CRISTAL – Copernicus' Next Cryosphere Altimetry Mission

Enrico Mank*, Franck Borde**, Friedhelm Rostan*, Yves Le Roy ***, Faviola Romero ***, Nicolas Taveneau ***, Valerie Bourlon ***

(*): Airbus Defence and Space, Claude Dornier Straße, 88090 Immenstaad, Germany

(**): ESTEC, Keplerlaan 1, PO Box 299, 2200 AG Noordwijk, The Netherlands

(***): Thales Alenia Space, Domain Observation and Science, 26, av. J.-F. Champollion – B.P. 33787, 31037 Toulouse Cedex 1, France

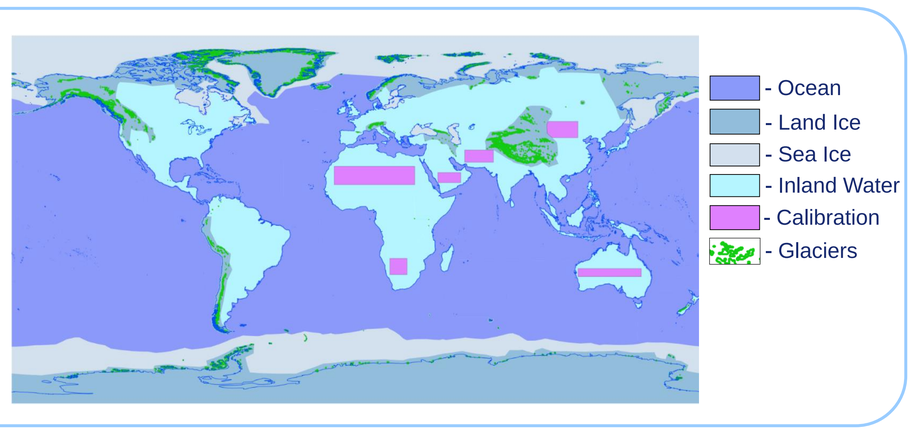
The Copernicus Polar Ice and Snow Topography Altimeter (CRISTAL) mission is planned to be launched in 2027 and will carry the first interferometric Ku and Ka band altimeter (IRIS) for enhanced sea ice thickness measurement and overlying snow depth retrieval.
CRISTAL is strongly benefiting from the Airbus heritage in altimetry missions like CryoSat and Sentinel-6 and the satellite will embark the following payloads:

- **IRIS (Interferometric Radar altimeter for Ice and Snow)** with 500 MHz bandwidth dual Ku/Ka bands, high resolution SAR (<10m) and interferometry in Ku-band
- **Advanced Microwave Radiometer (AMR-CR)** providing tropospheric correction for the altimeter also in coastal areas due to high frequency channels (footprint <4 km) and for sea and land ice type classification
- A multi-constellation, multi-frequency **GNSS receiver (PODRIX)** used for POD and frequency monitoring of the IRIS Ultra Stable Oscillator (USO)
- Three **Star Tracker (STR)** optical heads mounted on the IRIS antenna subsystem for interferometric calibration
- **Laser Retroreflector Array (LRR)** for POD
- Embarkation of a potential **Payload of Opportunity** to be agreed in the coming phase

The System and Instrument PDR have been successfully completed and the project is now in the detailed design in phase C

The CRISTAL mission is a continuation of CryoSat-2 with a polar orbit (92° inclination) and a repeat cycle of 367 days.
The mission covers primarily polar regions and secondarily oceans and hydrological targets (see mode mask):

- **Sea Ice and Icebergs (SII)**
  - Sea ice thickness calculated out of freeboard measurement and snow loading via Ka band
  - Improved number of sea leads measured by SAR and interferometry
- **Land Ice and Glaciers (LIG)**
  - Long range window length (256 m) and open loop tracking to cover complex terrain and quickly varying surface height further supported by SAR measurements providing along track resolution better than 100 meters
- **Open Ocean (OCO) and inland waters**
  - CRISTAL uses a reduced data rate mode with RMC processing (as validated on Sentinel-6)



Major Challenges and evolutions since Sentinel-6:

- Stringent POD required (< 1.9 cm radial) for altimetry via GNSSR and LRA only
- Stringent CoG knowledge for POD requirements (thus body mounted solar array)
- Controlled de-orbiting after lifetime for a sustainable space environment
- Up to 7 times higher instrument data rates and 2.0 GBit/s Wizardlink
- Capability of single or dual/consecutive science downlinks per orbit over lifetime
- 40 times higher DEM storage demand for instrument open-loop tracking

Major Improvements since CryoSat-2:

- Improved instrument performances based on POS-4 digital architecture
- More frequent interferometric calibration (with and without satellite roll) improving Angle of Arrival performances

CRISTAL in Figures	Value
Mission Lifetime (nominal/extended)	7.5 years / 12.5 years
Ground station candidates	Svalbard, Inuvik, Troll
Launcher	Vega-C, Ariane-6
Mass	1800 kg
Dimensions [X,Y,Z]	[5.7; 4.0; 2.2] m
Mainbus power load average	960 W
Altimeter power demand avr.	230 W
Onboard memory for science	4 TBit
X-band downlink	888 Mbps

The instrument parameters such as RF pulse chronogram, range window length and tracking are optimized to fulfil the mission needs and performance while maintaining a sufficient data rate:

Mission Mode	Instrument Mode	Range Window Length	Data Rate	Closed Loop Tracking	Open Loop Tracking
Sea-Ice and Icebergs	SARIn OB	64 m	199 MBit/s	X	X
Land-Ice and Glaciers	SARIn CB	256 m	256 MBit/s	X	X
Open and Coastal Oceans, Inland Waters	SAR CB RMC	32 m	22 MBit/s	X	X
	SAR CB RAW	64 m	43 MBit/s		X

Note 1: open-loop will be the operational tracking scheme but closed-loop may be used whenever needed
Note 2: SAR CB RAW used during commissioning and confirmation of RMC baseline

IRIS, an Interferometric Radar altimeter for Ice & Snow

Thales Alenia Space has been responsible for Radar altimeters dedicated to the cryosphere since 1996.
Cristal provides continuity and improvement on the Cryosat Ku-band Interferometer heritage:

- Addition of **Ka-Band** to measure snow loading on sea ice
- Addition of **SARIn_OB** mode to enhance azimuth resolution
- Performance improvement for the following parameters:
  - Chirp bandwidth: **500 MHz** (Siral: 320 MHz)
  - Antenna Interferometric baseline: **1.33 m** (Siral: 1.2 m)
  - Angle of Arrival error budget: **<23"** (Siral: 31.1")

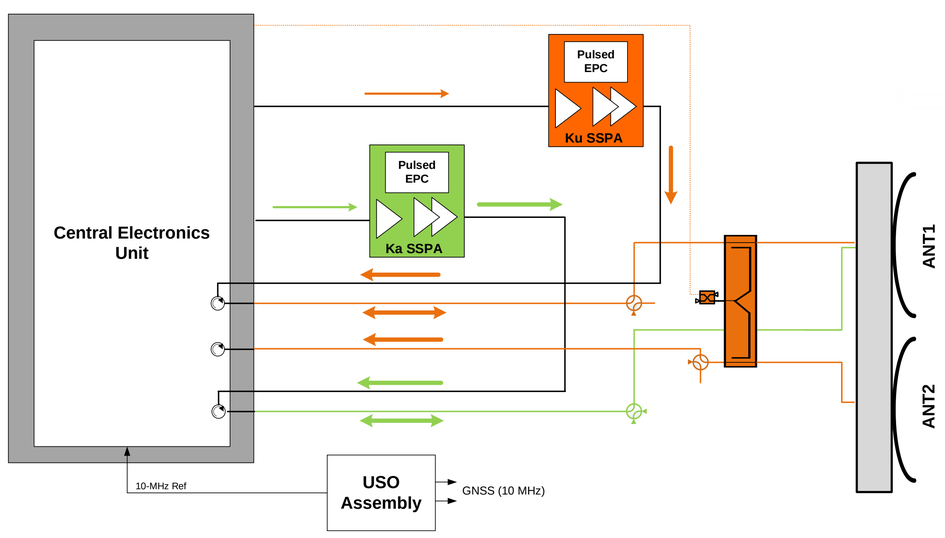
IRIS main performances	
SNR (after SAR processing)	Ku-Band: > 16 dB (σ_0=-10 dB) Ka-Band: > 10 dB (σ_0=-8 dB)
Range accuracy for sea echoes @ SWH=2 m over 1 s	5mm
Maximum slope for echo acquisition	≤ 5°

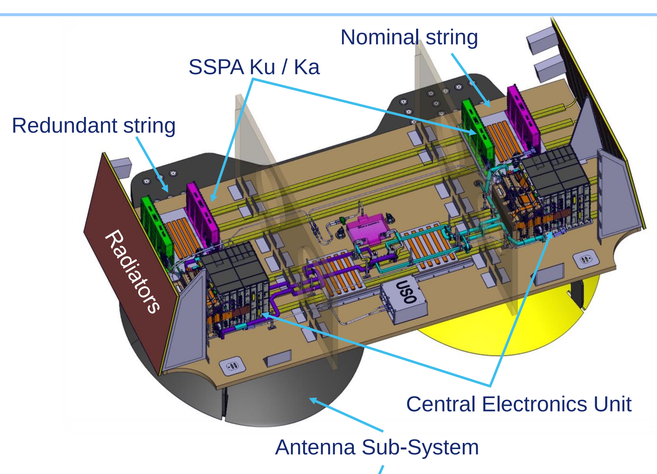
Tracking schemes:

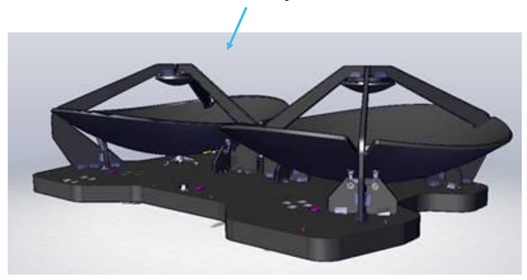
- **Closed-Loop Tracking:** targeted over flat ice surfaces such as ocean, coastal zones, sea ice and inland ice sheets
- **Open-Loop Tracking:** nominal mode over Oceans. Storage of DEM over Ocean, Sea Ice, Land Ice and Hydrology

Major Technological evolutions

- Calibration via switch matrices instead of Duplexers
- Central Electronics Unit integrates low-level RF functions
- Internal 10-MHz Ultra-Stable Oscillator instead of DORIS
- Antenna Sub-system integrates Dual Ku/Ka Band





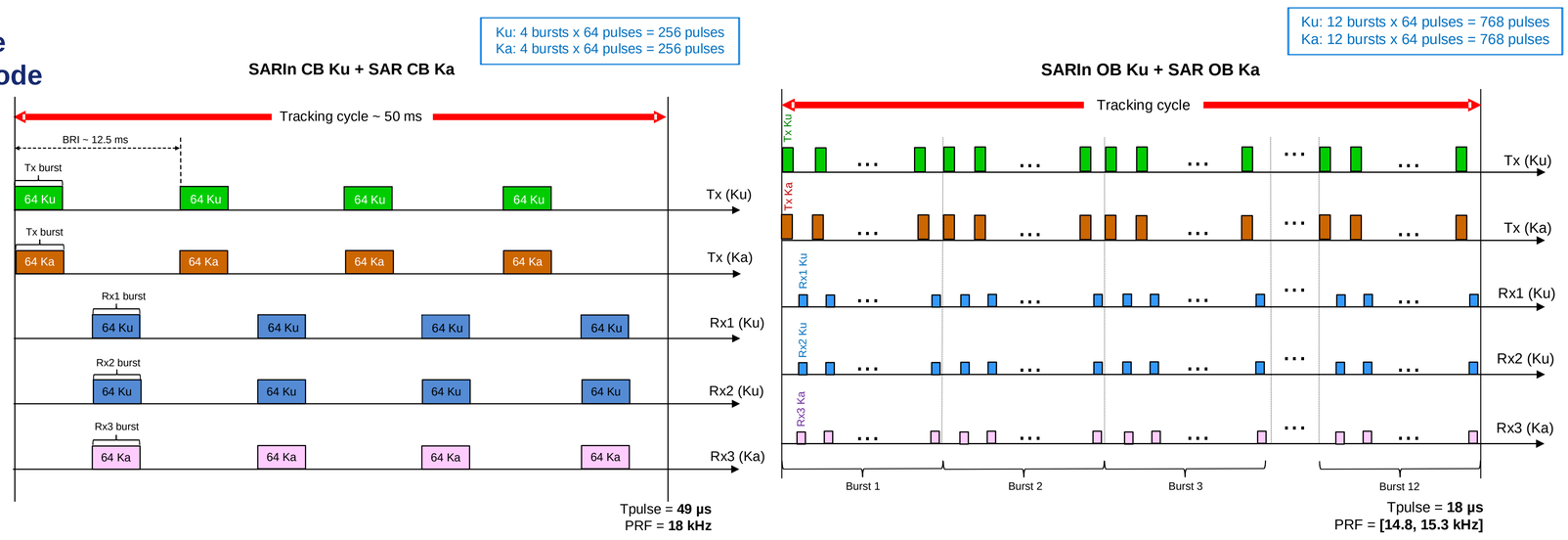


Mass: 129 kg
Power demand CB/OB: 222 W / 236 W

IRIS modes associated to surfaces:

- Open and Coastal Oceans (OCO): **SAR Closed-Burst (CB) mode**
- Land Ice and Glaciers (LIG): **SAR Interferometric (SARIn) CB mode**
- Sea Ice and Iceberg (SII): **SARIn Open-Burst (OB) mode**

IRIS main parameters	Value
Central Frequency	Ku / Ka : 13.5 GHz / 35.75 GHz
Ku/Ka Chirp bandwidth	500 MHz
Range resolution	30 cm
Interferometric baseline	1.33 m
Pulse duration	CB/OB: 49 µs / 18 µs
Pulse Repetition Frequency (PRF)	CB (fixed PRF): 18.0 kHz OB (adaptive PRF): 14.8 kHz – 15.3 kHz
Burst Repetition Frequency (BRF)	Closed-Burst: 80 Hz
Azimuth resolution in CB mode	Ku / Ka : 264 m / 99 m
Azimuth resolution in fully focused mode (SARIn OB)	≤10 m



Simultaneous transmission in Ku- and Ka-band with Interferometric reception in Ku-band, and single reception in Ka-band thanks to the physical implementation of 3 receive chains (2 Rx Ku + 1 Rx Ka)

AIRBUS

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