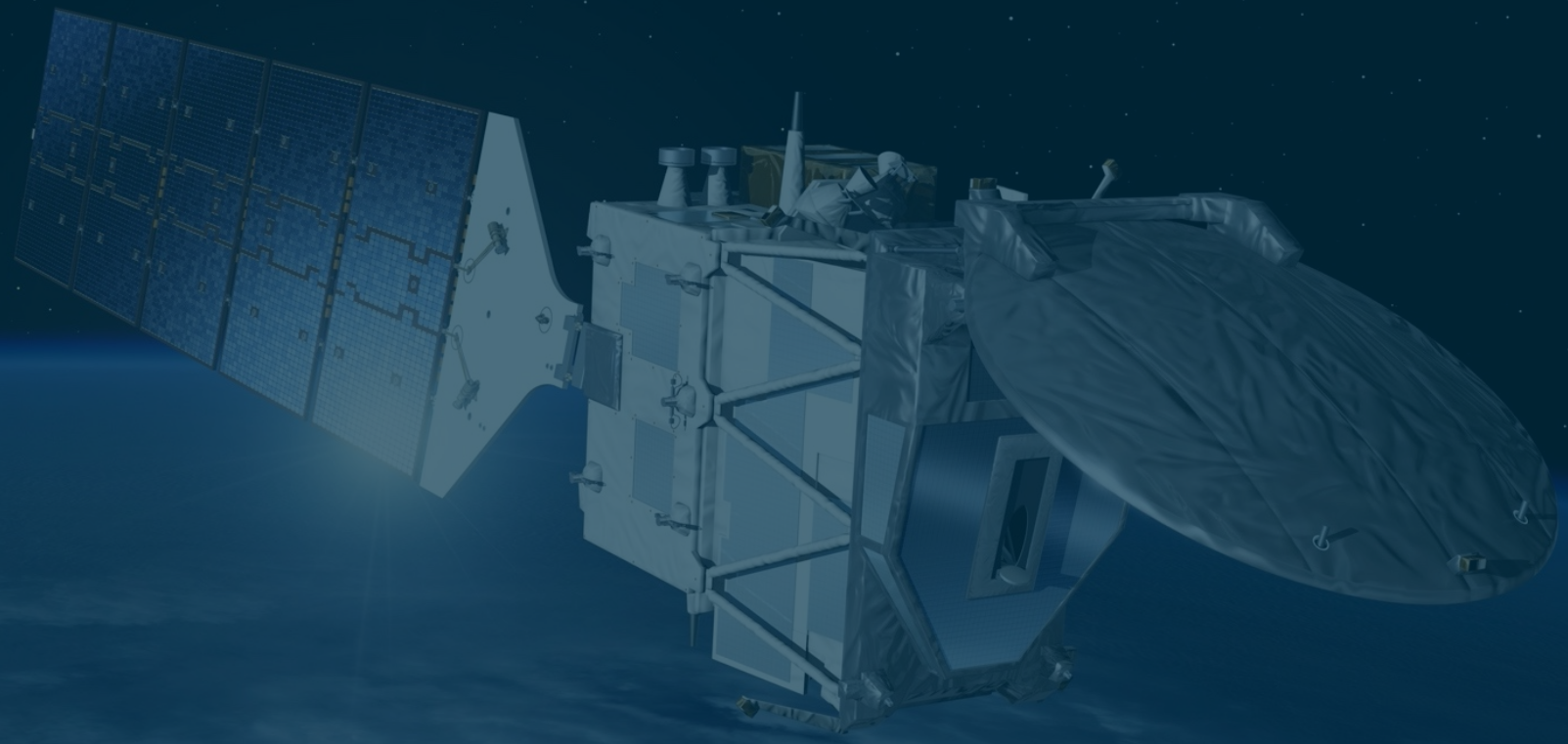


EarthCARE Status – May 2021

2nd ESA EarthCARE Validation Workshop

Dirk Bernaerts, EarthCARE Project Manager

25-28 May 2021 (online)

EarthCARE Status

Since beginning of May 2021, all 4 instruments integrated on EarthCARE spacecraft.

EarthCARE Mission

Earth, Cloud, Aerosols and Radiation Explorer

Mission Objective:

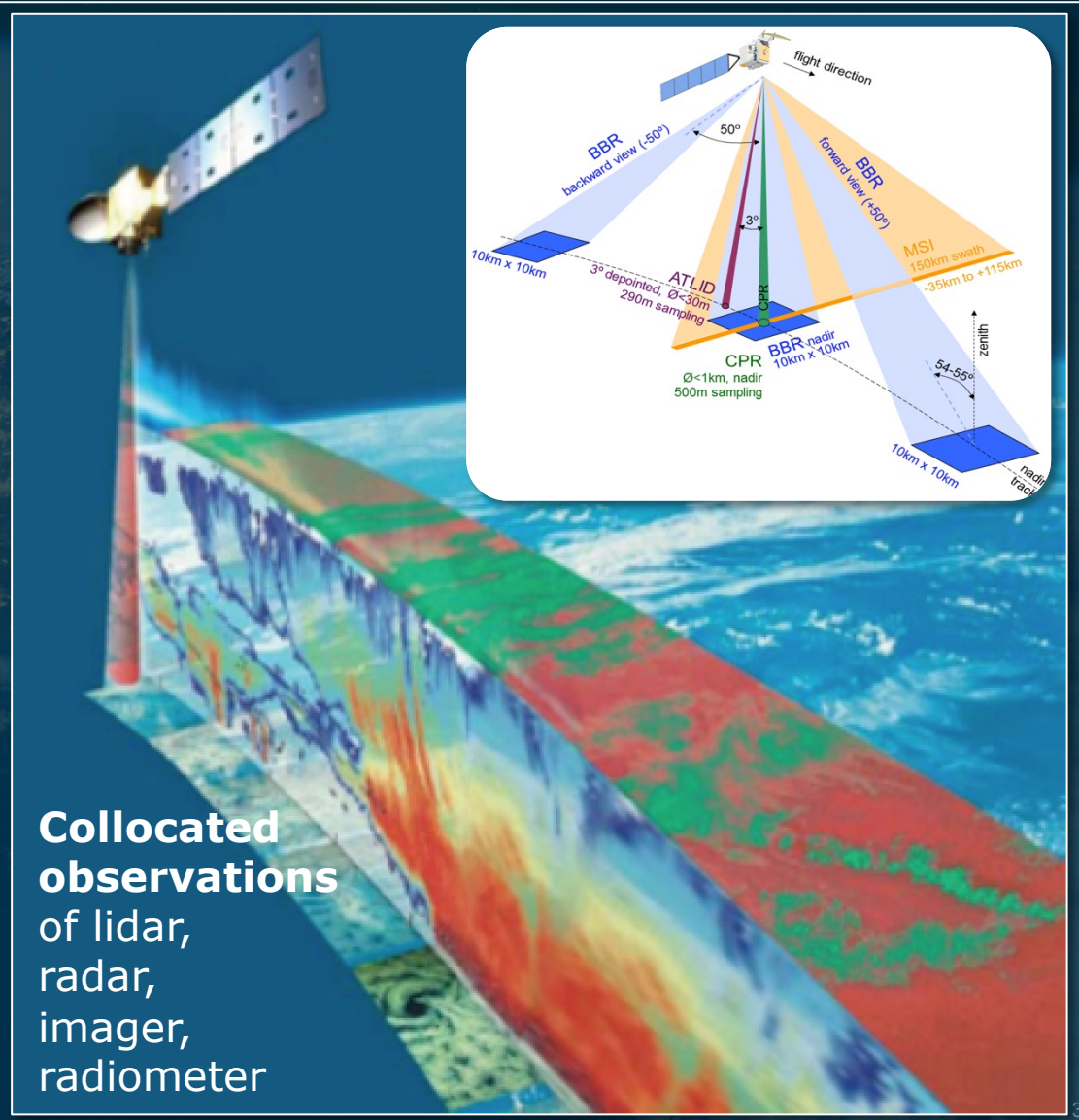
Understanding of cloud-aerosol-radiation interactions to improve climate & NWP models

Required collocated observations:

- Vertical profiles of aerosols and their radiative properties
- Vertical profiles of liquid and ice clouds and their rad. prop.
- Cloud distribution, overlap, precip and vertical motion
- Reflected solar and emitted thermal radiation at TOA

Observations goal:

- Radiation modelled from observed cloud/precip. and aerosol profiles matches observed TOA radiances and fluxes



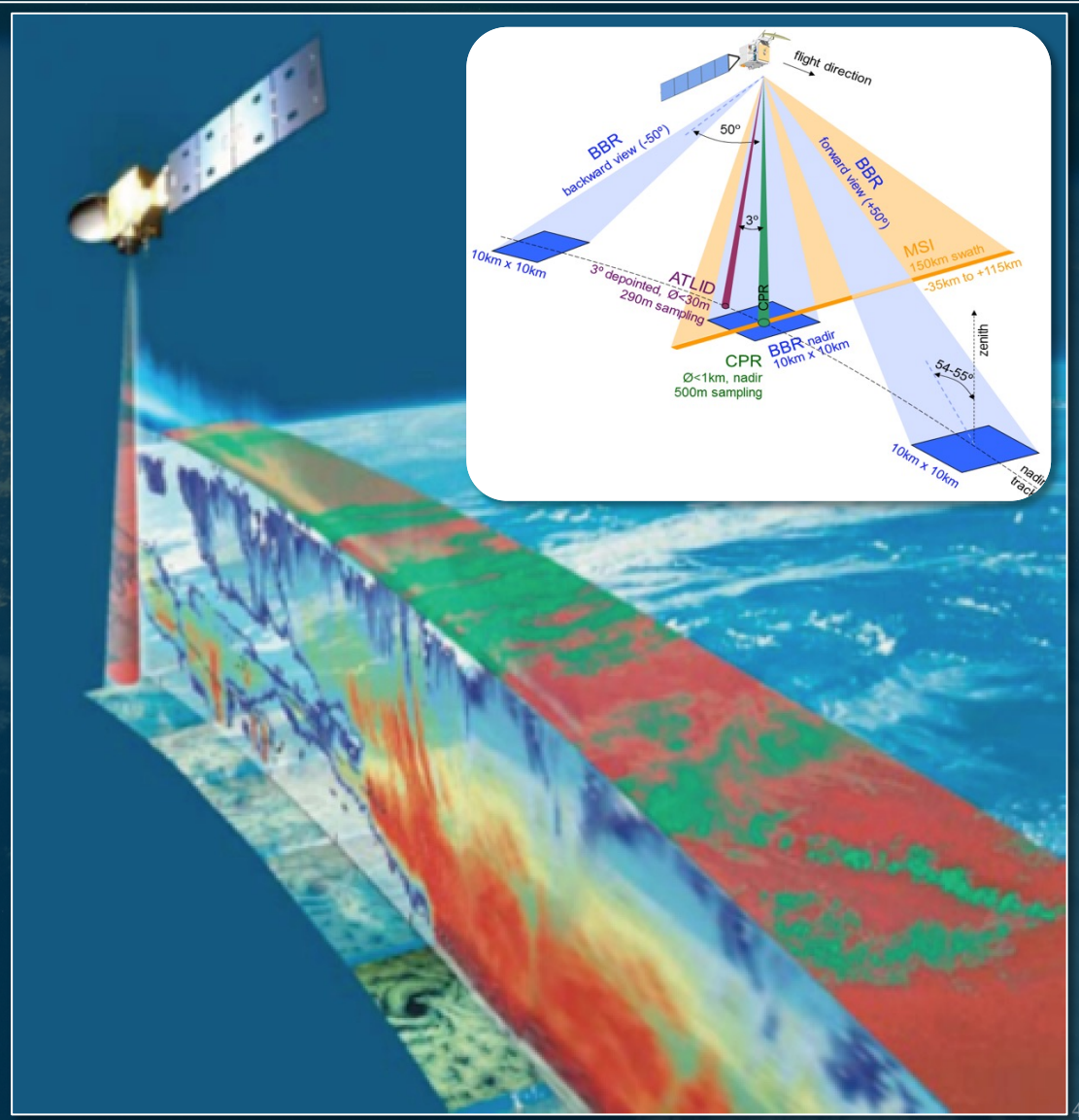
Collocated observations of lidar, radar, imager, radiometer

EarthCARE Mission

6th Earth Explorer Mission
Largest, most complex Earth Explorer Mission so far

Considerable expectations, from scientific and operational community

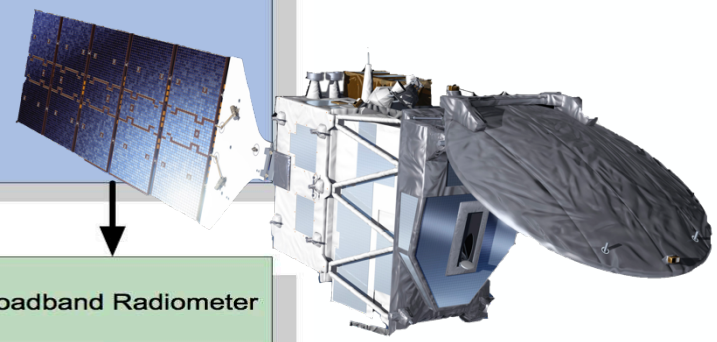
"Potential for EarthCARE to emulate Aeolus with rapid progression to positive operational impact!" F. Rabier, ECMWF



EarthCARE Mission

Needs	• Convective updraft and ice fall speed	• Vertical profiles of liquid, supercooled and ice water, cloud overlap, partical size and extinction • Cloud top and base height • Quantitative precipi-tation measurements • Ice water content	• Vertical profiles of extinction and characteristics of aerosols • Cloud top height • Occurrence of layer of super cooled cloud	• Horizontal structure of clouds and aerosols • Cloud type • Ice/water discrimination • Cloud and aerosol optical depth • Cloud top temperature • Effective droplet radius • Cloud cover fraction • Cloud effective emissivity	• Shortwave and longwave fluxes at top of the atmosphere
Techniques	Doppler Radar	Radar	High spectral resolution Lidar	Multispectral Imager	Broadband Radiometer
Instruments	CPR		ATLID	MSI	BBR
Geophysical Products	Precipitation	Ice and water clouds	Aerosols	TOA Flux	

Synergy *Synergy* *Synergy*



Synergy Cooperation

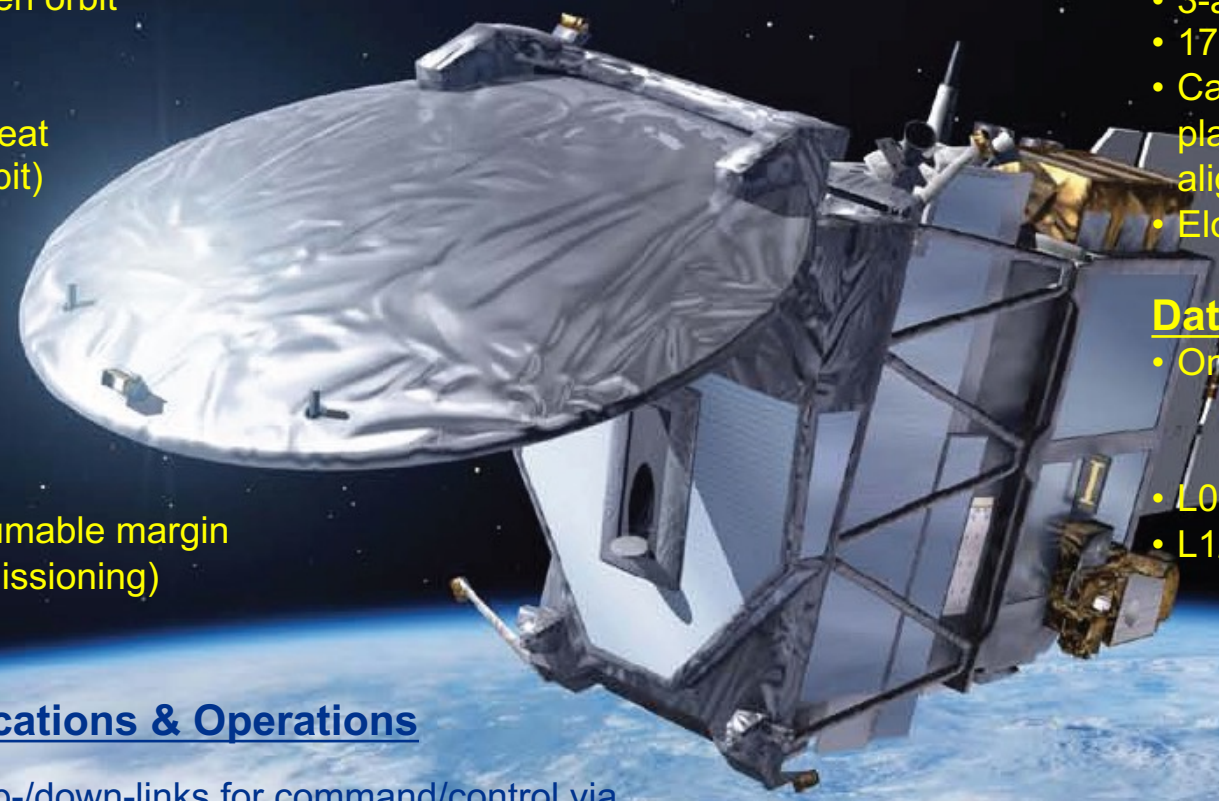
EarthCARE Spacecraft - Datasheet

Orbit:

- 393 km mean altitude
- Sun Synchronous frozen orbit
- 14h00 DSN MLST
- 97° Inclination
- 25-days/389 orbits repeat cycle (93-minutes orbit)
- +/- 25km deadband

Lifetime:

- 3 years + 1 year consumable margin (incl. 6-months commissioning)

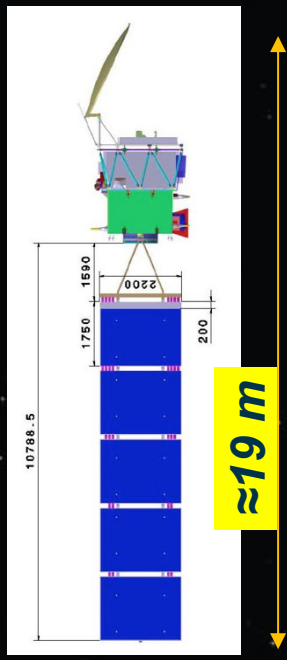


Satellite:

- 2350 kg (incl. 313 kg propellant)
- 3-axis stabilized / yaw-steering
- 1700W
- Carbon-fiber structure & compact platform design (for pointing and co-alignment)
- Elongated shape (for drag reduction)

Data volumes:

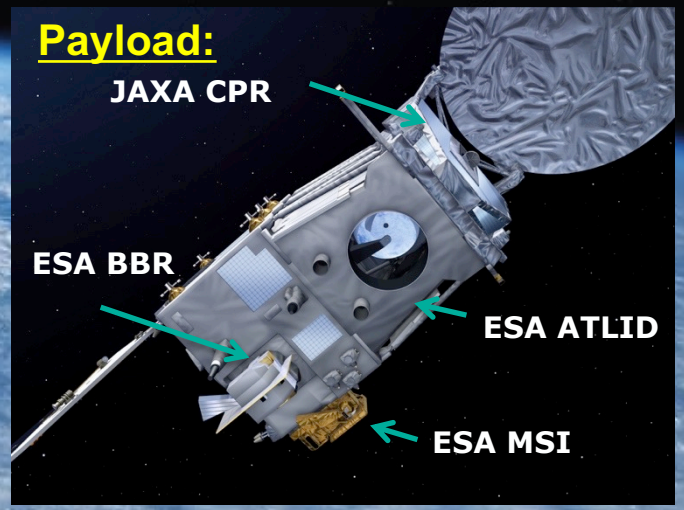
- On-board data rates:
  - <15 kbps (HKTM)
  - <2.5 Mbps (science)
- L0: 1.7 GB / orbit
- L1/L2: 70 GB / orbit



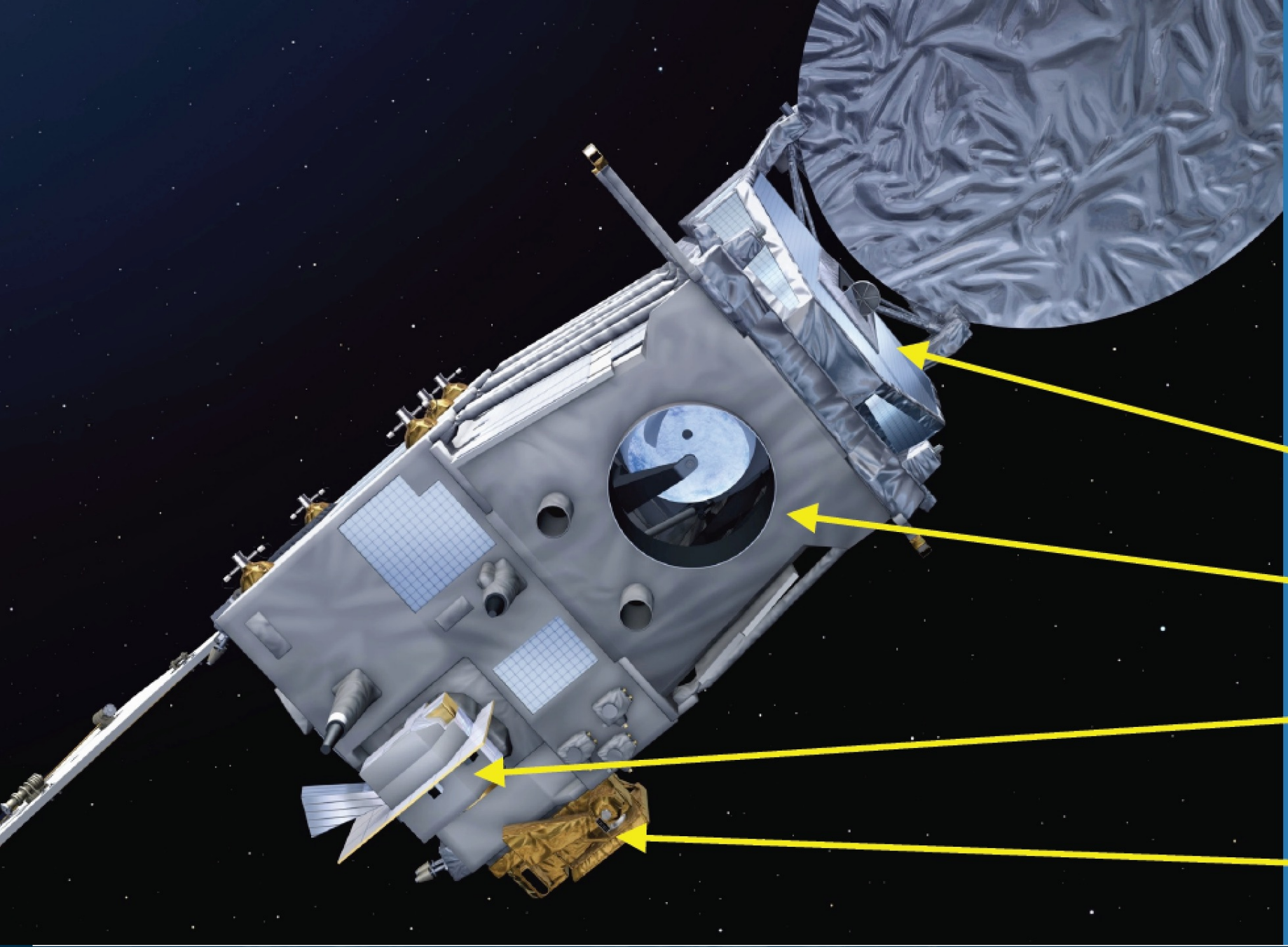
Communications & Operations

- S-Band up-/down-links for command/control via Kiruna station (2 passes per day)
- X-Band 150-Mbps for downlinking science/recorded TM via Kiruna-Esranges & Inuvik stations (10 passes per day)
- 5-day operational autonomy via uploading of the Orbit Position Sequencer

Payload:



EarthCARE Payload



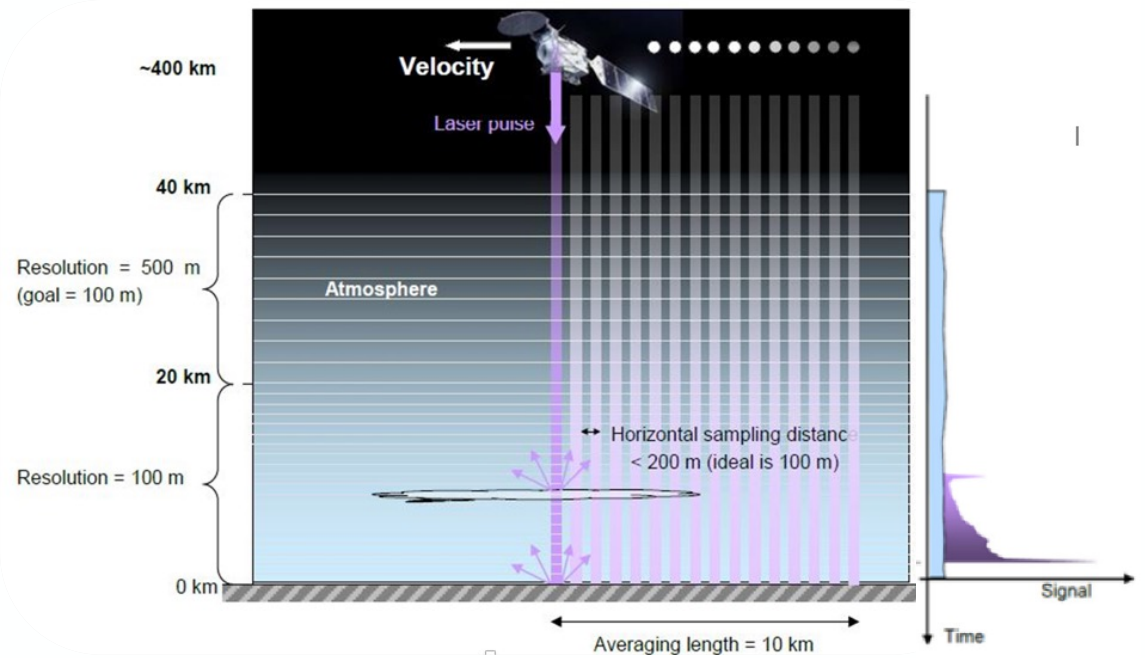
ATLID

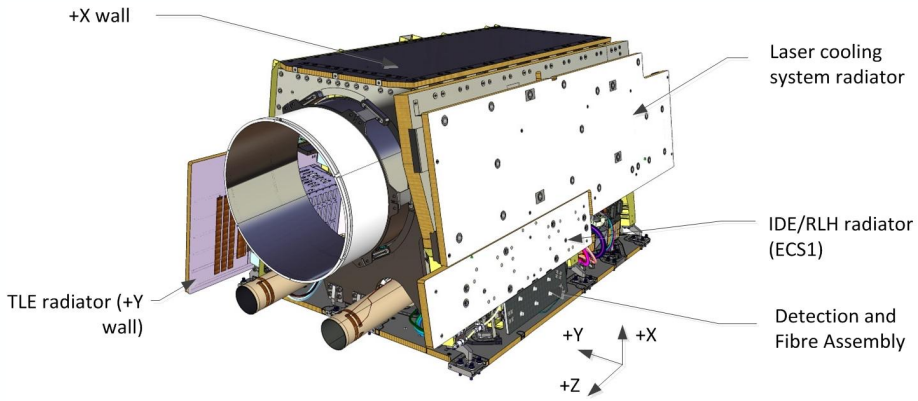
Detection of small ice particles and water droplets
Vertical profiles of thin cloud and aerosol layers, cloud boundaries.

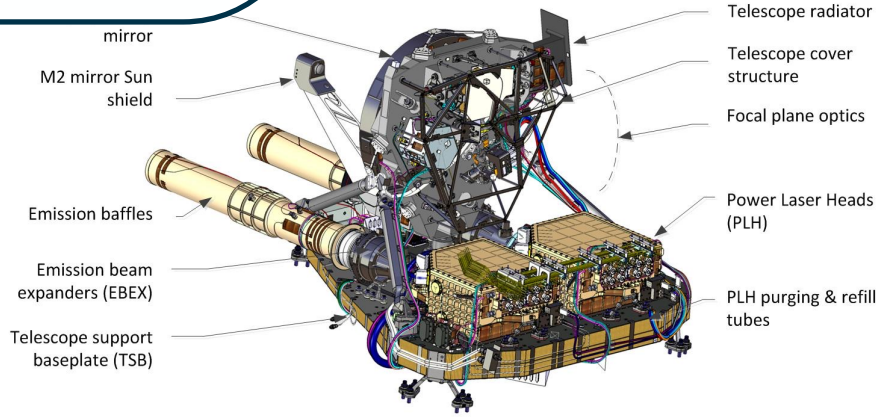
Atmospheric LIDAR with 355nm source
Vertical Profiles 0-40km, 100-500 m resolution
Horizontal sampling 280m
Return signal in 3 science channels:

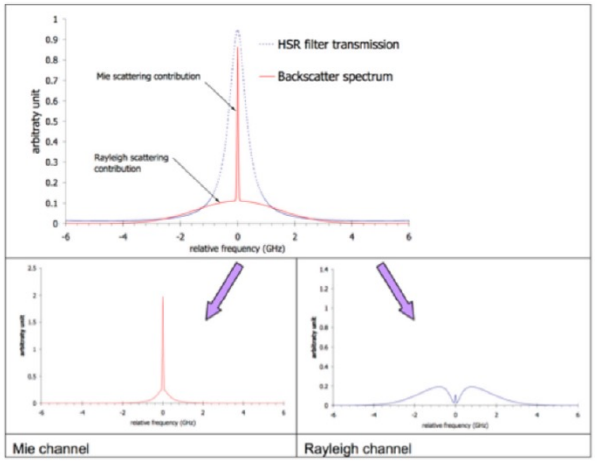
- Rayleigh co-polarisation -> molecular backscatter
- Mie co-polarisation -> aerosol and thin clouds backscatter
- Mie cross polarisation -> polarisation ration of backscatter

L1 product: attenuated backscatter profiles

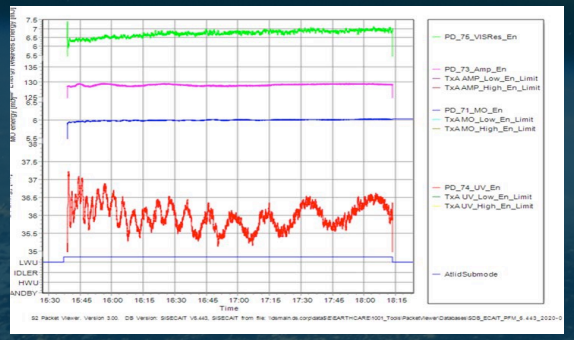


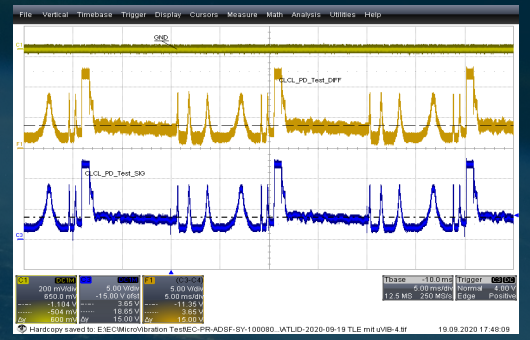






ATLID - Status





ATLID integrated on spacecraft, Performance Check and Integrated System Test successfully performed in 2020.

Performance budgets updated, Delivery Review Board ongoing.

Open Work: Life test on flight spare PLH

MSI

Provide contextual imagery information to support geophysical parameters retrieval from the active instruments data.

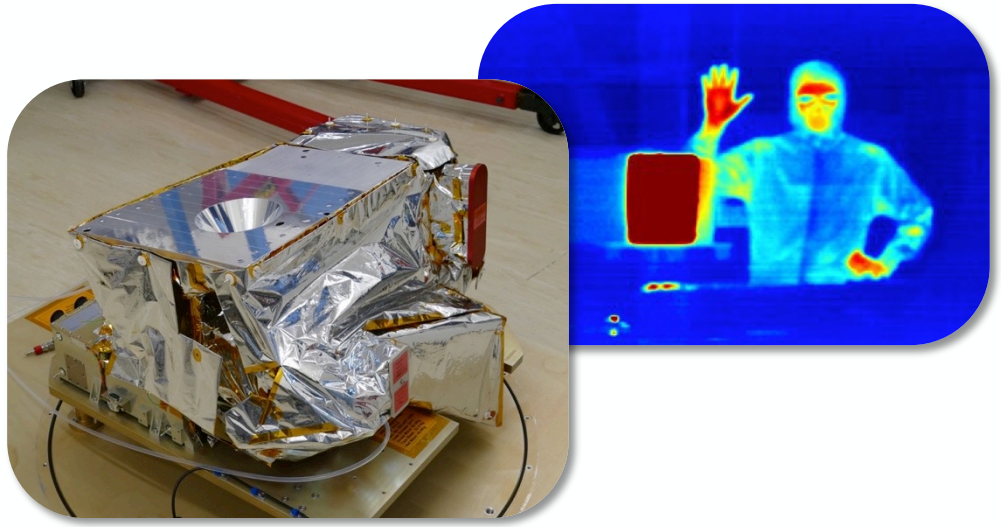
- Aerosol optical properties/type
- Support BBR calibration

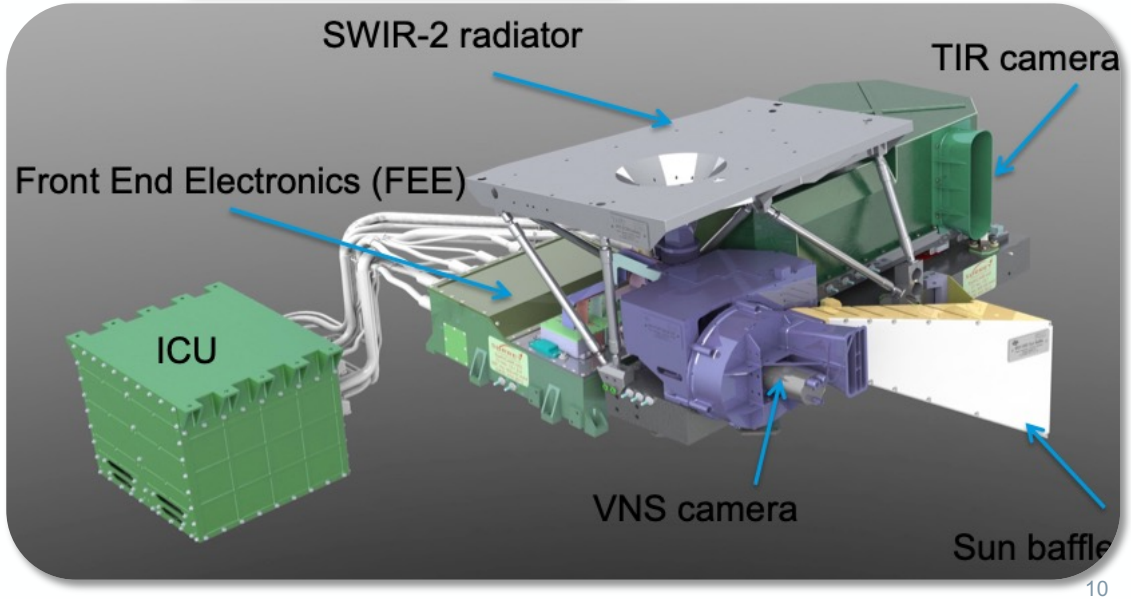
Multi-Spectral Imager

Swath 150km (-35km to +115km)
Ground sampling distance 500m
Spectral channels: 0.67μm, 0.86μm, 1.65μm, 2.2μm, 8.8μm, 10.8μm, 12.0 μm

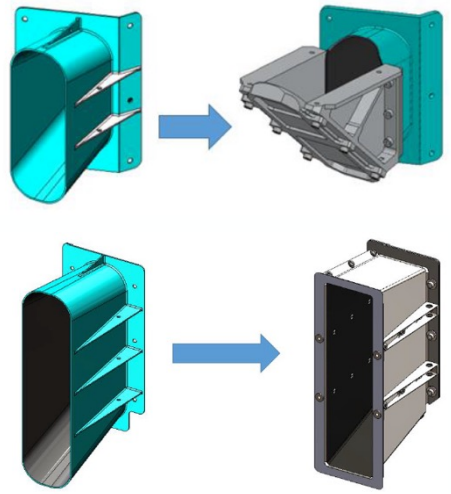
Visible, Near IR, SWIR (VNS) Camera
Thermal Infrared (TIR) Camera

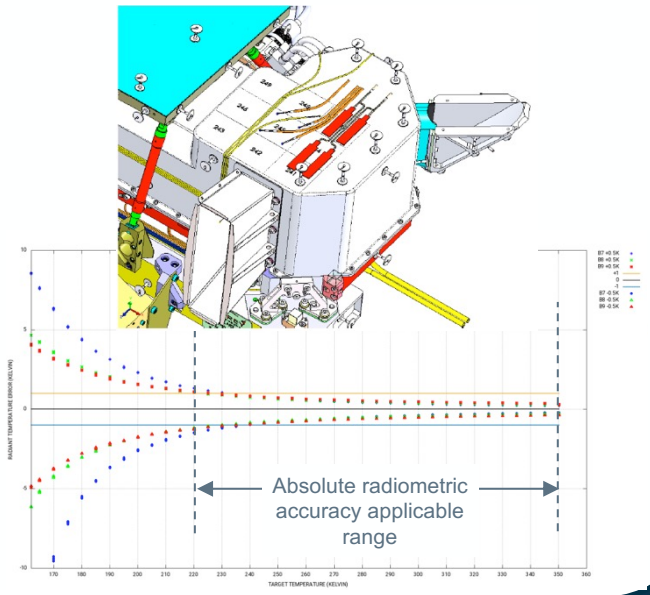
L1 product: radiances (VNS), brightness temperatures (TIR)





MSI - Status





MSI integrated on spacecraft, Performance Check and Integrated System Test performed since Q4 2019.

Open Work: Modifications to improve TIR thermal straylight (modifications to baffles design and thermal control -> apply in-situ on spacecraft) + additional system tests

BBR

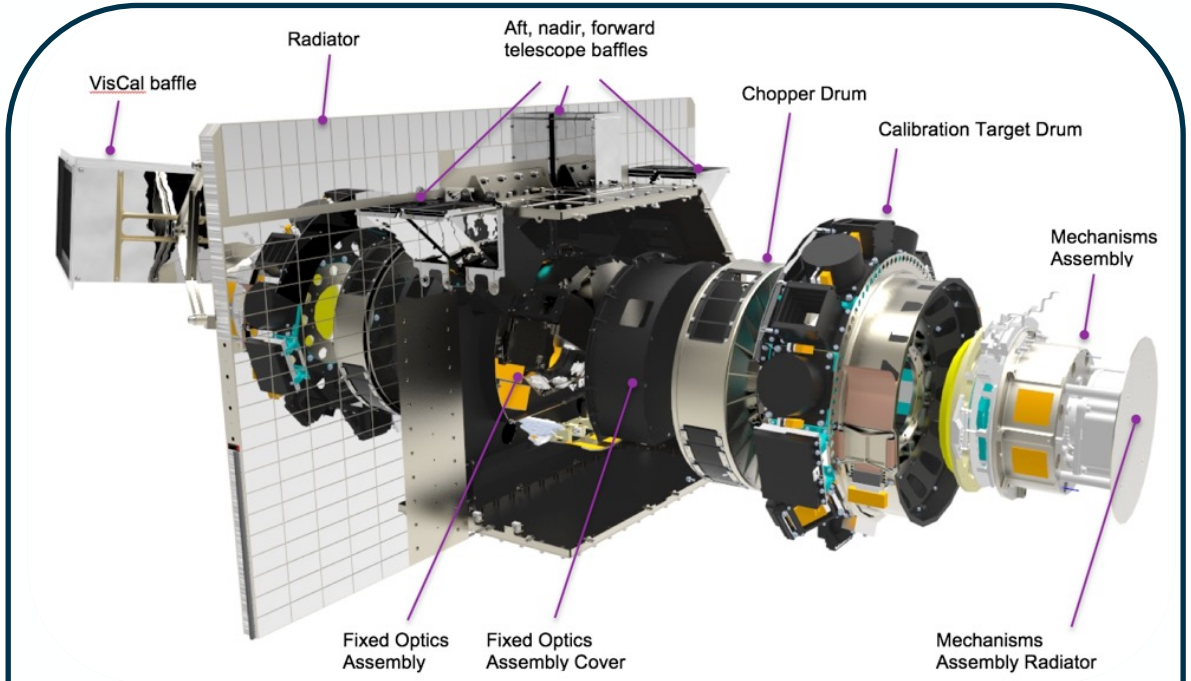
Derive instantaneous TOA fluxes with accuracy better than 10Wm^{-2}

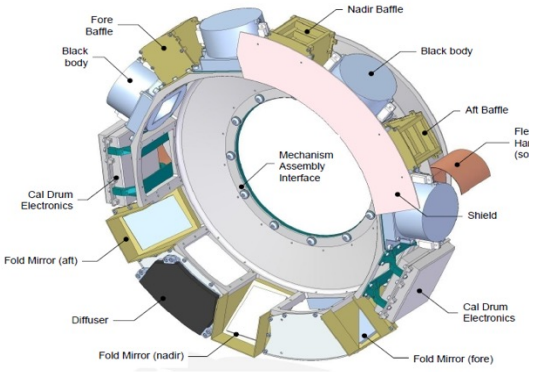
- Estimate outgoing solar reflected & emitted thermal fluxes
- Cross-check radiation balance estimates from other EarthCARE instruments

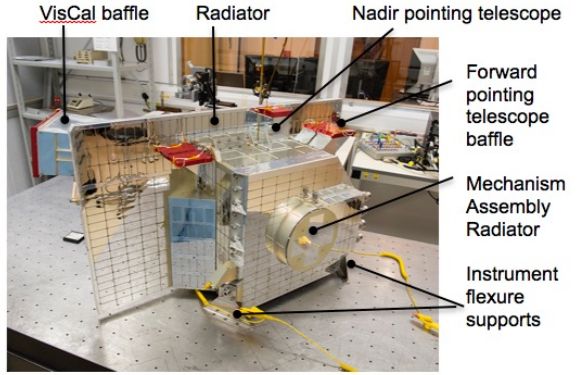
3 telescopes measuring Total Wave & Short Wave radiance at same location but different angles.

- SW channel 0.25 to 4µm
- LW channel 4µm to >50µm
- Angular sampling 0, + / - 55°
- Spatial resolution 10km x 10km
- Spatial sampling distance 1km

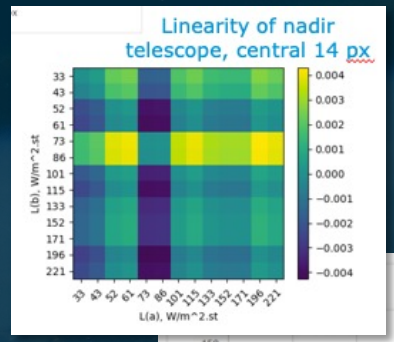
L1 product: solar and thermal TOA radiances

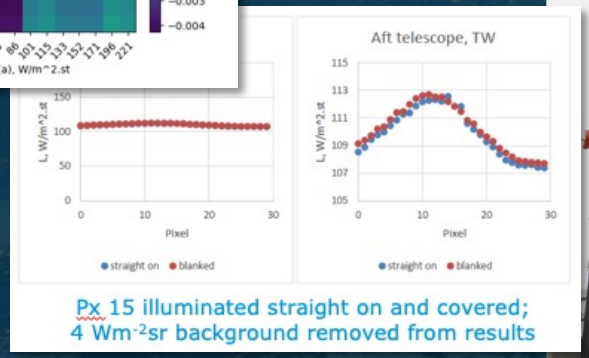




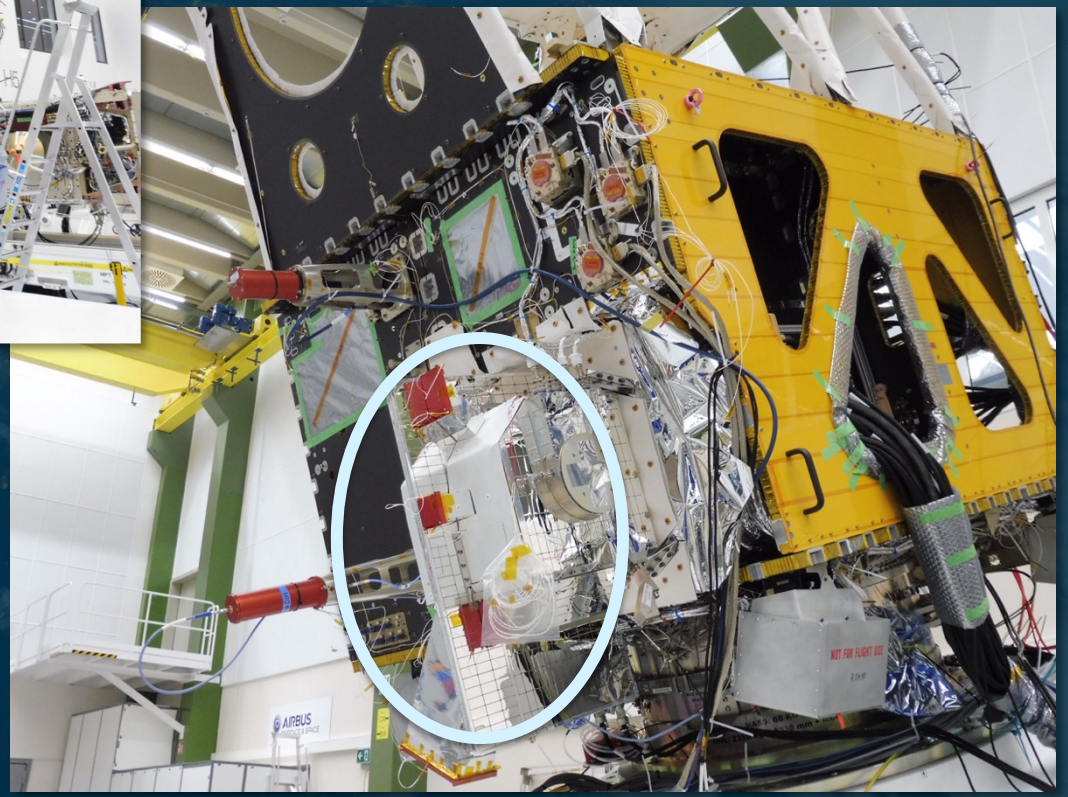


BBR Status





Px 15 illuminated straight on and covered;
4 $Wm^{-2}sr$ background removed from results

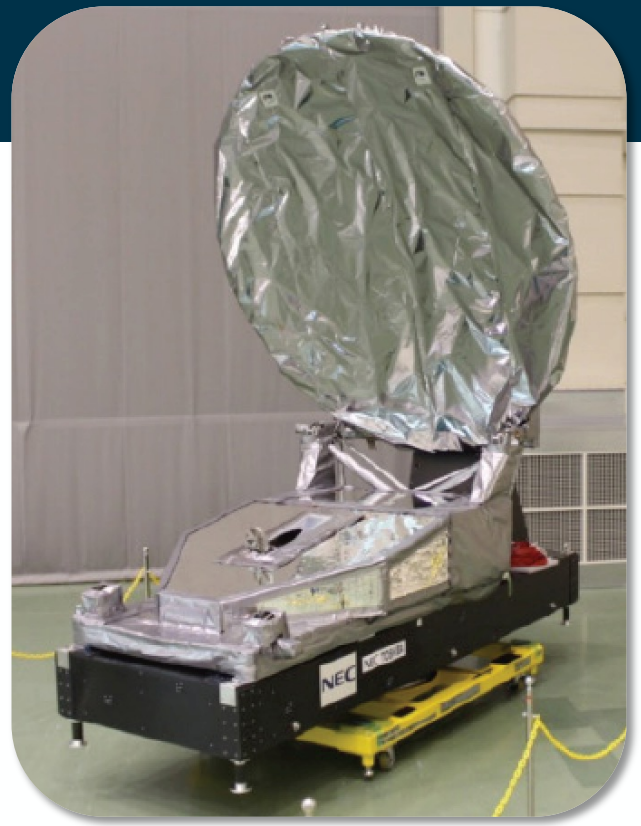


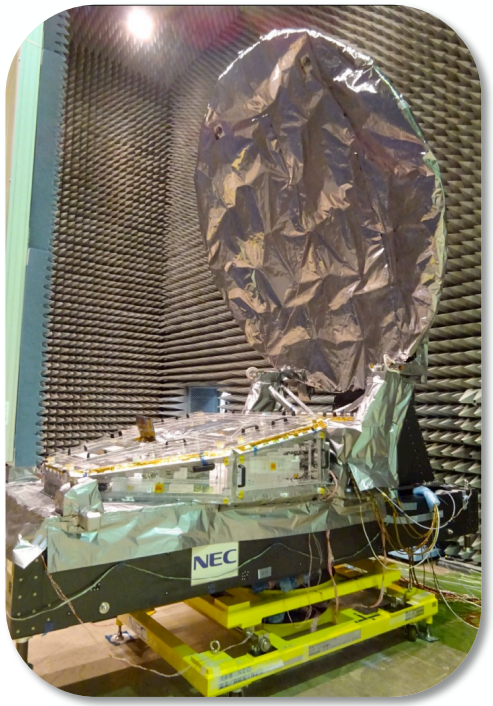
BBR integrated on spacecraft, Performance Check and Integrated System Test performed in 2018.
BBR covers in place and instrument protected by instrument specific tent (to protect Optical Surface Reflectors)

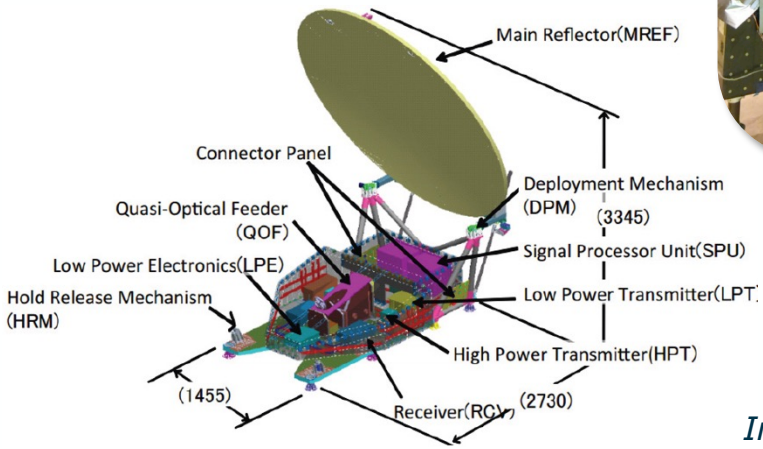
Measure vertical cloud structure for retrieval of cloud microscopic and macroscopic properties and vertical velocity of cloud particles.

High Power 94 GHz Doppler Radar with deployable 2.5m antenna

- Center frequency 94.05 GHz
- Horizontal resolution 800m (sampling interval 500m)
- Vertical resolution 500m (sampling interval 100m)
- Measurement from -1km (surface backscatter) up to 20km
- Doppler capability allows to derive information about particle motion in atmosphere, providing novel information on convection, precipitating ice particles and raindrop fall.

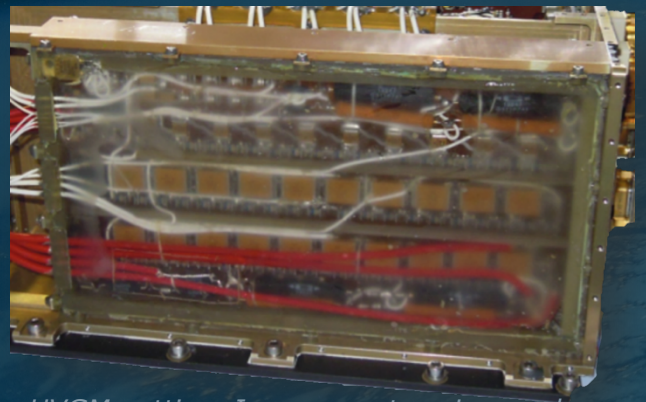






Images courtesy JAXA

CPR Status



HVGM potting. Image courtesy Leonardo

Movie and image courtesy Airbus

CPR mechanically and electrically integrated on spacecraft.

Open Work: Instrument Performance Check, Integrated System Tests and deployment test ongoing in Q2 2021. Manufacturing of redundant HPT ongoing for later integration in CPR.

EarthCARE Spacecraft Status

EarthCARE integrated at Airbus. System level functional and performance tests ongoing.

Open Work: 2021 Complete CPR testing, MSI modifications, Perform all system level tests, including System Validation Tests. **2022** Environmental test campaign @ESTEC, CPR HPT-A integration, Acceptance Review.

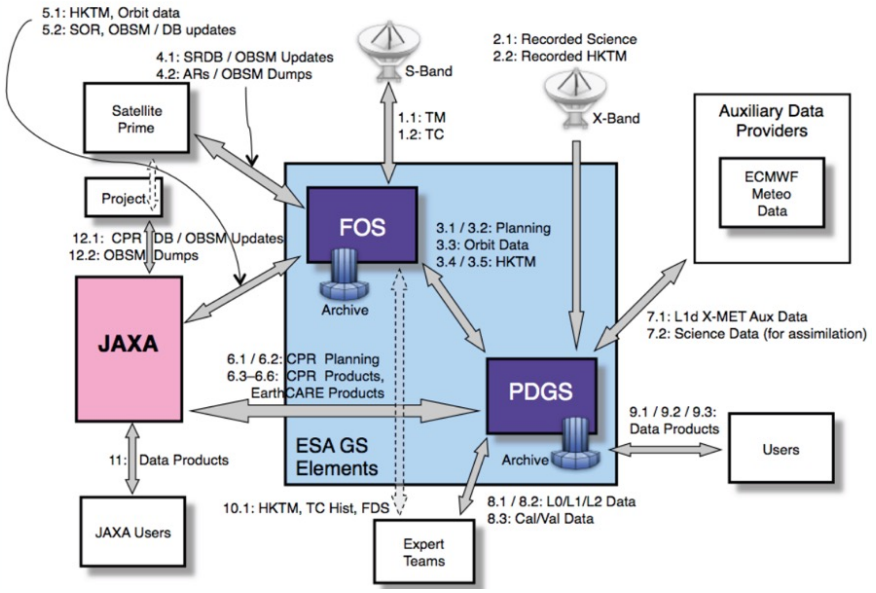
EarthCARE Ground Segment

ESA Flight Operations Segment (FOS/ESOC): Spacecraft commanding/health monitoring/orbit control

ESA Payload Data Ground Segment (PDGS/ESRIN): science data acquisition, processing, archiving and distribution of (L0)L1/L2 data products to JAXA and users community

JAXA CPR Ground Segment (EORC): produce L1 CPR data products, support CPR calibration, operations and dissemminate/archive L1/L2 data products back to PDGS and users community

Other parties: S/C prime, ECMWF, Expert Teams, Users Community



All Ground Segment activities restarted/ramping up after period of “on-hold”/”lower pace”

EarthCARE Ground Segment – Data Production Model

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
Note: uncorrected for instrument effects

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 & depol. profiles, aerosol properties, ice cloud properties, ...

MSI Level 2a
Cloud mask, cloud micro-physical parameters, cloud top height, aerosol parameters, ...

BBR Level 2b
Unfiltered top-of-atmosphere radiances, short-wave and long-wave fluxes
Products are enhanced by using MSI

Synergistic Level 2b
Target classification, cloud & aerosol prof. at x-sectn, ...

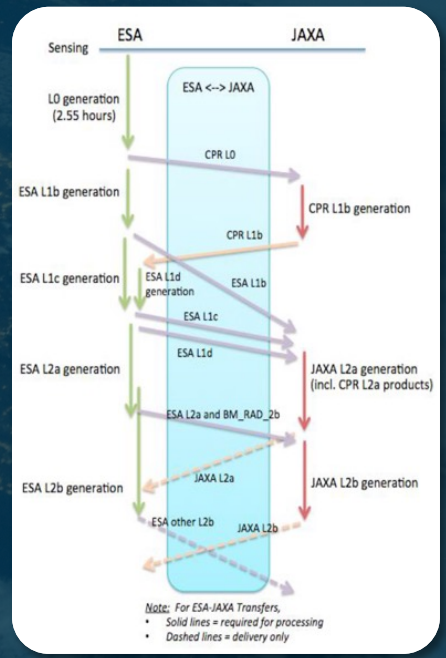
EarthCARE Data Production Model

3D Scenes Construction
Expand syn. retrievals across-track using MSI; ≈40km wide

Radiative Transfer Products
calculated radiances, fluxes, heating rate profiles

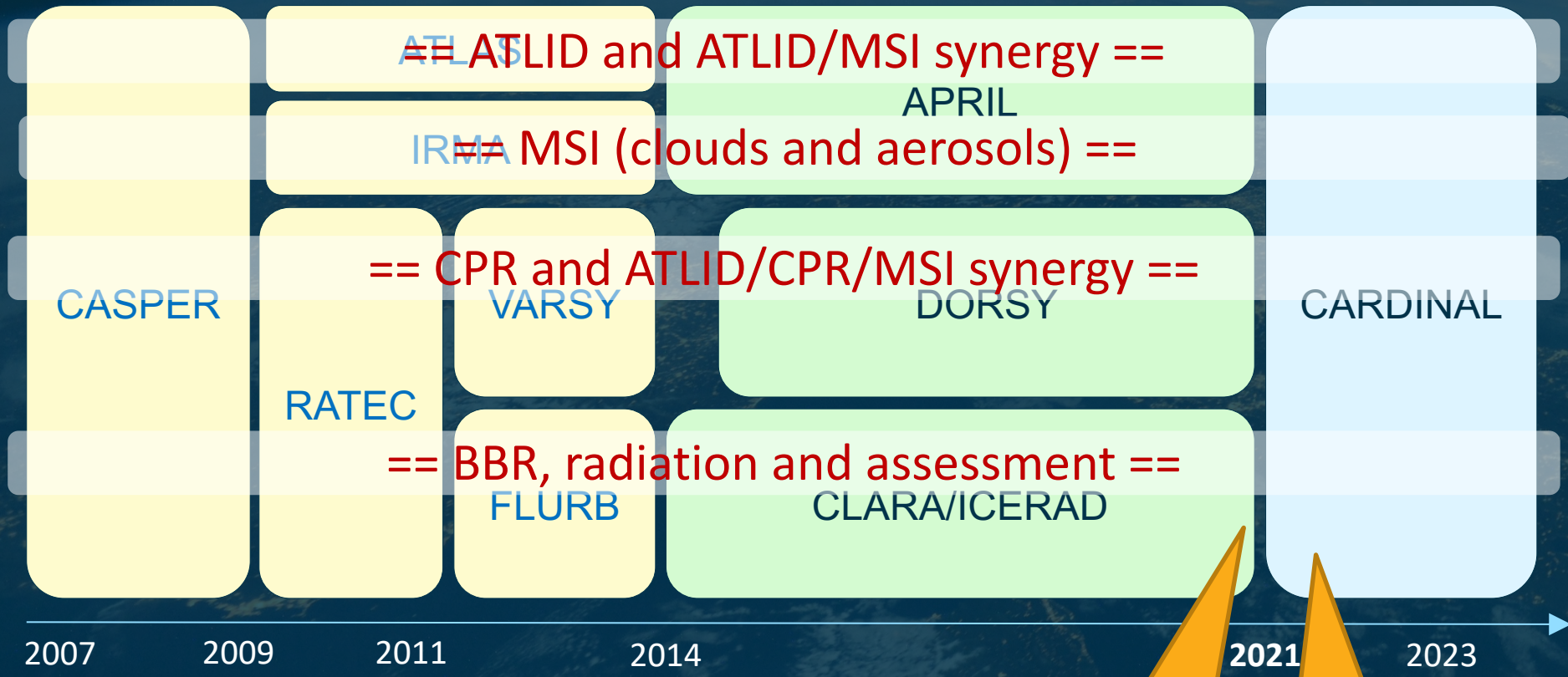
Assessment
Comparison of calculated fluxes and radiances to BBR observations

Operational software developed directly by science teams



EarthCARE Ground Segment – L2

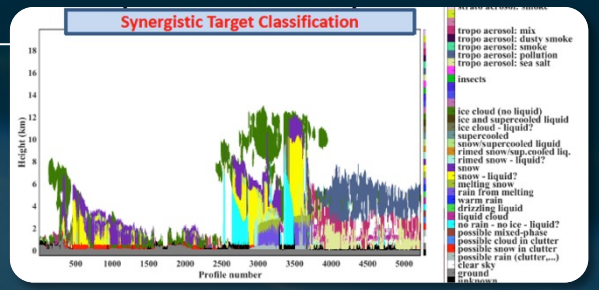
From CASPER to CARDINAL

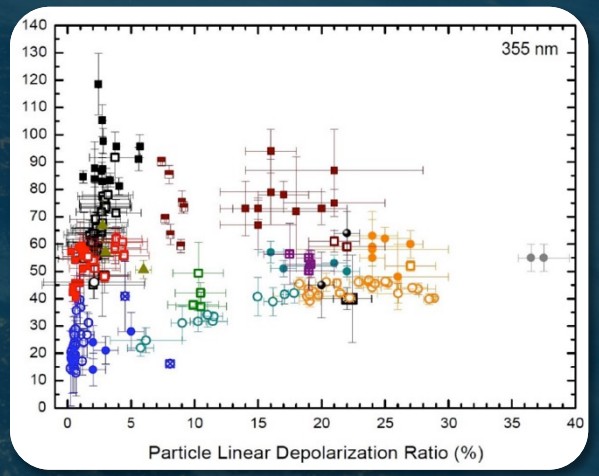


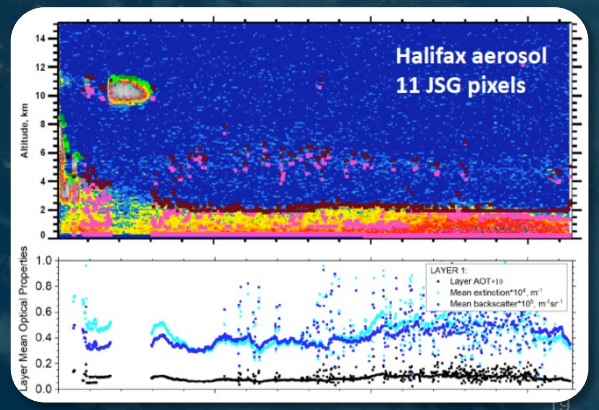
Remaining activities: Focus on completing processing chain, PDGS integration, GS Verification/Validation

Final Presentations 3/2021

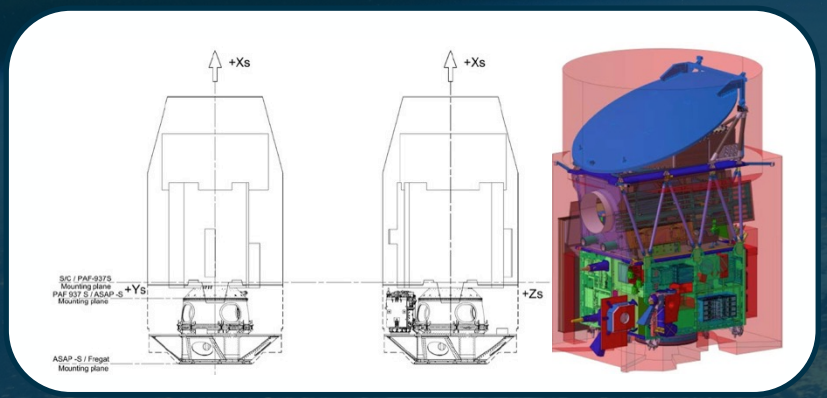
Kick-Off 5/2021







Launcher



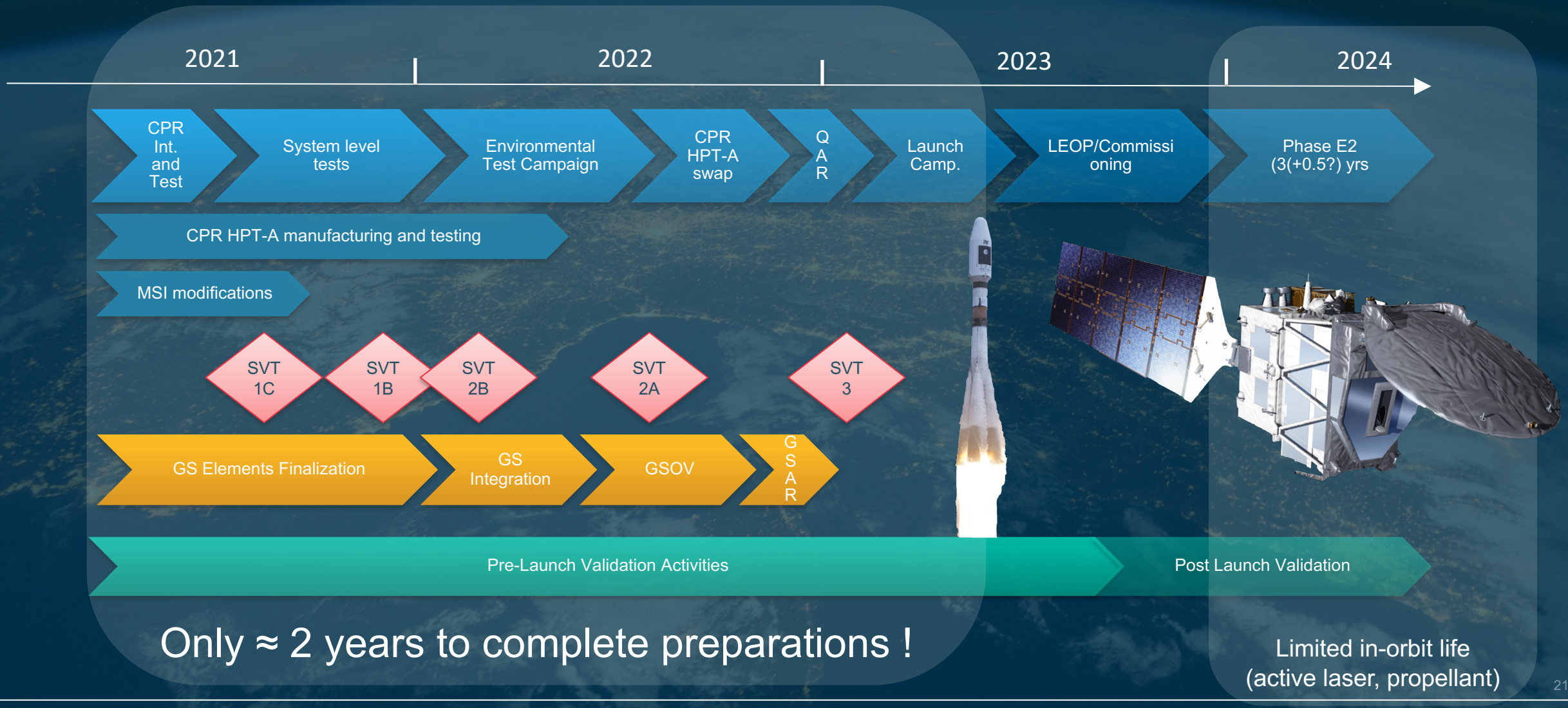
Soyuz from European Spaceport in French Guyana

Contract signed, and fully kicked-off. Activities ongoing towards PMAR (Preliminary Mission Analysis Review) starting 9/2021.

Note: before PMAR, injection orbit optimization to be performed (mission during solar max)

Launch Window opening end Q1/2023.

EarthCARE planned activities



Only ≈ 2 years to complete preparations !

Limited in-orbit life
(active laser, propellant)

Conclusion

All EarthCARE segments ramped-up from bridging phase and progressing full speed.

All instruments integrated on platform and system level tests ongoing.

Launcher activities ongoing. Launch window opening Q1 2023 !!

EarthCARE = Complex
EarthCARE = Cooperation
EarthCARE in-orbit lifetime limits
Preparation = key !

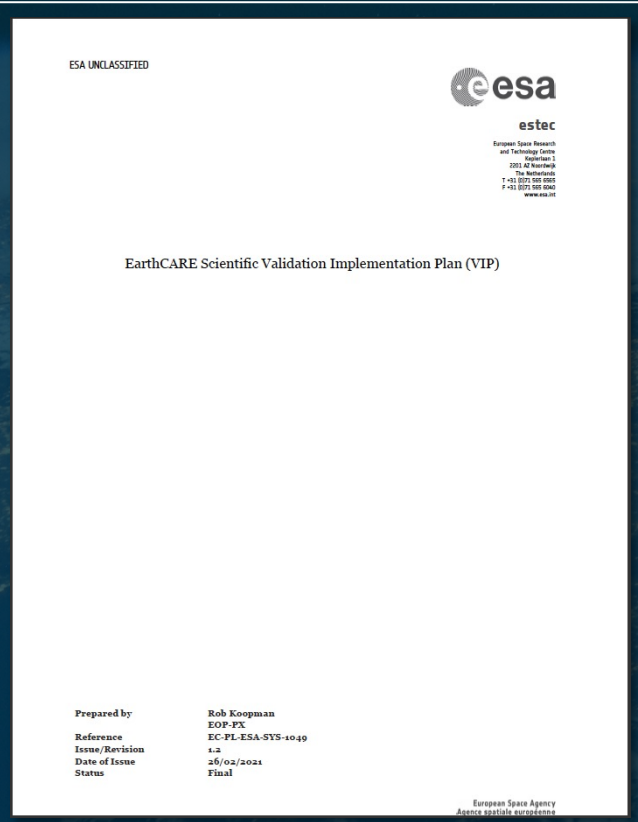
…only mission success once its data is extensively used by the scientific community.

=> Timely preparation of validation and scientific utilization !!

Thank you for your support !

More info…

https://earthcare-val.esa.int/



Scientific Validation Plan

Presentations 1st and 2nd Validation Workshop

ESA Project Team contacts

Rob Koopman	***Cal/Val***
Tobias Wehr	***Project Scientist***
Michael Eisinger	*Performance and Products*
Kotska Wallace	*Mission & Optical Payloads Manager*
Georgios Tzeremes	*ATLID*
Matthias Gollor	*CPR*
Mehrdad Rezazad	*Spacecraft & AIT/AIV Manager*
Patrick Deghaye	*Ground Segment / Commissioning*
Dirk Bernaerts	*Project Manager*