Sentinel-1 Mission Overview

Marcus Engdahl, Pierre Potin, ESA

Conference on “Synthetic Aperture Radar: A global solution to geological hazards”
2 to 6 September 2013, ICTP, Trieste, Italy
• Copernicus / GMES context, the Sentinels

• Sentinel-1 Mission Overview, SAR Modes & Products

• Sentinel-1 Preliminary Observation Scenario, Sentinels Data Policy

• ESA Capacity-building, Training, SAR Toolboxes
Global Monitoring for Environment and Security (GMES): now called “Copernicus”

- EU/ESA co-funded program aiming at providing operational services based on Earth observation, and in-situ data.
- Provides relevant information to policy-makers, institutional EU + MS authorities (Core services), and local/regional users (Downstream services)

**Space Component – developed & coordinated by ESA**

- Sentinels
- Contributing (national) Missions

**In-situ component – coordinated by EEA**

- Observations mostly within national responsibility, with coordination at European level
- Air, sea- and ground-based systems and instrumentations

**Service component – coordinated by EC**

- Mapping and forecasting services: Land, Marine, Atmosphere, Emergency, Security and Climate Change
<table>
<thead>
<tr>
<th>Mission</th>
<th>Description</th>
<th>Launch Date(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sentinel-1 (A/B) – SAR imaging</td>
<td>All weather, day/night applications, interferometry</td>
<td>2014 /2015</td>
</tr>
<tr>
<td>Sentinel-2 (A/B) – Multi-spectral imaging</td>
<td>Land applications: urban, forest, agriculture,... Continuity of Landsat, SPOT</td>
<td>2014 /2016</td>
</tr>
<tr>
<td>Sentinel-3 (A/B) – Ocean and global land monitoring</td>
<td>Wide-swath ocean color, vegetation, sea/land surface temperature, altimetry</td>
<td>2014/2017</td>
</tr>
<tr>
<td>Sentinel-4 (A/B) – Geostationary atmospheric</td>
<td>Atmospheric composition monitoring, trans-boundary pollution</td>
<td>2019/2027</td>
</tr>
<tr>
<td>Sentinel-5 precursor/ Sentinel-5 (A/B) – Low-orbit atmospheric</td>
<td>Atmospheric composition monitoring</td>
<td>2015/2020/2027</td>
</tr>
<tr>
<td>Jason-CS (A/B) – Low inclination Altimetry</td>
<td>Sea-level, wave height and marine wind speed</td>
<td>2018/2023</td>
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</tbody>
</table>
Sentinel–1: C-band SAR mission

✓ Data continuity of ERS and ENVISAT missions

✓ Dedicated Copernicus radar imaging mission for ocean, land and emergency services

✓ Applications:
  • monitoring sea ice zones and the arctic environment
  • surveillance of marine environment (e.g. oil spill monitoring)
  • maritime security (e.g. ship detection)
  • wind, wave, current monitoring
  • monitoring of land surface motion (subsidence, landslide, tectonics, volcanoes, etc.)
  • mapping of land surfaces: forest, water and soil, agriculture, etc.
  • support to emergency / risk management (e.g. flooding, etc.) and humanitarian aid in crisis situations
Sentinel-1 Mission Facts

- **C-Band** Synthetic Aperture Radar Payload (at 5.405 GHz)
- Constellation of two satellites (A & B units)
  - Launch of Sentinel-1A scheduled for early 2014 (Sentinel-1B launch indicatively mid 2015, subject to EC funding)
  - 7 years design life time with consumables for 12 years
- Near-Polar sun-synchronous (dawn-dusk) orbit at 698 km
  - 12 days repeat cycle (1 satellite), 6 days for the constellation
  - Both Sentinel-1 satellites in the same orbital plane (180 deg phased in orbit)
  - Orbital tube 100m
- **Duty cycle**: 25 minutes of High Bit Rate imaging per orbit
  - On-board data storage capacity (mass memory) of 1400 Gbit
  - Two X-band RF channels for data downlink with 2 X 260 Mbps
  - On-board data compression using Flexible Dynamic Block Adaptive Quantization (FDBAQ)
  - Optical Communication Payload (OCP) for data transfer via laser link with the GEO European Data Relay Satellite (EDRS)
Sentinel-1 Spacecraft – SAR elements

SAR Antenna Subsystem (SAS)
Aperture: 12.3 m x 0.84 m,
14 Tiles each with 20 dual polarized resonant waveguide arrays (5 SAS Panels)

SAR Electronic Subsystem (SES)
on S/C SES Panel
Sentinel-1A platform
Sentinel-1A SAR Antenna
Sentinel-1 SAR can be operated in 4 exclusive imaging modes with different resolution and coverage:

<table>
<thead>
<tr>
<th>Mode Rate</th>
<th>SAR Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Bit Rate (HBR)</td>
<td>IW</td>
</tr>
<tr>
<td></td>
<td>EW</td>
</tr>
<tr>
<td></td>
<td>SM (S1 → S6)</td>
</tr>
<tr>
<td>Low Bit Rate (LBR)</td>
<td>WV</td>
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</table>

Polarisation schemes for IW, EW and SM:
- single polarisation: HH or VV
- dual polarisation: HH+HV or VV+VH

For Wave mode: HH or VV

For all of these operating modes, the same family of products is available to the users.
Terrain Observation by Progressive Scans

- The beam is swept forward in the direction of travel
- Results in time-varying Doppler centroid
- Requires adaptation of InSAR processing chains
## Sentinel-1 SAR Modes Performance

<table>
<thead>
<tr>
<th>Mode</th>
<th>Access Angle</th>
<th>GR Single Look Resolution</th>
<th>Swath Width</th>
<th>Polarisation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strip Map (SM)</td>
<td>20-45 deg.</td>
<td>Range 5 m</td>
<td>&gt; 80 km</td>
<td>HH or VV or HH+HV or VV+VH</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Azimuth 5 m</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interferometric Wide Swath (IW)</td>
<td>&gt; 25 deg.</td>
<td>Range 5 m</td>
<td>&gt; 250 km</td>
<td>HH or VV or HH+HV or VV+VH</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Azimuth 20 m</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extra Wide Swath (EW)</td>
<td>&gt; 20 deg.</td>
<td>Range 20 m</td>
<td>&gt; 400 km</td>
<td>HH or VV or HH+HV or VV+VH</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Azimuth 40 m</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wave mode (WM)</td>
<td>23 deg.</td>
<td>Range 5 m (TBC)</td>
<td>&gt; 20 x 20 km</td>
<td>HH or VV</td>
</tr>
<tr>
<td></td>
<td>&amp; 36.5 deg.</td>
<td>Azimuth 5 m (TBC)</td>
<td>Vignettes at 100 km intervals</td>
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</table>

### For All Modes

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<tbody>
<tr>
<td>Radiometric accuracy (3 $\sigma$)</td>
<td>1 dB</td>
</tr>
<tr>
<td>Noise Equivalent Sigma Zero</td>
<td>-22 dB</td>
</tr>
<tr>
<td>Point Target Ambiguity Ratio</td>
<td>-25 dB</td>
</tr>
<tr>
<td>Distributed Target Ambiguity Ratio</td>
<td>-22 dB</td>
</tr>
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</table>
LEVEL-0 PRODUCTS
Compressed, unprocessed instrument source packets, with additional annotations and auxiliary information to support the processing.

LEVEL-1 PRODUCTS
Level-1 Slant-Range Single-Look Complex Products (SLC):
Focused data in slant-range geometry, burst-by-burst, single look, containing both phase and amplitude information.

Level-1 Ground Range Detected Geo-referenced Products (GRD):
Focused data projected to ground range, detected and multi-looked. Data is projected to ground range using an Earth ellipsoid model, maintaining the original satellite path direction and including complete geo-reference information.

LEVEL-2 PRODUCTS
Level-2 Ocean products
Ocean wind field, swell wave spectra and surface radial velocity information as derived from SAR data.
Preliminary Sentinel-1 Observation Scenario

For observation of land motion
Implement a **pre-defined** and **conflict-free** observation plan, aiming at fulfilling, to the maximum feasible extent, the observation requirements from:

- The **mission requirements**
- The **Copernicus services**
- The **use by ESA / EU Member States**

In addition, on best effort basis and in order to ensure some **continuity of ERS/ENVISAT**, requirements from the **science** community are also considered, as well as contributions to **international cooperation** activities.

→ Need to find *a priori* the **solutions on the potential conflict** among users (e.g. different SAR operation modes / polarisation required over same geographical area)

→ Clear **priority** given to Copernicus use, National services and use by ESA/EU Member States

→ The aim is to image **all land-masses** on a regular basis.

→ The pre-defined mode over land is **IWS**

→ The **Full Operations Capacity is reached with the 2-satellite constellation + the European Data-Relay Satellite (EDRS)**.
Tectonic Areas consist of:
- Land motion Areas Europe, acquired in IWS, polarization VV and
- Global Land motion Areas, acquired in IWS, polarization HH

Observation frequency:
- Ascending and descending acquisitions, every 2\textsuperscript{nd} cycle (once every 24 days)
Possible extension of the observation scenario (red zones):

- Feasibility is being evaluated through satellite acquisition planning simulations
- Whether this can be realised depends on experience gathered during the ramp-up phase
- More imaging resources available after launch of S-1B
- A procedure is in place for regular updates of the observation scenario during routine operations
Sentinel Data Policy

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full and open access to Sentinel data to all users

- Aim for maximum availability of data & corresponding access services
- Support to increasing demand of EO data for
  -> implementation of environmental policies
  -> climate change initiatives

In practical terms:

- Anybody can (has the right to) access acquired Sentinel data
- Licenses for the Sentinel data are free of charge
- Online access with simple user registration, for free, within the technical and financial limits (available operations budget)
- Datasets over selected supersites (for example Etna) will be made available early
- More information will be available next week in The Living Planet Symposium
The Sentinel-1 mission will provide **continuity** to ERS and ENVISAT C-band SAR with **improved performance and revisiting times**

Sentinel-1 will be operated with a **predefined routine observation plan** currently under definition, fulfilling in priority the **requirements from the Copernicus services and from the ESA / EU Member States**

Main tectonic areas will be covered **in both ascending and descending acquisitions every 24 days. (preliminary plan!)**

Towards a **free and open access** to Sentinel data for all users, **within technical and budget constraints / restrictions.**
ESA Capacity-Building: Training Courses

ESA organises a large number of **EO training** at several levels:

- **Eduspace** – a website for secondary schools and schoolteachers
- **EO Summer School** – for Early Career Scientists. A two-week intensive course organised every two years in *ESA-ESRIN, Frascati, Italy.*
- **Advanced EO Training for PIs** – a series of regular one week long advanced thematic training courses.
  - *Advanced Ocean Training Course*: 2006, 2009, **2013**
  - *Advanced Atmospheric Training Course*: 2008
  - *Advanced Course on Radar Polarimetry*: 2011, 2013
- **“Tiger” Training Courses** – capacity-building in Africa
- **Other Training Courses** are organised on an ad hoc basis.
Next ESA SAR Toolbox: A free, open-source multi-mission SAR and InSAR toolbox.

**InSAR functionality in NEST 5A:**
- Co-registration, resampling, spectral and phase filtering
- Interferogram and coherence-image generation
- Spectral and Phase Filtering
- Topographic phase removal, DEM generation and DEM assisted co-registration
- Optimal Master selection
- Integrated Unwrapper + Bridge to 3rd party Unwrapper (SNAPHU)
- DEM generation and DEM assisted co-registration
- (3-4 passes) DInSAR
- ERS-Envisat Cross-InSAR

**Sentinel-1 Toolbox will be based on NEST 5A**
- Full SAR and InSAR support including InSAR with TOPS
- Development will start in Q4 2013
Thank You!
# Process for collecting and implementing the Sentinel observation requirements

<table>
<thead>
<tr>
<th>Group</th>
<th>Source of Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>GMES services and GMES use</td>
<td>Extrapolation of GMES Data Access Data Warehouse requirements</td>
</tr>
<tr>
<td></td>
<td>Direct discussions with GMES services and EU Agencies (e.g. EMSA)</td>
</tr>
<tr>
<td>National services and use by ESA and EU Member States</td>
<td>Discussions with Member States Delegations</td>
</tr>
<tr>
<td></td>
<td>Reply to Collaborative Ground Segment questionnaire (in the framework of the GOCG)</td>
</tr>
<tr>
<td>Scientific use, on-going projects, continuity of ERS/ENVISAT</td>
<td>Recommendations from scientists at key SAR workshops (FRINGE, SEASAR), Sentinel-2 and -3 workshops, SEN4SCI, etc.</td>
</tr>
<tr>
<td></td>
<td>ESA GSE Projects (e.g. Polar View, MARISS, Terrafirma, GMFS, etc.)</td>
</tr>
<tr>
<td></td>
<td>Glob-series projects, CCI, SEOM, etc.</td>
</tr>
<tr>
<td></td>
<td>Extrapolation of ERS/ENVISAT projects</td>
</tr>
<tr>
<td>International Initiatives, International cooperation</td>
<td>GEO/CEOS (e.g. FCT, GFOI, Geo-hazard Supersites), IGOS, FAO, REDD, PSTG, IICWG, GCOS, CliC, TIGER, DRAGON, etc.</td>
</tr>
<tr>
<td></td>
<td>Requests from international partners (e.g. US (NOAA / NASA / USGS), Australia, China, etc.)</td>
</tr>
<tr>
<td>Other use including use for commercial value-adding</td>
<td>EARSC, etc.</td>
</tr>
</tbody>
</table>