Sentinel-1 Next Generation Mission Advisory Group

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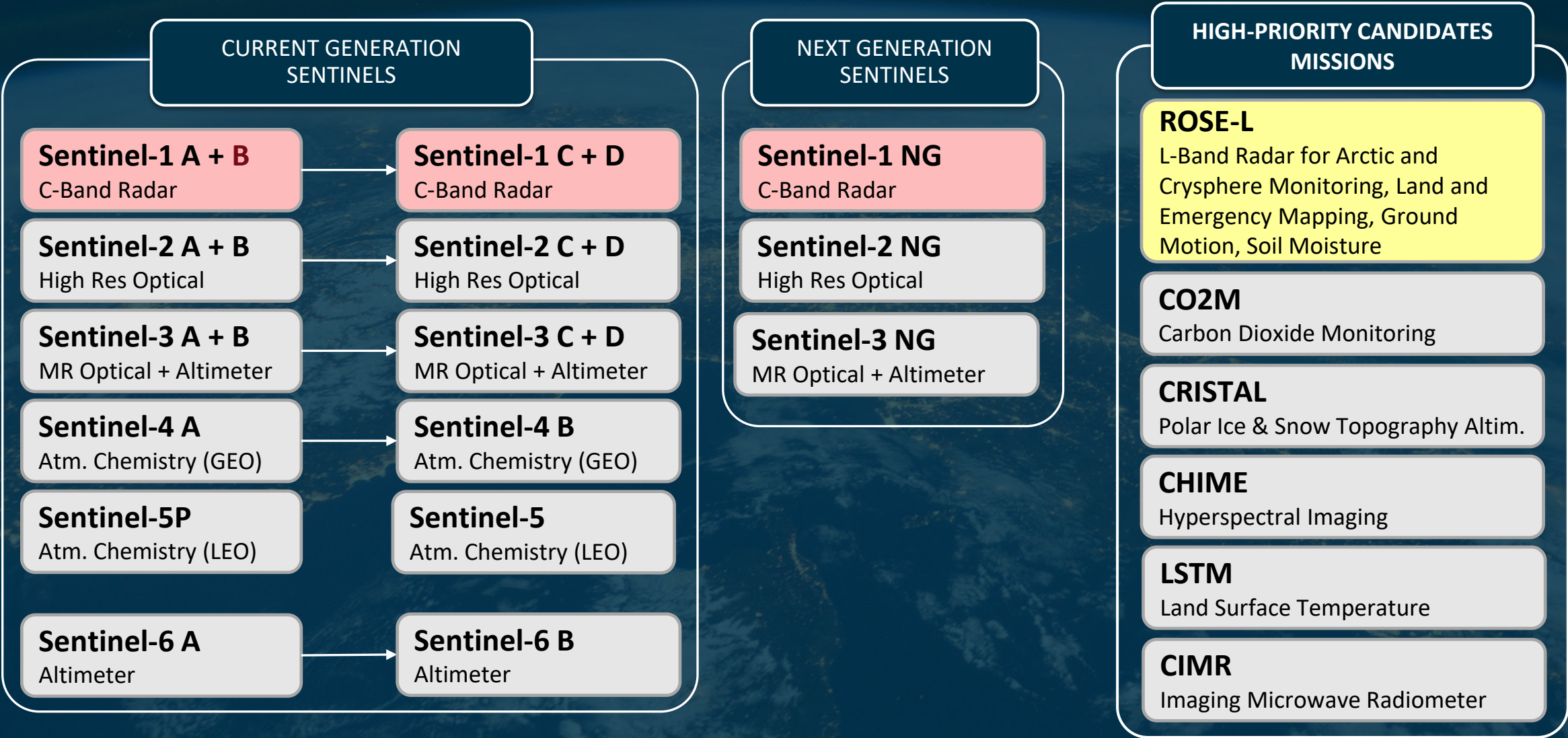
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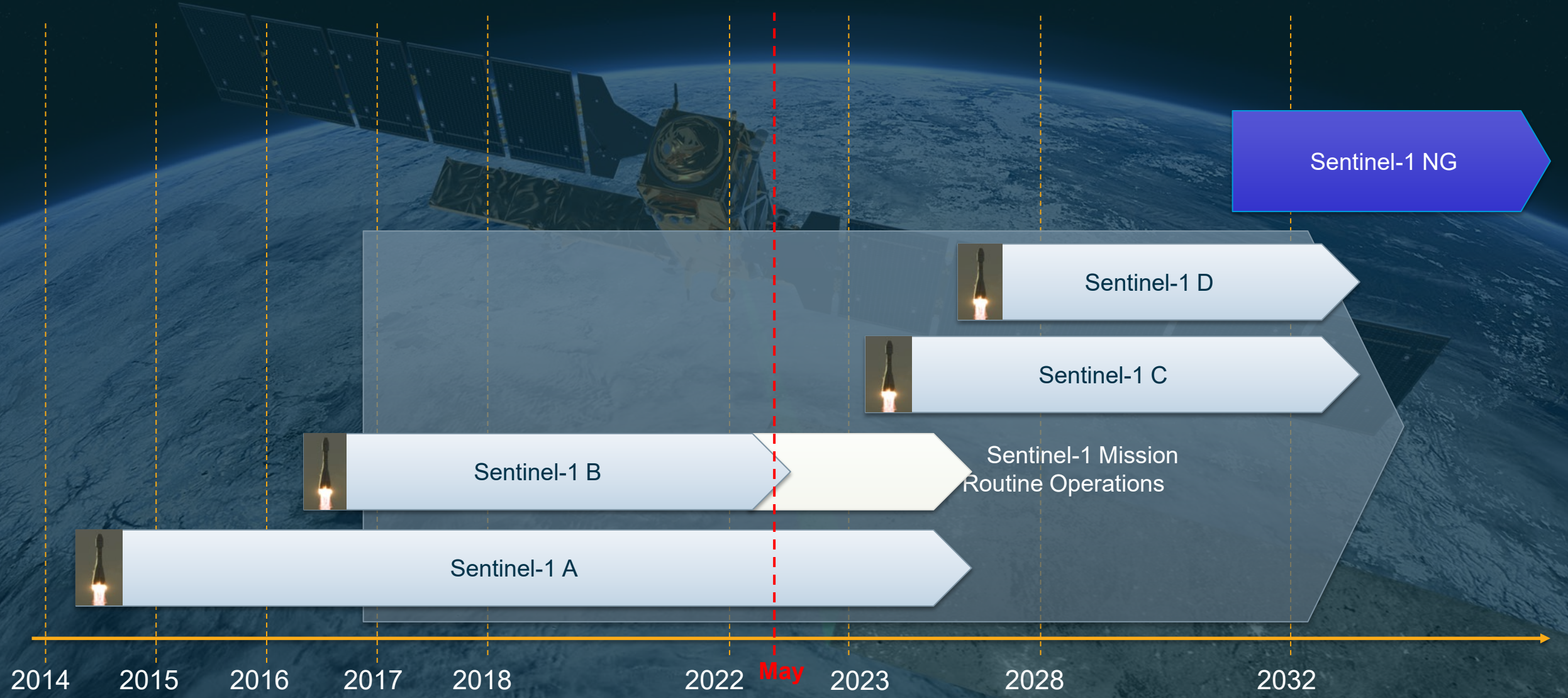Prof. Andy Hooper (Univ. Leeds), UK

Riccardo Lanari (CNR) , Italy

Attilio Gambardella (EC Observer)

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Copernicus Context

CURRENT GENERATION SENTINELS

Sentinel-1 A + B
C-Band Radar

Sentinel-1 C + D
C-Band Radar

Sentinel-2 A + B
High Res Optical

Sentinel-2 C + D
High Res Optical

Sentinel-3 A + B
MR Optical + Altimeter

Sentinel-3 C + D
MR Optical + Altimeter

Sentinel-4 A
Atm. Chemistry (GEO)

Sentinel-4 B
Atm. Chemistry (GEO)

Sentinel-5P
Atm. Chemistry (LEO)

Sentinel-5
Atm. Chemistry (LEO)

Sentinel-6 A
Altimeter

Sentinel-6 B
Altimeter

NEXT GENERATION SENTINELS

Sentinel-1 NG
C-Band Radar

Sentinel-2 NG
High Res Optical

Sentinel-3 NG
MR Optical + Altimeter

HIGH-PRIORITY CANDIDATES MISSIONS

ROSE-L
L-Band Radar for Arctic and Crysphere Monitoring, Land and Emergency Mapping, Ground Motion, Soil Moisture

CO2M
Carbon Dioxide Monitoring

CRISTAL
Polar Ice & Snow Topography Altim.

CHIME
Hyperspectral Imaging

LSTM
Land Surface Temperature

CIMR
Imaging Microwave Radiometer

Copernicus C-Band SAR Evolution Context

Sentinel-1 NG

Sentinel-1 D

Sentinel-1 C

Sentinel-1 B

Sentinel-1 Mission Routine Operations

Sentinel-1 A

2014 2015 2016 2017 2018 2022 May 2023 2028 2032

Sentinel-1 Mission in Brief

eesa

MISSION PROFILE

- ❖ Constellation of two identical SAR C-band (5.405 GHz) satellites: (A & B → C units)
- ❖ Near-Polar, sun-synchronous (dawn-dusk) orbit at 693 km altitude
- ❖ 7 years lifetime (consumables for 12 years)
- ❖ 12-day repeat cycle (each satellite), 6 days for the constellation

OPERATIONS

- ❖ Systematic SAR data acquisition using a predefined observation scenario
- ❖ Instrument duty cycle of max. 25 min/orbit in High Bit Rate modes (30 min outside eclipse) and 75 min/orbit in Low Bit Rate mode (Wave)

PROGRAMMATICS

- ❖ Sentinel-1C launch Q2 2023
- ❖ Sentinel-1D currently in storage to be launched as needed

PAYLOAD

- ❖ C-Band SAR
  - Centre frequency: 5.405 GHz
  - Polarizations: HH, VV, HH/HV, VV/VH
  - Incidence angle: 20º - 45º
  - Radiometric accuracy: 1 dB (3σ)
  - Radiometric stability: 0.55 dB (3σ), 0.45 (3σ) for S-1 C/D
  - NESZ: -22 dB
  - DTAR: -22 dB
- ❖ AIS Instrument marine surveillance (for S-1 C and D)

IMAGING MODES

- ❖ Strip Map Mode: 80 km swath and 5x5 m (range x azimuth) resolution
- ❖ Interferometric Wide-Swath Mode: 250 km swath, 5x20 m resolution
- ❖ Extra-Wide-Swath Mode: 400 km swath and 20x40 m resolution
- ❖ Wave Mode: 5x5 m resolution, leap-frog sampled images of 20x20 km
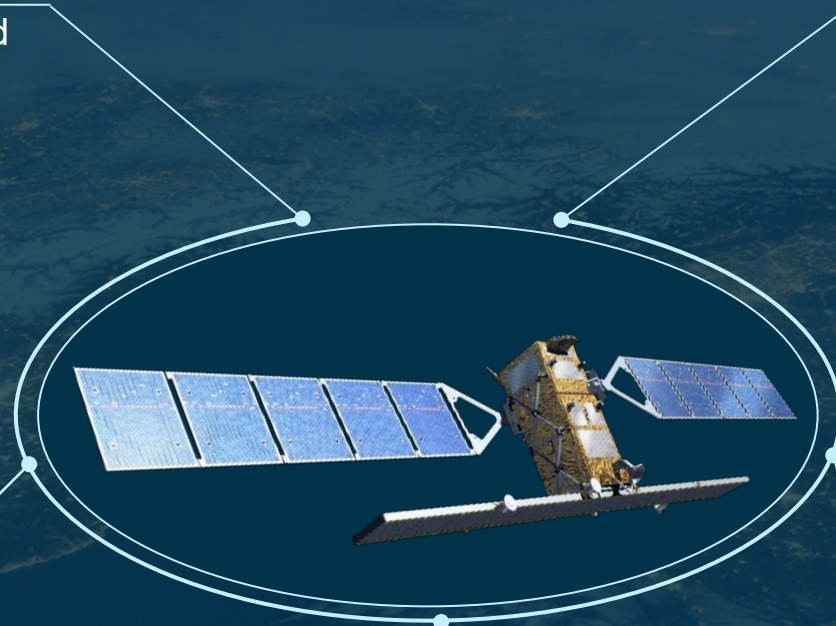
Sentinel-1 NG and Copernicus Services

Sentinel-1 NG Mission Requirements

Mission Requirement Process

- Ad-hoc Expert Group (AHEG) October'20-January'21 – drafted the preliminary MR for the Phase A/B1 ITT
- Mission Advisory Group (MAG) to support the Mission Trade-offs during Phase A and the System Requirements definition during Phase B
- Thematic Splinter meetings (November 2021 – Jan 2022) to define in detail application context, driving requirements and trade-offs
- Updated MRD June 2022

Main Mission Requirements (high-level)

- ensure continuity and expansion of services and applications relying on Sentinel-1
- enhance existing services and applications (e.g. improved resolution)
- enable new application developments building on improved performance and observation gaps (e.g. revisit, coverage of North Pole)

Sentinel-1 NG Requirements

Performance Requirements	Sentinel-1 NG	Sentinel-1
Latitude coverage	-80 to +90 deg	North-pole gap
Revisit	Goal: 3 days Global Goal: 0.5 days Arctic and Sea Ice	Up to 12 days
Latency	10 min European Waters 120 min Global	10 min RT, 1 h NRT emergency, > 3 h Global
Repeat pass InSAR	6 / 12 days (S1 & ROSE-L orbit)	6 / 12 days
Incidence angle access	Better than 20 – 45 deg	20 – 45 deg
Swath width	Larger than 400 km	250 IW – 400 EW
Resolution	25 m2	~100m2 IW - ~800m2 EW
NESZ	-26 dB	-22 dB
Polarization capability	SP, DP and QP	SP and DP
Duty cycle	43% (~43 min/orbit) with 53min any orbit	25min/orbit

Other Mission Requirements
Enhanced operations through the **potential integration of additional satellites**
Automatic Identification System (AIS) payload to augment maritime services
Over open oceans the mission shall support the generation of **wave mode products**

Radar data processing, quality analysis and level-1b product generation for

AGRISAR and EAGLE campaigns

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INTRODUCTION

For the assessment of specific programmatic needs of the Sentinel program and for the understanding and quantification of bio-geophysical parameters of different vegetated surfaces ESA has initiated and partially funded two airborne campaigns in 2006, AGRISAR and EAGLE [1,2]. In both campaigns the airborne SAR system of DLR, E-SAR was employed to acquire multi-frequency and multi-polarisation data over the different test sites. For a detailed description of the E-SAR system, please refer to [3,4].
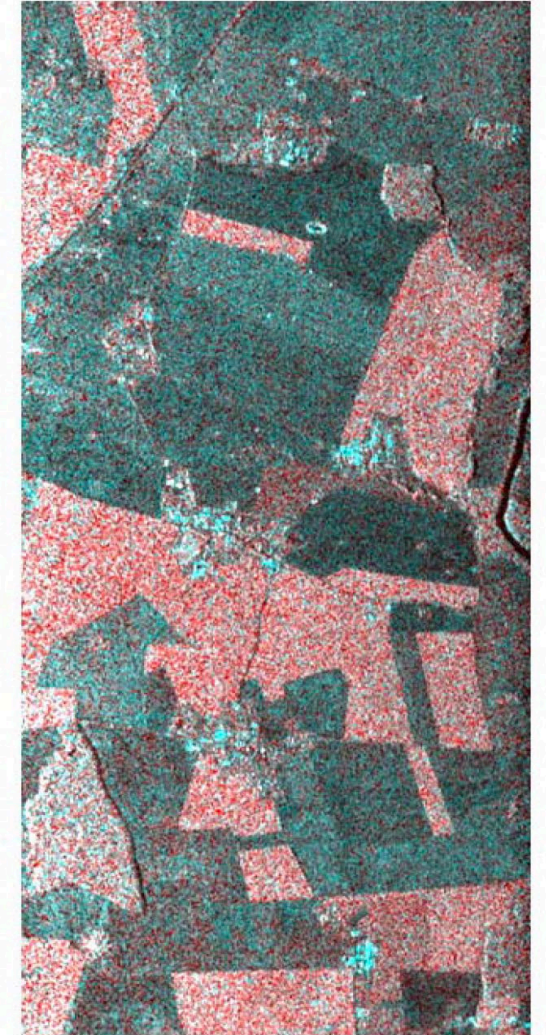
For the AGRISAR campaign 16 E-SAR flights have been conducted over Görmin test-site in the period from April-August 2006 to acquire representative data sets which cover the complete agricultural vegetation period of different crops [1]. For the EAGLE project two test-sites have been flown, Cabauw for specific investigations on agricultural areas and Speulderbos for forest parameter assessment [2].

The present paper describes the adopted methodology for processing the acquired E-SAR data and some of the results. First the SAR data sets acquired during AGRISAR and EAGLE campaigns are summarised. Then the standard E-SAR processing approach which leads to RGI (radar geometry images) and GTC (geocoded terrain corrected) products is described. Further discussion is included with respect to the mosaicked DEM which was generated for the AGRISAR test site from E-SAR single-pass SAR interferometry as well as to the obtained radiometric accuracy.

The generation of synthetic QUAD-POL products in C-band (performed for both AGRISAR and EAGLE projects) is described in a dedicated section. Another section is devoted to the generation of Sentinel-1 like data quality products from high resolution C-band data as is requested by the specific programmatic needs of ESA. The paper concludes with further remarks on data quality.
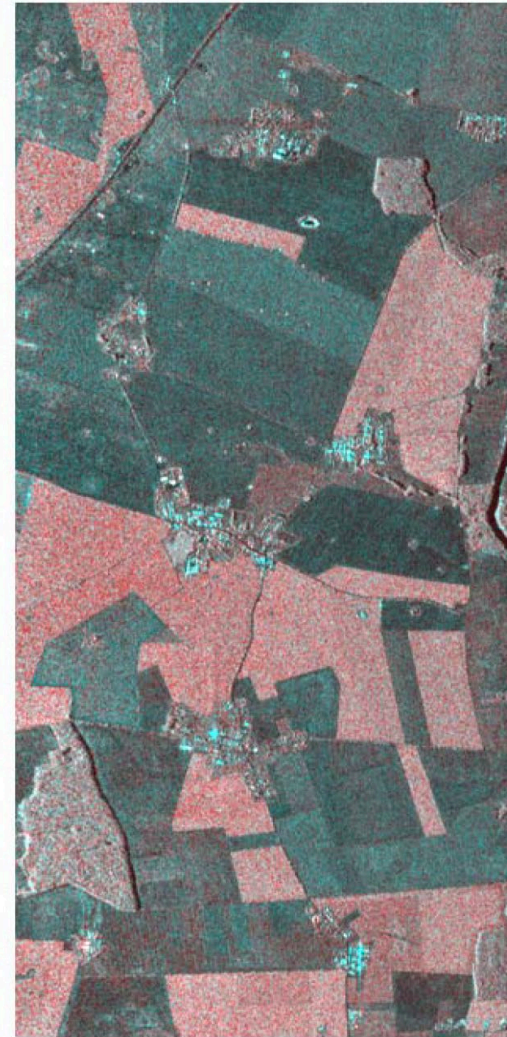
Sentinel-1 stripmap (4 looks)   Sentinel-1 IWS (4 looks)

Sentinel-1NG

- Two Phase A/B1 Contracts lead by TAS-I and ADS-D are progressing nominally
  - Preliminary Requirements Review (PRR), end of Phase A, took place in Feb/Mar for ADS, and Mar/Apr 2022 for TAS-I
  - Phase B1 kick-offs took place on 5 and 13 April for the two consortia
  - Intermediate System Requirements Reviews (ISRR) are planned from Dec 2022 to Mar 2023

- The two proposed baselines are based on Planar Phase Array SAR Antennas

- After Phase A completion, System Requirements update (issue 2) is currently being formalised:
  - Higher resolution 25 m^2 and better NESZ -26dB
  - Adoption of the Sentinel-1 first generation / ROSE-L orbit,
  - Full continuity in dual-pol (quad pol capability), and
  - Use of a dedicated Mission Mode to cover the North Pole region in a seasonal basis

- Technology pre-developments are in progress. Related to SAR technologies both for the SAR Antenna and for the SAR Electronics
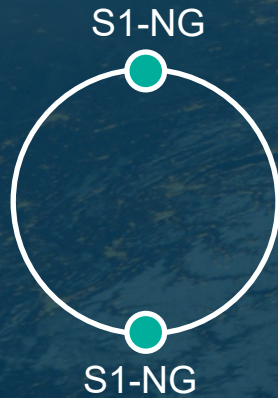
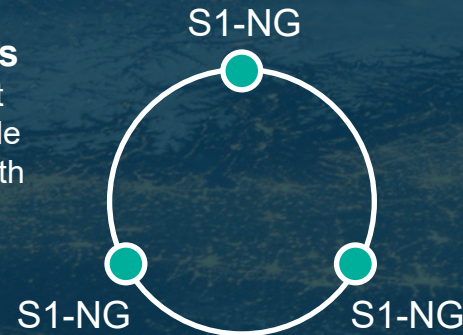**TAS Italia**

ADS GmbH

Open Orbit Scenarios

- Orbit height and phasing with Sentinel-1 FG still TBD

Examples of mission scenarios
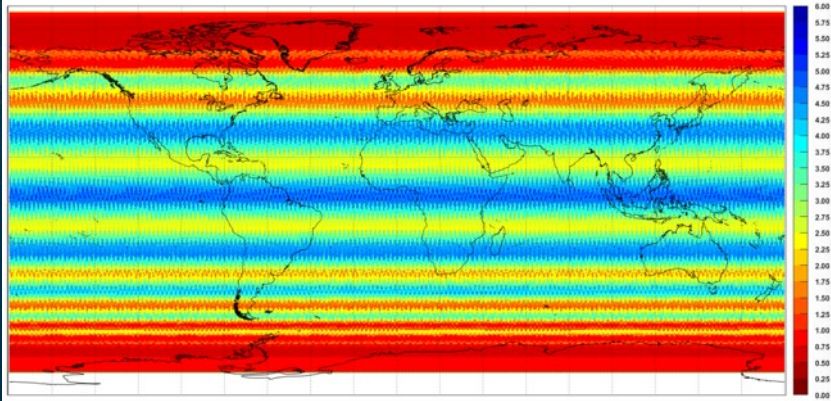

2 satellites
693 km orbit
12 days cycle
400 km swath

S1-NG
S1-NG

Maximum revisit time (days)

3 satellites
693 km orbit
12 days cycle
400 km swath

S1-NG
S1-NG   S1-NG

Maximum revisit time (days)

2+2 satellites
693 km orbit
12 days cycle
400 km swath
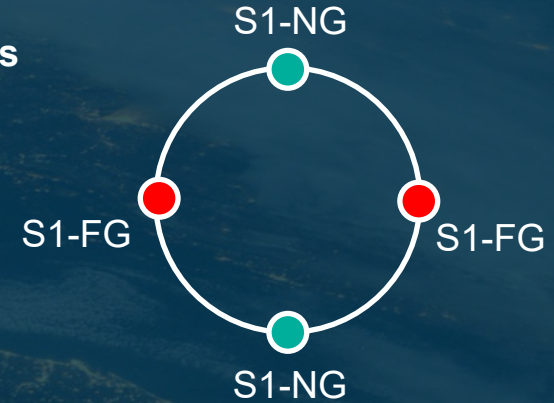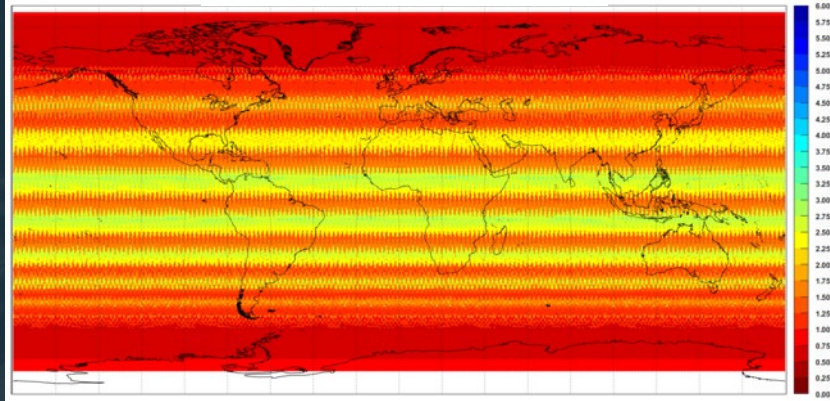
S1-NG
S1-FG   S1-FG
S1-NG

Maximum revisit time (days)
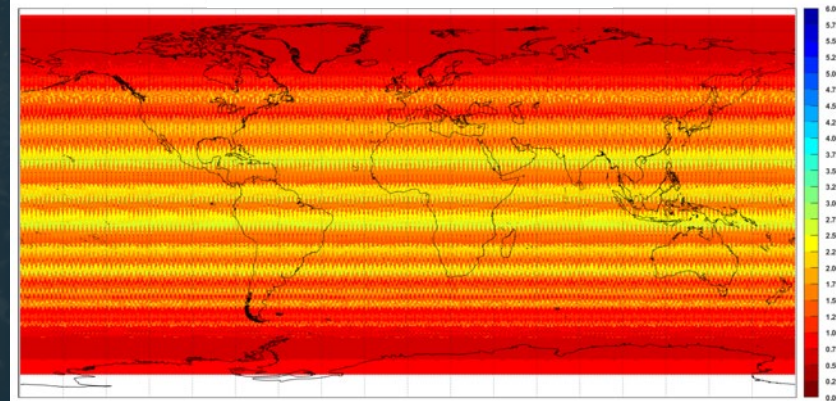
Mission analysis carried out by DLR/GMV

Synergies with Third-Party Missions

- S1 NG "companion friendly" e.g. stringent requirements on on-board timing linked to GNSS

- Promising synergy opportunities with **NewSpace** missions (Iceye, …)

- Small-sat constellations provide NRT on-demand acquisitions based on S1-NG target detection on wide swath

  - Critical role of latency and eventual onboard processing

  - Such **"Tip and cue"** process can be applied e.g. to vessel tracking
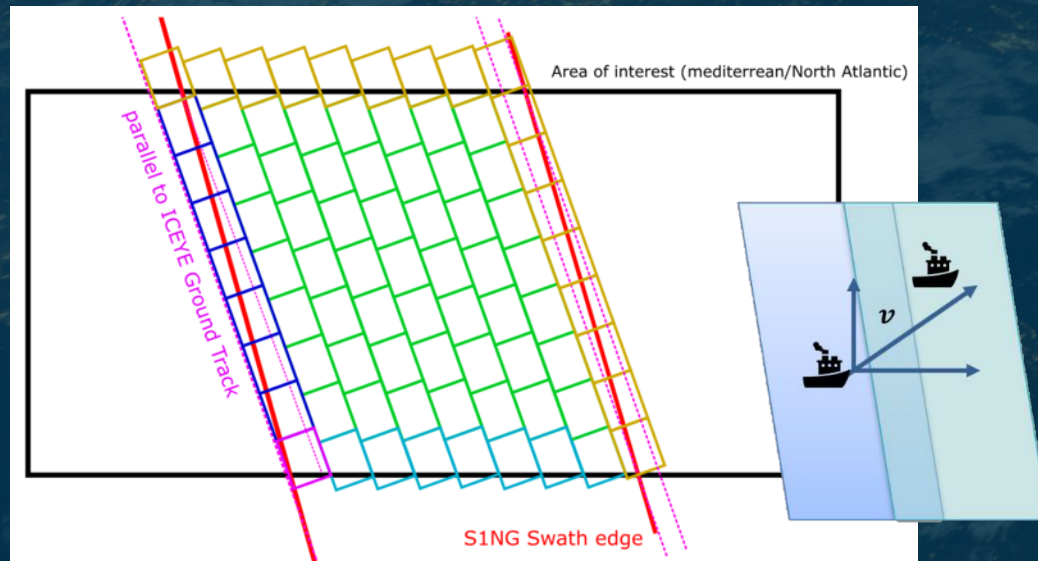
S1NG observation tiling with ICEYE observations (DLR)
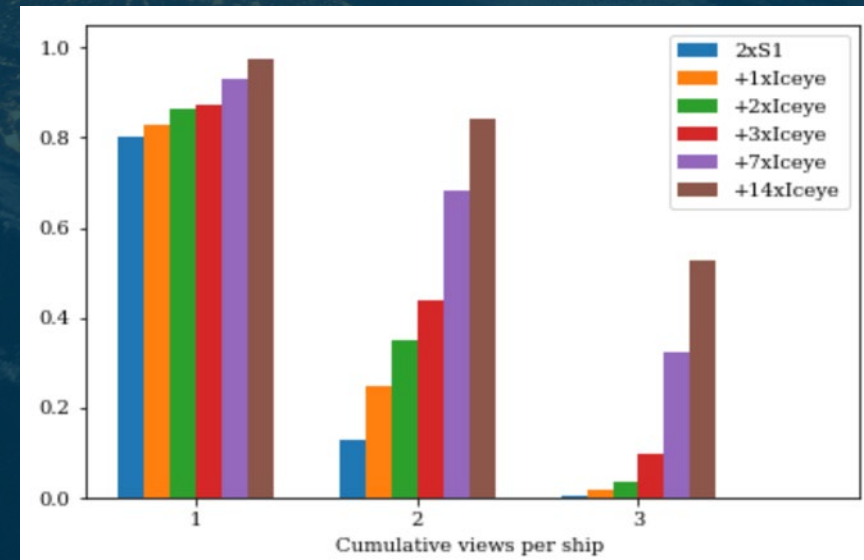
Analysis of vessels navigating E-W through the Strait of Gibraltar. S1-NG and Iceye swaths of 400 km and 100 km respectively (TU-Delft)

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Conclusions

Sentinel-1 First Generation has enabled the development of new operational applications

Sentinel-1 Next Generation at C-band to

- *ensure continuity* and expansion of services and applications relying on Sentinel-1

- *enhance* existing services and applications

- *enable* new application developments building on improved performance and observation gaps (e.g. resolution, revisit and others)

Sentinel-1 NG will bring new and enhanced capabilities

- Higher resolution (25m2 for S1NG)

- Low NESZ (-26 dB for Sentinel-1 NG)

- Wide swath and frequent revisit capability and greatly enhanced duty cycle

Sentinel-1, ROSE-L and Sentinel-1 NG are addressed as a system (not in isolation).

Sentinel-1 currently in Phase-B1 (12 months) with launch dates in 2032 timeframe

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Sentinel-1NG Industrial Consortia