Potential of DMC to support a European Global Monitoring System

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Background

- Europe is in process of developing an operational programme for environmental monitoring called Global Monitoring of the Environment and Security (GMES).
- The GMES programme will include space, ground and service segments and has been derived to serve European policies.
- SSTL is reviewing the ability of small satellites to add complementary capability to GMES.
- As part of this activity SSTL is undertaking a study for ESA to:
  - review the ability of the proposed GMES space segment (the Sentinel Missions) to satisfy the service requirements.
  - Assess how the SSTL Disaster Monitoring Constellation (DMC) of satellites can add additional value.
  - Assess how the envisaged enhanced DMCs can further support the GMES programme.
  - Select one of a suite of new candidate missions and study in detail.
GMES Space Segment

- Sentinel 1: C-band interferometric SAR mission;
- Sentinel 2: Multi-spectral high resolution optical imager mission;
- Sentinel 3: Wide-swath low-medium resolution optical and infrared radiometric mission with a radar altimetry package
- Sentinel 4: Geostationary satellite(s) for atmospheric chemistry monitoring;
- Sentinel 5: LEO satellite(s) for atmospheric chemistry/climate change monitoring.
The GMES Service Element (GMES)

- The GSE is supporting the development of sustainable service networks following a two phase approach:
  - A **Consolidation Phase** to assess:
    - the user information needs,
    - the current service provision
    - and the stakeholder benefits
  - The **Scaling-up Phase** that aims to:
    - demonstrate progress towards service sustainability,
    - service delivery and benefits to users,
    - to establish a GMES Service Provision Network,
    - to establish standards and working practices.
Seven service portfolios have been assessed:
- European level service portfolios:
  - Marine and coastal environmental information services
  - Polar environment information services
  - Land cover and land use change information services
- Regional level service portfolios
  - Forest monitoring information services
  - Flood and fire risk management services
  - Geotechnical risk management services
  - Food security information services
- Two further service portfolios will complete the Scaling-up Phase over the period 2006-2009:
  - Humanitarian aid
  - Atmospheric pollution monitoring.
- A tenth service - maritime security – is a later service development and is presently proceeding through the Consolidation Phase.
- In addition, key elements will form a foundation for the ‘Fast Track’ or GMES Pilot Services. The three fast track services are:
  - The Emergency Response Core Service
  - The Land Monitoring Core Service
  - The Marine Core Service
GMES Sentinel MRDs – Service Network Feedback Overview
## GMES Service Review

### Sentinel-2 MRD: Service Network Feedback

<table>
<thead>
<tr>
<th>GSE Services</th>
<th>Sensors</th>
<th>Operations</th>
</tr>
</thead>
<tbody>
<tr>
<td>European Urban Atlas</td>
<td>Spectral</td>
<td>Geo Accuracy</td>
</tr>
<tr>
<td>Impervious Areas and Sealing Levels</td>
<td>Bands</td>
<td>Data Delivery T</td>
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<tr>
<td>Inland Water Quality / Contamination</td>
<td>Resolution</td>
<td>Data Order T</td>
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<tr>
<td>Pan-European Forest Monitoring Service</td>
<td>Radiometry</td>
<td></td>
</tr>
<tr>
<td>National UNFCCC &amp; LULUCF Kyoto Protocol Rep</td>
<td>Revisit</td>
<td></td>
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<tr>
<td>Forest Information Update Service</td>
<td>Cycle</td>
<td></td>
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<tr>
<td>Environmental Monitoring</td>
<td></td>
<td></td>
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<tr>
<td>Forest Disturbances Detection &amp; Monitoring</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LULUCF CDM Projects Management &amp; Reporting</td>
<td></td>
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<tr>
<td>Asset Mapping</td>
<td></td>
<td></td>
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<tr>
<td>Flood Risk Analysis Information Services</td>
<td></td>
<td></td>
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<tr>
<td>Burn Scar Mapping and Asset Mapping</td>
<td></td>
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<tr>
<td>Rapid Mapping</td>
<td></td>
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</tr>
</tbody>
</table>

Legend:
- **Compliant**
- **Partial Compliant**
- **Non-Compliant**
- **Missing in MRD**
## Gap Analysis (Core Services)

<table>
<thead>
<tr>
<th>Gap</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>LMCS, ERCS - sub 2.5m imagery</td>
</tr>
<tr>
<td>1.2</td>
<td>LMCS, ERCS - High Resolution DEM's</td>
</tr>
<tr>
<td>1.3</td>
<td>LMCS, ERCS - sub 10m imagery</td>
</tr>
<tr>
<td>1.4</td>
<td>LMCS - coverage (crop yield forecasts and <strong>frequency</strong>), ERCS, MCS SST</td>
</tr>
<tr>
<td>1.5</td>
<td>LMCS - Satellite Replacement (redundancy, continuity, lead time to launch)</td>
</tr>
<tr>
<td>1.6</td>
<td>LMCS - Higher resolution Biophysical measurements</td>
</tr>
<tr>
<td>1.7</td>
<td>MCS - <strong>Oil Spill Repeat</strong> (C-Band)</td>
</tr>
<tr>
<td>1.8</td>
<td>MCS - Flexibility of payload / orbit to produce optimal observations plus cost impact</td>
</tr>
<tr>
<td>1.9</td>
<td>MCS - Coastal altimetry spatial and temporal resolution</td>
</tr>
<tr>
<td>1.10</td>
<td>MCS - Altimeter Coverage</td>
</tr>
<tr>
<td>1.11</td>
<td>MCS - Coastal SST spatial and <strong>temporal resolution</strong></td>
</tr>
<tr>
<td>1.12</td>
<td>MCS - Coastal Ocean Colour spatial and <strong>temporal resolution</strong></td>
</tr>
<tr>
<td>1.13</td>
<td>MCS, ERCS - SAR <strong>Coverage limitation</strong> (even with 4 satellite constellation)</td>
</tr>
<tr>
<td>1.14</td>
<td>FIRE Monitoring / Detection element</td>
</tr>
</tbody>
</table>

**ERCS** | Emergency Response Core Service  
**LMCS** | Land Monitoring Core Service  
**MCS**  | Marine Core Service

NB. The above the gaps against Core User Requirements
Overview of DMC

- One candidate mission that could supplement the GMES programme is the Disaster Monitoring Constellation (DMC) developed by SSTL together with its international partners.
- Constellations could address the coverage and repeatability issues.
- The DMC has 5 original stakeholders:
  - Centre National des Techniques Spatiales, Algeria
  - National Space Research and Development Agency, Nigeria
  - British National Space Centre, UK
  - TUBITAK-ODTU BILTEN, Turkey
  - Ministry of Science & Technology of China, China
- The first satellite in the DMC, ALISAT-1 for Algeria, was launched on 28 November 2002.
<table>
<thead>
<tr>
<th>Satellite</th>
<th>Payload</th>
<th>Image sizes</th>
<th>LTAN</th>
<th>Launch date</th>
<th>Country ownership</th>
</tr>
</thead>
<tbody>
<tr>
<td>AISAT-1</td>
<td>32m GSD, 3 band MS</td>
<td>Up to 640×512km</td>
<td>10:00</td>
<td>28/11/02</td>
<td>Algeria</td>
</tr>
<tr>
<td>NigeriaSat-1</td>
<td>32m GSD, 3 band MS</td>
<td>Up to 640×512km</td>
<td>10:00</td>
<td>27/9/03</td>
<td>Nigeria</td>
</tr>
<tr>
<td>BILSAT-1</td>
<td>Mission completed</td>
<td></td>
<td></td>
<td>27/9/03</td>
<td>Turkey</td>
</tr>
<tr>
<td>UK-DMC</td>
<td>32m GSD, 3 band MS</td>
<td>Up to 640×512km</td>
<td>10:00</td>
<td>27/9/03</td>
<td>UK</td>
</tr>
<tr>
<td>Beijing -1</td>
<td>32m GSD, 3 band MS 4m GSD Pan</td>
<td>Up to 640×4000km Up to 24×4000km</td>
<td>10:45</td>
<td>27/10/05</td>
<td>China</td>
</tr>
<tr>
<td>UK DMC2</td>
<td>22m GSD, 3 band MS</td>
<td>Up to 640×4000km</td>
<td>10:30</td>
<td>Oct 2008 Launch</td>
<td>UK</td>
</tr>
<tr>
<td>DEIMOS -1</td>
<td>22m GSD, 3 band MS</td>
<td>Up to 640×2000km</td>
<td>10:30</td>
<td>Oct 2008 Launch</td>
<td>Spain</td>
</tr>
</tbody>
</table>
DMC 32m GSD MSI Payload

DMC MSI Payload: 32m GSD, 3 spectral bands, 600km swath.

The Mississippi delta after Hurricane Katrina
UK-DMC

Imaging the whole of England and Wales in one pass
Current DMC Coverage (days)
DMC European Coverage since mid-2006

Snapshot of DMC European archive coverage from Mid-2006
DMC Applications

Hurricane Katrina and the Gulf coast of the United States.
Charter activation 2 September 2005
DMC Applications

GEOSYS France
Precision farming service, FARMSAT. Nitrogen application distribution maps.

Control with Remote Sensing (CwRS). Monitoring whether area-based crop subsidies are in-line with EC policy.
<table>
<thead>
<tr>
<th>Service</th>
<th>Application</th>
<th>EO Level 2/3 product</th>
<th>Spatial resolution</th>
<th>Geographical coverage</th>
<th>Update frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSE Respond</td>
<td>Mapping, Damage Assessment &amp; Thematic mapping for humanitarian aid and disaster management (including services in rush provision)</td>
<td>Basic mapping at large scale</td>
<td>30-500m (5-15m for data capture)</td>
<td>Global</td>
<td>Weekly</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Basic mapping at medium scale</td>
<td>10-30m (5-15m for data capture)</td>
<td>Global</td>
<td>Weekly</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Crisis/damage mapping (Plain flood monitoring)</td>
<td>10-30m (5-15m for data capture)</td>
<td>Global</td>
<td>Daily</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Situation mapping - medium scale</td>
<td>2-25m</td>
<td>Global</td>
<td>Daily</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Thematic mapping including maps for prevention, reconstruction, health and environmental impact assessment) - medium - large scale</td>
<td>10-20m</td>
<td>Global</td>
<td>Daily</td>
</tr>
<tr>
<td>Geoland</td>
<td>Monitoring of land Cover and vegetation</td>
<td>Land cover and use maps</td>
<td>20m</td>
<td>Regional</td>
<td>Weekly</td>
</tr>
</tbody>
</table>

Currently DMC could contribute
Currently flying DMC plus DEIMOS1 and UK DMC2 could contribute
An exercise has been undertaken to assess how one could further enable DMC to satisfy some of the GSE requirements by implementing enhanced constellations.

SSTL has a range of payload technologies that have been considered.

These range from payloads that have been demonstrated in orbit to those that have been breadboarded.

Payloads that have been reviewed include:

- Hyperspectral Imager
- VHR/HR Multispectral and PAN
- SWIR Imager
- TIR/MIR Imager
- GPS Reflectrometry

Each of these have been reviewed with respect to the GSE requirements to identify which gaps can be satisfied.
Enhanced Constellations

Hyper-spectral Imager
(Coastal Ocean Colour spatial & temporal resolution)

VHRI/MSI
(High Resolution DEMs Sub-metre imagery)

GPS Reflectometer
(Sea state timeliness & observational frequency)
New Concept Options

SSTL and ESA considered a number of new concept options to study in Phase 2 of the programme, these included:

- Mini-SAR
- 1-m high resolution imager
- Hyperspectral (Visible to SWIR)
- Altimeter
- LEO Atmospheric Chemistry Mission
- GEO Atmospheric Chemistry Mission
- GPS radio occultation

A number of aspects were considered in the selection:

- value to GMES
- maturity of the requirements
- alternative programmes
- tension with commercial interests
- uniqueness of the proposed constellation

Finally it was decided to progress the altimeter constellation approach into Phase 2.
Future Study Direction in Phase 2

DNEPR housing 8 Altimeter
Small satellites

Radar Altimeter Geometry

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Range</th>
<th>Fast Delivery (&lt;3 hr)</th>
<th>Climate Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSH</td>
<td>-</td>
<td>10 cm</td>
<td>3.5 cm</td>
</tr>
<tr>
<td>Significant Wave Height</td>
<td>0.5 – 20 m</td>
<td>8% (8 cm @ 2m)</td>
<td>1% (2 cm @ 2m)</td>
</tr>
<tr>
<td>Wind speed</td>
<td>0-20 m/s</td>
<td>2.0 m/s</td>
<td>1.5 m/s</td>
</tr>
<tr>
<td>Along Track Sampling</td>
<td>-</td>
<td>&lt; 10 km (open ocean)</td>
<td>&lt; 1 km (open ocean)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&lt; 300m (over sea ice)</td>
<td>&lt; 300m (over sea ice)</td>
</tr>
<tr>
<td>Coverage</td>
<td>-</td>
<td>3-10 days</td>
<td></td>
</tr>
<tr>
<td>Revisit Time</td>
<td>-</td>
<td>2-3 days</td>
<td></td>
</tr>
</tbody>
</table>

* Match
** Requirement relaxation
Tsunami detection from altimeter

Satellite track (26/12/04)

Change in sea level produced by tsunami (m)

Used data available within 3hr - 24 satellite constellation able to do much better, e.g. better space-time sampling + direct readout
Conclusion

- SSTL is undertaking a study for ESA looking at the potential of DMC concepts to complement the planned GMES programme
- An overview of DMC has been provided and some of the current applications illustrated that are already addressing European environmental requirements
- A gap analysis has been implemented and identified areas where the current Sentinel Mission cannot satisfy the user requirements
- The study has shown that the DMC concept can address some of these gaps, particularly frequency of revisits.
- Enhanced concepts of the DMC have also been reviewed and shown to further address some of the identified gaps
- Finally, SSTL plans to review in greater depth a constellation approach for a suite of altimeters with a high frequency of observations
Thank you

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