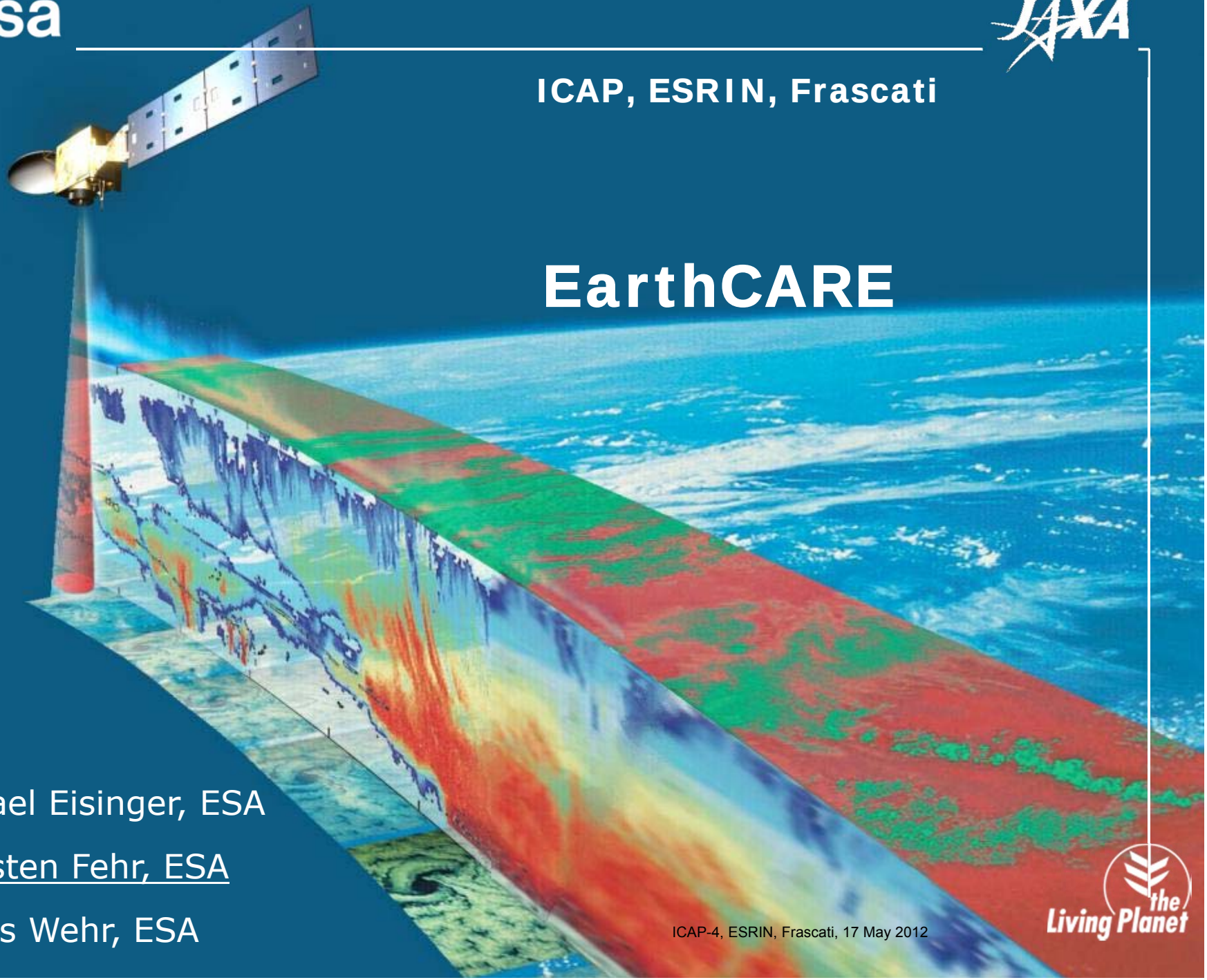
ICAP, ESRIN, Frascati

EarthCARE



Michael Eisinger, ESA

Thorsten Fehr, ESA

Tobias Wehr, ESA

the Living Planet

Scientific Justification

There is a need to quantify aerosol-cloud-radiation interactions in order to correctly represent them in climate and weather forecasting models

1. Aerosols Direct Effects
    a. Direct blocking sunlight → cooling
    b. Absorbing aerosols → heating
2. Aerosol Indirect Effects
    a. Aerosols as cloud condensation nuclei
    b. more aerosol lead to more reflective cloud and less precipitation
3. Clouds radiation and climate
    a. More low clouds reflecting sunlight → cooling
    b. More high (cold) clouds, less IR to space → warming
    c. Cloud feedbacks remain the largest source of uncertainty for climate sensitivity with models differing significantly
4. Convection and precipitation
    a. Convective precipitation is produced by sub-grid-scale vertical motions of cloud condensate.
    b. Passive satellite observations suggest 0.5% of convection penetrates

Mission Objective

To quantify Aerosol-Cloud-Radiation interactions so they may be included correctly in climate and numerical weather forecasting models to provide

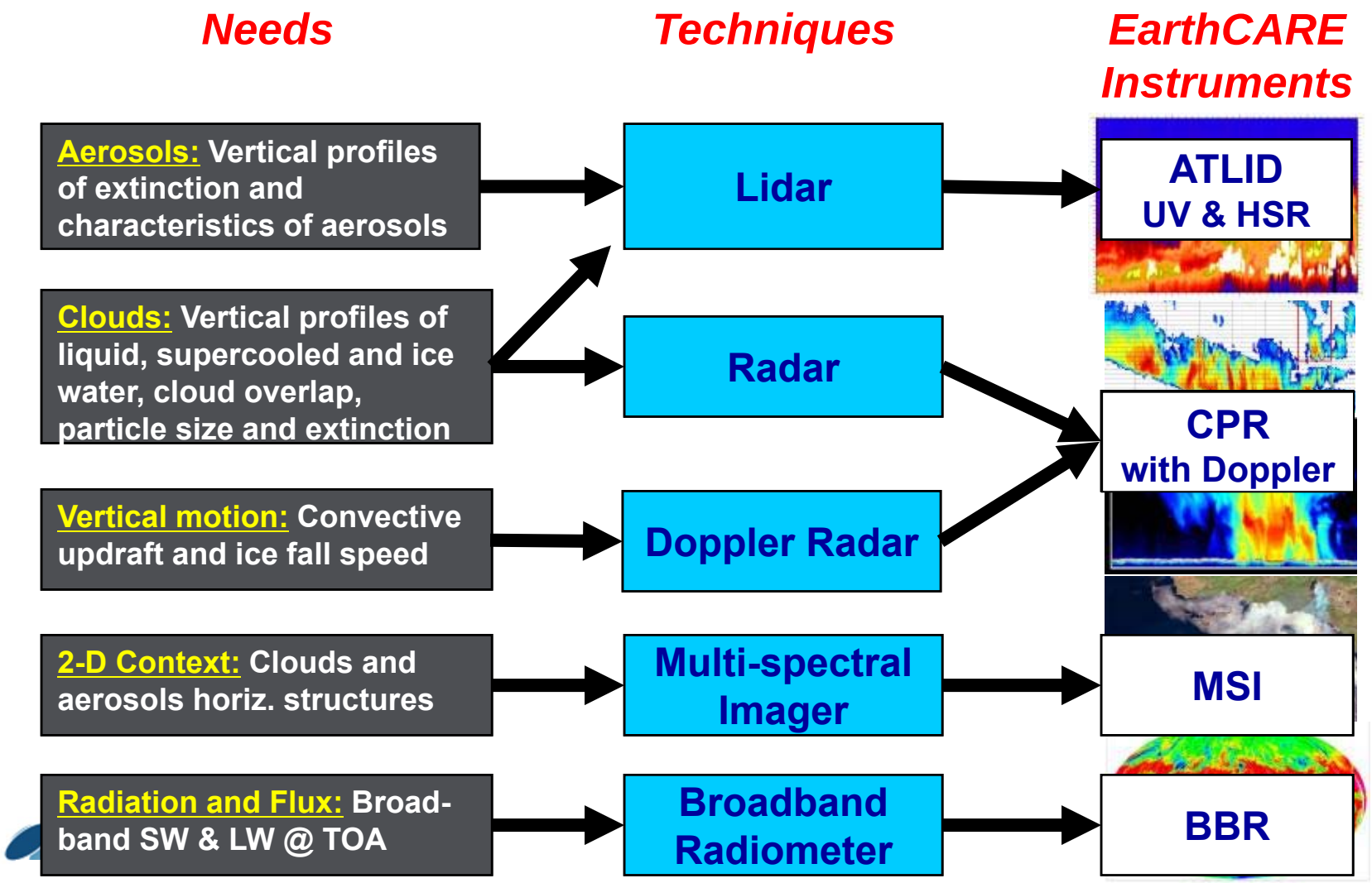
1. Vertical profiles of natural and anthropogenic aerosols on a global scale, their radiative properties and interaction with clouds.

2. Vertical distribution of atmospheric liquid water and ice on a global scale, their transport by clouds and radiative impact.

3. Cloud overlap in the vertical, cloud-precipitation interactions and the characteristics of vertical motion within clouds.

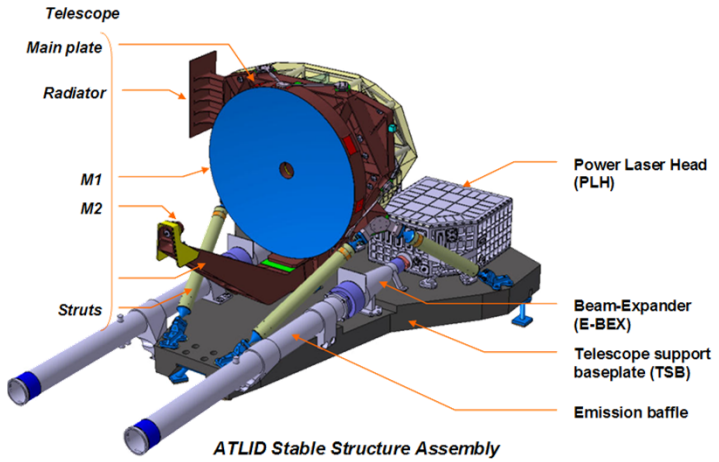
4. The profiles of atmospheric radiative heating and cooling through a combination of retrieved aerosol and cloud properties.

Mission Summary



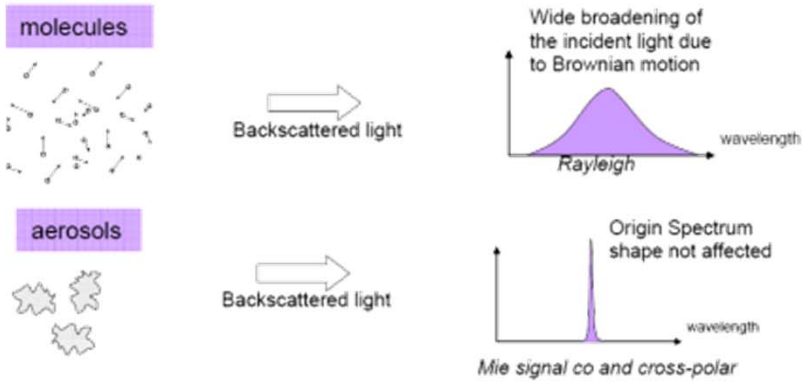
ATmospheric LIDar (ATLID)

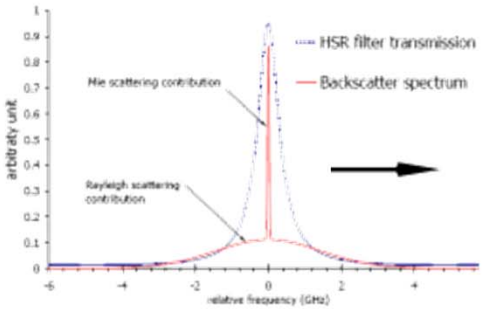
- Backscatter UV (355nm) with high spectral resolution receiver, bistatic design
- 3 channels receiver:
  - Rayleigh,
  - co-polar Mie
  - cross-polar Mie
- Separation Rayleigh-Mie by narrow bandwidth Fabry-Perot Etalon
  → backscatter and extinction can be measured independently
- Pulse repetition rate 51 Hz, Laser energy: 34 mJ
- Sampling: horizontal: 280m (=2x140m integrated), vertical: 100m
- Receiver footprint on ground < 30 m
- 3° off-nadir (backwards) pointing to reduce specular reflection on ice clouds

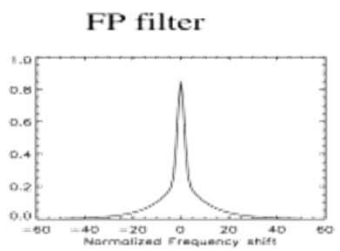


ATLID Stable Structure Assembly (SSA) and equipments

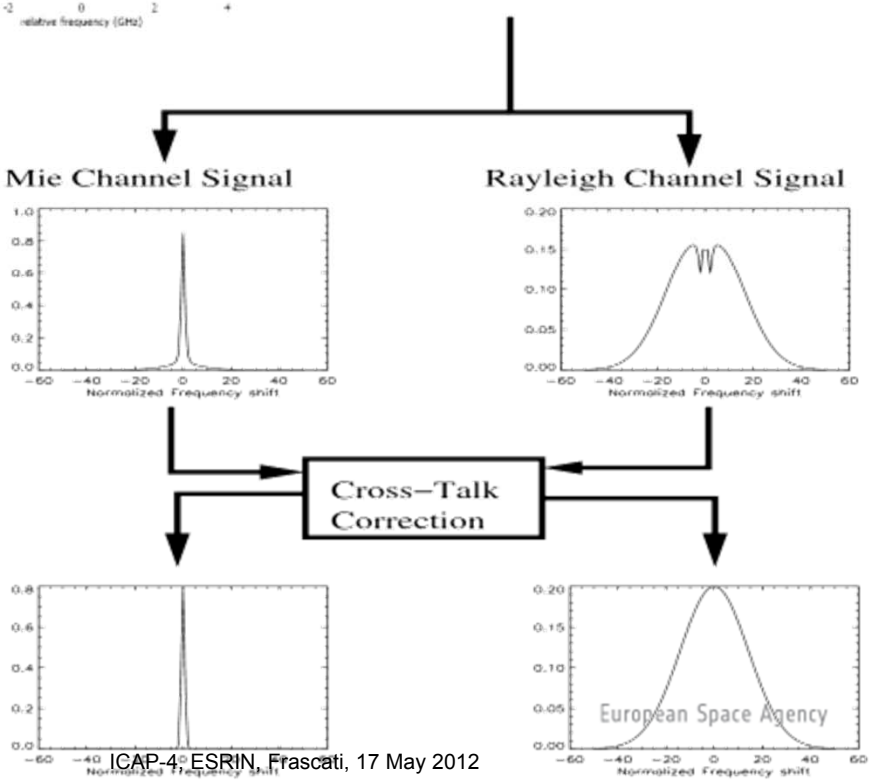
ATLID: HSRL Principle







1. ALTID design will use a Fabry-Perot etalon to 'imperfectly' separate the molecular and the aerosol/cloud contributions.
2. Cross-Talk correction is needed to correct for the imperfection.
3. The Rayleigh signal will enable a direct extinction retrieval for high SNR data



ATLID vs. Calipso

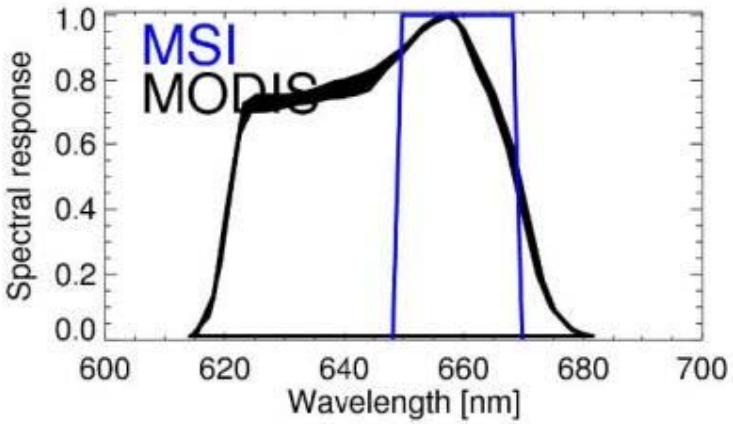
Parameter	ATLID / EarthCARE	Caliop / Calipso
Satellite altitude	409 km	705 km
Orbital inclination	97 deg	98 deg
Ascending node	14:00	13:30
Repeat cycle	389 orbits/25d [nom] 140 orbits/9d [cal]	233 orbits/16d
Orbits per day	15.6 / 11.6	15
Laser Divergence/Footprint	< 30 m	100 µrad / ≈ 70 m
Telescope Divergence/ Footprint		130 µrad / ≈ 90 m
Laser Wavelength	355 nm	532 nm
Laser Pulse Energy	34 mJ	110 mJ
Laser Pulse Length	30 ns	20 ns
Repetition Rate	50 Hz	20 Hz
Single Shot Ground Distance	140 m	380 m

Multi Spectral Imager (MSI)

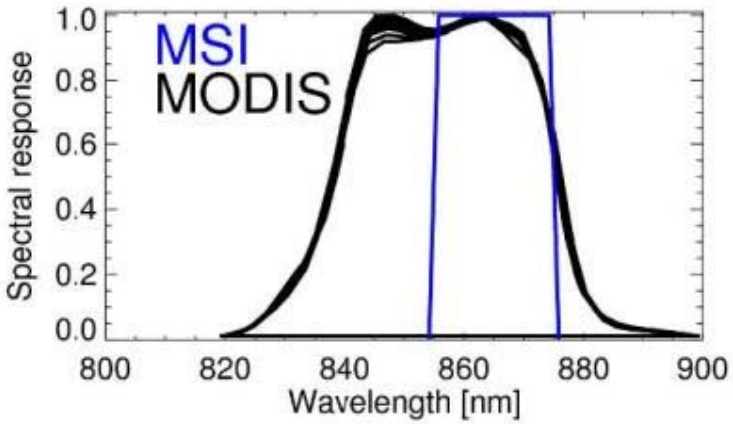
- Nadir viewing push-broom imager
- Swath:
  - 150 km (-35km to +115km tilted away from sun to minimize sunglint)
- Sampling (eff.): horizontal 500m x 500m
- Calibration views:
  Sun, on-board warm blackbody, cold space
- 7 Spectral Bands
  - VIS, NIR, 2 x SWIR
  - 3 x TIR

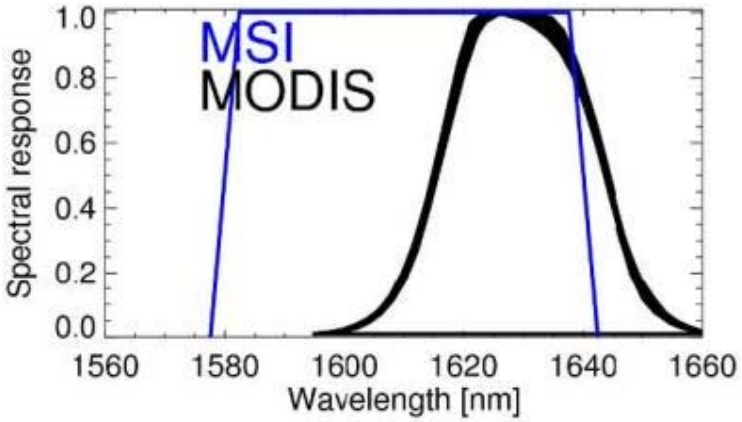
MSI vs. MODIS Spectral Response

VIS	0.67 µm	20 nm

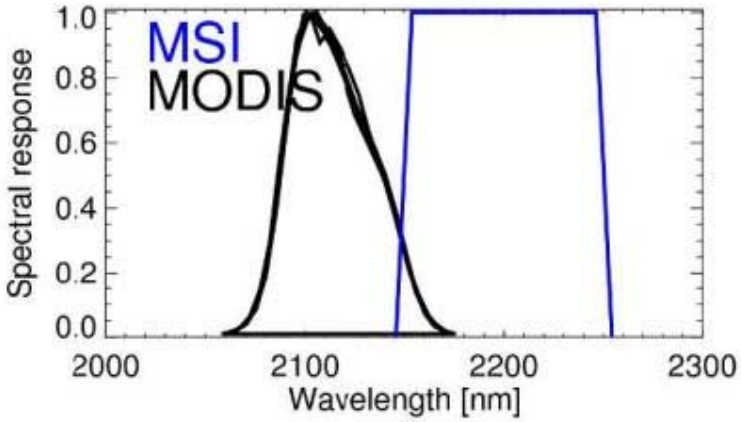


NIR	0.865 µm	20 nm





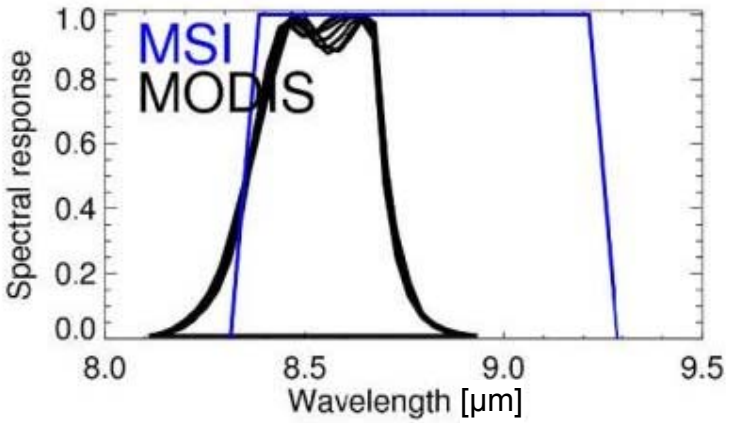
SWIR-1	1.65 µm	50 nm



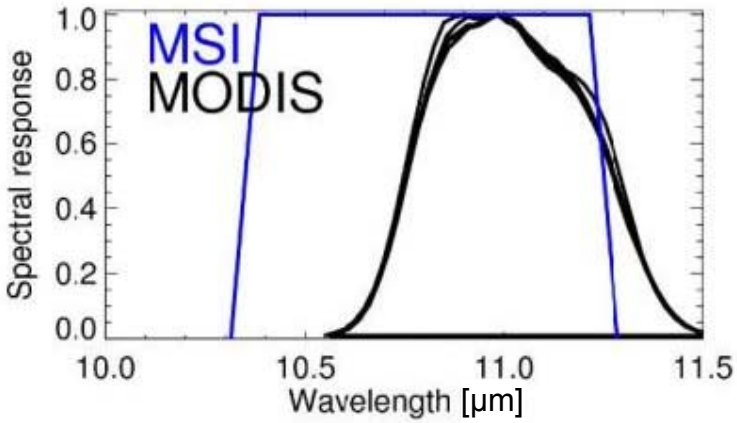
SWIR-2	2.21 µm	0.1 µm

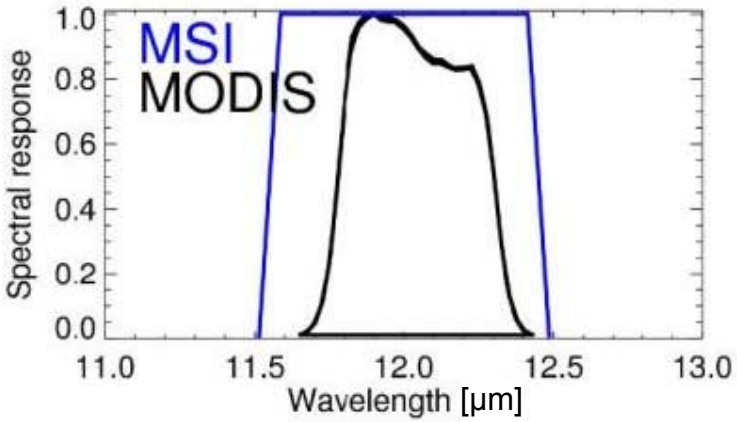
MSI vs. MODIS Spectral Response

TIR-1	8.80 µm	0.9 µm



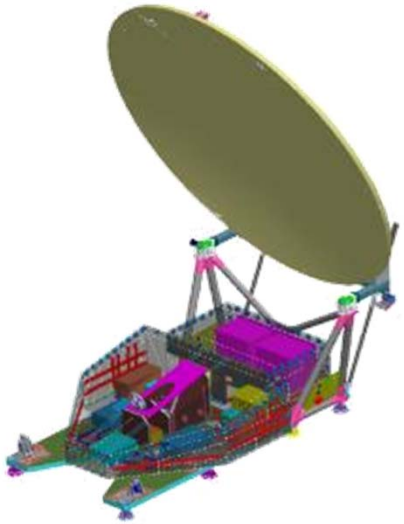
TIR-2	10.8 µm	0.9 µm





TIR-3	12.0 µm	0.9 µm

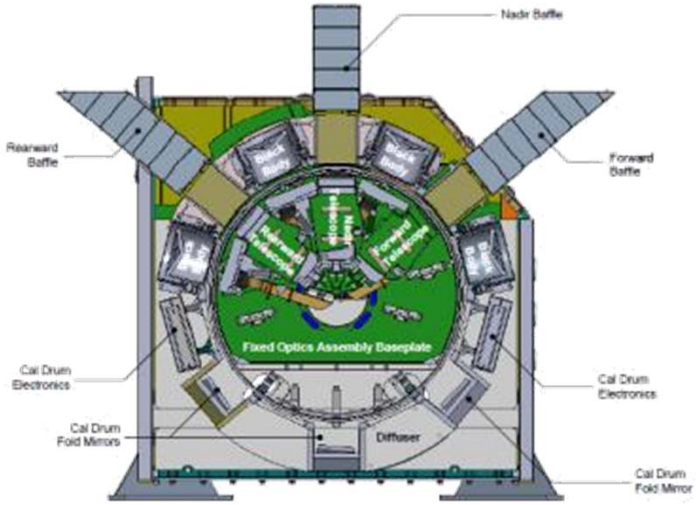
Cloud Profiling Radar



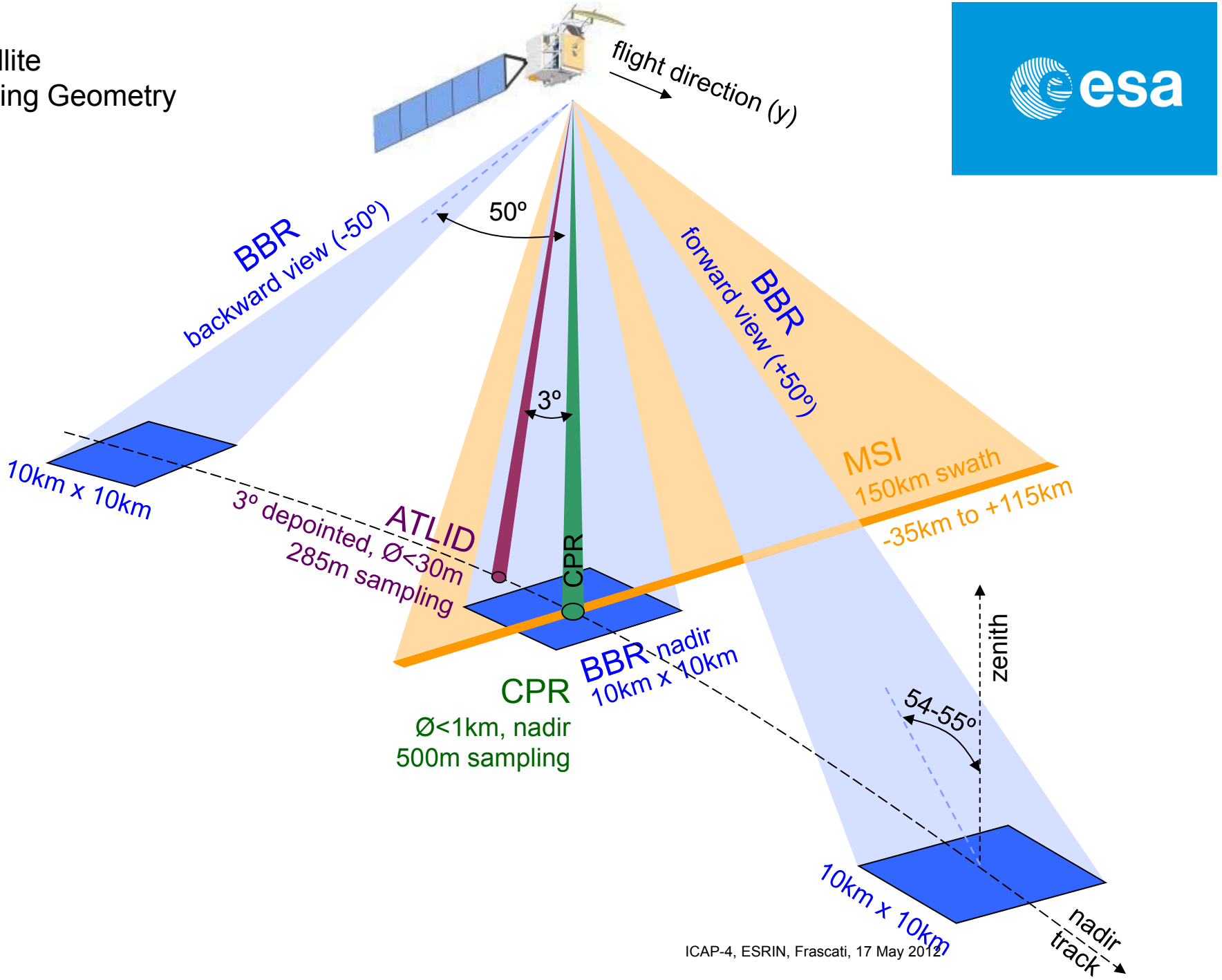
- Contribution by JAXA
- High power W band (94GHz) nadir-pointing radar with Doppler capability
- Antenna subtended aperture 2.5 m
- Variable Pulse Repetition Frequency (PRF) 6100-7500 Hz
- Sensitivity at least -35dBZ @ 20km height
- Sampling:
    - horizontal: 500m
    - vertical 100m (vertical resolution 500m)
- Beam footprint on ground < 800 m
- Doppler accuracy 1 m/s (for 10 km along-track integration 19dBZ)

Broad Band Radiometer (BBR)

- Short-wave (0.2μm-4μm) and
  total wave channel (0.2μm-50μm)
- 3 views: nadir, forward (+50°),
  backward (-50°)
- Linear microbolometer array detectors,
  ground pixels < 1km x 1km
- Rotating chopper wheel (261 rpm)
- Calibration views: sun, internal cold and warm blackbodies
- 10km x 10km pixels spatially integrated in ground processing
- Radiometric accuracy: 2.5 W/m^{2}sr (SW), 1.5 W/m^{2}sr (LW)

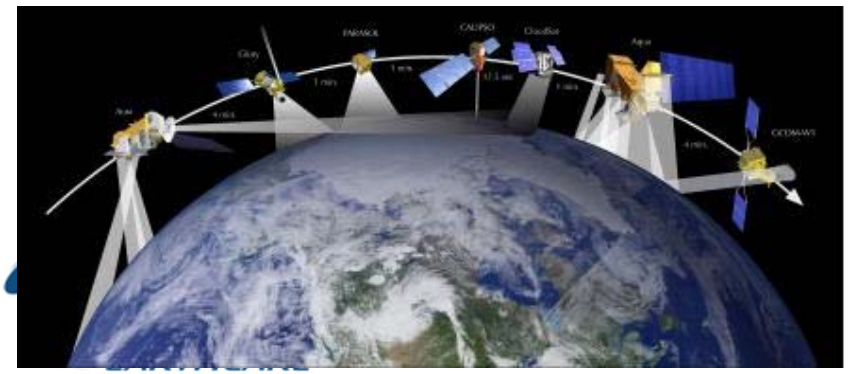


Satellite
Viewing Geometry



EarthCARE and A-TRAIN

1. EarthCARE: Selected elements of the A-Train on one platform
    a. Calipso → ATLID, but at 335 nm and HSRL
    b. CloudSAT → CPR, but Dopplerized
    c. MODIS → MSI, but only 7 bands and 150 km swath
    d. CERES → MSI, but different scan strategy/footprint
    e. Altitude: 700 km → 400 km
    f. Mean Local Solar Time: 13:30 → 14:00
    g. Potential Gab between Missions
2. Key A-Train Scientists are part of the EarthCARE Mission Advisory Group
3. Basically all Calipso, Cloudsat and MODIS Aerosol/Clouds geophysical parameters produced by EarthCARE



Products: Level 1

1. ATLID
    a. Level 1b: Attenuated backscatter profiles
2. MSI
    a. Level 1b: Top-of atmosphere radiances and brightness temperatures in 7 spectral bands
    b. Level 1c: Regridded of all bands to a common grid
3. CPR:
    a. Level 1b: Reflectivity and Doppler profiles
4. BBR:
    a. Level 1b: Filtered top-of-atmosphere radiances short- and long-wave
5. ATLID/CPR
    a. Level 1d: Level 1b on Joint Standard Grid

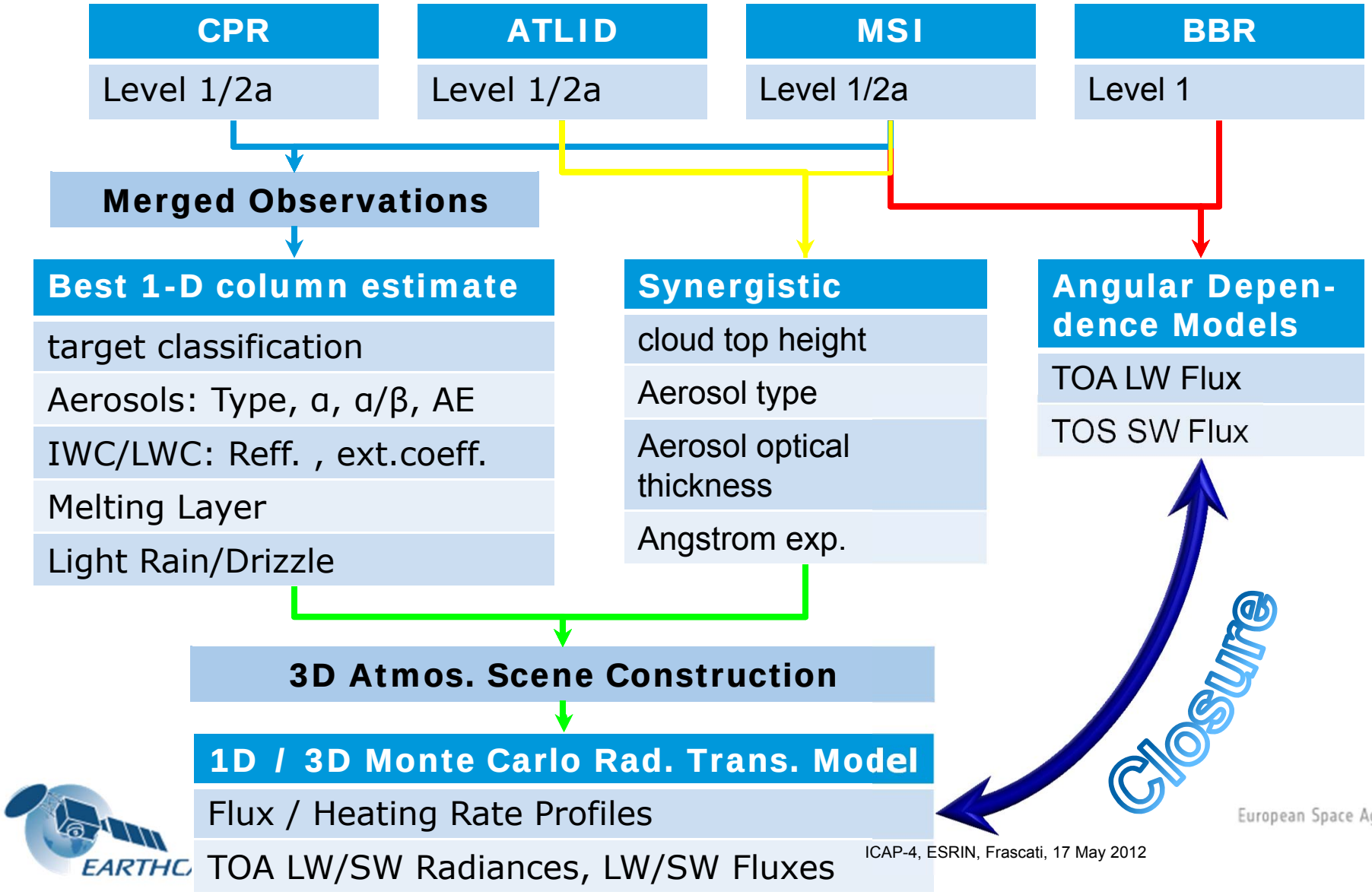
Products: Single Instrument Level 2 Key Parameters

CPR	ATLID	MSI	BBR
Feature Mask	Feature Mask	Cloud Mask: Flag/Type/ Phase	Unfiltered Solar Radiance
Target Classification	Target Classification	Cloud µ-Phys: OT, R_{eff}	Unfiltered Thermal Radiance
Ice Water Content/ Effective Radius	Extinction, Back-scatter, Depolarisation	Liq./Ice Water Path	
Liquid Water Content/ Effective Radius	Aerosol Extinction, Backscatter, Type	Cloud Top Height/T,/p	
Vertical motion	Ice Water Content	Aerosol OT & Angström Exp	
Precipitation/Snow	Cloud Top Height		
Melting Layer	Aerosol Layer Descriptors		

Products: Single Instrument Level 2 Key Parameters

CPR	ATLID	MSI	BBR
Feature Mask	Feature Mask	Cloud Mask: Flag/Type/ Phase	Unfiltered Solar Radiance
Target Classification	Target Classification	Cloud µ-Phys: OT, R_{eff}	Unfiltered Thermal Radiance
Ice Water Content/ Effective Radius	Extinction, Back-scatter, Depolarisation	Liq./Ice Water Path	
Liquid Water Content/ Effective Radius	Aerosol Extinction, Backscatter, Type	Cloud Top Height/T,/p	
Vertical motion	Ice Water Content	Aerosol OT & Angström Exp	
Precipitation/Snow	Cloud Top Height		
Melting Layer	Aerosol Layer Descriptors		

Products: Synergistic Level 2



Products: Size, Format and Latency

- Harmonisation between ESA and JAXA products
- Data provision from sensing
  - Level 1: 24 hours
  - Level 2: 48 hours
  - NRT not baseline, but still under discussion
- Data will be provided in netCDF/HDF5 format
- Products Sizes in MByte / orbit (estimates):

MByte / Orbit	ATLID	CPR	MSI	BBR	Total	Contingency
Level 0	660	218	468	100	1446	20%
Level 1b	7500	510	5500	15	13525	50%
Level 1c	–	–	1200	–	–	50%
Level 1d	–	–	–	–	3200	50%
Level 2a	7400	TBD	8500	20	15920	100%
Level 2b	–	–	–	–	40000	100%

Products: Size, Format and Latency

- Harmonisation between ESA and JAXA products
- Data provision from sensing
  - Level 1: 24 hours
  - Level 2: 48 hours
  - NRT not baseline, but still under discussion
- Data will be provided in netCDF/HDF5 format
- Products Sizes in MByte / orbit (estimates):

MByte / Orbit	ATLID	Calipso		CPR	CloudSAT
Level 0	660	156		218	NA
Level 1b	7500	945		510	20
Level 1c	–	–		–	–
Level 1d	–	–		–	–
Level 2a	7400	773		TBD	415
Level 2b	–	–		40000	52

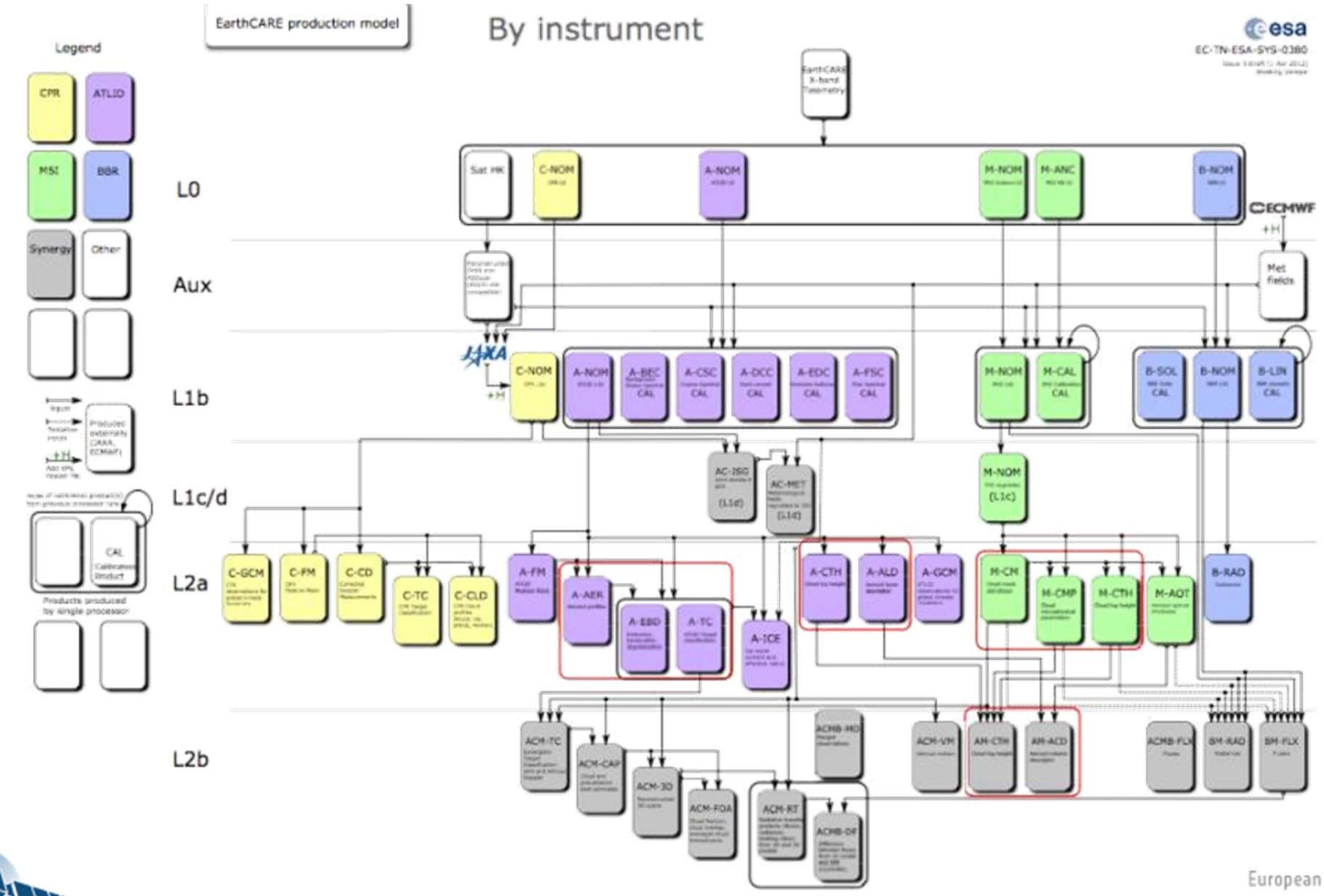
EarthCARE: Community Approach

1. EarthCARE is a multi-sensor mission addressing multiple thematic areas
2. Collocated observations on one platform offer novel product retrieval approaches
3. Wide expertise form heritage missions
4. Free and Open data policy
5. Constant increase in processing and archiving capabilities available to users
6. Major developments in Web 2.0 and Social Media applications
7. Paradigm change towards transparency, in particular in the Climate change discussion

Vision for Phase E2:

EarthCARE for Open Science

Production Model



EarthCARE: Level 2 Strategy

Three basic Level 2 (or higher) product categories:

Cat A: Complete ESA product

- Development funded by ESA
- Provided to the user community in the breadboard
- Products generated in the ESA PDGS

Cat B: ESA processor

- Development funded by ESA
- Provided to the user community in the breadboard
- Products generated by the user

Cat C: Science Product/Collaborative product

- Developed not funded by non-ESA entities
- Can be provided to the user community in the breadboard upon review of ESA → EarthCARE Collaborative Product
- Products generated by the user

EarthCARE: Communication Offensive

Information Portal

- Key information on the mission
- Communication platform with ESA and among researcher
- Presentation of Collaborative EC Products (Groudsegments)
- Communication of community Key achievements

Validation/Calibration Portal

- Validation data/Validation tools
- On-line Validation
- Information exchange with ESA and among cal/val scientists

Level 2 Development Portal

- Development Environment
- Source code and Documentation
- Development Tools and Test Environment

EarthCARE:
Breadboard and Workshops

Algorithm Breadboard

- Hosting all ESA algorithms
- Hosting ESA collaborative algorithms
- Virtual environment to be run locally on ESA provided computing environments (and/or locally at developers TBD)
- Plug-in capability for user S/W development

Workshops

- Regular "face-to-face" meetings
- Web meetings for dedicated groups/discussions
- Confrences, e.g., ESA/JAXA/NASA Cloud/Aerosol/Radiation

EarthCARE: Level 2 Strategy

ESA EarthCARE Products Development Portal

→ i.e. user "forum" around L2 products

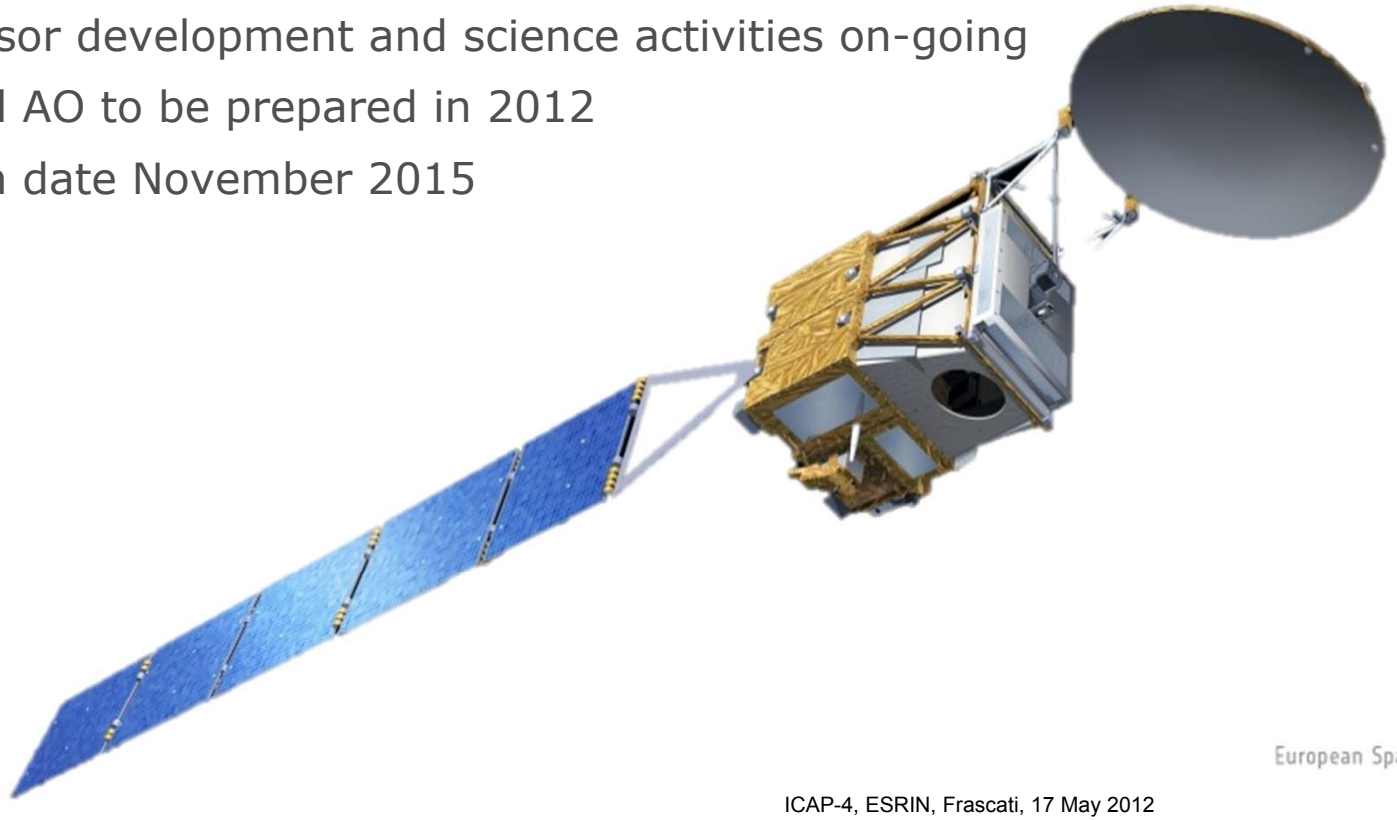
Cat. A processors **Available in "breadboard"**	**Cat. B processors** **Available in "breadboard"**	**Cat. C processors** **(collaborative products)** **Available in "breadboard" with "ESA stamp"** ***no ESA funding***
Products generated by ESA	**Products generated by users** ***no ESA funding***	**Products generated by users** ***no ESA funding***

Annual EarthCARE Algorithm Science Workshops

(could even be virtual, i.e. web only)

EarthCARE Status

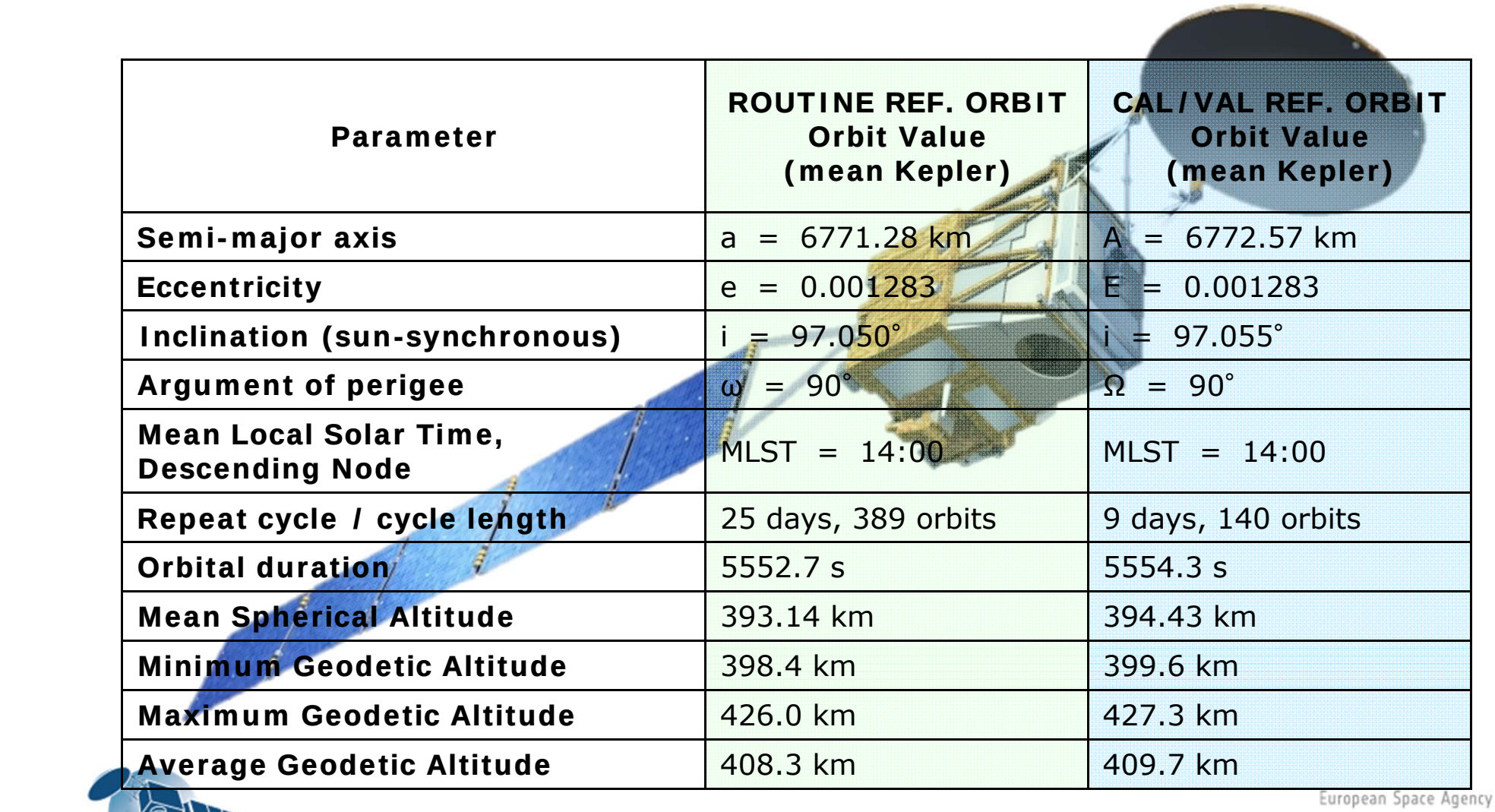
1. EarthCARE Project in Phase C/D
2. Launcher Studies progressing nominally
3. Industrial activities S/C and Instruments ongoing
4. Processor development and science activities on-going
5. Cal/Val AO to be prepared in 2012
6. Launch date November 2015



EARTHCARE


esa
JAXA
Japan Aerospace Exploration Agency
esa
P.CARRIL 2008

Orbit



Parameter	ROUTINE REF. ORBIT Orbit Value (mean Kepler)	CAL/VAL REF. ORBIT Orbit Value (mean Kepler)
Semi-major axis	a = 6771.28 km	A = 6772.57 km
Eccentricity	e = 0.001283	E = 0.001283
Inclination (sun-synchronous)	i = 97.050°	i = 97.055°
Argument of perigee	ω = 90°	Ω = 90°
Mean Local Solar Time, Descending Node	MLST = 14:00	MLST = 14:00
Repeat cycle / cycle length	25 days, 389 orbits	9 days, 140 orbits
Orbital duration	5552.7 s	5554.3 s
Mean Spherical Altitude	393.14 km	394.43 km
Minimum Geodetic Altitude	398.4 km	399.6 km
Maximum Geodetic Altitude	426.0 km	427.3 km
Average Geodetic Altitude	408.3 km	409.7 km

Aeolus vs. EarthCARE vs. Calipso

Parameter	Aeolus / Aladin	ATLID	Calipso / Caliop
Satellite altitude	408 km	409 km	705 km
Orbital inclination	90 deg	97 deg	98 deg
Ascending node	18:00	14:00	13:30
Repeat cycle	**109** orbits/7d	389 orbits/25d [nom] 140 orbits/9d [cal]	**233** orbits/16d
Orbits per day	16	15.6 / 11.6	15
Laser Divergence/Footprint	12 µrad / ≈ **6 m**	< **30 m**	100 µrad / ≈ **70 m**
Telescope Divergence/ Footprint	19 µrad / ≈ **9 m**		130 µrad / ≈ **90 m**
Laser Wavelenth	355 nm	355 nm	532 nm
Laser Pulse Energy	120 mJ	34 mJ	110 mJ
Laser Pulse Length	30 ns	30 ns	20 ns
Repetition Rate	**50 Hz**	**50 Hz**	**20 Hz**
Single Shot Ground Distance	**140 m**	**140 m**	**380 m**

Products and Grids

Native Instrument Grids						
Instrument	Prod. Lev.	Sampling			Range	
		X [km]	Y [km]	Z [km]	s [km]	Direction
ATLID	L1b		0.285	0.103	20.5	Z
CPR	L1b		0.5	0.1	20.5	Z
MSI	L1b	1	1		150	X
BBR	L1b	1	1		3x10 10x10	XY

Joint Standard Grid						
		X [km]	Y [km]	Z [km]	s [km]	Direction
JSG - hor.		1	1		150	X
JSG – vert.				0.1	20.5	Z