Industrial Day
EC.HO.ASD.SY.00003
ESTEC, 19th June 2009

ASTRIUM SATELLITES
Earth Observation & Science
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1 Introduction
1 Introduction

Background

- Earth Explorer Core Missions are an element of the Earth Observation Envelope Programme. They are defined as major missions led by ESA to cover primary research objectives set out in the Living Planet Program (ESA, 1998). The Earth Clouds, Aerosols and Radiation Explorer Mission (EarthCARE) has been approved for implementation as the third Earth Explorer Core Mission.

- EarthCARE is a cooperative mission between ESA and JAXA, where JAXA will provide a Cloud Profiling Radar. ESA is responsible for the entire system including the Spacecraft, three instruments, the Launcher and the Ground Segment with the exception of the CPR data segment.

- The EarthCARE Mission will help in determining the Earth radiation budget by providing global observations of vertical cloud and aerosol profiles. The mission is centered on the synergetic use of the data provided by an instrument suite consisting of an ATmospheric LIDar (ATLID), a Cloud Profiling Radar (CPR), a Multi-Spectral Imager (MSI) and a BroadBand Radiometer (BBR).
1 Introduction

Mission Objectives

Radiation Budget

Evaporation of Water

Reflection

Absorption

Short Wave

Absorption

Reflection

Emission

Long Wave

Emission

Cloud top height

Change in cloud amount, liquid and ice water content, effective radius, convective updraft and ice fall speed

Cloud base height

Convection

Condensation

Preceptation

Evaporation of Water

Absorption

Reflection

Emission

Water

Earth Surface

Planetary Boundary Layer

Free Atmosphere

Top of Atmosphere
1 Introduction
Mission Objectives

Needs

- Convective updraft and ice fall speed
- Vertical profiles of liquid, supercooled and ice water, cloud overlap, partial size and extinction
- Cloud top and base height
- Quantitative precipitation measurements
- Ice water content

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

- Shortwave and longwave fluxes at top of the atmosphere
- Horizontal structure of clouds and aerosols
- Cloud type
- Icewater discrimination
- Cloud and aerosol optical depth
- Cloud top temperature
- Effective droplet radius
- Cloud cover fraction
- Cloud effective emissivity

All the space you need
1 Introduction

Mission Operations
1 Introduction
Mission Overview

Ground Segment

Flight Operations Segment (FOS)
TT&C (S-Band)

Payload Data Ground Segment (PDGS)
Science Data (X-Band)

Examples of Candidate Launchers

Slowed EarthCARE Satellite under SOYUZ and Zenit Fairing

Ground Station Location: KIRUNA

EarthCARE End-to-End Simulator (ECEESIM)

EC Scenery Simulator
EC Satellite System Simulator (ESSS)
EC Level-1 Ground Processor (ECGP)
EC Higher Level Products Processor
1 Introduction

Spacecraft Configuration with 4 Instruments

- The EC Satellite consists of:
  - 2 Active Instruments
    - ATmospheric LIDar
    - Cloud Profiling Radar
  - 2 Passive Instruments
    - Broad Band Radiometer
    - Multi-Spectral Imager
  - Base Platform
    - Mechanical / Thermal PF
    - Propulsion System
    - Power Generation & Harness
  - Platform Avionics
    - Data Handling & SW
    - AOCS
    - Power Distribution & Storage
    - Communication Systems
1 Introduction
Spacecraft Model Philosophy

EarthCARE Spacecraft Model Philosophy

Electrical Functional Model

Structural Model

Platform SM

Instrument SMs

Spacecraft SM

Platform PFM

Instrument PFM

Platform EM Units

Instrument EMs

Electrical Functional Model
1 Introduction Programmatic

EarthCARE Industrial Kick Off
12.02.2008

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2 System Design
2 System Design
Payload Synergy Aspects

- The 4 Instruments measure the same atmospheric scene to allow for synergy aspects (Level 2 products based on combined Level 1 products)

- Co-registrations requirements between all instrument line of sights are established.

Requirements:
Absolute Pointing
Pointing Knowledge
Co-Registration

Co-Registration Knowledge

- CPR
  2 mrad 1 sigma towards Nadir; Geo-location 500m; Altitude 50 m RMS;
  across track 1000 m
  along track 1000 m
- BBR
  Nadir and Forward & Backward View with 55° OZA; Geo-location 500m
  across track 1000 m
  along track 1000 m
- ATLD
  3° LOS offset along track to Nadir; Geo-location 500m; Altitude 100 m RMS;
  across track 350m (goal 200m)
  along track 350m (goal 200m)
- MSI
  Swath -35km,+115km; Geo-location 500m (goal 250 m); GSD < 200m; Goal 100m

- CPR
  < 30 m GSD < 0.5 km Goal 100m
- BBR
  Forward view 54-55° GSD < 10 km; Goal 500 m x 500 m, GSD < 500 m
  Backward view GSD < 10 km averaging < 500 m
- ATLD
  < 1 km GSD < 200m Goal 100m
- MSI
  GSD < 200m Goal 100m

All the space you need
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2 System Design

Principle Design Considerations

- Low earth orbit constraints (386-402km):
  - Minimum flight cross-section to reduce the atmospheric drag
  - Power generator with trailed single SA wing (19.25m²)
  - ATOX protection (Beta cloth)

- Instrument Accommodation:
  - ATLID and CPR instruments in stacked configuration
  - Field of view orientation and alignment accuracy

- Instrument & Equipment accommodation on structure:

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<tr>
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</thead>
<tbody>
<tr>
<td>ATLID</td>
<td>MTQ, RW</td>
<td>S-Band</td>
<td>Tanks</td>
<td>OBC, RIU,</td>
<td>Radiators</td>
</tr>
<tr>
<td>CPR</td>
<td>MAG, AAD</td>
<td>PDHT X-Band</td>
<td>Thrusters</td>
<td>EPS</td>
<td>C/C Doubler MLI</td>
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<tr>
<td>BBR</td>
<td>STR, CESS, RMU, GPS</td>
<td>MMFU</td>
<td>Valves, pipe work, etc</td>
<td>PCDU, SA Battery</td>
<td>paint, coatings heaters</td>
</tr>
<tr>
<td>MSI</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\[≈17\,\text{m}\]
2 System Design
Spacecraft Configuration

- Stowed configuration & instrument & equipment accommodation

Spacecraft wet mass 2024.5 kg.
2 System Design
Spacecraft Configuration

- Internal equipment accommodation

![Diagram of spacecraft configuration with labels for various components such as ATLID, CESSH3, CESSH4, CESSH5, STR1, STR2, SA-HDRMs, RWs, RCS, X-Band, S-Band, GPA, RMU, Battery, PCDU, MMFU, MSI, OBC, RIU, BBR, CESSH2, and CESSH4.]
2 System Design

Design Features of Satellite Configuration

- **Power generator and drive mechanism**
  - The SA unshaded structural size 18.5m².
  - Minimize number of HDRMs.
  - Two-stage deployment movement
  - Required angular range +/-80° (X-axis)

- **Deployed stiffness incl. SADM and S/C I/F**
  - First bending mode (out-of plane):  ≥ 0.1Hz

- **Mass properties:**
  - Allocated Mass: 104kg (SA, -Yoke, -HDRM)

- **AIV**
  - Integration and test aspects
2 System Design
Electrical Architecture
2 System Design

Major Electrical Architecture Aspects and Performances

- **Core Data Handling System (CHDS):**
  - The OBC contains all functions needed to perform satellite data handling, attitude and orbit control tasks (S/W)
  - The RIU provides the standard and mission dedicated I/O interfaces

- **Electrical Power System (EPS):**
  - The power is provided by a single deployable Solar Array, 5 panels (Triple Junction GaAs cells).
  - Energy is stored in Li-Ion batteries
  - PCDU is based on an unregulated primary power bus

- **Tracking, Telemetry and Command System (TT&C):**
  - 2 x S-Band Transponder and 2 x Low gain antenna
  - Telecommand / Telemetry: 64 kbps / 128 kbps and 2048 kbps

- **AOCS / RCS:**
  - 3-axis stabilized earth orientated

- **Platform Thermal Control System (TCS):**
  - Heater switching controlled by thermistor readings

- **Payload Data Handling and Transmission (PDHT):**
  - MMFU storage capability: 740 Gbits (EoL).
  - X-band System primarily for science data transmission

- **Four instruments (ATLID, BBR, MSI, CPR)**
Key System Parameter

3
## 3 Key System Parameter

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Unit</th>
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<tr>
<td>Mission Name</td>
<td>EarthCARE</td>
<td></td>
</tr>
<tr>
<td>Mission Time</td>
<td>3 + 1 extension</td>
<td>[years]</td>
</tr>
<tr>
<td>Launch Date</td>
<td>31.10.2013</td>
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<tr>
<td>Reference Orbit</td>
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<tr>
<td>Mean Altitude</td>
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<td>Inclination</td>
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<td>[°]</td>
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<td>LTDN</td>
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<td>Repeat Cycle / cycle length</td>
<td>25; 391</td>
<td>days; orbits</td>
</tr>
<tr>
<td>Orbit Period</td>
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<td>[min]</td>
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<tr>
<td>Revolutions per day</td>
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<td>Eclipse Time (average)</td>
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<td>[min]</td>
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### 3 Key System Parameters

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<td><strong>Spacecraft</strong></td>
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<td>Principle Dimensions (Stowed)</td>
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<td>Length (Z)</td>
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<td>[mm]</td>
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<td>Height (X)</td>
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<td>[mm]</td>
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<tr>
<td>Width (Y)</td>
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<td>[mm]</td>
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<tr>
<td>Principle Dimensions (Deployed)</td>
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<tr>
<td>Width (Y)</td>
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<td>Cross-Section</td>
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<td>[m²]</td>
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<td><strong>Mass</strong></td>
<td></td>
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<tr>
<td>Dry Mass</td>
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<td>[kg]</td>
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<tr>
<td>Propellant Mass</td>
<td>231</td>
<td>[kg]</td>
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<tr>
<td>Launch Mass</td>
<td>2025</td>
<td>[kg]</td>
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### 3 Key System Parameter

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<tr>
<td><strong>Power</strong></td>
<td></td>
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<tr>
<td>Solar Array Area</td>
<td>19,25</td>
<td>m²</td>
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<tr>
<td>Regulation Concept</td>
<td>MPPT</td>
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<tr>
<td>System Power (av.)</td>
<td>1630</td>
<td>W</td>
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<tr>
<td>Voltage unregulated</td>
<td>20 - 34</td>
<td>V</td>
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<tr>
<td><strong>Battery</strong></td>
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<tr>
<td>Type</td>
<td>Li-Ion</td>
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<td>Capacity (BoL)</td>
<td>216</td>
<td>Ah</td>
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## 3 Key System Parameter

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<tr>
<td>Data</td>
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<tr>
<td>Ground Station</td>
<td>Kiruna</td>
<td></td>
</tr>
<tr>
<td>min. Elevation</td>
<td>5</td>
<td>[°]</td>
</tr>
<tr>
<td>TT&amp;C / S-Band</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TT&amp;C uplink rate</td>
<td>64</td>
<td>[kbit/s]</td>
</tr>
<tr>
<td>TT&amp;C downlink high rate</td>
<td>1024</td>
<td>[kbit/s]</td>
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<tr>
<td>TT&amp;C downlink low rate</td>
<td>128</td>
<td>[kbit/s]</td>
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<tr>
<td>Ranging capability</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>Science / X-Band</td>
<td></td>
<td></td>
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<tr>
<td>Modulation</td>
<td>QPSK</td>
<td></td>
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<tr>
<td>Downlink Rate</td>
<td>150</td>
<td>[Mbit/s]</td>
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<tr>
<td>Science Data during 72h GS outage</td>
<td>736</td>
<td>[Gbit]</td>
</tr>
<tr>
<td>MMFU Storage Capability</td>
<td>736</td>
<td>[Gbit]</td>
</tr>
<tr>
<td>EOL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S/C Command &amp; Control Bus</td>
<td>MIL-Bus 1553</td>
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### 3 Key System Parameter

#### Propulsion System

<table>
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<th>Parameter</th>
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<tbody>
<tr>
<td>Propellant</td>
<td></td>
<td></td>
</tr>
<tr>
<td>∆v</td>
<td>158</td>
<td>[m/s]</td>
</tr>
<tr>
<td>Mass (incl. Margin)</td>
<td>231</td>
<td>[kg]</td>
</tr>
<tr>
<td>Hydrazin</td>
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<td></td>
</tr>
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</table>

#### Other Launcher Candidates (H2, PSLV*)

* would require mass reduction

### Launcher

<table>
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<th>Launcher</th>
<th>(TBC)</th>
<th>Value</th>
<th>Unit</th>
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<tbody>
<tr>
<td>Soyuz</td>
<td>(TBC)</td>
<td>primary</td>
<td></td>
</tr>
<tr>
<td>Zenit</td>
<td>(TBC)</td>
<td>backup</td>
<td></td>
</tr>
<tr>
<td>Lift Off Capacity</td>
<td>≈ 4700</td>
<td>[kg]</td>
<td></td>
</tr>
<tr>
<td>Lift Off Capacity</td>
<td>≈ 8800</td>
<td>[kg]</td>
<td></td>
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</table>
EarthCARE Procurement
Administrative and Planning Status

- The EarthCARE Implementation Phase covers the period from February 2008 (Kick-off) until completion of the Launch in End September 2013 and is sub-divided into

- Phase B, devoted to the spacecraft preliminary design & analyses, release of all sets of specifications, and to the industrial team build-up

- Phase C/D, for the detailed design & analyses, the units, sub-systems and module MAIT, the qualification and acceptance of the spacecraft PFM, up to the Flight Acceptance Review (FAR)

- Phase E1, which covers the transport, launch campaign, launch, mission commissioning up to MCRR (Mission Commissioning Results Review)
EarthCARE Phase B, C/D, E1 negotiation completed and agreement between Astrium FN and ESA achieved Dec. 2007.

Kick-off Phase B1 performed in Feb. 2008 at ESA followed by Kick-off's for Core Team Members.

Phase B1 (Trade-off's, system definition, requirement freeze etc.) System Design Consolidation Phase - SRR at Dec. 2008 up to Feb. 2009

Phase B2 (Prelim. Design, Proc. Spec's, ITT's etc. and further Industrial Team build-up) – up to PDR.

Procurement has started after SRR
4 EarthCARE Procurement
Industrial Team at SRR

Industrial team expansion after SRR via ESA
Best Practices
Contribution from all ESA Member states expected
4 EarthCARE Procurement Policy

- The objectives of the EarthCARE procurement policy are in line with ESA policy and IPC decision:
  - Achieve technically excellent solutions
  - Achieve cost effective solutions
  - Maximum level of competition
  - Pursue geographical distribution objectives
  - Procurement items are foreseen to be selected via „open competition“ following the rules of „ESA Best Practices“. 
The Prime Contractor is responsible for the Industrial Team build-up, which is performed in two steps:

1. The selection of the Core Team members already performed during the proposal preparation as requested in the ESA ITT.

2. The selection of the Equipment Suppliers for H/W, S/W and GSE will be mostly performed by the “issuing companies” starting in 2nd quarter 2009 with the aim to be finalised up to the PDR (for the majority of the procurement items).
4 EarthCARE Procurement Policy

- Within the EarthCARE Core Team the following companies act as ITT “issuing companies”:
  - Astrium GmbH *Avionics & System*
  - Astrium Ltd. *Base Platform*
  - Astrium SAS *ATLID*
  - SSTL Ltd. *MSI*
  - SEA Ltd. *BBR*

- The ITT’s will be published via EMITS
4 EarthCARE Procurement

ITT Datapackage

- For all items to be procured via competition, an ITT package will be issued in accordance to ESA’s Code for Best Practices

- All ITT Datapackages will contain as a minimum:
  - Cover Letter
  - Special Conditions of Tender
  - Evaluation Criteria
  - Draft Contract
  - Statement of Work
  - DRL/DIL/DRD
  - Equipment Requirements Specification
    - incl. applicable Design, Environment, Test & Interface Requirements
  - PA Requirements
  - Management Requirements
# 4 EarthCARE Procurement

## Typical Process Duration

<table>
<thead>
<tr>
<th>Step</th>
<th>Duration</th>
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</thead>
<tbody>
<tr>
<td>Draft ITT Package Available</td>
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</tr>
<tr>
<td>ITT Package Review</td>
<td>1 week</td>
</tr>
<tr>
<td>Pre-TEB Meeting</td>
<td></td>
</tr>
<tr>
<td>ITT-Package Update</td>
<td>1 week</td>
</tr>
<tr>
<td>ITT-Package Release on EMITS</td>
<td></td>
</tr>
<tr>
<td>Bidders Proposal Preparation</td>
<td></td>
</tr>
<tr>
<td>ITT Closing</td>
<td>6 to 8 weeks</td>
</tr>
<tr>
<td>TOB</td>
<td>1 week</td>
</tr>
<tr>
<td>TOB Report</td>
<td></td>
</tr>
<tr>
<td>Proposal Evaluation</td>
<td></td>
</tr>
<tr>
<td>TEB Meeting &amp; Recommendation</td>
<td>2 weeks</td>
</tr>
<tr>
<td>TEB Report</td>
<td></td>
</tr>
<tr>
<td>Agency/SPB Decision *</td>
<td>1 week</td>
</tr>
<tr>
<td>Start Negotiations</td>
<td></td>
</tr>
</tbody>
</table>

*) if required
4 EarthCARE Procurement Process - Durations

- Real time information of procurement status to Industry via EMITS:
  - Procurement planning,
  - Intended ITT’s
  - Publication of ITT's on EMITS (companies need to be registered to be able to retrieve documentation)
  - Answers to requests for clarification
  - Extension of proposal preparation period, if any
During tender period, possible communications with potential bidders shall be in writing and limited to provide clarifications on the requirements.

Answers to questions raised will be subject to ESA review prior to be published through EMITS together with original questions.

Any correspondence from or to potential bidders will be copied to the Agency’s responsible Contract Officer.
The bidder's proposal shall comprise the following volumes:

- Cover Letter
- Executive Summary
- Technical Proposal
- Management Proposal
- Financial & Contractual Proposal
- Statement of Compliance
Evaluation Criteria – in general the proposals to ITTs/RfQs are evaluated against the following criteria:

1. Background and experience (general and related to the particular field concerned) of the company(ies) and staff (including adequacy of proposed facilities)
2. Understanding of the requirements and objectives, discussion of problem and risk areas and appropriate mitigation actions
3. Quality and suitability of proposed programme of work; adequacy of engineering approach
4. Adequacy of Management, Costing and Planning for the execution of the work
5. Compliance with Administrative Tender Conditions and Acceptance of Contract Conditions
4 EarthCARE Procurement
Sub-contractor Selection Procedure

- The selection of all equipment suppliers is governed by the rules laid down in the EarthCARE Sub-contractor Selection Procedure:
  - Preparation of the ITT/RfQs by the issuing companies under the authority of the Prime and supervision of the Agency.
  - Evaluation of offers are performed by Joint Tender Evaluation Boards comprising personnel of the Issuing Company, the Prime and the Agency.
  - The Joint Procurement Board (JPB) comprising the project management from the Agency, the Prime and the Issuing Company makes a recommendation for the final decision.
  - In case of different position the final decision will be taken by the Senior Procurement Board (SPB) comprising the senior management of the Agency and the Prime.
4 EarthCARE Procurement Sub-contractor Selection Procedure

- Enhancement of the role of ESA in case of bids from Issuing Company
  - if the issuing company or affiliated bids, fairness implies that this company cannot be involved in the evaluation process.
  - However, their inputs to the meeting are necessary since the issuing company will take over the activity. They are Observers and not members in the TEB meeting.
  - The evaluation is performed by the next contractual level up or ESA if the Prime company bids
  - The composition of the TEB participants is adjusted at Tender Opening Board.
4 EarthCARE Procurement

Commonality

- Commonality is the intentional common procurement approach between Sentinel 2 and EarthCARE derived from:
  - same performance / design requirement
  - same or modular equipment design
  - Statement of Work adapted to EC programmatic
  - ESA Best Practice Process performed by Sentinel 2

- Candidates / equipments for the common procurement approach were identified by Sentinel-2 and EarthCARE projects

- ESA will support commonality in GMES programmes & EarthCARE, where appropriate

- For commonality items, Sentinel 2 ITT’s will call in their options a binding proposal for additional procurement by other ESA programmes (Sentinels / EarthCARE)
4 EarthCARE Procurement
Points of Contact

- Astrium GmbH
  EarthCARE Project AED65
  Earth Observation & Science
  D-88039 Friedrichshafen
  Germany

- EarthCARE Project Manager
  Uwe Slansky
  Tel.: +49 7545 8 4073
  e-mail: Uwe.Slansky@astrium.eads.net

- EarthCARE Industrial Development
  Wolfgang Rühe
  Tel.: +49 7545 8 3058
  e-mail: Wolfgang.Ruehe@astrium.eads.net

- EarthCARE System Eng. Manager
  Michael Gotsmann
  Tel.: +49 7545 8 9348
  e-mail: Michael.Gotsmann@astrium.eads.net
5 Spacecraft Sub-systems

- Structure is a central cylinder based CFRP box, with an upper CFRP strut space-frame supporting the CPR instrument interfaces on an upper floor. Internal CFRP struts support instrument optical bench interfaces.

- Central cylinder provides interface to Launch Vehicle Adaptor and accommodates single propellant tank

- Two sets of equipment panels are required:
  - one set delivered for SM test campaign
  - one set for early delivery for S/C flatsat integration campaign
5 Spacecraft Sub-systems
Structure

- Structure is supplied for SM programme, refurbished for flight and tested in PFM satellite programme

- Structure mass < 270 kg
5 Spacecraft Sub-systems

Thermal Sub-system

- **External MLI**
  - Fitted to all external structure
    - Except for areas dedicated to radiators
  - Beta-cloth as outermost layer to protect against ATOX
    - Except ATLID cavity
      (ITO coated Kapton)
  - High temperature blankets around thrusters with Titanium foil outer layer to protect against thruster plume impingement

- **Internal MLI**
  - Fitted to batteries & RCS
  - Mylar blanket with VDA outermost layer
### Essential requirements derived from system and payload performance

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>PERFORMANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>attitude knowledge on-board</td>
<td>&lt; 90 µrad (rms) bias</td>
</tr>
<tr>
<td></td>
<td>&lt; 5 µrad (rms) harmonic error</td>
</tr>
<tr>
<td></td>
<td>&lt; 40 µrad (rms) random error</td>
</tr>
<tr>
<td>position knowledge on-board, 3-D</td>
<td>&lt; 20 m (rms)</td>
</tr>
<tr>
<td>velocity knowledge on board, 3-D</td>
<td>&lt; 0.03 m/s (rms)</td>
</tr>
<tr>
<td>absolute pointing error</td>
<td>&lt; 150 µrad (rms) bias (roll,pitch,yaw)</td>
</tr>
<tr>
<td></td>
<td>&lt; 150 µrad (rms) harmonic error (roll,pitch,yaw)</td>
</tr>
<tr>
<td></td>
<td>&lt; 150 µrad (rms) random error (roll,pitch,yaw)</td>
</tr>
<tr>
<td></td>
<td>Pitch (harmonic+random): &lt; 500 µrad (3-σ)</td>
</tr>
<tr>
<td>relative pointing error</td>
<td>&lt; 50 µrad/s (3-σ) per axis</td>
</tr>
</tbody>
</table>
5 Spacecraft Sub-systems
Attitude & Orbit Control System (AOCS)

Sub-modes of AOC-ASM:
- RD: Rate Damping
- EA: Earth Acquisition
- YA: Yaw Acquisition
- DEP: Deployment

Sub-modes of AOC-NOM:
- AH: Attitude Hold
- FP: Fine Pointing
- AM: Attitude Manoeuvre (for CPR Calibration)

Sub-modes of AOC-OCM:
- SL: Slew
- STAB: Stabilized
- DV: Delta-V
- BSL: Back-Slew

3-axis stabilized Spacecraft
### 5 Spacecraft Sub-systems

#### Attitude & Orbit Control System (AOCS)

**Sensors:**
- **CESS**: Coarse Earth and Sun Sensor
- **MAG**: Magnetometer
- **RMU**: Rate Measurement Unit
- **AAD**: Attitude Anomaly Detector
- **STR**: Star tracker
- **GPS**: GPS Receiver Assembly

**Actuators:**
- **RCS**: Reaction Control System
- **MTQ**: Magnetic Torquer
- **RW**: Reaction Wheels

**Other, non-AOCS Eqmt:**
- **OBC**: On-board Computer
- **RIU**: Remote Interface Unit

---

**AOCS-Mode**

<table>
<thead>
<tr>
<th>AOCS-Mode</th>
<th>CESS</th>
<th>AAD</th>
<th>RMU</th>
<th>MAG</th>
<th>STR</th>
<th>GPS</th>
<th>RW</th>
<th>MTQ</th>
<th>RCS</th>
</tr>
</thead>
<tbody>
<tr>
<td>SBM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ASM</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>NOM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>OCM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

---

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5 Spacecraft Sub-systems
AOCS - Sensors

- Fully redundant GPS assembly with 2 antennas, 2 receivers, LNCs(tbc) and interconnecting harness (GPS)

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>PERFORMANCE</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>position accuracy each axis</td>
<td>&lt; 20 m (rms)</td>
<td></td>
</tr>
<tr>
<td>velocity accuracy each axis</td>
<td>&lt; 0.03 m/s (rms)</td>
<td></td>
</tr>
<tr>
<td>timing (PPS) accuracy, PPS @ 1 Hz</td>
<td>&lt; 0.5 μs (1-σ)</td>
<td></td>
</tr>
<tr>
<td>Time to first fix</td>
<td>&lt; 20 min</td>
<td></td>
</tr>
<tr>
<td>Time to first fix after data outage due to insufficient number of GPS S/C</td>
<td>&lt; 10 min</td>
<td></td>
</tr>
<tr>
<td>Full performance with angular rates of</td>
<td>&lt; 0.7 deg/s</td>
<td></td>
</tr>
<tr>
<td>Interface</td>
<td>MIL-1553 B</td>
<td></td>
</tr>
</tbody>
</table>
5 Spacecraft Sub-systems
AOCS - Sensors

- Star tracker assembly with 2 optical heads (STR)

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>PERFORMANCE</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>attitude accuracy perpendicular to LOS, random</td>
<td>&lt; 7 μrad (1 sigma), 10 Hz</td>
<td></td>
</tr>
<tr>
<td>attitude accuracy around LOS, random</td>
<td>&lt; 42 μrad (1 sigma), 10 Hz</td>
<td></td>
</tr>
<tr>
<td>Update rate</td>
<td>1 Hz – 10 Hz</td>
<td></td>
</tr>
<tr>
<td>Sun/Earth exclusion angle</td>
<td>&lt; 26 deg / 20 deg halfcone</td>
<td></td>
</tr>
<tr>
<td>Moon exclusion angle</td>
<td>Full performance with moon in FOV</td>
<td>APS technology</td>
</tr>
<tr>
<td>Initial acquisition from lost in space</td>
<td>&lt; 5 s</td>
<td></td>
</tr>
<tr>
<td>Slew rate with full performance</td>
<td>Up to 0.1 deg/s</td>
<td></td>
</tr>
<tr>
<td>Slew rate with degraded performance</td>
<td>Up to 1 deg/s</td>
<td></td>
</tr>
<tr>
<td>Time stamp accuracy</td>
<td>&lt; 0.1 ms</td>
<td></td>
</tr>
<tr>
<td>Detector type</td>
<td>APS CMOS detector</td>
<td></td>
</tr>
<tr>
<td>Interface</td>
<td>MIL-1553 B</td>
<td></td>
</tr>
</tbody>
</table>
5 Spacecraft Sub-systems
AOCS - Sensors

- Two 3-axis rate measurement units (RMU)

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>PERFORMANCE</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angular random walk, EOL</td>
<td>$&lt; 0.24$ deg$/\sqrt{h}$ (3 sigma)</td>
<td></td>
</tr>
<tr>
<td>Noise equivalent rate</td>
<td>$&lt; 1$ deg$/h$ (3 sigma)</td>
<td></td>
</tr>
<tr>
<td>Scale factor</td>
<td>$5000$ ppm (3 sigma)</td>
<td></td>
</tr>
<tr>
<td>Angular rate bias</td>
<td>$&lt; 10$ deg$/h$</td>
<td></td>
</tr>
<tr>
<td>Rate measurement bandwidth</td>
<td>$10$ Hz</td>
<td></td>
</tr>
<tr>
<td>Measurement output rate</td>
<td>Up to $10$ Hz</td>
<td></td>
</tr>
<tr>
<td>Measurement range</td>
<td>Up to $\pm 10$ deg$/s$</td>
<td></td>
</tr>
<tr>
<td>mass</td>
<td>$&lt; 1.1$ kg</td>
<td></td>
</tr>
<tr>
<td>Interface</td>
<td>UART</td>
<td></td>
</tr>
</tbody>
</table>
5 Spacecraft Sub-systems
AOCS - Sensors

- Two 3-axis magnetometer units (MAG)

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>PERFORMANCE</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measurement range</td>
<td>± 75000 nT</td>
<td></td>
</tr>
<tr>
<td>Measurement accuracy</td>
<td>&lt; 0.5 % of full scale</td>
<td></td>
</tr>
<tr>
<td>Residual Bias and Linearity Error</td>
<td>&lt; 750 nT</td>
<td></td>
</tr>
<tr>
<td>Noise at 1 Hz</td>
<td>&lt; 10 nT rms</td>
<td></td>
</tr>
<tr>
<td>Minimum measurement bandwidth</td>
<td>&gt; -3dB at 20 Hz</td>
<td></td>
</tr>
<tr>
<td>Update rate</td>
<td>2 Hz</td>
<td></td>
</tr>
<tr>
<td>Input axis stability wrt mechanical frame</td>
<td>&lt; 0.1 deg</td>
<td></td>
</tr>
<tr>
<td>mass</td>
<td>&lt; 0.3 kg</td>
<td></td>
</tr>
<tr>
<td>Interface</td>
<td>Discrete voltage or RS 422</td>
<td></td>
</tr>
</tbody>
</table>
5 Spacecraft Sub-systems
AOCS - Sensors

- Three attitude anomaly detectors (AAD)

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>PERFORMANCE</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sun detection range</td>
<td>17 deg half cone (tbc) around ATLID line-of-sight direction (nadir tilted by 3 deg backward)</td>
<td></td>
</tr>
<tr>
<td>mass</td>
<td>&lt; 0.2 kg</td>
<td></td>
</tr>
<tr>
<td>Interface</td>
<td>Analogue sensor current</td>
<td></td>
</tr>
</tbody>
</table>
### 5 Spacecraft Sub-systems

**AOCS - Actuators**

- **Reaction wheel assembly with 4 units in pyramidal arrangement**

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>PERFORMANCE</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angular momentum within operational speed range</td>
<td>20 Nms</td>
<td></td>
</tr>
<tr>
<td>Reaction torque up to operational speed limit</td>
<td>≥ 0.21 Nm</td>
<td></td>
</tr>
<tr>
<td>Operational speed range</td>
<td>± 6000 rpm (tbc)</td>
<td></td>
</tr>
<tr>
<td>Static imbalance</td>
<td>&lt; 0.7 * 10⁻⁵ kgm</td>
<td></td>
</tr>
<tr>
<td>Dynamic imbalance</td>
<td>&lt; 8 * 10⁻⁷ kgm²</td>
<td></td>
</tr>
<tr>
<td>Mass (including associated drive electronic)</td>
<td>&lt; 4x8.6 kg</td>
<td></td>
</tr>
<tr>
<td>Interface</td>
<td>Discrete signal lines or MIL-1553 Bus</td>
<td></td>
</tr>
</tbody>
</table>
5 Spacecraft Sub-systems
AOCS - Actuators

- Three magnetic torquers with redundant coils

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>PERFORMANCE</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear dipole moment</td>
<td>± 140 Am^2</td>
<td></td>
</tr>
<tr>
<td>Maximum remanent dipole moment</td>
<td>&lt; 0.6 Am^2</td>
<td></td>
</tr>
<tr>
<td>Linearity factor</td>
<td>1 %</td>
<td></td>
</tr>
<tr>
<td>Mass</td>
<td>&lt; 6 kg</td>
<td></td>
</tr>
<tr>
<td>Input voltage</td>
<td>± 10 V</td>
<td></td>
</tr>
</tbody>
</table>
Semi Regulated Architecture @ SRR:
- propellant load capability 255 kg
- Growth margin up to ~ 275 kg
- Meet the RCS performance requirements (Isp, Thrust) with margin
- Widen propellant tank selection within following constraints:
  - ~255 kg propellant requirement
  - Tank accommodation within central cylinder
  - Equatorial mounting
- Thrusters provide 1N thrust at 22 bar BOL inlet pressure and ≥ 0.3N at 5.5 bar EOL thruster inlet pressure. Thrusters should operate on demand both in continuous and pulse mode operation.
5 Spacecraft Sub-systems
Core Data Handling System - OBC

- **On-board Computer (OBC)**
  - Processing Module (using ERC 32)
    - 2 separate MIL-STD-1553 B bus (P/L & P/F)
    - 2 separate SpaceWire links to RIU or MMFU
  - On-board time (OBT) generation, synchronisation, distribution and services of the OBT
  - TC reception function & Decoder:
    - 64 kbps uplink rate
    - Command Pulse Distribution Unit (CPDU)
  - TM Encoder & transmission function
    - 128 kbps downlink data rate, R-S, SP-L
    - 2048 kbps downlink data rate, OQPSK (R-S & Convolutional encoded)
  - Mass Memory Unit (MMU): 6 GBit EoL
  - Safeguard Memory (SGM):
    - 512 KBytes SRAM, 128 KBytes EEPROM
  - Reconfiguration Unit (RU) incl. external alarm inputs
  - Mass < 11.5 kg
Remote Interface Unit (RIU) Block Diagram

- the RIU provides the TM/TC interfaces to all platform equipment (except Milbus and High Priority TM/TC)
- OBC controls RIU via a redundant SpaceWire link or MIL-Bus 1553
- RIU converters and controllers operate in cold redundancy
- RIU I/O interfaces operate in hot redundancy (except Solar Array Drive Electronic, MTQ and thrusters)
- Mass < 17.3 kg
5 Spacecraft Sub-systems
Electrical Power System (EPS)

- Bus concept:
  - 28 V non-regulated power bus, voltage range: 24 V to 34 V (for NEL)
  - Lowest battery voltage > 20 V
  - Essential units specified for 20 to 34 V

- Battery:
  - Inside mounted Li-Ion battery
  - 216 Ah BOL
  - 8 cells in series
  - Battery split in two identical modules
  - Mass 2 x < 36 kg
  - Battery size driven by LEOP case (5 orbits with battery power only)
5 Spacecraft Sub-systems

Electrical Power System (EPS)

- **Solar Array:** Mass < 96 kg
  - One deployable & steerable wing
  - 5 equally sized panels 19.25 m² (18.5 m² unshaded area)
  - 21 x 235 cells BOL (TBC) based on European standard cell AZUR 3G-ID2* / 150-8040
    - 5200 W (@ 78°C, AM0, BOL)
  - SA size driven by nominal mode

- **SADM:** Mass < 5 kg
  - Power- & signal transfer via twist-capsule, no slip rings
  - Nominal rotation range: +/- 72.5°
5 Spacecraft Sub-systems
Electrical Power System (EPS)

Power Control and Distribution Unit (PCDU)
- S/A regulation by buck-type MPPT (2/3 redundant)
- Main bus EOCV control (2/3 redundant)
- Bus voltage filter (capacitor)
- Battery isolation switch (for on-ground use only)
- Umbilical I/F
- Power distribution:
  - 62 LCLs
  - 10 FCLs (OBC, RIU, S-Band Rx)
  - 144 TSW
  - 24 Release Initiators I/Fs of NSI- / NEA-type
- TM/TC via redundant MIL-bus to OBC
- Programmable EOCV and DNEL levels
- Mass < 30 kg
5 Spacecraft Sub-systems
Payload Data Handling and Transmission System - MMFU

- Mass Memory and Formatting Unit (MMFU)
  - The MMFU stores CCSDS source packets
    - Instrument data
    - HK data and ancillary data from the platform
  - The MMFU formats the data, and sends it to the X-band
  - MMFU inputs, outputs, converters, controllers and part of the memory array operate in cold redundancy
  - MMFU storage area can be accessed by the nom. and red. MMFU chain
  - The nominal and redundant input channels are internally cross-coupled to the nominal and redundant instrument data interface controllers
  - The EoL capacity of the MMFU is at least 740 Gbits.
  - Mass < 15,6 kg
5 Spacecraft Sub-systems
Payload Data Handling and Transmission System - XBS

- X-Band System (XBS)
  - X-Band Transmitter
    - Two cold redundant channels with 150 Mbps Input data rate each
    - 2 OQPSK Modulators
      - Each receiving
        - 8 NRZ-L coded data lines and
        - 1 common clock
    - 2 Solid State Power Amplifiers
    - 1 Wave Guide Switch
    - 1 Band and Low Pass Filter
    - Mass < 7,1 kg
  - X-Band Antenna
    - Antenna elevation angle +/- 70°
    - Polarization RHCP
    - Mass < 0,4 kg
5 Spacecraft Sub-systems
Tracking, Telemetry and Command System (TT&C)

- **S-Band Transponder**
  - Two transponders
    - Each Transmitter cold redundant,
    - Each Receiver hot redundant,
  - One 3dB Coupler
  - Each transponder offers
    - Coherent / Non Coherent
    - Ranging ON/OFF
  - Uplink Data Rate and Modulation:
    - 64kbps SP-L/PM, on carrier
  - Downlink Data Rates and Modulation:
    - 128 kbps SP-L/PM
    - 2048kbps OQPSK
      (R-S & Convolutional encoded)
  - Mass < 6.6 kg

- **S-Band Low Gain Antennas**
  - Antenna elevation angle +/- 95°
  - Polarization: Nadir RHCP, Zenith LHCP
  - Mass < 0.2 kg
5 Spacecraft Sub-systems

Harness

- **Main requirements**
  - Electrical interconnection between platform equipments and instruments via panel connector brackets
  - Includes thermal harness
  - PFM Harness Mass < 130 kg (incl. connectors)

- **Main experience**
  - Qualified space processes (continuity, crimping…)

- **The Harness consist of:**
  - **EFM Test Harness**
    Harness for S/C Engineering Functional Model
  - **Flatsat Interpanel Harness**
    Test Harness for FM Test Bed (flatsat configuration)
  - **PFM Harness**
    Consist of flight panel harnesses and inter panel harness
  - **Panel Extension Harness**
    Test harness to operate the satellite while the equipment panels are dismounted
6 Instruments

Atmospheric Lidar (ATLID) – Measurement Objective

**Needs**
- Convective updraft and ice fall speed
- Vertical profiles of liquid, supercooled and ice water, cloud overlap, particle size and extinction
- Cloud top and base height
- Quantitative precipitation measurements
- Ice water content
- Vertical profiles of extinction and characteristics of aerosols
- Cloud top height
- Occurrence of layer of supercooled 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
6 Instruments

ATLID – Measurement Principle

- Atmospheric Lidar in UV range
- Measure of vertical profiles of optically thin clouds and aerosols layers
- Principle:
  - 1) Emission of short laser pulses towards the atmosphere at a high repetition rate
    - several samples along the track
  - 2) Collecting and spectral filtering of the (weak) backscattered signal
  - 3) Acquisition of signal versus arrival time
    - several slices through the atmosphere
  - 4) Processing of the signal: Products level 1B
- Products
  - molecular backscatter (Rayleigh)
  - Clouds and aerosols particles return (Mie)
  - Co and cross polarised components of signal backscattered by clouds
**6 Instruments**  
**ATLID - Satellite Configuration**

**ATLID (Atmospheric Lidar)**
- Mounted on S/C Floor 2
- Accommodated within CPR support structure
- Pointing stability to CPR 30-60arcsecs
- Radiator shading by CPR & support structure

**Mass properties:**
- Allocated Mass < 380 kg

**AIV:**
- Integration via access panel
6 Instruments

**ATLID – Instrument Concept / Architecture**

- **Transmitter**
  - power laser head
  - transmitter laser electronics
  - reference laser seeding the laser oscillator

- **Telescope**
  - A focal Cassegrain: Collect of the back-scattered light & Emission of the laser beam

- **Receiver**
  - emit / receive diplexer and focal plane optics including High Spectral Resolution filter.
  - detection functions from the detector to the analog-to-digital convertor

- **Control and data management unit**
  - synchronisation between laser emission and data acquisition
  - data processing and data stretching toward the S/C ;
  - mechanism drive and thermal regulation functions
  - TM/TC and commandability / observability management.
6 Instruments

ATLID – Instrument Concept / Architecture

- A self-standing instrument, supporting its electronics and radiators

Self standing: radiators and MLI blankets supported by secondary structures

Stability: laser + optics in one assembly

Detectors: linked by fibre to the optical bench

Single mechanical interface to the platform
6 Instruments
ATLID – Instrument Concept / Architecture

- Telescope
  - SiC technology
  - Primary Mirror (Ø 600mm)
  - Secondary Mirror

- Cooling System
  - Heat Pipes

- Thermal Hardware & MLI

- ATLID Control and Data Management Unit (ACDM)
  - Control of ATLID Operations
  - TM/TC Interface to EarthCARE

- High Spectral Resolution Etalon (HSRE)
  - Spectral Discriminator for Detection

- Laser Chopper Assembly (LCA)
  - Chopper in Receiving Optics

- Flip Flop Mechanism (FFM)
  - Switch between nom. & red. Laser Transmitter

- Fiber Coupler Assembly (FCA)
  - Coupling of optical detection channels to detectors

- Mechanical Elements
  - Isostatic Mounts
  - Fixations
  - Covers

- ATLID Structure
  - Incl. CFRP

- Transmitter
  - Pulsed Laser System

- Emit and Receive Optics (ERO)
- Detector Assemblies
- Instrument Detection Electronics (IDE)
- Harness
- EGSE
6 Instruments

Multi Spectral Imager (MSI) – Measurement Objective

Needs

- Convective updraft and ice fall speed
- Vertical profiles of liquid, supercooled and ice water, cloud overlap, parcel size and extinction
- Cloud top and base height
- Quantitative precipitation 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
- Icewater 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
6 Instruments
MSI – Measurement Principle

- MSI is a Pushbroom Imager
  - Provides a continuous strip image
  - MSI is always nadir viewing
  - Nominal ground pixel period is 70 ms
6 Instruments
MSI – Satellite Configuration

MSI (Multi Spectral Imager)

- Allowable launcher envelope for MSI-OU
- Free FoV in -X/+Z (Nadir) direction
- In-Orbit pointing stability w.r.t. STRs 45-60 arcsecs

- MSI Mass Properties:
  - Mass < 53.5kg (Optical Head and ICU)

- AIV:
  - On-ground Alignment w.r.t. ATLID
  - Moderate accuracy < 2 arcmin
6 Instruments
MSI – Instrument Concept / Architecture

- MSI consists of two main units
  - Optical Bench Module (OBM)
  - Instrument Control Unit (ICU)

- OBM
  - 2 Nadir viewing cameras
    - VNS Optical Unit (Visible / Near-IR / 2 Shortwave IR)
    - TIR Optical Unit 3 Thermal Infrared (TIR)
  - Front End Electronic (FEE)
    - Signal conditioning
    - Data pre-processing

- ICU
  - Control and monitoring of the MSI
  - Data processing toward the S/C ;
  - Mechanism drive and thermal regulation functions
  - TM/TC and commandability / observability management.
6 Instruments
MSI – Instrument Concept / Architecture

MSI OBM shown in plan view (left), rear view (right).
6 Instruments

**Broad Band Radiometer (BBR) – Measurement Objective**

- **Needs**
  - Convective updraft and ice fall speed
  - Vertical profiles of liquid, supercooled and ice water, cloud overlap, partial size and extinction
  - Cloud top and base height
  - Quantitative precipitation 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

---

All the space you need
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EarthCARE Industrial Day - EC.HO.ASD.SY.00003
6 Instruments
BBR – Measurement Principle

By rapidly viewing the same area of ground from three views, a radiance-to-flux conversion algorithm can be established, and the total Top Of Atmosphere flux determined. This can then in turn be used as verification of atmospheric models of the Earth's radiation budget using input data from the remaining EarthCARE instruments.

The BBR observes the Earth’s radiance at three observation zenith angles OZA

- Nadir: a downward facing view (OZA 0°).
- Fore: a forward looking view, that views the ground at an angle of 55 degrees (OZA +55°). This is the ground that will be viewed by the nadir view a short time later.
- Aft: a backward looking view, that views the ground at an angle of 55 degrees (OZA -55°). This is the ground that was previously viewed by the Fore and Nadir views.

and in two bands

- Short Wave (SW): 0.2 - 4.0 μm. This band is dominated by reflected sunlight.
- Long Wave (LW): 4 - 50 μm. This band is dominated by the thermal emissions from the Earth.
6 Instruments
BBR – Satellite Configuration

BBR (Broad Band Radiometer)

- Allowable launcher envelope for BBR-OU
- Free FoV in +/-X/+Z (Nadir) direction
- In-Orbit Pointing stability w.r.t. STRs 30arcsecs

Mass properties:

- Allocated Mass < 35.2kg (Optical head and ICU)

AIV:

- On-ground Alignment w.r.t. ATLID
- Moderate accuracy < 2 arcmin
6 Instruments

BBR – Instrument Concept / Architecture

- **Radiometric Detection Concept**
  - thermal detector with black coated absorbing layer, to give very broad-band response (~0.2 μm to 50 μm), and sensing temperature of the absorbing layer by resistive change.
  - linear array detector in push-broom format, to build-up the 10km footprint from images at ground sampling distance (GSD) of approximately 5/6km along track

- **Architecture**
  - Telescope Assembly (TA)
    - 3 Telescopes
    - 2 channels (alternate)
  - Mechanism Assembly (MA)
    - Chopper Drive Mechanism (CDM)
    - Calibration Target Mechanism (CTM)
  - Instrument Control Unit (ICU)
    - Instrument control and monitoring
    - TM/TC interface via MILBus
    - Packet Utilisation Standard for TM/TC
6 Instruments
CPR – Measurement Principle

- **Principle**
  - high power millimetre-wave radar
  - operating frequency 94.05 GHz.
  - The radar waves penetrate deep into lower cloud layers, not visible for optical instruments.
  - measurement of cloud return echoes and radar signal doppler shift, also from cloud layers not visible for optical instruments
  - measurement range between ground and 20 km altitude
  - vertical resolution of 400 m

- **Products**
  - cloud boundaries (top and base), even of multi-layer clouds
  - vertical profiles of liquid & ice water contents and ice particle size
  - detection of precipitation
  - convective motions in clouds

---

3.3 μs pulse @ 94 GHz
PRF: 6…7.4 kHz

100 m vertical sampling interval

20 km max. altitude

< 0 km min. altitude

400 m vertical resolution

500 m ground sampling distance

foot print < 1 km

10 km integration distance
6 Instruments

CPR – Instrument Concept / Architecture

- **Antenna**
  - deployable offset Cassegrain antenna
  - main reflector diameter 2.5 m

- **Frontend**
  - quasi-optical diplexer
  - mechanisms for redundancy switching

- **Transmitter**
  - short pulse (3.3 µs) high power transmitter
  - extended interaction klystron (EIK)
  - high voltage power convertor (EPC)

- **Receiver**
  - superhet receiver with I/Q detector
  - measurement of return signal power and doppler frequency

- **Control and data management unit**
  - instrument control and surveillance
  - autonomous adaptation of pulse repetition frequency
  - science data processing
  - TM/TC interface
6 Instruments
CPR – Instrument Concept / Architecture

- CPR Characteristics and Performance
  - Antenna aperture: 2.5 m
  - Operating frequency 94.05 GHz
  - Peak transmit power 1.8 kW
  - Transmit pulse width 3.3 µs
  - Dynamic range -36 dBZ to +20 dBZ
  - Doppler range ±10 m/s
  - Velocity accuracy < 2 m/s
EarthCARE is a cooperative mission between ESA and JAXA, where JAXA will provide the Cloud Profiling Radar (CPR).

The CPR will be developed / procured according to JAXA rules, terms and conditions not to ESA Best Practice.

The CPR is a Customer Furnished Item for Astrium GmbH.
7 Ground Support Equipments
AIT - Test Facilities

- special test facilities for S/C level tests required for satellite environmental tests (TB/TV, sine vibration, acoustic noise & radiated EMC tests) and mass property measurements

- Selection of test facility for environment tests is driven by …
  - …satellite attitude and accommodation requirements in TV chamber
    - X axis vertical driven by operation of ATLID and CPR internal heat-pipes
    - CPR antenna deployed (full angle is tbc, pending on CPR test configuration and CPR heat rejection needs)
  - … CPR operation at 94 GHz during radiated EMC test in anechoic chamber
Satellite GSE needs are derived from satellite AIT programme and functional verification approach on test benches.

System MGSE is defined to support satellite transport, lifting, handling, integration, and test and launch operation activities.

MGSE is a combination of reuse of existing MGSE from former ESA programmes + new procurement.

OGSE and FGSE: reuse of existing standard equipment.
System EGSE for functional verification testing on test benches and to support integration, test and verification of the S/C on ground and interface verification with ground segment (figure below shows EGSE building blocks)
PISA is used for early verification of instrument interfaces to the platform during instrument test programme.

PISA FE Controller provides electrically & functionally the S/C interfaces to the instrument + real time S/W e.g. for handling MIL Bus & communication.

PISA MMI provides basic monitoring and control for the PISA FE Controller and communication with instrument CCB and DAPB via CCSDS protocol & Science Data LAN.
Objectives

- Validation and Verification of the instrument performance (ESSS), provided by the instrument supplier, and L1 processing (ECGP)
- Overall mission performance assessment (within the ECSIM)
- Basis for the Satellite In-Orbit Verification Tool (SIOVT)
9 Procurement Status

- The following tables identify the present EarthCARE procurement items sorted by issuing company.

- In the process of design consolidation, additional procurement elements may be identified or existing items further sub-divided.
# 9 Procurement Status

<table>
<thead>
<tr>
<th>Procurement Item</th>
<th>Procurement Method</th>
<th>Procurement Resp.</th>
<th>Supplier / Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATmospheric LiDaR [ATLID]</td>
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<td>ASD</td>
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<td>SIC Parts</td>
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<td>OC</td>
<td>ASF</td>
<td>ITT to be prepared</td>
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<td>Isostatic Mounts, Fixation &amp; Covers</td>
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<td>Transmitter S/S (TxA)</td>
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<td>Harness</td>
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<td>Altid EGSE</td>
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<td>Detector</td>
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