ESA update on Sentinel-2 and Sentinel-3

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IOCCG-222, Perth, Australia 8th February 2017
Overview
Copernicus Overview

In-situ component not represented here

- Overall Programme Management
- Coordination of the Services Component
- Cross-cutting user-uptake activities

EUMETSAT
- Operations of S3 (marine part), S4, S5, S6 and Jason-3

- Technical coordination of the Space Component
- Development and procurement of Copernicus Sentinel missions
- Coordination and procurement of Contributing Missions data
- Operations of S1, S2, S3 (land part), S5P

...plus other partners...

A Programme of the European Union

www.copernicus.eu
The Copernicus Sentinel Deployment Schedule

Legend:
- QAR: Qualification Acceptance Review
- FAR: Flight Acceptance Review
- PSR: PreStorage Review
- In-orbit Commissioning

Sentinel 1A
- 2014: Flight Acceptance Review
- 2015: On-ground Storage

Sentinel 1B (recurrent)
- 2016: Flight Acceptance Review
- 2017: On-ground Storage

Sentinel 1C (recurrent)
- 2018: Flight Acceptance Review
- 2019: On-ground Storage

Sentinel 1D (recurrent)
- 2020: Flight Acceptance Review
- 2021: On-ground Storage

Sentinel 2A
- 2016: Flight Acceptance Review
- 2017: On-ground Storage

Sentinel 2B (recurrent)
- 2018: Flight Acceptance Review
- 2019: On-ground Storage

Sentinel 2C (recurrent)
- 2020: Flight Acceptance Review

Sentinel 2D (recurrent)
- 2021: Flight Acceptance Review

Sentinel 3A
- 2017: Flight Acceptance Review
- 2018: On-ground Storage

Sentinel 3B (recurrent)
- 2019: Flight Acceptance Review
- 2020: On-ground Storage

Sentinel 3C (recurrent)
- 2021: Flight Acceptance Review

Sentinel 3D (recurrent)
- 2022: Flight Acceptance Review

Sentinel 4A (on MTG-S1)
- 2018: Flight Acceptance Review
- 2019: On-ground Storage

Sentinel 5 Precursor
- 2018: Flight Acceptance Review
- 2019: On-ground Storage

Sentinel 5A delivery to MetOp-SG
- 2019: Flight Acceptance Review
- 2020: On-ground Storage

Sentinel 5B Acceptance Review
- 2021: Flight Acceptance Review
- 2022: On-ground Storage

Sentinel 5C Acceptance Review
- 2022: Flight Acceptance Review
- 2023: On-ground Storage

Sentinel 4B delivery to MTG-S2 (tbc)
- 2021: Flight Acceptance Review

Sentinel 4A delivery to MTG-S1 (tbc)
- 2019: Flight Acceptance Review

Sentinel 5A (on MetOp-SG A)
- 2020: Flight Acceptance Review
- 2021: On-ground Storage

Sentinel 5B (tbc)
- 2022: Flight Acceptance Review

Sentinel 5C (tbc)
- 2023: Flight Acceptance Review

Sentinel 6A
- 2024: Flight Acceptance Review
- 2025: On-ground Storage

Sentinel 6B
- 2026: Flight Acceptance Review

Legend:
- Tentative launch date
- In-orbit Commissioning

Status: 22 March 2016
Sentinel-2
Superspectral imaging mission

Mission profile

- **Two** Spacecraft operating in twin configuration
- Sun-synchronous orbit **786 km**, **LTDN** 10:30 AM
- Multispectral instrument with **13** spectral bands (**VIS, NIR & SWIR**), at **10**, **20** and **60 m** spatial resolution
- **290 km** swath width
- **5 days** revisit at Equator with 2 satellites
- **7 years** design life time, consumables for 12 years

Sentinel-2 A/B/C/D
Super-spectral imaging

Source: http://esamultimedia.esa.int/docs/EarthObservation/Sentinel-2_ESA_Bulletin161.pdf

↑ Spatial resolution versus wavelength: Sentinel-2’s span of 13 spectral bands, from the visible and the near-infrared to the shortwave infrared at different spatial resolutions ranging from 10 to 60 m on the ground, takes land monitoring to an unprecedented level.
An ever increasing range of applications for Sentinel-2

- **Regional to Urban Applications**
  - European Land cover classification, high resolution layers & change.
  - Coastal zones/bathymetry

- **Emergency management**

- **Global Land use & change**

- **Geology**

- **Glaciers & Ice**

- **Agriculture, Forests & Carbon, Vegetation monitoring**

- **Water quality**
### Sentinel-2 Products

<table>
<thead>
<tr>
<th>Name</th>
<th>High-level Description</th>
<th>Production</th>
<th>Preservation Strategy</th>
<th>Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level-1B</td>
<td><em>Top-of-atmosphere radiances in sensor geometry</em></td>
<td>Systematic</td>
<td>Long-term</td>
<td>~27 MB (each 25x23km²)</td>
</tr>
<tr>
<td>Level-1C</td>
<td>Top-of-atmosphere reflectances in cartographic geometry</td>
<td>Systematic</td>
<td>Long-term</td>
<td>~500 MB (each 100x100km²)</td>
</tr>
<tr>
<td>Level-2A</td>
<td>Bottom-of-atmosphere reflectances in cartographic geometry</td>
<td>On user side*</td>
<td>N/A</td>
<td>~600 MB (each 100x100km²)</td>
</tr>
</tbody>
</table>

*Pilot processing in preparation - See next slides*

*: Systematic global production of L2A is currently being prepared.

**: [https://sentinels.copernicus.eu/web/sentinel/toolboxes/sentinel-2](https://sentinels.copernicus.eu/web/sentinel/toolboxes/sentinel-2)
S2 Data Quality Organization

- **S2 Mission Performance Centre (MPC)**
  - Calibration of the MSI sensor and L1/L2A processors
  - Validation of L1/L2A products
  - L1 Production Quality Control
  - L1/L2A processors prototyping/maintenance

- **Centre National d’Études Spatiales (CNES)**
  - Support for L1 products validation
  - Support for GRI validation

- **S2 Quality Working Group (QWG)**

- **Sentinel-2 Validation Team**
  - Meeting held in Nov 2016
### L1C Product Data Quality

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Description</th>
<th>Measured performance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Absolute geolocation (without ground control points)</strong></td>
<td>The geo-location uncertainty shall be better than 20 m at 2σ confidence level (without Ground Control Points).</td>
<td>&lt; 9.2 m at 2σ</td>
</tr>
<tr>
<td><strong>Multi-spectral Registration</strong></td>
<td>The inter-channel spatial co-registration of any two spectral bands shall be better than 0.30 of the coarser achieved spatial sampling distance of these two bands at 3σ confidence level.</td>
<td>&lt; 0.26 pixel at 3σ</td>
</tr>
<tr>
<td><strong>Absolute radiometric uncertainty</strong></td>
<td>The absolute radiometric uncertainty shall be better than 5 % (goal 3%).</td>
<td>B1 to B9: &lt; 5%±2%</td>
</tr>
<tr>
<td><strong>SNR</strong></td>
<td>The Signal-to-Noise Ratio (SNR) shall be higher than specified values</td>
<td>All bands compliant with &gt; 20% margin</td>
</tr>
</tbody>
</table>

- Fore more details on products quality status and validation, see
- [http://esaconferencebureau.com/2016-events/16c20/presentations](http://esaconferencebureau.com/2016-events/16c20/presentations)
L2A Production Pilot Project

✓ A systematic production of L2A products over Europe started in September 2016.

✓ The Sen2Cor processor (version 2.3.0) has been integrated in the ESA-RSS environment (Research and Support System).

✓ It generates daily up to 300GB of L2A products data (~600 Tiles per Day).

✓ L2A products will be made available in Q1 2017 through http://scihub.esa.int

✓ Products granularity of L2A will be the same of L1C available on SciHub.

✓ L2A product format is aligned with the new compact naming convention.
Sentinel-2 acquisition plan

The Sentinel-2 baseline observation scenario systematically covers all land surfaces between 56° South latitude and 84° North latitude, including also:

- Major islands (greater than 100 km² size), EU islands and all the other small islands located at less than 20 km from the coastline
- The whole Mediterranean Sea as well as all inland water bodies and closed seas

Currently 10 days revisit in Europe, Africa and Greenland

Rest of the World alternating in 10 days and 20 days

→ 10 days revisit of all land masses to be reached Q1/2017, using EDRS service / 4th X-band station

Sentinel-2 acquisition plan published online ahead of every repeat cycle at https://sentinels.copernicus.eu/web/sentinel/missions/sentinel-2/acquisition-plans
Sentinel-2 acquisition plan: “Winter 2016/2017” EASTERN cycle
Sentinel-2 acquisition plan: “Winter 2016/2017”
WESTERN cycle
Use of temporary S2A spare capacity (Northern Winter 2016/2017) to monitor Antarctica:

S2B will bring more capacity for special campaigns (coral, ice)
Mission Status

- The mission operated nominally during the reporting period. Access to the routine production of Sentinel-2A ortho-rectified Level-1C products is available at https://s1hub.copernicus.eu.
- To date, a total of 60,528 users have self-registered on the Sentinel Scientific Data Hub. About 301 thousand Level-1C products are available for download, cumulating a total volume of 538 TB. Overall, a total volume of 2.37 Petabytes has been downloaded by the user communities.
- The acquisition scenario has been executed with an average of 13.7 minutes of MSI sensing time per orbit. Sentinel-2A is acquiring Europe, Africa and Greenland at 10 days revisit. The northern latitudes ‘winter scenario’ is being executed whereby the whole of Asia/Oceania and the Americas are acquired with a 10-day revisit, in an alternating pattern.
- The Flight Operations Segment (FOS) is ensuring the monitoring, control and commanding of the satellite is operating normally.
- The status of the satellite is nominal. The validation campaign for the final software update for the MMFUs in its final stage, the first part of the MMFU final software update will take place on 17 January, a second step is planned later.
- The OCP Experimentation Phase is ongoing with Alphasat.
- X-band data acquisitions are routinely performed by the PDGS over Mares, Marañon and Oviedo core stations. The acquired data is systemically processed to Level-0 and Level-1 products, circulated, and archived.
- Operations are nominally performed at the Processing and Archiving Centres and other PDGS operational services (i.e. Mission Performance Centre, Precise Orbit Determination, Wide Area Networks).
- The reprocessing of the data acquired during the SZA commissioning phase and up to the data access opening in early December 2015 is progressing; reprocessed products in baseline 02.04 are available for downloads up to 20th November 2015.

Outlook

- MSI decontamination, resulting in a planned mission outage, will take place between 09/01 07:30 UTC and 10/01 06:30 UTC.
- The first step of the final MMFU software update will take place 17 January, resulting in a planned mission outage between 05:44:46 UTC and 18:46:12 UTC.
- Continued reprocessing campaign: expected finalisation within Q3 2017.

https://sentinel.esa.int/web/sentinel/missions/sentinel-2/mission-status
S2 Next steps

Reprocessing archive to single tiles & new format

New Format (TCI, filenames)

Single tiles

Atmospheric correction ‘Pilot Europe’

EDRS/ 4th X-band: global 10-day revisit S2A

Atmospheric correction operational

Large reprocessing campaign with new geometry & atm. correction

~5 PB

Validated Geo Reference (GRI) DEM evolution?

INCerase OF CAPACITY, PERFORMANCE and HOMGENEITY

Continued harmonisation with partner missions (e.g. GRI for Landsat-8)

S2B Space Segment

S2B Launch
6 Mar 2017

S2 Mission
ROR
~ autumn 2017

S2 geometric Baseline
2018
S2B launch preparations

- Spacecraft and GSE packing: prior to Christmas 2016 DONE
- Antonov S2B cargo shipment: 5 Jan. 2017 DONE
- S2B fueling: 7 Feb. 2017 DONE
- Dress rehearsal prior to launch: 2 Mar. 2017

S2B Launch: 6 Mar. 2017 (CET)
Marine Applications of S2A

Craig Donlon @craigdonlon · 5h
Superfine details of the Carrarang region in Western Australia seen by @ESA_EO @CopernicusEU #sentinel2 on 01/12/2016
The Copernicus Sentinel-3B Mission:
Craig Donlon Sentinel-3 Mission Scientist (ESA/ESTEC)
**Sentinel-3B: status**

- Sentinel-3B FAR planned for Sept-Oct 2017, still compatible with a launch before end 2017
- Flight Acceptance Review – October 2017
- Launch on Rockot from Plesetsk in late 2017.
Sentinel 3 Overall Status: Sentinel-3B

- Sentinel-3B activities restarted in Q2 2016 after Sentinel-3A launch
- Implementation of REX (Return of Experience) from S3A on-going
  a. More than 350 “lessons learned items” identified
- Key activities performed so far
  a. Swap of MWR RPM after retrofit
  b. Execution of reduced Platform health check (after several month of storage)
  c. Execution of reaction wheels run down test
  d. Installation of Platform MLI
  e. Integration of CRS, delivered after repair and retest
  f. Integration of SADM, delivered after execution of “extended” acceptance testing agreed after lengthy investigation of issue on A model
  g. Integration and test of Topo Payload (SRAL, MWR and DORIS)
  h. IST-1 (Integrated System Test) Part 1 on-going
Sentinel 3 Overall Status: Sentinel-3B

- **At instrument level**
  
a. Topo payload fully available and integrated, no open issues
b. SLSTR PFM assembly and testing so far according to plan, with no specific issue
   - OME completed all testing and was delivered by JOP to Leonardo before summer
   - SLSTR integration, test in ambient and mechanical test campaign completed by mid-October
   - Instrument now at RAL for TVAC Calibration before delivery to Prime planned mid-Feb 2017
c. OLCI-B model suffered major anomaly (repeat of anomaly which affected the A instrument) during Instrument TVAC in July 2016
   - Decision to refurbish all 5 cameras, with new gluing process. This implies:
     i. Refurbishment and Test of 5 FPAs (TAS-I)
     ii. Re-assembly and Test of 5 cameras (TAS-F)
     iii. Re-assembly and Test of OLCI-B
   - Delivery of OLCI-B for S/L integration by mid June 2017
Sentinel-3B Detailed Status: Current Scenario for S/L finalisation and launch

- In view of late delivery of OLCI, Sentinel-3B S/L Integration and test activities reorganised as follows:
  
b. Satellite TVAC Test without OLCI FM (OLCI simulator used)
  
c. Integration of OLCI and execution of following system tests
    - Acoustic
    - Radiated Emissions
    - IST2
    - PVT & Mission Profile test (with S3B flight Software)
    - SVT (part2)

- Sentinel-3B FAR planned for Set/Oct 2017, with a launch on Rockot currently scheduled end of Nov. 2017
User driven evolution...

- The science of today become the operations of tomorrow...
- Several elements of user driven evolution for the S3A mission have emerged and have been addressed:
  - 100% SRAL SAR coverage instead of just coastal zones and sea ice → better SNR
  - New products requested including L1A SAR data → Performance Evolution
  - Orbit phase optimization for topography mission → better sampling of mesoscale structure
  - Tandem flight for S3A/B
- Each has been taken up by the EC following user request and extensive technical and programmatic discussions with ESA and EUMETSAT
- An excellent process has been established to respond effectively and relatively quickly to these large mission changes.

<table>
<thead>
<tr>
<th>Product Level</th>
<th>Product Description</th>
<th>Relevance for</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1A</td>
<td>Unpacked L0 data processed to engineering parameters with geo-location information</td>
<td>SAR processing specialists allowing fundamental studies on SAR processing such as Doppler beam formation and calibration studies using ground-based Transponders</td>
</tr>
<tr>
<td>L1B-S</td>
<td>Geo-located, Calibrated gathered azimuth formed complex (I and Q) power echoes after slant/Doppler range correction</td>
<td>geophysical retrieval algorithm developers (over ocean, land and ice surfaces), surface characterisations studies (e.g. impact of sea state bias, wave directional effects etc) and QC systems</td>
</tr>
<tr>
<td>L1B</td>
<td>Geo-located, Calibrated Multi-looked power waveforms</td>
<td>geophysical retrieval algorithm developers and QC systems</td>
</tr>
</tbody>
</table>
Optimized orbit phasing of S3A and S3B

- The current baseline orbit phasing between S3A and S3B is a 180° angle phase separation on the same orbital plane.
  - This minimises the optical mission coverage revisit time.
- For the Topography mission in the baseline scenario S3B essentially duplicates the information acquired by S3A at the mesoscale (25-50 km)
  - measurements are separated by 2 days and 50 km and are consequently highly correlated.
  - Significant areas remain poorly sampled after 4 days
- In terms of CMEMS, in the baseline orbit configuration S3B will be of marginal value for ocean topography applications.
- What could be an alternative orbit phasing for S3A and S3B?
Mesoscale sampling...
Optimising the Constellation: Sentinel-3B phasing to 140° (instead of 180°) after 4 days
Figure 7. Complete coverage of OLCI after mitigation of sun-glint with S3B set in 140° phasing with S3A is reached after 3 days.
le fameux tandem
Outline

- Scientific Motivation
- Key Elements Per Sensor
- Draft Requirements
- Implementation status
A multi-Satellite mission

To meet Mission Requirements

The Sentinel-3 Mission is composed of two identical satellites

Flown together in the same orbital plane separated by 140°

Follow-on Satellites (Sentinel-3C and Sentinel-3D) are now being procured.

Sentinel-3A: 2015-

Sentinel-3B: 2017-
**Sentinel-3: Satellite Orbit details**

S3B has a 140° phase separation on the same orbital plane

**Instrument Swath Patterns**

SRAL tracks at the equator:
- S3A = 104 km track separation
- S3A+B = 52 km separation

- **SRAL (＞2 km) and MWR (20 km) nadir track**
- **1400 km SLSTR (nadir)**
- **740 km SLSTR (oblique)**
- **1270 km OLCI**

**Ground Track Pattern after 4 days (S3A and S3B)**

**SRAL orbit drivers:**
- Ground track repeatability,
- Dense spatial sampling

**Orbit control requirement:**
- Ground track dead-band ±1km

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<table>
<thead>
<tr>
<th>Orbit type</th>
<th>Repeating frozen SSO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repeat cycle</td>
<td>27 days (14 + 7/27 orbits/day)</td>
</tr>
<tr>
<td>LTDN</td>
<td>10:00</td>
</tr>
<tr>
<td>Average altitude</td>
<td>815 km</td>
</tr>
<tr>
<td>Inclination</td>
<td>98.65°</td>
</tr>
</tbody>
</table>
A tandem phase operation of the A/B pair (and indeed other pairs or triplets of Sentinel-3 satellites) with ~30 s separation will support this level of relative cross-calibration, and will be significantly more effective than relying on coincidences between the sensors flying with significant separation in time. Most obviously, this is because the amount of data that overlaps between the sensors with suitable characteristics will be orders of magnitude greater.

- **The S3 mission includes 4 satellites**

The main challenge is to reduce uncertainties when comparing data from different satellite missions within the Sentinel-3 constellation. When data are obtained from two satellites at different times but at the same location, there is significant correlated uncertainty:

- Uncertainty due to ocean geophysical space and time variability that complicates inter-comparison, especially in regions dominated by mesoscale structure (1-10 days, <10-50 km) that are particularly lucrative to understand inter-satellite bias;
- Uncertainty due to atmospheric space and time variability,

Both issues introduce uncertainty to the direct inter-calibration of S3A and S3B. However by flying S3A and S3B in tandem separated by ~30 seconds on the same ground track (±1 km) maximizes the correlation between these uncertainties so that for all practical purposes they can be ignored: the difference between any S3A and its corresponding S3B measurement is solely due to instrumental aspects.
A tandem phase for the S3 Mission was studied at PDR AT missions but not a true tandem (ERS2/ENVISAT) and 24 hours (ERS1/2)) (eg. JASON)

The Copernicus Climate Service has been introduced only recently

Climate data records require that differences in calibration between sensors are characterised so that these calibration differences can be adjusted for in the creation of the multi-sensor climate data records.

Atmospheric and oceanographic variability can be ignored when comparing data reducing uncertainty in this respect

Need to consider tandem in A, B, C and D satellites

We can maximise the amount of data available for inter-satellite comparisons

Some aspects are unique (eg. Run S3A SRAL in SAR mode and S3B...
Tandem: Science Benefits SLSTR

- A4- 6 month Tandem is useful to all channels of the SLSTR
- ~30 s separation will support an appropriate level of relative cross-calibration, and will be more effective than relying on co-incidences between the sensors flying with significant separation in time. (cf. issues with AATSR and ATSRs)
- The distribution of target scenes available for inter-comparison will be significantly more favourable:
  - wide range of scene temperatures;
  - multiple coincidences extracted across a full range of atmospheric conditions;
  - at all latitudes;
  - No VIS BRDF correction needed as using same geometry will give the statistical power to characterise relative calibration to the precision required.
- With a tandem phase having a satellite to satellite separation of ~30s, the change in the scene between the successive sensors becomes small enough that extreme targets such as convective cloud tops and hot deserts can be included.
- Cloud motions are small and can be adjusted for with high confidence if necessary.
- The degree of surface heating/cooling in this time is small enough to neglect.
- Data gap between ENVISAT AATSR and Sentinel-3A SLSTR: provide a means to transfer the AATSR through to SLSTR-A/SLSTR-B era using IASI-A&B(&C) colocations.

AATSR - ATSR2 12um BT (K) with 30 minutes difference
Tandem: Science Benefits OLCI

- Tandem allows OLCI A & B inter-comparisons at practically identical times and geometries
- Understanding the absolute and relative bias between the in-flight OLCI-A diffusers and the pristine OLCI-B unit diffusers provides a unique reference to link both missions together.
- General benefit as for SLSTR (more data, limit atmosphere and ocean variability, BRDF same)
- Important at vicarious adjustment sites (MOBY, BOUSSOLE)
- Continuous comparisons are possible between both missions over all target surfaces – especially snow calibration and validation sites and around solstices
- Land BRDF is identical
- Rayleigh analysis can be improved because a tandem flight allows acquisitions with quasi-identical illumination and very close view conditions over the same surface
- Acquisitions over very similar surfaces (e.g. gyres) with exactly the same illumination/view conditions.
- A unique opportunity to improve our knowledge on the essential assumptions of such methodologies based on surface reflectance climatology, with potential insights on the methodology uncertainty analysis

Figure 6. Left: Location of MODIS-Aqua and SeaWiFS with matched solar and viewing geometries within 1°. Left: Results of the inter-comparison showing sparse matchups and large uncertainties.
Requirements (1/2)

**S3-TAN-100: A Tandem mission**, composed of a launcher injection and drift towards the Tandem position, followed by a Tandem phase and completed by a last drift phase towards the nominal operational position, shall be flown as soon as practically possible following the launch of a new satellite into the Sentinel-3 constellation (ie. in the short term this applies to the S3B. In the case of the S3C and S3D satellites the approach to be used depends on the status of the S3A and S3B satellites and will be determined closer to their respective launches). [Note: Due to the limited duration of the commissioning Phase, this implies that the Tandem phase will be flown during the Phase E1 commissioning and PDGS ramp-up phase activities.]

**S3-TAN-200:** The separation of the Sentinel-3 satellites configured in a Tandem phase shall be nominally 30 seconds or shorter.

**S3-TAN-250:** During the Tandem phase, Sentinel-3B shall be operated on the same nominal track as of Sentinel-3A.

**S3-TAN-300:** Maintaining a strict separation between satellites during the Tandem phase shall not be a driving requirement.

**S3-TAN-400:** Drift between satellite separation during the Tandem phase can be tolerated up to a maximum separation among the satellite of 60 seconds. Knowledge of the separation drift is required.

**S3-TAN-500:** The duration of a the Tandem phase shall encompass a minimum of 4 months of functional availability. [Note: SLSTR takes the longest time to switch-on due to outgassing requirements. In case of a very short initial drift phase, some more time may be required before the Instrument becomes functional. In that case, the Tandem phase should be extended accordingly].

**S3-TAN-600:** There is no requirement for near real time data feeds from the satellite being commissioned. However, data shall be made available to commissioning teams from both satellites operating in Tandem. [Note: For example, Sentinel-3B may be processed to timeliness criteria approximating a 140deg phase separation compared to Sentinel-3A allowing PDGS operations to prepare for the operational phase.]
Requirements (2/2)

**S3-TAN-700:** During the Tandem phase the requirement SY-OR-230 (The actual satellite ground track shall differ from the nominal one by less than ±1km max) applies simultaneously to both S3A and S3B satellites. [Note: As S3A and S3B shall overfly the Crete CDN1 transponder, this requirement shall ensure that the cross track separation between the transponder and each Satellite ground track will be < 1 km. This requirement does not apply to the S3B during the drift phases.]

**S3-TAN-710:** During the Tandem phase, Sentinel-3B shall acquire one full cycle of SRAL LRM that shall be directly compared to Sentinel-3A SAR acquisitions.

**S3-TAN-800:** Sentinel-3A shall maintain nominal operations throughout the Tandem phase (i.e. manoeuvres for maintaining the Tandem position shall be performed by the Sentinel-3B).

**S3-TAN-900:** Data shall be acquired continuously in normal acquisition mode from all payload instruments on Sentinel-3A and Sentinel-3B throughout the Tandem mission. It is anticipated that S3B commissioning activities and S3A manoeuvres may occur during this period and these shall take precedence over Tandem operations.

**S3-TAN-1000:** Crete CDN1 Transponder acquisitions shall be planned for each cycle of the Tandem phase for both S3A and S3B.

**S3-TAN-1100:** The introduction of the Tandem mission shall not reduce the nominal operational lifetime of the mission. Therefore the drift phases and the Tandem phase duration shall be planned to ensure the acquisition of the nominal orbit (i.e. 140deg phasing) and the completion of any remaining commissioning activity prior to the nominal start of the operational phase. [Note: The RORR –marking the start of the routine operations of S3B mission- is currently planned 9 months after the launch of S3B satellite]
Proposed scenario for a S-3 Tandem flight (Draft to be finalised)

- **S-3B Satellite commissioning phase**
  - LEOP: 3 days
  - SIOL: 2 weeks
  - Cal/Val-E1 phase: 3 - 4 months
  - Drift phase to tandem position: 1.5 months max

- **S-3B PDGS commissioning and ramp-up phase**
  - Tandem phase: 4 - 5 months

- **S-3B IOCR**
  - Cal/Val-E1 phase completion
  - OLTC validation: 2 months

- **S-3B FOS Handover**
  - Drift phase to +/- 140 deg nominal position: 1.5 months

- **S-3B Routine Operations**
  - 7 months max

- **S-3B PDGS Routine Operations**
  - 2 months min

- **Total duration**: 9 months
Implementation

- **Launch S3B higher than S3A.** The Launch of S-3B will already initiate the drift to arrive close to S-3A.

- **Drift phase1:** S-3B to reach S-3A, over 1.5 months. While still in sufficient safety distance from the S-3A position, SIOV/LEOP and commissioning of S-3B command and control can be performed in this phase. S-3B data commissioning can start.

- **Tandem Phase:** Once the commissioning of the command and control of S-3B is completed and confirmed to be OK, the approach to the actual tandem position will be initiated. A Tandem phase of 4-5 months then follows.
  a. S-3A maintains normal operations.
  b. S-3B follows S-3A with a time distance of 30 seconds, which corresponds to a separation in position of 210 km.
  c. S-3B is recording data which will then be compared with the S-3A data and used as common reference.

- **Drift phase2:** S-3B to move away from S-3A and arrive at its baseline position at +/- 140 deg to S-3A. Typical duration of this phase would be 1.5 months.
Next Steps

- Detailed discussions and preparations for the tandem phase with EUMETSAT
- Detailed discussions and preparation with Sentinel-3B (contracted) validation teams on what to implement to gain maximum benefit from the Tandem
- Detailed discussion with S3VT activities to gain maximum benefit from the Tandem
- Discussion with CCI regarding potential support for climate assessment activities associated with the Tandem
• Launch S3B higher than S3A. The Launch of S-3B will already initiate the drift to arrive close to S-3A.

• Drift phase1: S-3B to reach S-3A, over 1.5 months. While still in sufficient safety distance from the S-3A position, SIOV/LEOP and commissioning of S-3B command and control can be performed in this phase. S-3B data commissioning can start.

• Tandem Phase: Once the commissioning of the command and control of S-3B is completed and confirmed to be OK, the approach to the actual tandem position will be initiated. A Tandem phase of 4-5 months then follows.
  a. S-3A maintains normal operations.
  b. S-3B follows S-3A with a time distance of 30 seconds, which corresponds to a separation in position of 210 km.
  c. S-3B is recording data which will then be compared with the S-3A data and used as common reference.

• Drift phase2: S-3B to move away from S-3A and arrive at its baseline position at +/- 140 deg to S-3A. Typical duration of this phase would be 1.5 months.
Current status

- Detailed discussions and preparations for the tandem phase with EUMETSAT
- Detailed discussions and preparation with Sentinel-3B (contracted) validation teams on what to implement to gain maximum benefit from the Tandem
- Detailed discussion with S3VT activities to gain maximum benefit from the Tandem
- Discussion with CCI regarding potential support for climate assessment activities associated with the Tandem
Conclusions

- Successful launch of Sentinel-3A on 16th February 2016
- Satellite and payload is stable and fully commissioned
- All ground segment facilities supporting Sentinel-3 are being commissioned both at ESA and EUMETSAT to full operations
- Validation activities are well advanced and dedicated projects are in place to develop a culture of FRM validation.
- The Mission is responding to user needs and evolving to meet those needs (e.g., instrument operating modes, orbit optimisation, new products, tandem...)
- Contract signed with Thales Alenia Space to build Sentinel-3C and -3D Satellites on 9th February 2016
  - Delivery of the C and D models by end 2021, well in advance compared to the predicted lifetime of the A and B models (7 years min from start of operations)
- With the inclusion of the C and D models to the fleet of Sentinel-3 satellite, mission continuity is ensured for at least 25 years from the launch of the first Satellite
Thank You – any Questions
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