TECHNIQUES AND PROCESSES FOR PRE-LAUNCH CHARACTERISATION OF NEW INSTRUMENTS

Dieter Klaes
EUMETSAT
OUTLINE

1. Introduction
2. Identification of requirements
3. Development activities
4. Operations preparation and testing
5. Commissioning activities
6. Summary and Conclusion
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**Current EUMETSAT satellites**

**METOP-A (98.7° incl.)**
EUMETSAT POLAR SYSTEM
Kept in its nominal mid-morning sun synchronous orbit at 817km altitude as part of the EUMETSAT Polar System (EPS)

**JASON-2 (66° incl.)**
OCEAN SURFACE TOPOGRAPHY
Kept in its nominal non-synchronous low Earth orbit at 1,336km altitude, in support of the Ocean Surface Topography Mission.

**METOP-B (98.7° incl.)**
EUMETSAT POLAR SYSTEM
Successfully launched into low Earth orbit on 17 September. Commissioning activities ongoing at the end of 2012.

**METEOSAT-7 (57.5° EAST)**
INDIAN OCEAN DATA COVERAGE
Operated in support of the Indian Ocean Data Coverage (IODC) mission, bridging an observational gap in this region

**METEOSAT-10 (3.4° W-0°)**
METEOSAT FULL DISC IMAGERY
Declared operational on 18 December, delivering full disc imagery on its way to 0° longitude.

**METEOSAT-9 (0°)**
METEOSAT FULL DISC IMAGERY
Positioned at 0° in support of the prime Meteosat full disc imagery service over the European continent, Africa and parts of the Atlantic and Indian oceans.

**METEOSAT-8 (9.5° EAST)**
RAPID SCANNING SERVICE (RSS)
Positioned at 9.5° East delivering the Rapid Scanning Service (RSS) over Europe and adjacent seas.
Benefit areas of weather forecasting

Safety of life, property and infrastructure...

Transport ...

...Energy, agriculture, tourism....

...Climate policy and environment protection
From observation to decision making: EUMETSAT’s role in the value adding chain
How we deliver programmes

- Interface with users and definition of user and system level requirements
- Overall system design and development
- Procurement of ground segment & launch services
- Operation of full satellite systems & ground infrastructure
- Delivery of data, products and support services to users
ESA-EUMETSAT cooperation model

- **EUMETSAT council**
  - Customer authority

- **Operational service provider**

- **Users**
  - Management of interactions with users

- **System operations, maintenance & upgrades**
  - Delivery of agreed products and services

- **Procurement of rec. Spacecraft**
  - Support to launch campaign

- **Manufacturing and support**

- **Customer**
- **EUMETSAT**
- **ESA**
- **Industry**
This is a long process

• Project phases
  • In a space project there are several phases which proceed the project towards operational implementation
  • Phase 0 – Mission Analysis/Needs Identification
  • Phase A – Feasibility
  • Phase B – Preliminary Definition
  • Phase C – Detailed Definition
  • Phase D – Production/Ground Qualification Testing
  • Phase E – Utilisation
  • Phase F – Disposal
• ECSS Standard (European Cooperation for Space Standards)
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Identification of Requirements: Long term aspect

• Long term preparation: Think of new programmes before the actual one has been launched its satellites
• That means: need to know
  • Applications in the future
  • Possible Improvements
  • Extended and New Applications
  • Possible Technological Developments
  • Limits
Identification of Requirements: Unknown Terrain

• Projection of the future
• Adaptation of observations to the applications e.g.
  • Model grid size
  • New parameters
  • Timeliness
  • Performances to get an improvement
  • Knowledge of available requirements
• What is possible?
Identification of Requirements

• What are the applications?
• Who are the Users? Are there Users?
• What parameters will be needed?
• What are the observation requirements?
• Which missions can satisfy the requirements?
• Where are gaps?
• Which other developments are there?
Assess available information

Find and Assess Sources of Information

• Heritage
• WMO data bases
  • RRR
  • OSCAR
• CEOS
• Gap analysis for GCOS
• Others
User Consultation process

• Involve Users
• Involve Experts in the field
• Stakeholders
• Bring them together
  • Application Expert Groups – by themes
  • Users – from “Customers” related to applications
  • Experts for measurement systems
  • Other experts
Establish the requirements

• Mission requirements
• Observation Requirements
• User Requirements
• Proposal/Payload requirements
• -> Candidate missions
• -> Selected missions

• Illustrated at the example of EPS-SG
Step 1

Initial formulation of potential user requirements in terms of

- List of objective and threshold requirements,
  - Objective: Observation goal
  - Threshold: Minimum level for usefulness
- Accuracy
- Spatial sampling
- Temporal sampling
- Reporting delay
- Breakthrough level: Expected to make a delta improvement in the targeted service
- Priority

Basis for AEG discussion and subsequent user consultation
User Requirements Definition Steps (2/5)

**Step 2**

Initial assessment of suitable observation techniques

For each potential user requirement:

- Broad identification of observation techniques
- Identification of precursor instruments/missions
- Estimation of performance against threshold-objective range
User Requirements Definition Steps (3/5)

**Step 3**
Generation of Mission Requirements

- Grouping of user requirements in candidate missions
- Definition of data levels
  - (raw, calibrated, resampled at satellite radiances, level 2 data, ...)
- Derivation of observation requirements
  - (spatial, spectral resolution, radiometric accuracy, ...)
- Identification of non-observation requirements / user services

**Step 4**
Technical Requirements (ESA)

- Derivation of technical requirements for sensor/system studies
  - (e.g. MTF, spectral response, pointing accuracy, ...)
User Requirements Definition Steps (4/5)

1. Initial Formulation

User Consultation

2. Observation Techniques

Remote Sensing Experts Assessment

3. Mission Requirements

Requirements and Mission Analysis
Scientific/Technical Studies

Delegate Bodies Decisions

4. Technical Requirements

Sensor/System/Mission Analysis
Technical Studies
User Requirements Definition Steps (5/5)

from Phase 0 to Phase A

(mission definition) \rightarrow \textit{(feasibility)}

Requirements and Mission Analysis
Scientific/Technical Studies

Mission Requirements
End-User Requirements

Sensor/System/Mission Technical Studies

Technical Requirements
System Requirements

Programme Proposal (Phase B)
Initial Scope of Tentative Missions

Initial scope of tentative missions given by requirements based on

- EUMETSAT (MTG) User Consultation - NWC, NWP position papers
- WMO database of requirements
- GCOS
- IGOS Themes
  - Ocean
  - Atmospheric Chemistry
  - Carbon Cycle
  - Water Cycle
- GOOS
- GMES Themes
  - Ocean
  - Land
  - Atmospheric Chemistry
Application Experts Groups – Example EPS-SG

- Support of EUMETSAT user consultation towards EPS-SG

- Analysing the needs of EUMETSAT users in the 2020+ timeframe
  - Starting with MTG Position Papers
    - Global numerical weather prediction
    - Regional numerical weather prediction
    - Now-casting
  - Analysing the evolution of those applications
  - Taking account of further applications:
    - Operational oceanography
    - Atmospheric chemistry and carbon cycle (protocol monitoring and air quality)
    - Land surface analysis at large scale
    - Climate monitoring

- Formulation of EUMETSAT user needs: Position Papers
Requirements from NWP and Climate Monitoring

- **Numerical Weather Prediction:**
  - Most substantial improvement in global and regional NWP is expected from use of more detailed 3D observations of horizontal wind vector.
  - Wind vector measurements over Europe are currently obtained from radiosonde and aircraft ascent/descent.
  - Strong need to extend the observation network to oceans, tropics, and polar regions.
  - Dynamical aspects of the atmosphere will increasingly require observation of small-scale phenomena in wind fields.

- **Climate Monitoring:**
  - Assessment of eventual decadal to century scale changes.
  - Essential to determine causes of change (natural or anthropogenic).
Initial list of instruments identified (1/2)

- Atmospheric Sounding
  - Hyper-spectral infrared sounder
  - Microwave radiometer
  - Radio occultation sounding
  - Differential Absorption lidar

- Wind Profiling
  - Doppler wind lidar

- Cloud, precipitation, and land surface imaging
  - Optical high-resolution imager
  - Microwave imager
  - Cloud/precipitation radar
Initial list of instruments identified (1/2)

- Ocean imaging
  - Optical high-resolution imager
  - Microwave imager
  - Scatterometer

- Ocean topography
  - Altimeter

- Atmospheric chemistry
  - High-resolution infrared sounding
  - Nadir-viewing UV-SWIR spectrometer
  - Limb-viewing IR sounder
  - Limb-viewing mm-wave sounder
Identification of Missions

- Heritage instrument, mission continuity
- Mission continuity, but also improvements and new requirements, challenging technology
- Complementary mission contributions by partners
## EPS-SG payload complement and targeted applications

### EPS-SG Satellite-A missions

<table>
<thead>
<tr>
<th>EPS-SG Satellite-A missions</th>
<th>Instrument (and provider)</th>
<th>Predecessor on Metop</th>
<th>Applications benefitting</th>
</tr>
</thead>
<tbody>
<tr>
<td>INFRARED ATMOSPHERIC SOUNDING (IAS)</td>
<td>IASI-NG (CNES)</td>
<td>IASI (CNES)</td>
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<tr>
<td>MICROWAVE SOUNDING (MWS)</td>
<td>MWS (ESA)</td>
<td>AMSU-A (NOAA)</td>
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<td>VISIBLE-INFRARED IMAGING (VII)</td>
<td>METIMAGE (DLR)</td>
<td>AVHRR (NOAA)</td>
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<td>RADIO OCCULTATION (RO)</td>
<td>RO (ESA)</td>
<td>GRAS (ESA)</td>
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<tr>
<td>UV/VIS/NIR/SWIR SOUNDING (UVNS)</td>
<td>SENTINEL-5 (COPERNICUS, ESA)</td>
<td>GOME-2 (ESA)</td>
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<tr>
<td>MULTI-VIEWING, -CHANNEL, -POLARISATION IMAGING (3MI)</td>
<td>3MI (ESA)</td>
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</table>

### EPS-SG Satellite-B missions

<table>
<thead>
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<th>EPS-SG Satellite-B missions</th>
<th>Instrument (and provider)</th>
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</thead>
<tbody>
<tr>
<td>SCATTEROMETER (SCA)</td>
<td>SCA (ESA)</td>
<td>ASCAT (ESA)</td>
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<td>RADIO OCCULTATION (RO)</td>
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<td>GRAS (ESA)</td>
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<tr>
<td>MICROWAVE IMAGING FOR PRECIPITATION (MWI)</td>
<td>MWI (ESA)</td>
<td>-/-</td>
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<tr>
<td>ICE CLOUD IMAGER (ICI)</td>
<td>ICI (ESA)</td>
<td>-/-</td>
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<tr>
<td>ADVANCED DATA COLLECTION SYSTEM (ADCS)</td>
<td>ARGOS-4 (CNES)</td>
<td>A-DCS (CNES)</td>
<td></td>
</tr>
</tbody>
</table>

### Legend

- Atmospheric Chemistry
- Climate Monitoring
- Hydrology
- Land
- Nowcasting (NWC) at high latitudes
- Numerical Weather Prediction (NWP)
- Oceanography
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EPS-SG: Joint EUMETSAT-ESA planning

EPS-SG SYSTEM DEVELOPMENT (EUMETSAT)

EPS-SG SATELLITE DEVELOPMENT (ESA)

Operations

Phase C/D

Launch readiness SAT A
Launch readiness SAT B

Pre-Phase A  Phase A/B1  Phase B2/C/D  Phase E support

Phase 0  Phase A  Phase B


We are here
End User Requirements

- EURD (End User Requirements Document), owned by Council
  - Basis for the development
  - Derived: SRD (System requirements), GSRD (Ground Segment Requirements) etc.
- Specifications for processors
- Instrument development as part of satellite development (see co-operation model)
- Instruments provided from Partners
Development activities and milestones

- System approach
- Baseline documents, cooperation industry – partners – EUMETSAT
- SDP – System Development Plan
- Specially for processors
  - ATBD – Algorithm Theoretical Basis Document
  - PGS / PFS / ADS
    - Product Generation Specification
    - Product Format Specification
    - Auxiliary Data Specification
- Prototype Processors
Development activities and milestones

• Instrument Development
  • IRS – Instrument Requirements Specifications
  • PDS – Payload Data Simulator
  • GPP – Ground Processor Prototype

• Instrument and product TEST data
  • Testing the System
  • Testing the Throughput
  • Testing the Performance
Atmospheric Profiling
Microwave and IR Sounding - selected highlights

Example from the MWS PT: Preliminary MWS Sampling Properties Based on End-User Requirements

- 87 pixels per scan line
- 2.55 seconds scan duration
- 49.25° maximum scanning angle
- 2202 km swath width
Atmospheric Profiling
Microwave and IR Sounding - selected highlights
Atmospheric Profiling
Microwave and IR Sounding - selected highlights
Atmospheric Profiling
Microwave and IR Sounding - selected highlights

Status of MWS Test Data: Validation of Test Data from an External Study (Informus)

Surface/Water Vapour Channel
Atmospheric Profiling
Microwave and IR Sounding - selected highlights

Status of MWS Test Data: Validation of Test Data from an External Study (Informus)

229 GHz Channel for Thin Cirrus Cloud Detection
Development activities

• Industrial development supported by
  • Simulations (test data etc.)
  • SAG, MAG (Science-, Mission Advisory Groups)
  • ISSWG (IASI Sounding Science Working Group)
  • IFCT (Instrument Functional Chain Teams)
  • MIST (MTG IRS Science Team)
  • LIST (Lightning Imager Science Team)
  • Task forces
Development activities

• Instrument construction
• Interaction with programmes, SAG, experts
• Instrument characterisation and tests
• Documented in Calibration Handbook (Calibration Log book)
• Contains all activities and measurements of the instrument
Calibration Handbook

- Highlights from a Calibration Log book (example AMSU-A1)
  - PRT Sensor and Circuit Calibration for In-Flight Warm Calibration Targets and AMSU components
  - Error Analysis of In-Flight Warm Calibration Target brightness Temperatures
  - Error Analysis of Primary Blackbody Calibration Standard Target Brightness Temperature
  - Thermal Vacuum Measurement Error Budget
  - Non-linearity of the Channels
  - Antenna Position data
  - Antenna Alignment data
  - Antenna Patterns
  - In-flight Cold Calibration
    - Antenna Side Lobe Interference/Earth and Spacecraft Radiation Analysis
    - Cosmic Background Temperature Via Planck's Radiation law
    - Bias and Random Errors for the in-flight cold calibration
  - Thermal vacuum Radiometric Performance and Calibration
    - Calibration of In-flight Warm Calibration target
    - Radiometer Transfer Function (84K to 330K Thermal/vacuum Measurements)
    - Recommended In-flight Transfer Function (3K to 330K)
    - Calibration Algorithm Least Squares Linear Fit
    - Calibration Curves of Housekeeping Analog Voltages and Temperature Sensors
- Allowable Temperature Ranges
- Channel Frequency and Bandwidth Characteristics
- Radiometric Counts Limits
Instrument deliveries

- Instrument
- Documentation
- Calibration algorithms
- Calibration parameters
- Thermal vac data
- Laboratory characterisation
- External calibration
Example IASI Sounder radiometric noise

- L0 NEDT

IASI-B CAL/VAL (05/03/2013) - BBT = 292.5 K
IASI-B TV METOP (11/07/2010) - BBT = 294.3 K
IASI-B TV TAS (16/10/2006) - BBT = 293.5 K
IASI-A Routine (10/10/2010) - BBT = 292.6 K
Specification

- IASI-A and IASI-B noise level have the same order of magnitude. IASI-B slightly lower than IASI-A (except between 850 and 1150 cm\(^{-1}\))

- Good agreement between IASI-B noise measured on ground and in flight

Credit CNES: Jordi Chinaud et al., 2013
Example IASI
Sounder radiometric noise

- L0 NEDT (zoom B1)

Credit CNES: Jordi Chinaud et al., 2013
Instrument delivery

• End item data pack (EIDP)
  • Delivered with instrument
  • Contains all documents including
    • Characterisation data, e.g. Antenna patterns, antenna corrections
    • Calibration handbook
    • Thermal vac data from the satellite
    • Drawings
    • etc.
Lunar contamination is flagged for angles smaller than 4°
Metop MHS Antenna Correction

MHS Signal Simulation
Input: * Antenna pattern
* Geometrical model of emitting and reflecting bodies in the MHS views

![Diagram of Metop MHS Antenna](image.png)
Metop-A MHS Antenna Correction

MHS Signal Simulation
Output: * Antenna correction

**Antenna Efficiency vs Earth pixel**

![Graph showing antenna efficiency vs Earth pixel.](image)

**Space View Corrections**

![Bar graph showing space view corrections.](image)

In-Orbit Verification Results

![Graphs showing in-orbit verification results.](image)

Bonsignori, 2006, 2007

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48 Seminar on the Use of Satellite Observations in Numerical Weather Prediction, 8 – 12 September 2014, ECMWF, Reading, UK
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Highlights

• Acceptance and testing
• Testing the system
• Rehearsals
• Availability of parameters to Users
• Early availability of specifications
• Availability of test data
• Availability of readers
• Global/Local processing
Rehearsals for Cal/Val in June 2012

- Metop-B data were simulated by Metop-A data
- Corresponding Metop-B processing nodes in GS-2 have been configured to simulate a true Metop-B processing as close as possible.
  - This means that the incoming Metop-A Level 0 data stream is processed with the specifications of the Metop-B instrument suite
- Validation was done as in the Commissioning Phase
- The simulated data cover three orbits starting at about 5:51, 7:33, and 9:15 UTC, respectively, on 25. June 2012.
- Validation was done as in the Commissioning Phase
- Example for ATOVS/AVHRR:
  - Calibrated Earth View Radiances
  - Geolocation
  - Satellite and Solar Azimuth and Elevation
  - Surface Type (for AMSU, MHS, and HIRS only)
  - Surface Altitude (for AMSU, MHS, and HIRS only)
ATOVS – AMSU-A from rehearsal

- Geolocated Earth View Radiances
  - Channel 1 (top)
  - Channel 8 (bottom)
- Values for all channels (1-15) in the expected ranges
- Validation against reference prototype
  - Very small differences in all channels
  - Differences due to handling of PRTs and are below noise level
  - Issue of PRTs is being investigated
- Geolocation is well within all limits
- All angles are in good agreement
- Surface height and surface type as well as land/sea mask have been visually inspected and seem reasonable

* Channel 7 cannot be simulated as it was out of spec on Metop-A
<table>
<thead>
<tr>
<th>Partner</th>
<th>Subject of support</th>
<th>POC</th>
<th>Status</th>
</tr>
</thead>
</table>
| ECMWF         | Monitoring and assimilation - IASI - ATOVS - ASCAT - GRAS - (GOME) - Polar winds | Jean-Noël Thépaut Stephen English Sean Healy | Agreed  
POC: Steve English |
| MetOffice UK  | Monitoring and assimilation - IASI - ATOVS - GRAS - Polar winds | Fiona Hilton | agreement expected |
| MetOffice UK  | JAIVEx2 (together with NASA/NOAA) | Jonathan Taylor | Contacted  
No replies received by MetOffice from the US side  
NO JAIVex in 2012 |
| Météo-France  | Monitoring and assimilation - IASI - ATOVS - GRAS ConcordIASI | Vincent Guidard Lydie Lavanant Florence Rabier | Agreement expected |
| NWP SAF       | Direct Readout with HRPT - AAPP - IASI OPS | Pascal Brunel Nigel Atkinson | Agreement expected |

Contacts established  
Agreements and POC being received
### Potential partners for support to Metop-B Cal/Val and candidates for (early) data access

<table>
<thead>
<tr>
<th>Partner</th>
<th>Subject of support</th>
<th>POC</th>
<th>Status</th>
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<tr>
<td>OSI SAF</td>
<td>ASCAT winds</td>
<td>Ad Stoffelen</td>
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<td>O3MSAF</td>
<td>GOME L2 products</td>
<td>DLR</td>
<td>Agreed</td>
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<td>POC: Diego Loyola (DLR)</td>
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<td>POC: Olaf Tuinder (KNMI)</td>
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<td>U Bremen</td>
<td>GOME L2 products</td>
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<td>Kristian Rune Larsen</td>
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<td>NWC SAF</td>
<td>Direct readout products</td>
<td>Adam Dybbroe</td>
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<td>POC: Adam Dybbroe</td>
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<td>NOAA</td>
<td>All instruments</td>
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<td>Agreement assumed as main partner, contacts ongoing</td>
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<td>IISWG Members</td>
<td>IASI L1/L2</td>
<td>According to list</td>
<td>Agreed</td>
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<td></td>
<td></td>
<td>POC: Daniel Hurtmans (ULB)</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>POC: Cathy Boonne and Juliette Hadi-Lazaro (LATMOS/IPSL)</td>
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</table>

Contacts established
Agreements and POC being received
Early product delivery (according to the schedule from launch date L)

- AMSU-A1,A2 < L+ 2 wk
- AVHRR/3 VIS < L+ 2 wk
- MHS < L+ 3 wk
- ASCAT < L+ 5 wk
- AVHRR/3 IR < L+ 4 wk
- HIRS/4 < L+ 4 wk
- GRAS < L+ 5 wk
- GOME-2 < L+16 wk
- IASI first interferogramme < L+ 5 wk
- IASI Early Level 1 spectra < L+16 wk
Coordination with Partners

Example:

- Coordination with NOAA on Calibration Coefficients for ATOVS/AVHRR
- Also relevant for AAPP (NWP SAF)
- Publication of coefficients as early as possible on web-page
- Participation in respective Cal/Val activities (ATOV/AVHRR is processed in both NOAA and EUMETSAT Ground Segments)
- Assuring coherence of calibration in both ground segments and also coherence with locally processed data (relevant for EARS)
Examples from CPIDS and Antenna Correction files

### AMSU Calibration Parameters for AI-108 and A2-106

<table>
<thead>
<tr>
<th>Year of the version</th>
<th>Speed of light m/s</th>
<th>Boltzmann constant J/K</th>
<th>First &amp; second radiations constants mw/(sq.cm.ster.cm-4) &amp; K/cm-1</th>
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<tr>
<td>2014</td>
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### Central wavenumbers

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<th>Central Wavenumber</th>
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<tr>
<td>1</td>
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<tr>
<td>2</td>
<td>98231.400</td>
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<table>
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<tr>
<th>Channel</th>
<th>Wavenumber</th>
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<tbody>
<tr>
<td>3</td>
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<tr>
<td>4</td>
<td>98360.000</td>
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<tr>
<td>5</td>
<td>98420.000</td>
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</table>

### Channel Correction Coefficients for the following instruments onboard Metop-B:

- AMSU-A/1 S/N 106 (Channels 1 and 2)
- AMSU-A/2 S/N 108 (Channels 3 to 15)
- AMSU-A/1 S/N 108 (Channels 16 to 20)

The ordering for each channel is:

- **Channel number**
- **Earth view efficiency starting with Earth view position 1 and ending with Earth view position 30 (AMSU) or 90 (MHS)**
- **Platform efficiencies starting with Earth view position 1 and ending with Earth view position 30 (AMSU) or 90 (MHS)**
- **Space view efficiencies starting with Earth view position 1 and ending with Earth view position 30 (AMSU) or 90 (MHS)**

AMSU-A1 and AMSU-A2 data were generated and made available by Tsam Po, NOAA/NESDIS MHS data were computed by Joerg Ackermann, EUMETSAT

This is version 1.1 (14 September 2011)

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### Antenna Correction Coefficients for the following instruments onboard Metop-B:

- AMSU-A/1 S/N 106 (Channels 1 and 2)
- AMSU-A/2 S/N 108 (Channels 3 to 15)
- AMSU-A/1 S/N 108 (Channels 16 to 20)

The ordering for each channel is:

- **Channel number**
- **Earth view efficiency starting with Earth view position 1 and ending with Earth view position 30 (AMSU) or 90 (MHS)**
- **Platform efficiencies starting with Earth view position 1 and ending with Earth view position 30 (AMSU) or 90 (MHS)**
- **Space view efficiencies starting with Earth view position 1 and ending with Earth view position 30 (AMSU) or 90 (MHS)**

AMSU-A1 and AMSU-A2 data were generated and made available by Tsam Po, NOAA/NESDIS MHS data were computed by Joerg Ackermann, EUMETSAT

This is version 1.1 (14 September 2011)

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This is version 1.1 (14 September 2011)
1. Introduction
2. Identification of requirements
3. Development activities
4. Operations preparation and testing
5. Commissioning activities
6. Summary and Conclusion
• SIOV (Satellite in Orbit Verification) and Cal/Val (Calibration/Validation)
• All stakeholders involved
• User participation
• Provide data as early as possible
• Obtain feedback
• Operational as early as possible
• Each step (data release) with a review
ATOVS – AMSU-A on Metop-B in Commissioning

- Geolocated Earth View Radiances
  - Channel 1 (top)
  - Channel 7 (bottom)
- Values for all channels (1-15) in the expected ranges
- Validation against reference prototype
  - Very small differences in all channels
  - Differences due to handling of PRTs and are below noise level
  - Issue of PRTs is being investigated
- Geolocation is between 0 and 900m (due to different orbit propagator handling), well within all limits
- All angles are in good agreement
- Surface height and surface type as well as land/sea mask have been visually inspected and seem reasonable
- Metop-B successfully launched 17 September 2012 from Baikonur Cosmodrome
- LEOP – 3 days by ESOC
- SIOV – 6 weeks, SIOV Handover end October 2012
- Cal/Val Phase in parallel, as status allowed,
- First products to users 4 days after launch
- Phase 1 until Commissioning Handover Review
- Commissioning Handover 29 January 2013 successful
- Cal/Val Phase 2 (included remaining IASI (L1 by CNES, L2 in house) ATOVS L2 and GOME-2 activities)
- Metop-B prime satellite 24 April 2013
- End of commissioning 31 July 2013
### Commissioning Results: Products Status Metop-B end of July 2013

<table>
<thead>
<tr>
<th></th>
<th>Special Trial Dissemination</th>
<th>Pre-Op Dissemination</th>
<th>End of Cal / Val</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMSU-A</td>
<td>L1</td>
<td>28/09/12 &lt;L+2w</td>
<td>11/12/12</td>
</tr>
<tr>
<td>AVHRR</td>
<td>L1</td>
<td>05/10/12 &lt;L+3w</td>
<td>11/12/12</td>
</tr>
<tr>
<td>HIRS</td>
<td>L1</td>
<td>26/10/12* &lt;L+6w</td>
<td>11/12/12*</td>
</tr>
<tr>
<td>MHS</td>
<td>L1</td>
<td>02/10/12 &lt;L+2w</td>
<td>11/12/12</td>
</tr>
<tr>
<td>ASCAT</td>
<td>L1</td>
<td>23/10/12 &lt;L+5w</td>
<td>04/12/12</td>
</tr>
<tr>
<td>GOME</td>
<td>L1</td>
<td>12/12/12 &lt;L+12w</td>
<td>13/02/13</td>
</tr>
<tr>
<td>GRAS</td>
<td>L1</td>
<td>01/10/12 &lt;L+2w</td>
<td>15/11/12</td>
</tr>
<tr>
<td>IASI</td>
<td>L1</td>
<td>22/01/13 &lt;L+17w</td>
<td>20/02/13</td>
</tr>
<tr>
<td>IASI</td>
<td>L2</td>
<td>07/03/13 &lt;L+6m</td>
<td>26/06/13</td>
</tr>
<tr>
<td>AVHRR Winds</td>
<td>L2</td>
<td>18/03/13 &lt;L+6m</td>
<td>26/06/13</td>
</tr>
<tr>
<td>ATOVS</td>
<td>L2</td>
<td>n/a</td>
<td>04/06/13</td>
</tr>
<tr>
<td>ASCAT SOMO</td>
<td>L2</td>
<td>13/11/12 &lt;L+2m</td>
<td>11/12/12</td>
</tr>
</tbody>
</table>

*noise degradation since January 2013*
6 SUMMARY & CONCLUSIONS
Concluding Remarks

• Long process
• Thorough preparation
• Instrument development with specialists
• Baseline
• User involvement – Mission Expert Teams
• SAGs
• Data as early as possible to Users
• Lessons learnt applied
EUMETSAT mission planning...

Only the full operational phase of each mission is represented, excluding commissioning.
* MSG-4/Meteosat-11 will be stored in orbit, before replacing Meteosat-10
Thank you for your attention!
User Consultation:
Example from EPS-SG in 2006, then called Post-EPS

Post-EPS
Mission Experts Team
1st Meeting
22 May 2006
Seminar on the Use of Satellite Observations in Numerical Weather Prediction, 8 – 12 September 2014, ECMWF, Reading, UK

Initial Scope of Tentative Missions
Introduction of Tentative Missions at MTG 2nd UC Workshop
Atmospheric Sounding & Wind Profiling AEG
Ocean Topography & Imaging AEG
Cloud, Precipitation & Land Surface Imaging AEG
Atmospheric Chemistry AEG
Introduction to SAF Network
Analysis by Climate Experts
Consolidation of Application Requirements
1st User Cons. Workshop
Observation Mission Req.
Support Mission Req.
Assess METOP Commissioning Results
Programmatic Requirements
Mission Definition Review

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J F M A M J J A S O N D
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Mission Requirements

Architecture Concepts

User Consultation

RSE Support to AEGs
Sensor Concepts & System Architecture Studies
Studies Review
Pre-Developments TRL-2
Mission Requirements Document

- Mission Requirements will be derived from the User Requirements as expressed in the Post-EPS Position Papers

- Mission requirements will address candidate observation missions related to the geophysical parameters specified in the Position Papers

- The requirements will be documented in a Mission Requirements Document (MRD)
  - The MRD be the basis for industrial studies led by ESA on sensor and system architecture concepts
  - The industrial studies will provide feedback from a technological viewpoint
  - The MRD will be updated iteratively aiming at confirmation and validation of requirements in view of remote sensing capabilities in the 2020 time frame

- Validation of requirements against programmatic requirements and constraints such as affordability are out of the scope of the present Phase 0
Post-EPS Mission Experts Group (1/2)

- Analysis of Position Papers towards possible observation missions
- Identification of observation missions
  - Basis are user needs and their priorities
  - Aim at maximising fulfilment of user needs while minimising diversity of solutions, risks, and cost
  - No exclusion of missions on sole cost basis
  - Solutions must have sufficient level of maturity for an operational mission
- Identify scientific/technical areas that need to be analysed in support of the definition of mission requirements
Provision of guidance and support to the definition of mission requirements for the identified missions and review of relevant issues

- Review of study results
  - Assessment of compliance with mission requirements
  - Assessment of impact on target service in case of incompliance
  - Advice on acceptable relaxations and trade-offs

- Response to queries on technical issues raised by EUMETSAT, ESA or industrial studies

- Support of meetings, reviews, and workshops

- PMET shall not participate to industrial studies in other frame than foreseen under the TOR
Schedule (in 2006)

- **April/May 2006**: Identification of candidate missions

- **Autumn 2006**: Review of technical documentation input to ESA led industrial studies on sensor/system concepts

- **Mid 2007**: Review of output from industrial studies at their mid-term review
Reserve slides: Benefits of satellite data and products
Diagnosing moist air flow

On 26 August 2012, 09:30 UTC, the high resolution visible (HRV) channel of Meteosat-8 observed the cold front that terminated the heat wave over Italy. Forecasters could diagnose from imagery the moist air flow ahead of it (“atmospheric moisture river”), which can, under certain conditions, lead to heavy rainfall and flash-floods.
Storm Ulli

Structure of Storm Ulli as observed on 3 January 2012, by Meteosat-9 (12:00 UTC, water vapour channel), and Metop-A ASCAT (winds) as it was centred over the North Sea between the British Isles and Norway. Wind gusts were recorded in Glasgow (78 knots at 08:20 UTC), Edinburgh (70 knots at 08:50 UTC) and in excess of 87 knots in other locations.
Comparison of Meteosat products and aircraft radar

EUMETSAT imagery compared with successive aircraft radar scopes during flight changes (about 60 nautical miles) decided by the pilot to avoid severe convection.
Meteosat-7 observes disastrous rainfall:
11 - 13 Aug. 2002, Elbe flood
Cold U-shaped storms over Southern Italy

Typically associated with severe weather such as heavy rain, hail and damaging winds

(Meteosat-8 IR10.8 BT RSS - 02/09/10 13:30 - 03/09/10 07:00 UTC)
Weather-related dispersion of volcanic ash

Eyjafjallajökull Ash cloud from 7 to 11 May (Second eruption)
Severe storm warning: Klaus, 24 January 2009 (MSG water vapour channel)
Generalisation of convection-resolving models for short range forecasts and support to nowcasting
The benefit of two Metop satellites in orbit

Impact of hurricane Sandy on total ozone, as observed by the GOME-2 instruments of Metop-A and Metop-B, on 30 October 2012. Only the combination of both instruments can map the full region impacted by the storm.
Extreme Greenland ice sheet melt

Metop-A ASCAT backscatter over Greenland changing dramatically from 8 and 11 July 2012. Imagery discriminates land (grey), summer melt (dark green), fast surface melt (red), refrozen melt (bright white) and non-melted (dark grey/blue). This event was likely due to extreme air surface temperature during those days.
Winter storm "Nicolas": DWD 45-hour forecasts of surface pressure (contour lines) and surface wind speed (shaded areas - units m/s) for 7 February 2011, 21:00 UTC with (left) and without (right) Metop observations, compared to operational analysis (best approximation of ground truth, centre)
Failing to forecast major storms without Metop-A

Winter storm “Nicolas”: 45 hour forecasts and operational analysis (best approximation of ground truth) of surface pressure (contour lines) and 10m wind speed (shaded areas – units M/S) for 7 February 2011
Hurricane Sandy

Five-day forecast of cyclone Sandy landfall on the US coast by the ECMWF global model, with (left) and without (right) ingestion of observations from polar orbiting satellites, compared to the operational analysis (best approximation of ground truth, centre)