristics of aerosols	Lidar	ATLID *UV & HSR*
Clouds: Vertical profiles of liquid, supercooled and ice water, cloud overlap, particle size and extinction	Radar	CPR *with Doppler*
Vertical motion: Convective updraft and ice fall speed	Doppler Technique	
2-D Context: Clouds and aerosols horiz. structures	Multi-Spectral Imager	MSI
Radiation and Flux: Solar and thermal broad-band at TOA	Broadband Radiometer	BBR



Temperature and humidity from operational analysis



EarthCARE

Payload & Level 1 Products

HSR Lidar

λ=355nm: Rayleigh, Mie, depol. channels

Level 1: attenuated backscatter profiles

94GHz Radar, with Doppler (JAXA/NICT)

Level 1: Reflectivity and Doppler profiles

Multi-spectral Imager:

4 solar + 3 thermal IR channels

Level 1: TOA radiances and brightness temperatures in 7 spectral bands

Broad-band Radiometer:

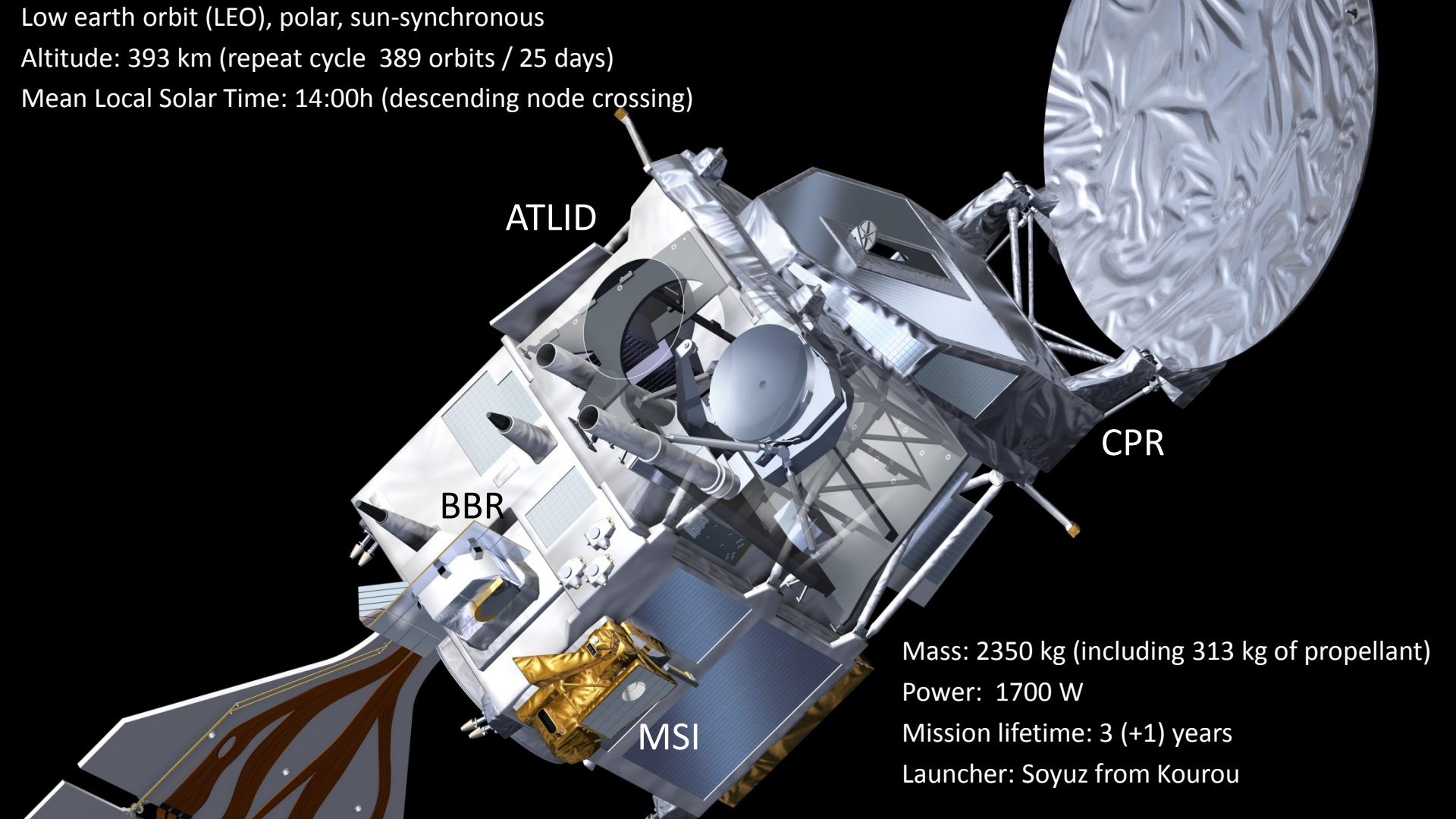
3 fixed FoV

Level 1: Solar and thermal TOA radiances (filtered, unfiltered as Level 2 product)

Low earth orbit (LEO), polar, sun-synchronous

Altitude: 393 km (repeat cycle 389 orbits / 25 days)

Mean Local Solar Time: 14:00h (descending node crossing)



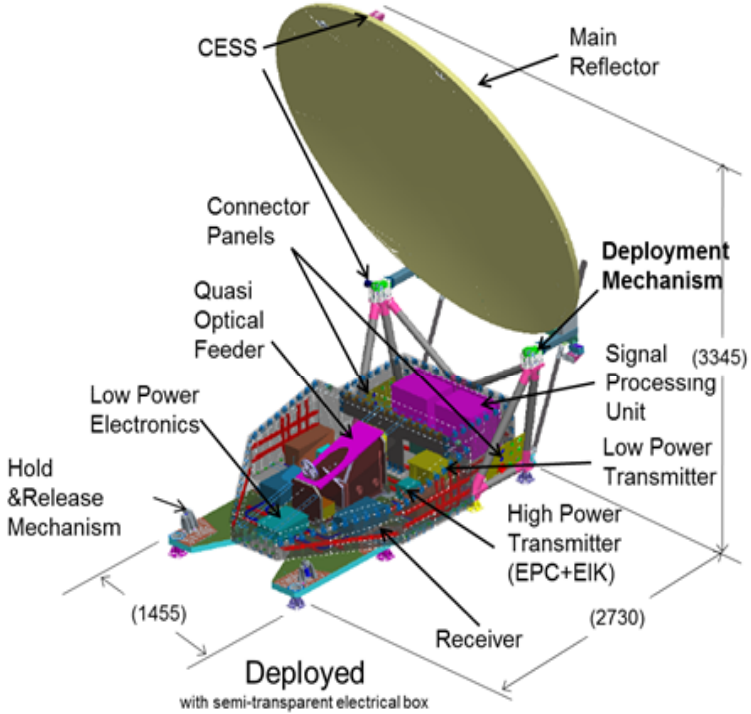
Mass: 2350 kg (including 313 kg of propellant)

Power: 1700 W

Mission lifetime: 3 (+1) years

Launcher: Soyuz from Kourou

The Cloud Profiling Radar – CPR

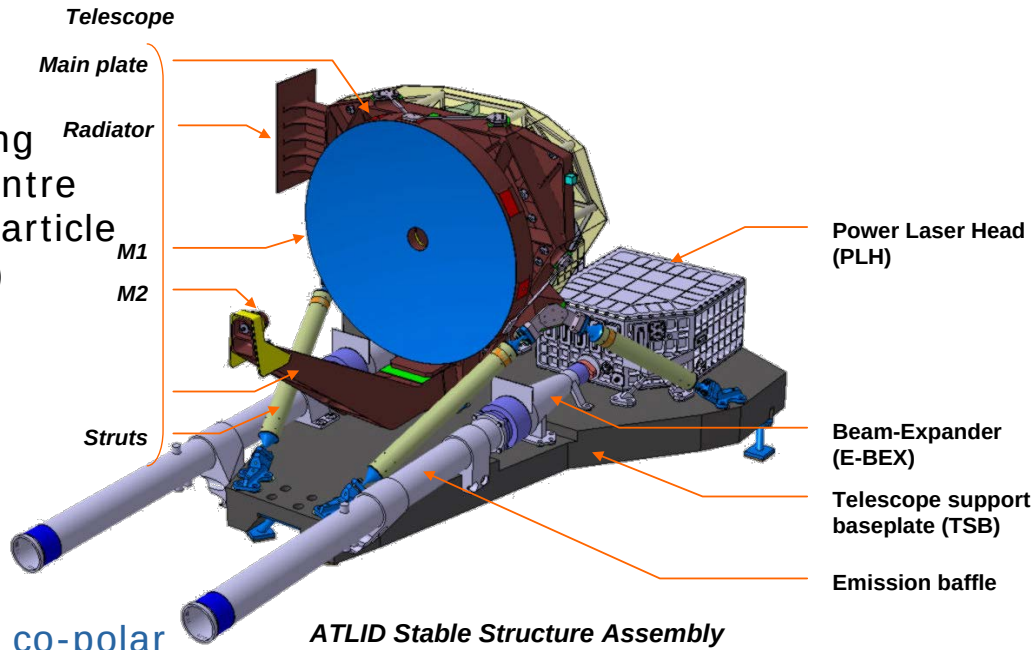


- High power W-band (94GHz), nadir-pointing
- Doppler capability
- Antenna aperture 2.5 m
- Variable PRF: 6100-7500 Hz
- Sensitivity at least -35 dBZ at 20 km height
- Sampling: 500 m horizontal, 100 m vertical
- Vertical range 16–20 km as function of latitude.
  Lower vertical range → higher PRF → better Doppler
- -3dB beamwidth = 0.09˚ → effective footprint on ground = 750m x 1000m
- Instrument: 321 W, 270 kg, 265 kbps
- Level 1 product: reflectivity & Doppler profiles

CPR

Atmospheric Lidar – ATLID

- Atmospheric Lidar
  laser wavelength λ = 355nm, lin. pol.
- High Spectral Resolution Lidar (HSRL) using Fabry-Perot etalon centred on the laser centre wavelength → separates molecular from particle backscatter signals (lidar ratio measured)
- 3 channels receiver :
  - Rayleigh scatter
  - co-polar Mie
  - cross-polar
- Main products are profiles of
  - molecular backscatter signal
  - cloud and aerosol backscatter signal, co-polar
  - cloud and aerosol backscatter signal, cross-polar
  - extinction

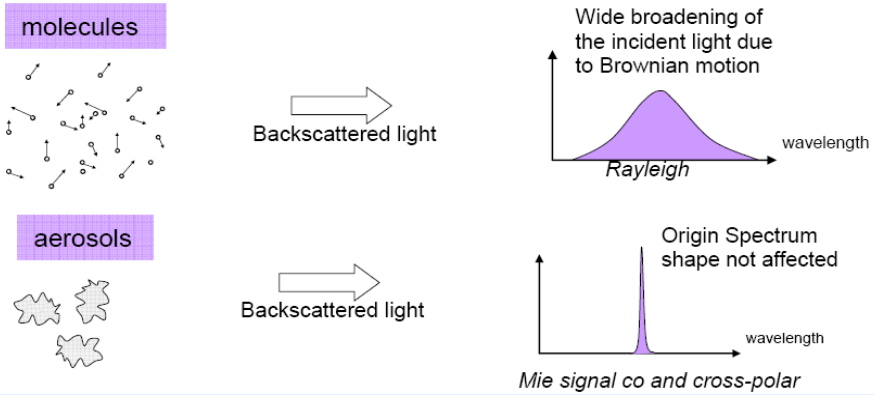


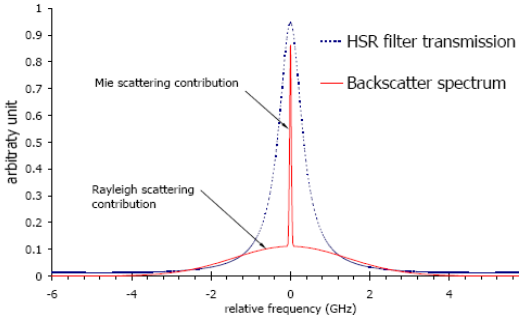
ATLID Stable Structure Assembly (SSA) and equipments

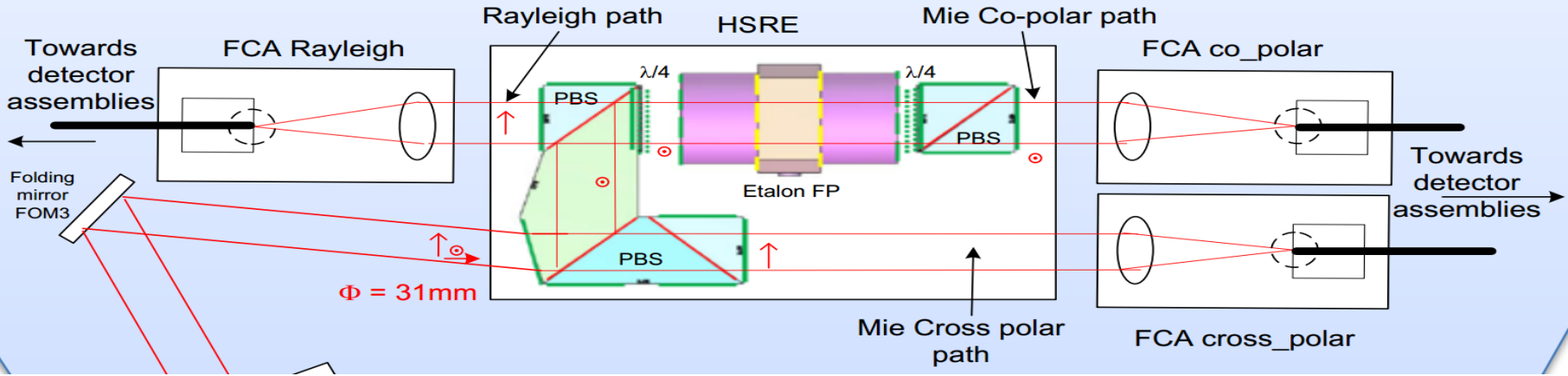
- Sampling: along-track 290m (2x integrated), vertical 103m (up to 20km)
- Mass: 558 kg, Power: 585 W, Data rate <660 kb/s

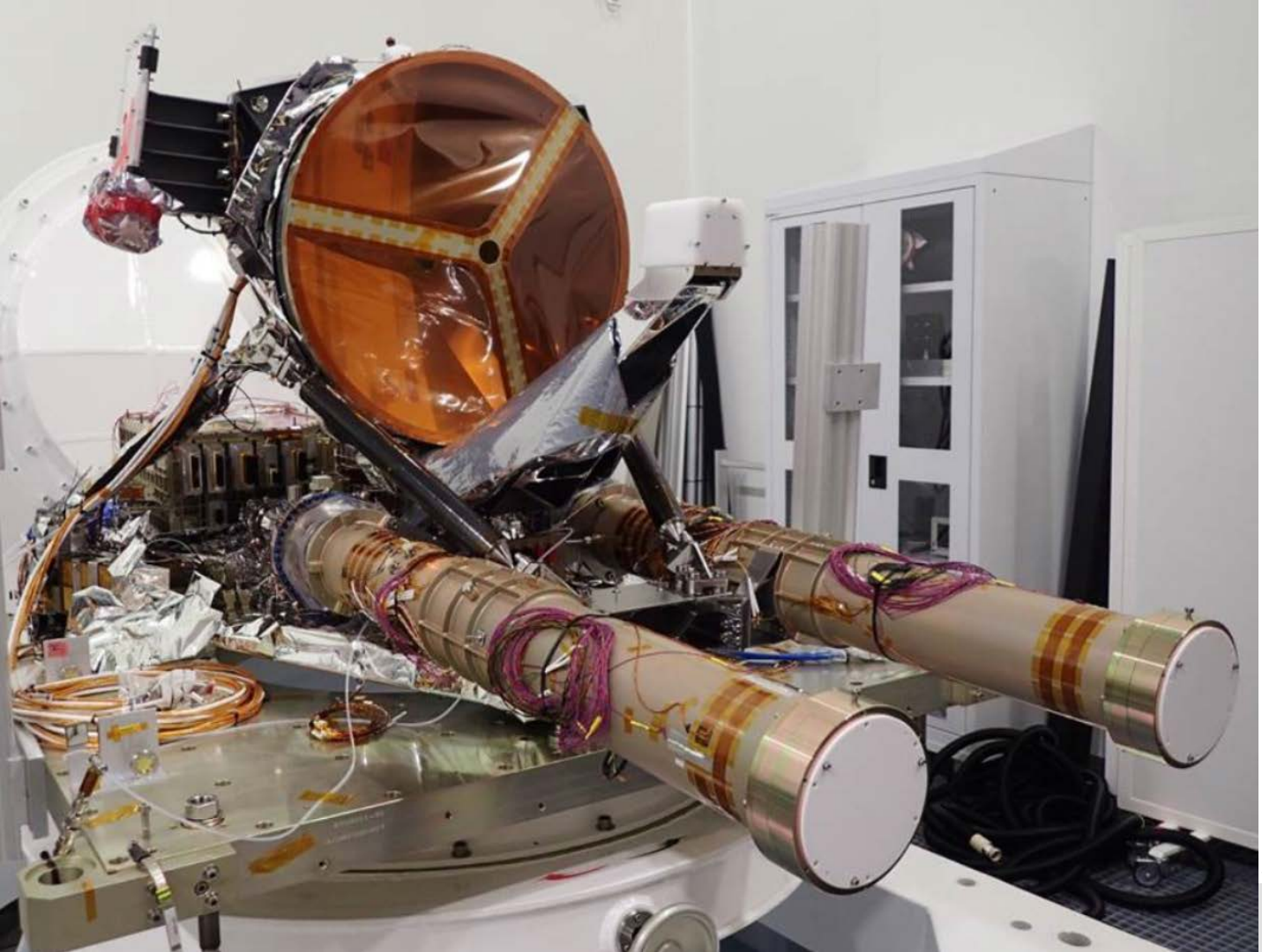
Industry: Airbus (F) + Selex ES (I)

ATLID


molecules
Backscattered light
Wide broadening of the incident light due to Brownian motion
wavelength
Rayleigh
aerosols
Backscattered light
Origin Spectrum shape not affected
wavelength
Mie signal co and cross-polar

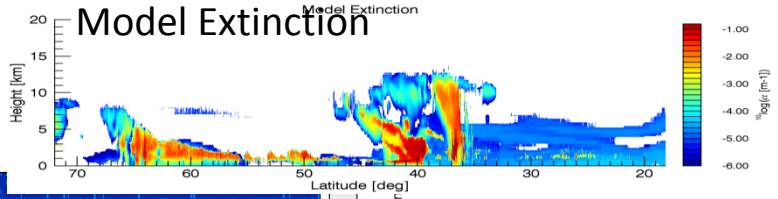

HSR filter transmission
Backscatter spectrum
Mie scattering contribution
Rayleigh scattering contribution
arbitraty unit
relative frequency (GHz)

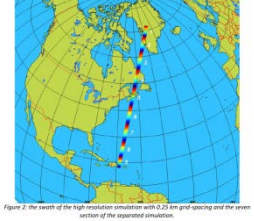

Towards detector assemblies
FCA Rayleigh
Rayleigh path
HSRE
Mie Co-polar path
FCA co_polar
λ/4
λ/4
PBS
PBS
PBS
Etalon FP
Folding mirror FOM3
Towards detector assemblies
Φ = 31mm
Mie Cross polar path
FCA cross_polar



ATLID

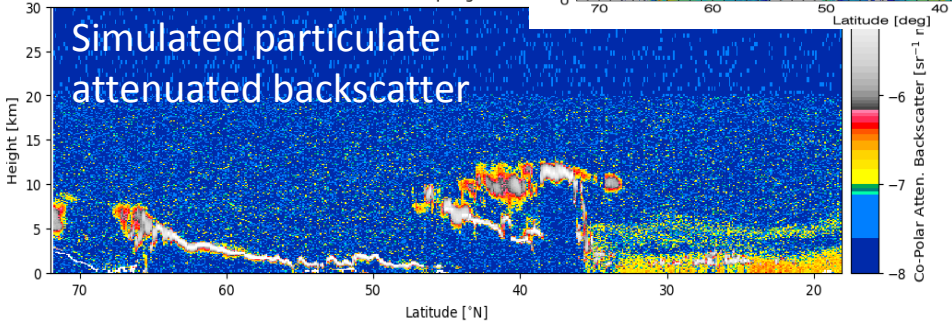
Model Extinction



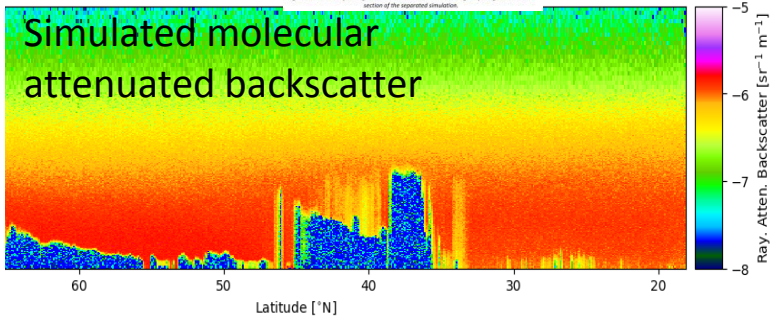


esa

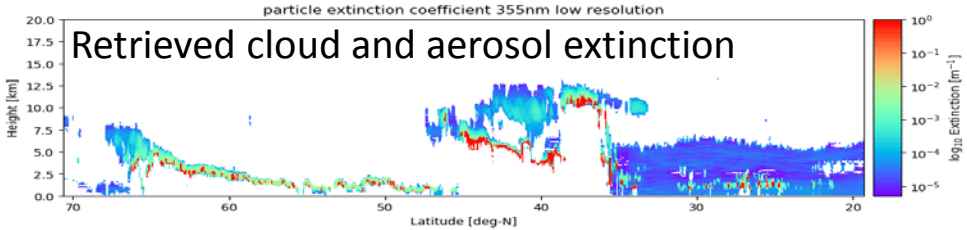
Simulated particulate attenuated backscatter



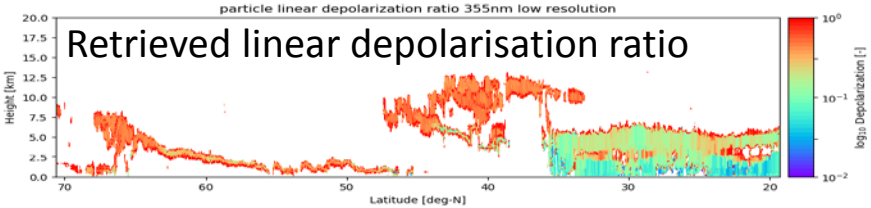
Simulated molecular attenuated backscatter



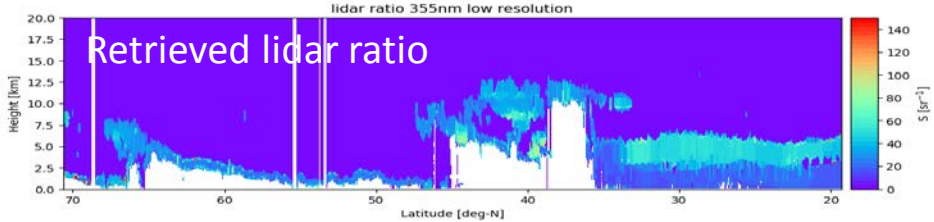
Retrieved cloud and aerosol extinction



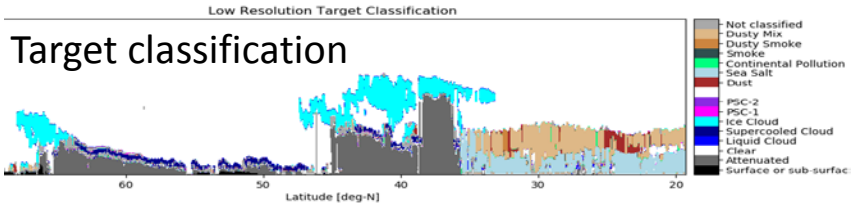
Retrieved linear depolarisation ratio



Retrieved lidar ratio



Target classification



Multi-Spectral Imager – MSI

Objective:

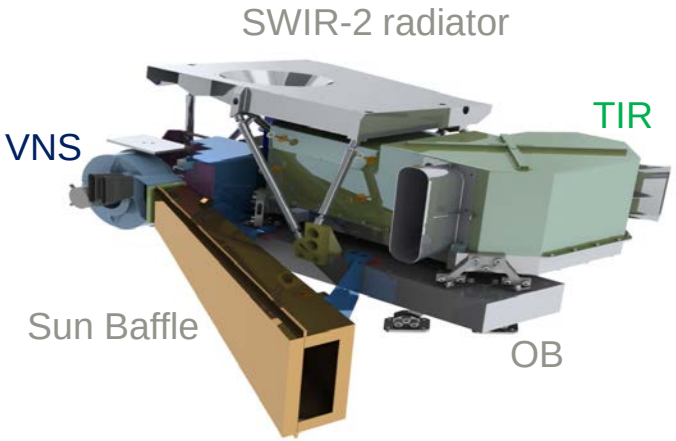
To provide contextual imagery information to support the retrievals of geophysical parameters by the active instruments on-board EarthCARE

Characteristics:

150 km swath (-35km to +115 km)
500 m ground sampling distance
57 W, 60 kg, 652 kbps

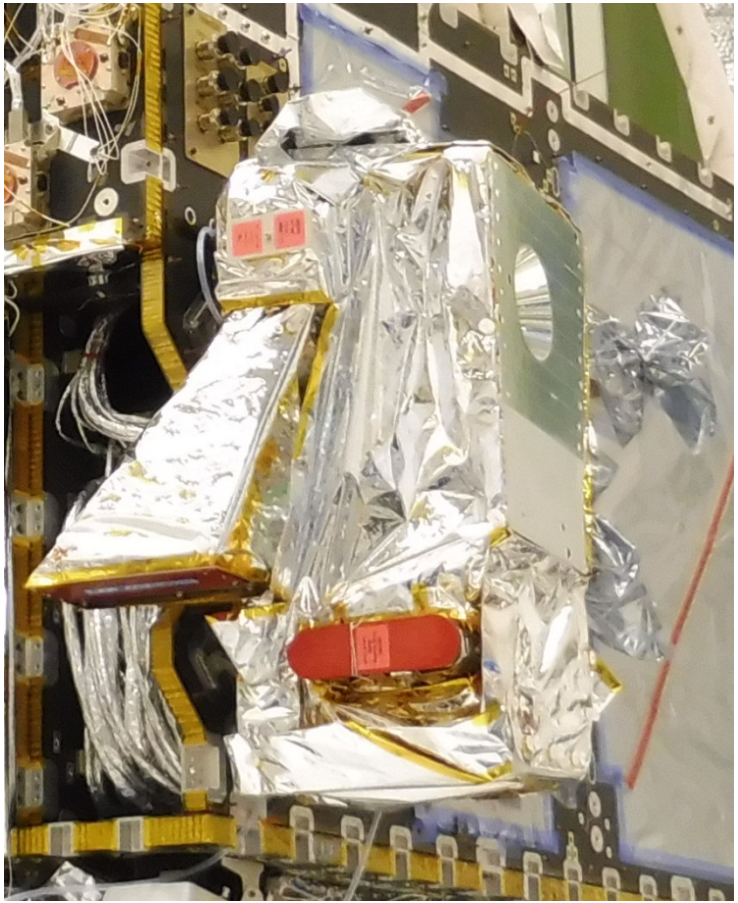
Level 1 product: radiances (VNS) & brightness temperatures (TIR)

Industry: SSTL (UK) + TNO (NL)



Signal to noise
VIS/NIR 70-500
SWIR 20-250
Noise (NEDT)
TIR 0.25-0.80 K

Channel	Centre Wavelength [µm]	Bandwidth (50%) [µm]
VIS	0.67	0.02
NIR	0.865	0.02
SWIR 1	1.65	0.05
SWIR 2	2.21	0.1
TIR 1	8.8	0.9
TIR 2	10.8	0.9
TIR 3	12.0	0.9



MSI

Broad-Band Radiometer – BBR

Three fixed telescopes:
forward (55˚), nadir, backward (-55˚)

Two channels:
Short-wave (SW) channel 0.25 µm to 4 µm
Total-wave (TW) channel 0.25 µm to >50 µm
→ Long-wave (LW) derived from TW-SW

Abs. accuracy 2.5 (SW) / 1.5 (LW) $Wm^{-2}sr^{-1}$

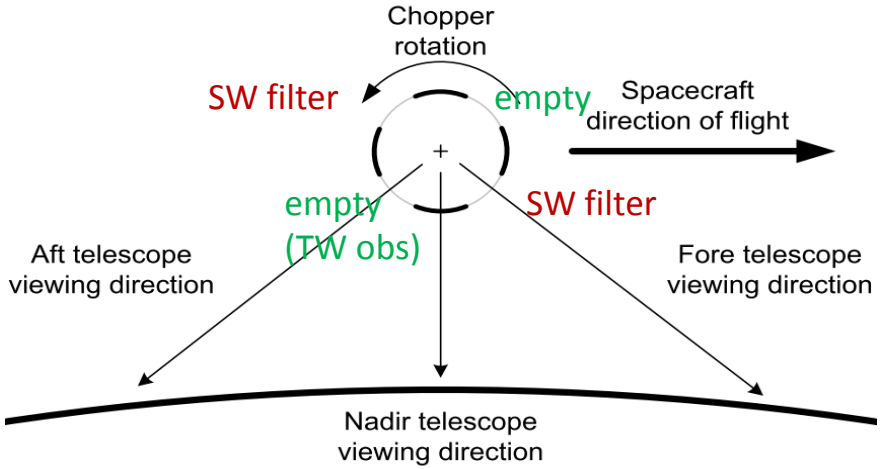
Spatial resolution nominal 10 km x 10 km

Spatial sampling distance 1 km

48 W, 45 kg, 145 kbps

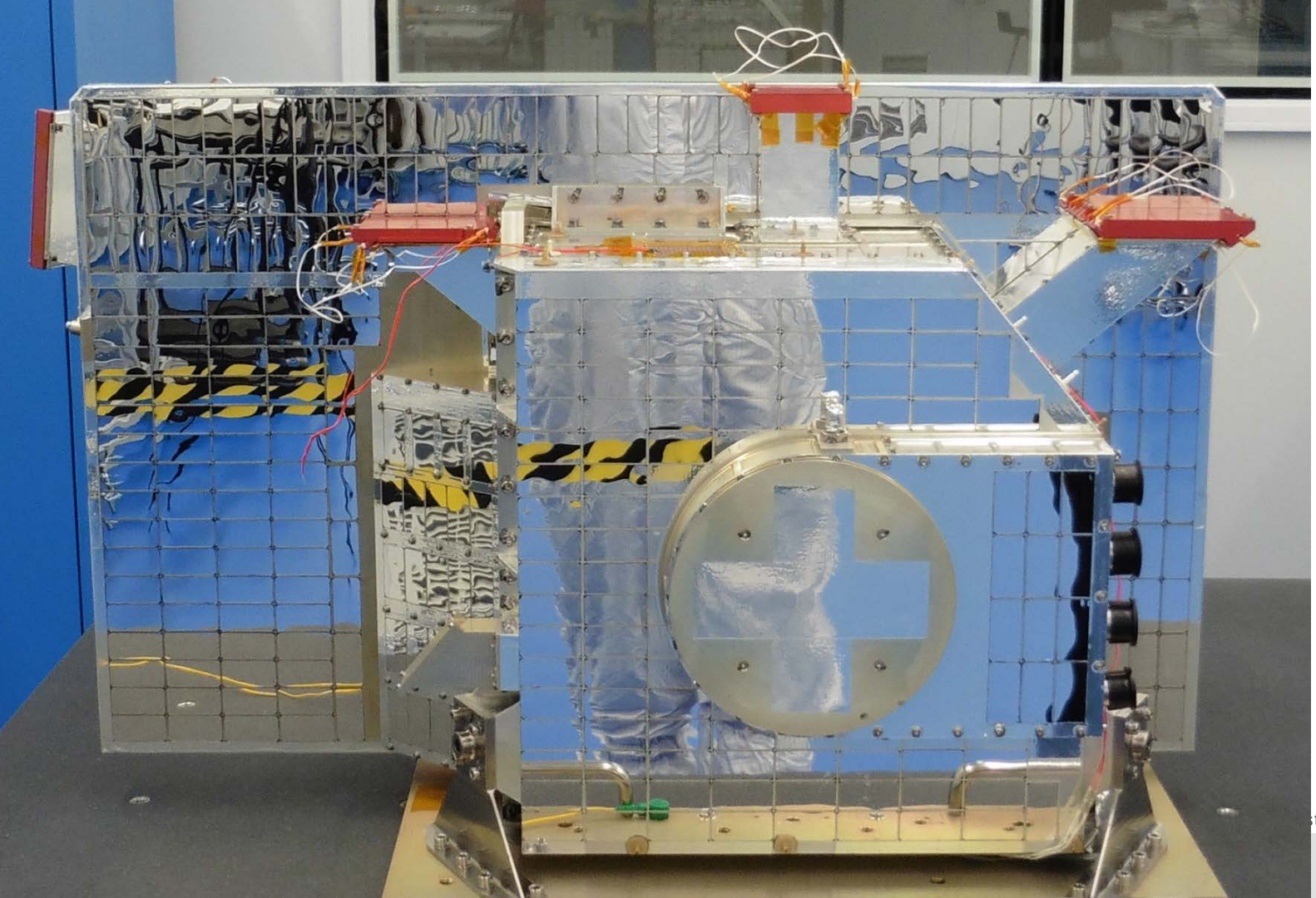
Products: TOA SW/LW radiances & flux

Industry: TAS (UK) + RAL (UK)

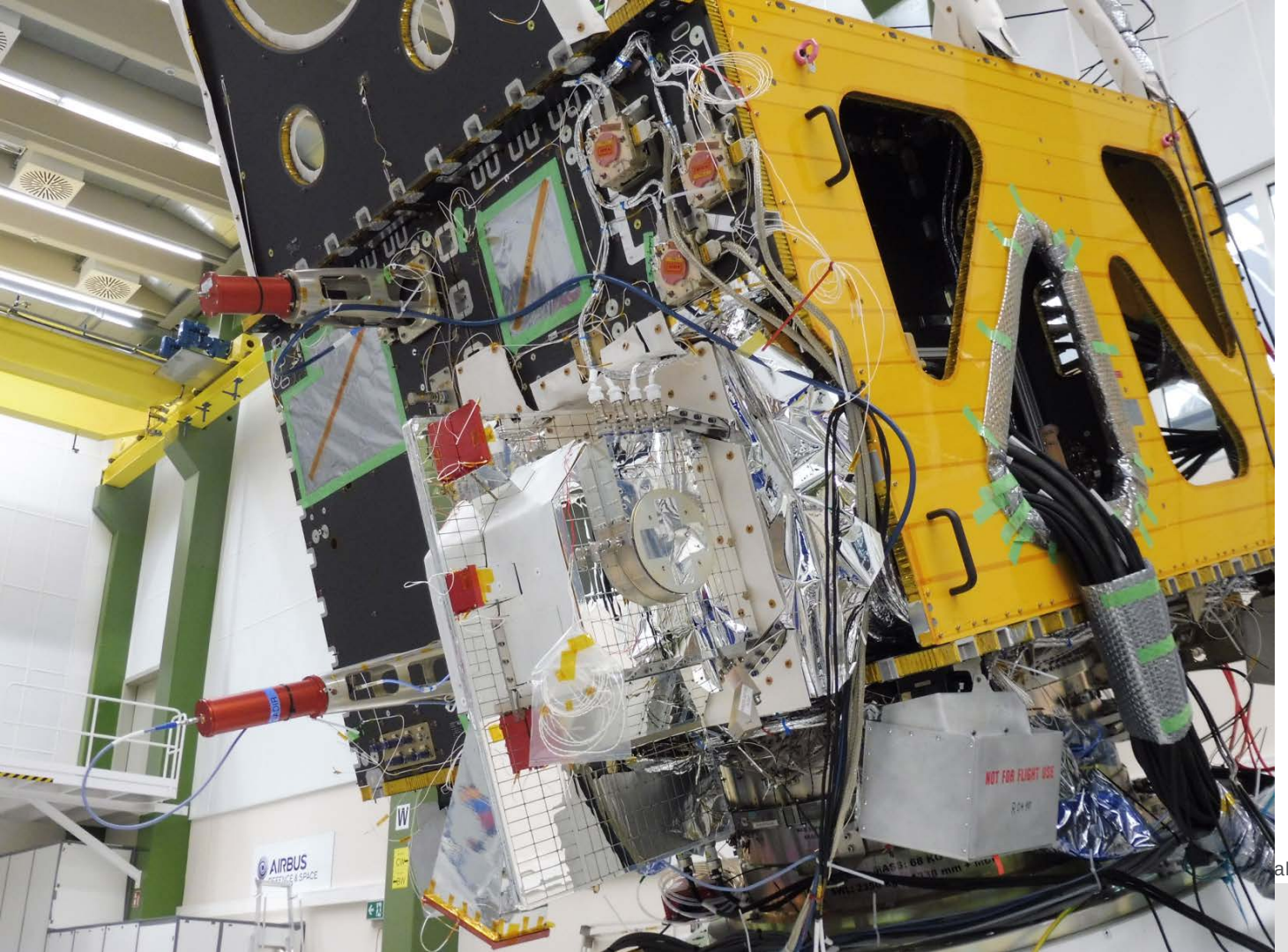


3 fixed, single mirror telescopes, each with a linear microbolometer detector array.
Chopper drum rotates continuously, chopping the signal between SW, drum & TW views
Calibration drum periodically rotates into view:

- Hot or cold blackbody, every 88s, to calibrate LW
- View to sun diffuser, every 2 months for 30 orbits, to monitor aging in the SW chain



BBR



BBR

on satellite

Science Preparation

Level 2 Developments
- clouds profiles from radar, lidar, imager
- aerosol profiles from lidar, imager
- calculated radiation from retrieved profiles and measured SW, LW
- closure assessment

Science Preparation
Building on CloudSat, Calipso, CERES/GERB, MODIS, ground-/air-based radar/lidar, modelling, campaigns …

Preparation of NWP Assimilation
ECMWF: preparation of radar and lidar assimilation

Campaigns
2016: NAWDEX
incl 355HSRL, 95GHz (F)
532HSRL, 35GHz (D)

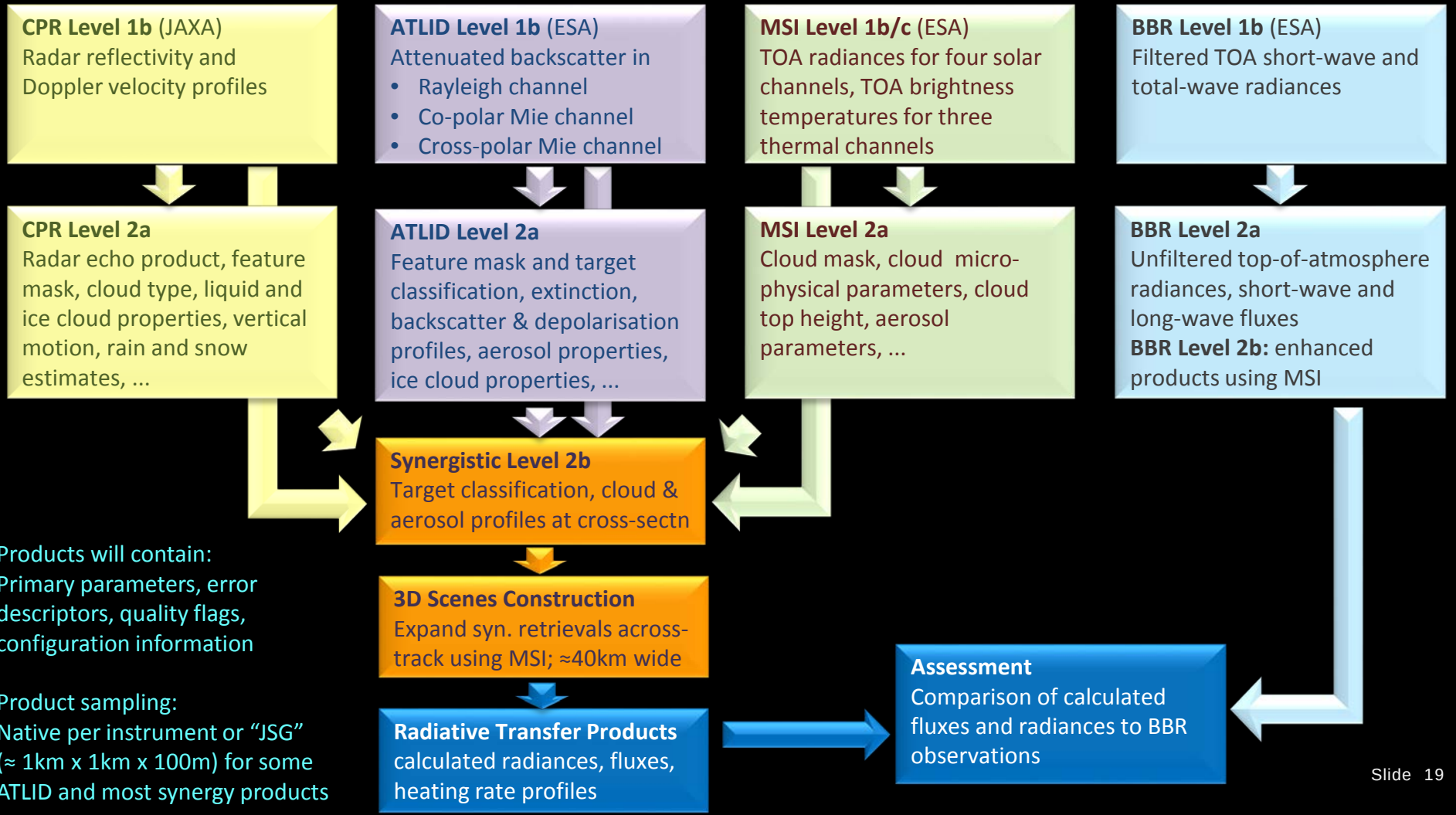
Joint Mission Advisory Group
Members: Europe, Japan, Canada
Observers: USA

Preparation GCM evaluation
Dedicated data processor (CFMIP-type) development

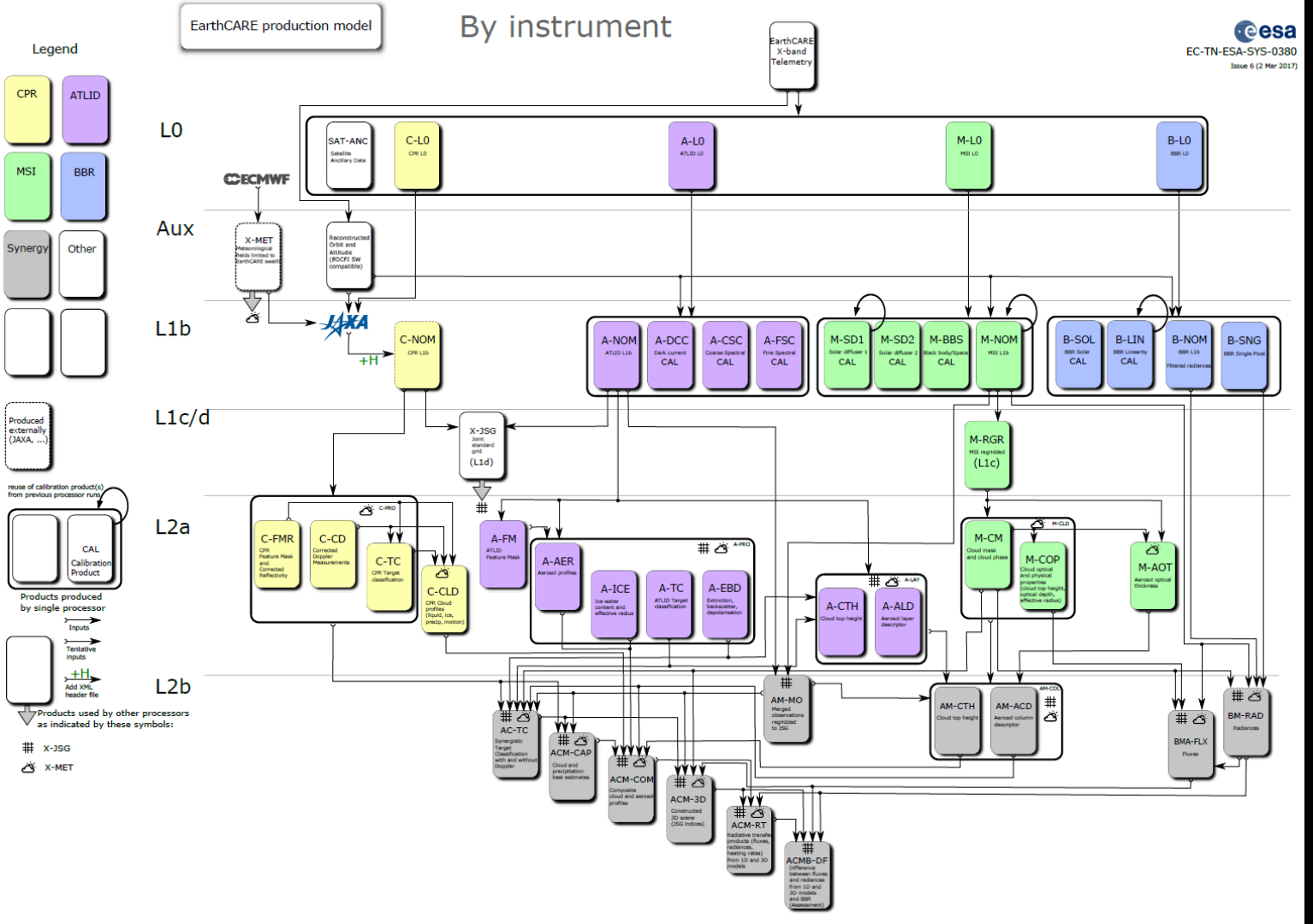
Validation preparation
- ESA announcement of opportunity (AO) 2017 (EarthCARE only, closed, 32 AO proposals accepted)
- JAXA 2nd research announcement (RA) 2018 (multi-mission including EarthCARE, closing 30 Nov)
- Joint validation workshop before launch

Scientific Workshops
- Kyoto 2009
- Paris 2012, jointly with CloudSat and CALIPSO
- Tokyo 2014
- Bonn 2018: science and validation

Proceedings and report available online
<short link goes here if available – Rob?>


CPR Level 1b (JAXA)
Radar reflectivity and Doppler velocity profiles
ATLID Level 1b (ESA)
Attenuated backscatter in
• Rayleigh channel
• Co-polar Mie channel
• Cross-polar Mie channel
MSI Level 1b/c (ESA)
TOA radiances for four solar channels, TOA brightness temperatures for three thermal channels
BBR Level 1b (ESA)
Filtered TOA short-wave and total-wave radiances
CPR Level 2a
Radar echo product, feature mask, cloud type, liquid and ice cloud properties, vertical motion, rain and snow estimates, ...
ATLID Level 2a
Feature mask and target classification, extinction, backscatter & depolarisation profiles, aerosol properties, ice cloud properties, ...
MSI Level 2a
Cloud mask, cloud micro-physical parameters, cloud top height, aerosol parameters, ...
BBR Level 2a
Unfiltered top-of-atmosphere radiances, short-wave and long-wave fluxes
BBR Level 2b: enhanced products using MSI
Synergistic Level 2b
Target classification, cloud & aerosol profiles at cross-sectn
3D Scenes Construction
Expand syn. retrievals across-track using MSI; ≈40km wide
Radiative Transfer Products
calculated radiances, fluxes, heating rate profiles
Assessment
Comparison of calculated fluxes and radiances to BBR observations
Products will contain:
Primary parameters, error descriptors, quality flags, configuration information
Product sampling:
Native per instrument or "JSG" (≈ 1km x 1km x 100m) for some ATLID and most synergy products

Data Product Tree



EarthCARE Mission Status

- Spacecraft platform integration completed → spacecraft ready for accomodating payload
- BBR completed, calibrated and integrated onto spacecraft in summer 2018
- MSI pre-integrated onto spacecraft in 2018, now back in UK for testing and TIR calibration. Delivery and final integration onto spacecraft 2019
- ATLID Optical Flight Model programme near completion. Testing, delivery and final integration onto spacecraft 2019
- CPR pre-integrated onto spacecraft in 2017, now back in Japan for refurbishment (repair) of High Power Transmitters (HPTs) and final testing
- Processor, end-to-end simulator (E3SIM) and ground segment development well advanced, integration of individual processors into overall system ongoing
- Spacecraft and ground segment activities currently in bridging phase (reduced teams)
- Launch 2021