Future Eumetsat-ESA Collaboration

Meteosat Third Generation, Post-EPS and Sentinels 3,4,5

“Bridging the Gap”

Portoroz, Slovenia
14 May 2008
The co-operation between ESA and EUMETSAT is based on the following principles:

- Following the demand of EUMETSAT, ESA will develop the next generation of meteorological satellites
- The 1st model of a series is developed as part of an ESA programme with a fixed financial contribution from EUMETSAT
- Recurrent models are procured by ESA on behalf of EUMETSAT
- The satellites are operated by EUMETSAT

**Existing Programmes**

*MSG (Meteosat Second Generation)*
*METOP/EPS (Meteorological Operational satellite)*

**Future Programmes**

*MTG (Meteosat Third Generation)*
*Post-EPS (Eumetsat Polar System)*
Meteosat Third Generation (MTG)

- Development of geostationary programmes:

1977 - 2002 - 2015

**MOP**

1 observation mission:
- MVIRI: 3 channels
- Spinning satellite

**MSG**

2 observation missions:
- SEVIRI: 12 channels
- GERB
- Spinning satellite

**MTG**

5 observation missions:
- HRFI: 5 channels
- FDHSI: 22 channels
- Lightning Imager
- Infra-Red Sounder
- 3-axis stabilised satellite

• The MeteoSat Third Generation baseline is a two-platform system (6 spacecraft)
MSG is the core programme of the European Satellite - Meteorology

MSG is a geostationary Satellite system (36000km) for realtime and midium term forcast

The development started in 1994. The system comprises 4 Satellites.

- MSG-1 launched 2002
- MSG-2 launched 2005
- MSG-3 planned launch 2011
- MSG-4 planned launch 2013
Overview MSG

First MSG-1 image:

colour composite derived from three of the twelve channels operating in the visible and IR parts of the spectrum (Spinning Enhanced Visible and Infra-red Imager (SEVIRI))
Enhanced composite image taken at 12:00 UT on 10 August 2003, by MSG-1
MTG Baseline System Concept Definition

**Launcher**
Ariane 5 (dual launch), Soyuz
Back-up: Delta, Atlas, Proton

**Space Segment (Reference Configuration)**
- 2 nominal (MTG-I+MTG-S)+1 back-up (MTG-I)
- 6 satellites (4 MTG-I + 2 MTG-S) for 20 years
- 3+ tons, 1+ kW
- Payload MTG-I: FCI, LI, DCS, S&R
- Payload MTG-S: IRS (FTS), S4

**Orbit**
- Geostationary orbit
- Nominal position: 0°
- Back-up: 10° E/10° W

**User Segment**
Real time users:
National Met. Centers, ECMWF, WMO...
Non-Real time users (archived products)

**MTG Mission Elements**

**Ground Segment**
- Data acquisition and TT&C ground stations
- Mission (Ground and S/C) control
- Image processing
- Met. Products extraction
- Data dissemination
- Archive & Retrieval
- External Data Collection & Dissemination
- User Services
MTG High Level Schedule

ESA roadmap

- Phase A
- Phase B
- Start Phase C/D

2007 PCR
2008 PRR
2009
2010
2011
2012
2013

EUMETSAT roadmap

- Phase A
- Preparatory Programme
- Council Full Programme Approval

2007
2008 PCR
2008 PRR
2009
2010
2011
2012
2013

ESA C-MIN 2008 Approval full Programme Go-ahead for Phase B

Council Approved the MTG PP

Council Full Programme Approval
MTG Deployment scheme – twin configuration

15 - 18 MSG-3
15 - 20 MSG-4
15 - 23 MTG-I-1
19 - 27 MTG-I-2
23 - 31 MTG-I-3
26 - 34 MTG-I-4
17 - 25 MTG-S-1
24 - 32 MTG-S-2
MTG Next Steps

- The MTG Programme Proposal has been issued to Member States in November 2007

- The draft Declaration together with the draft Enabling resolution has been presented to MS in February 2008; both are well advanced

- A MTG draft cooperation agreement with EUMETSAT shall be endorsed by the Special EUMETSAT Council in October 2008 and submitted for approval to ESA Council in October 2008
Post-EPS

Status of Preparation
Observation Mission Priorities

- according to PARD v. 1C, 29 March 2007
- prioritisation (#) based on application-weighted evaluation

<table>
<thead>
<tr>
<th>#</th>
<th>Name</th>
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<td>Scatterometry</td>
<td>Ocean surface wind vector</td>
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<td>Cloud mask, type, cover profile, optical depth, top temperature, top height, top effective radius; Water-vapour imagery; Aerosol optical depth</td>
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<td>5</td>
<td>Microwave Imaging - precipitation</td>
<td>Precipitation content (liquid/frozen; tot. column and gross profile), precipitation rate near the surface, precipitation detection, water vapour (total column and gross profile) temperature (gross) profile</td>
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<td>6</td>
<td>Microwave Imaging - land &amp; ocean</td>
<td>Soil moisture; Snow cover, water equivalent, depth, wet/dry status; Sea ice coverage, type; Sea surface salinity</td>
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<td>Radio Occultation Sounder</td>
<td>Temperature and water-vapour profile (all-weather)</td>
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<td>8</td>
<td>Nadir-viewing UV/VIS/ NIR/SWIR Sounder (S-5)</td>
<td>O\textsubscript{3} profile; SO\textsubscript{2}, NO\textsubscript{2}, H\textsubscript{2}O, CO, CH\textsubscript{4} total column; Aerosol optical depth</td>
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<td>9</td>
<td>Multi-viewing multi-channel multi-polarisation Imager</td>
<td>Aerosol optical depth, particle size, type, height index</td>
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<td>10</td>
<td>Doppler Wind Lidar</td>
<td>Horizontal wind vector profile</td>
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<td>Dual-view IR Radiometer (S-3)</td>
<td>Sea and sea ice surface temperature</td>
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<td>Cloud &amp; Precipitation Radar</td>
<td>3D cloud water and ice content 3D precipitation intensity and type</td>
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<td>Radiant Energy Radiometer</td>
<td>Solar reflected and terrestrial emitted radiation</td>
</tr>
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<td>16</td>
<td>Limb Infrared Sounder (S-5)</td>
<td>Temperature Profile in stratosphere and cloud-free UT; Profiles of H₂O, O₃, CH₄ in UTLS and LS</td>
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<td>Limb Millimeter Wave Sounder (S-5)</td>
<td>H₂O, O₃, CO profile in UTLS</td>
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<td>Ocean Colour Imager (S-3)</td>
<td>Chlorophyll; Yellow substance; Water sediment; Oil spill cover</td>
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<td>Differential Absorption Lidar</td>
<td>Water vapour profile</td>
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<td>Aerosol Profiling Lidar</td>
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Some primary objectives:

- Temperature profiles
- Humidity profiles
- Surface temperature
- Cloud parameters
- Sea and ice surface temperature
- Surface wind vectors

.. and secondary objectives:

- Cloud and precipitation products
- Atmospheric chemistry
- Aerosol parameters

Primary use of data

- Numerical weather prediction
- Nowcasting
- Climate monitoring

System to be deployed by:

- **2018** for primary observation missions (microwave and IR sounding, optical imaging)
- **2020** for other missions
ESA roadmap

Start Industrial Phase 0

2007

2008

2009

2010

2011

2012

2013

Phase A

ESA (MIN)-2011 Approval full programme
Go-ahead for Phase B

Post-EPS roadmaps

ESA roadmap

Phase B

Start Phase C/D

ESA C(MIN)-2011 Approval full programme
Go-ahead for Phase B

Phase A

Start Phase C/D

EUMETSAT roadmap

2nd User Consultation Workshop

MRD, PARD endorsement by STG/AFG

Phase A

Council Programme Approval

Council Approval
Prep. Programme
The GMES Sentinels

**Sentinel 1 – High-resolution SAR imaging**
All weather, day/night applications, interferometry

**Sentinel 2 – High-resolution multispectral imaging**
Continuity of Landsat, SPOT & Vegetation-type data

**Sentinel 3 – Medium-resolution Ocean monitoring**
Wide-swath ocean color and surface temperature sensors, altimeter

**Sentinel 4 – Geostationary atmospheric**
Atmospheric composition monitoring, trans-boundary pollution

**Sentinel 5 – Low Earth Orbit atmospheric**
Atmospheric composition monitoring
• European Radar Observatory: C-band Synthetic Aperture Radar
• Main operational mode: SAR imaging (Interferometric Wide Swath)
• Prime task: Continuity of operational SAR applications including interferometry
Examples of Services

Forest mapping by radar (ERS-1 & -2)

Radar-based flood mapping

Radar observation of ships and pollution

Sea ice monitoring
• Multispectral imaging
• Continuity of Landsat, SPOT & Vegetation-type data
• Continuity to services for multispectral high-resolution optical observations over global terrestrial surfaces

Configuration resulting from Phase A/B1
### Sentinel-2 Services

<table>
<thead>
<tr>
<th>GMES Initial Service</th>
<th>S-2 Features</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Global Change - Land</strong></td>
<td>mapping services for monitoring urban areas in Europe (urban sprawl, urban planning modelling &amp; forecasting, changes in urban land use, environmental monitoring and enforcement of urban planning discipline)</td>
</tr>
<tr>
<td><strong>Land cover &amp; Land use change</strong></td>
<td>Comprehensive information services for European users with respect to mainly European policies (Water, Soil, Integrated Coastal Zone Management, Urban Environment, Spatial Development)</td>
</tr>
</tbody>
</table>
| **Forest Monitoring**                | Forest area / forest area change map  
Forest type map  
Forest fragmentation |
| **Food Security early warning**      | Support to Crop and Food Supply Assessment  
Agricultural mapping  
Crop Yield assessment |
| **Humanitarian Aid**                 | Appropriate and reliable application of geographic information for humanitarian organisations |
| **Risk Management (flood and fires)**| Monitoring of floods, forest fires, volcano eruptions, subsidence and landslides |
Sentinel-3

- Consistent, long-term collection of remotely sensed marine and land data
- Operational ocean state analysis, forecasting and service provision
- Advanced Radar Altimeter concept
- Multi-channel optical imager (VIS, IR)
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<th>S-3 Features</th>
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<td><strong>Marine and Coastal Environment</strong></td>
<td>sea-surface topography</td>
</tr>
<tr>
<td></td>
<td>mesoscale circulation</td>
</tr>
<tr>
<td></td>
<td>water quality</td>
</tr>
<tr>
<td></td>
<td>sea-surface temperature</td>
</tr>
<tr>
<td></td>
<td>wave height and wind</td>
</tr>
<tr>
<td></td>
<td>sediment load and transport</td>
</tr>
<tr>
<td></td>
<td>eutrophication</td>
</tr>
<tr>
<td><strong>Polar Environment monitoring</strong></td>
<td>sea-ice thickness</td>
</tr>
<tr>
<td></td>
<td>ice surface temperature</td>
</tr>
<tr>
<td><strong>Marine Security</strong></td>
<td>ocean-current forecasting</td>
</tr>
<tr>
<td></td>
<td>water transparency</td>
</tr>
<tr>
<td></td>
<td>wind and wave height</td>
</tr>
<tr>
<td><strong>Global Change - Ocean</strong></td>
<td>global sea-level rise</td>
</tr>
<tr>
<td></td>
<td>global ocean warming</td>
</tr>
<tr>
<td></td>
<td>ocean CO₂ flux</td>
</tr>
</tbody>
</table>
Sentinel-3 Examples of Services

Ireland, Plankton bloom (ENVISAT)

Australia - bushfire plumes at top right (ENVISAT)

Significant Wave Height Map (JASON-1)

Sea surface Temperatures Around Crete (ENVISAT)
Sentinel-3 Payload Complement

• Topography Mission
  – Bi-frequency Synthetic Aperture Radar Altimeter
  – Microwave Radiometer (Bi- or Three-frequency)
  – Precise Orbit Determination (POD) including
    • GNSS Receiver
    • Laser Retro-Reflector
• Optical Payload
  – Ocean and Land Colour Instrument (OLCI)
  – See and Land Surface Temperature (SLST)
Environmental issues of changing atmospheric composition

- Climate Change and the Greenhouse Effect
- Stratospheric Ozone Depletion and enhanced surface UV
- Stability of the Atmospheric Oxidation Efficiency
- Information services needed for monitoring, forecasting, assessment, mitigation
- Increase in background tropospheric ozone
- Intercontinental transport of pollutants and aerosols
- Enhanced aerosol and photo-oxidant levels due to biomass burning
- Acid Rain
- Nutrification of coastal waters and freshwater lakes; eutrophication
- Aerosols in and downwind of regions of high population
- London Smog
- Los Angeles Smog or "summer" smog
Sentinels 4&5 support GMES atmospheric services:

**Core services**
- standard operational products and information services providing direct support to European policy and information on global issues
- Sustained public funding (EU & Member States)
- Pilot service “GMES Atmospheric Service (GAS)”: EU FP7 activity “MACC” to start 2009; negotiation ongoing
- precursor / development activities: GEMS (EU FP6 Integrated Project), PROMOTE (ESA GMES Service Element)

**Downstream services**
- targeted services that address specific user requirements, or trans-national, national, regional or local problems
- EU not directly driving the service and not responsible for service requirements
- use core service data as input
- call to be issued
- precursor / development activities: PROMOTE, national developments
Sentinel 4
The Sentinel-4 instrument is an UV-Vis-NIR spectrometer in GEO

<table>
<thead>
<tr>
<th>Band ID</th>
<th>Wavelength range [nm]</th>
<th>Spectral resolution [nm]</th>
<th>Spectral sampling ratio</th>
<th>SSD [km]</th>
<th>Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>GEO-UV-1</td>
<td>290-308</td>
<td>1</td>
<td>3</td>
<td>50 (T)</td>
<td>1</td>
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<tr>
<td>GEO-UV-2</td>
<td>308-400</td>
<td>0.5</td>
<td>3</td>
<td>5 (T)</td>
<td>1</td>
</tr>
<tr>
<td>GEO-VIS</td>
<td>400-500</td>
<td>0.5</td>
<td>3</td>
<td>5 (T)</td>
<td>1</td>
</tr>
<tr>
<td>GEO-NIR</td>
<td>750-775</td>
<td>0.5 (T)</td>
<td>3</td>
<td>5 (T)</td>
<td>1</td>
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Note: (T) indicates that the bandwidth includes the target wavelength range.
First design iteration shows that compliancy may be achieved for bands UV1, VIS and NIR considering:

- SNR at spectral resolution of:
  1.0 nm in 290-308 nm
  0.5 nm in all other bands

- SNR at spatial sampling distance of (at SSP):
  10 km nadir in 290-308 nm
  5 km nadir in all other bands (corresponds to 5.3 x 7.5 km² @ 40°N, 7.5°E)

- In UV2, SNR is not compliant in the region 308-[315 | 320] nm
Sentinel 5
• S5 to be embarked on Post-EPS with a launch date $\geq$ 2019

• S5 accommodation envelope (volume, mass, power, data rate and other constraints) to be defined in the frame of Post-EPS phase 0 study

• Possible enhancements w.r.t. S5 precursor:
  • Priority 2 (and possibly 3) SWIR bands (1.6 $\mu$m, 2.0 $\mu$m)
  • Improved performance in NIR and UV
  • Better SSD at level 0 data
  • Synergy with IRS and imager of Post-EPS
Sentinel 5 precursor
Mission

- **Launch date**: Q4 of 2013 (ENVISAT end of fuel reserve)
- **Lifetime**: 5 + 2 years (up to the launch of Post-EPS)
- **Orbit**: SSO at 817 / 828 km with LTAN at 13:30 / 13:45
- **Launcher**: VEGA, possibly using dual launch configuration
- **Ground Station**: Svalbard or Kiruna

Payload

- Development constraints (time, budget) achievable with a small mission, with UV-Vis-NIR-SWIR spectrometer payload derived through proper tailoring of S5 specifications (e.g., only high priority bands)
- Moderate size instrument (<150 kg, ~100 W) to fit in small platforms
- Involved technology being validated (e.g. SWIR channel)
- Take National developments into account
- Product and application experience preparing S5 on PostEPS
What do you consider validated fro SWIR. This is a new channel with respect to the detector and immersed garting.

Y. J. Meijer, 23/04/2008
Sentinel 5 precursor: Instrument concept

- Separate UVN and SWIR modules (2 telescopes), with passive cooling only
- Mass within the preliminarily allocated 150 kg
- Complexity driven by SSD and SNR around 310 nm (for SO₂ and TS O₃)
- Volume: 0.6 x 0.5 x 0.5 m³
- Data rate compatible with off-the-shelf X-band downlink
Sentinel 5 precursor: Programmatic assumptions

- Provision of payload currently assumed as in-kind contribution from National Developments, including ground processor algorithms and Cal/Val activities.

- Cost of FOS/PDGS integration in an existing set-up (e.g. EUMETSAT) included in Segment 2; operations not included.

- Streamlined procurement (2 phases: AB1, B2CD) with tailored quality approach (e.g., new simplified review process), benefiting of recent lessons learned (e.g., Giove-A).

- Launch foreseen in Q4 2013 for maximum user benefit.
D/EOP overall launch schedule

More missions are in the planning, yet not included due to not yet defined launch dates: Sentinel-4, Sentinel-5 and the 7th Earth Explorer.