SEA ICE RETRIEVAL FROM CRISTAL: DESIGN, DEVELOPMENT AND VALIDATION

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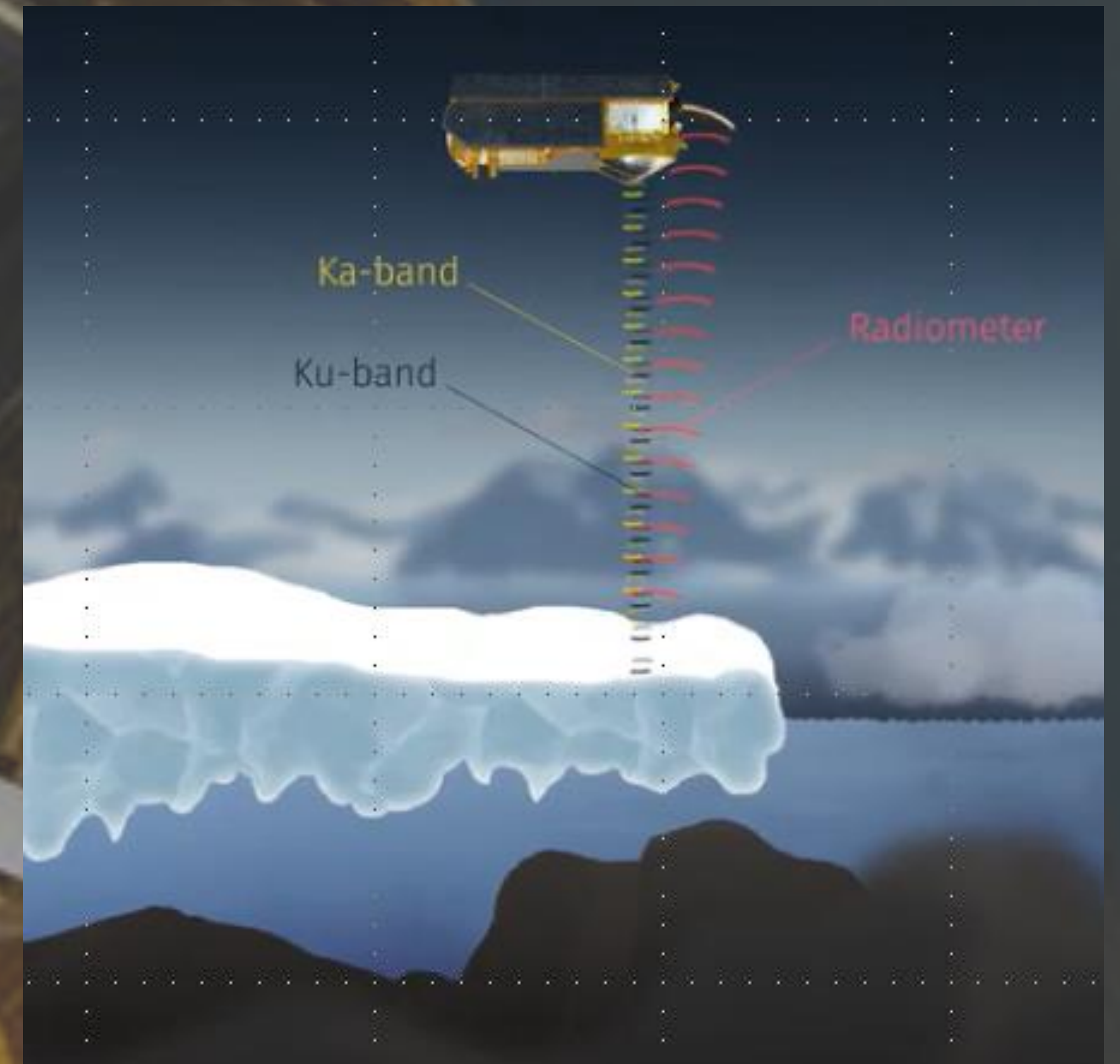## → CRISTAL

Objectives: Monitor sea ice, icebergs, land ice, glaciers (primary), but also ocean, coasts and all inland waters

- High inclination mission (92 deg), continues the legacy of CryoSat-2, with improved performance
- Dual-frequency Ku/Ka SAR altimeter, Ku is interferometric
- Improved bandwidth: 500 MHz in both Ku and Ka
- Improved interferometric measurements with 50% improvement on elevation error
- Higher precision monitoring of icebergs, ice lead discrimination etc. with very high along-track resolution (up to 0.5m with fully-focused SAR processing)
- Addition of Passive Microwave Radiometer for wet troposphere correction (secondary mission objective) and potential contribution to ice and snow classification (primary mission objective)
- SARin over all ice surfaces
- Open burst over sea ice and icebergs: improved azimuth (along-track) resolution & range precision
- Flexible open loop/closed loop tracking everywhere
- AMR-CR radiometer with HRMR for oceanography, coastal altimetry, ice classification, snow parameters

Ka-band
Ku-band
Radiometer

Status: system PDR successfully completed early 2022 – Now in Phase C
On track for CRISTAL-A launch in 2027
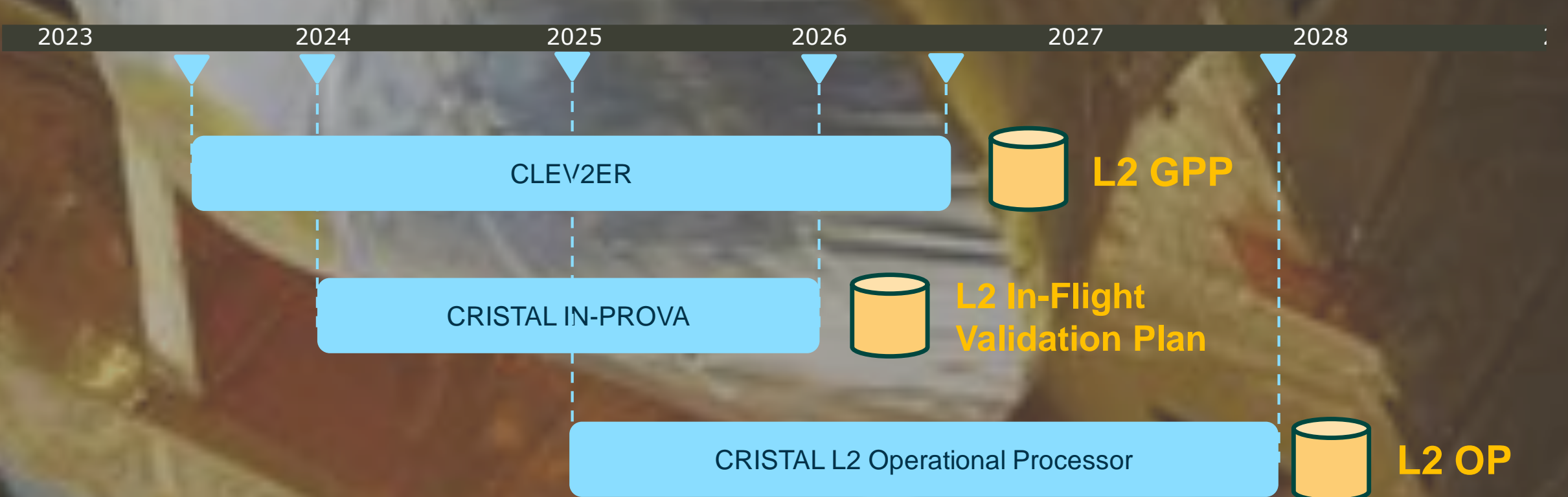(CRISTAL-B at some point in next decade)

→ CRISTAL: sea ice requirements

- CRISTAL shall be capable of retrieving year-round elevation measurements of the sea ice-covered oceans
- The along-track resolution of sea ice thickness measurements shall be 80 m
- CRISTAL shall be capable of delivering sea ice thickness measurements with a vertical uncertainty less than 0.15 m along orbit segments ≤ 25 km in winter.
- CRISTAL shall provide meaningful sea ice thickness estimates during summer.
- CRISTAL shall be capable of retrieving the depth of dry snow on sea ice
- CRISTAL shall deliver products in near real time
  - Sea ice freeboard in 6 hours
  - Sea ice thickness in 24 hours
  - Snow depth on sea ice in 24 hours
  - Iceberg detection products in 24 hours

→ ESA CRISTAL Level-2 development approach

The CRISTAL Level-2 products and algorithms are planned to be provisioned and validated prior to launch with the following approach
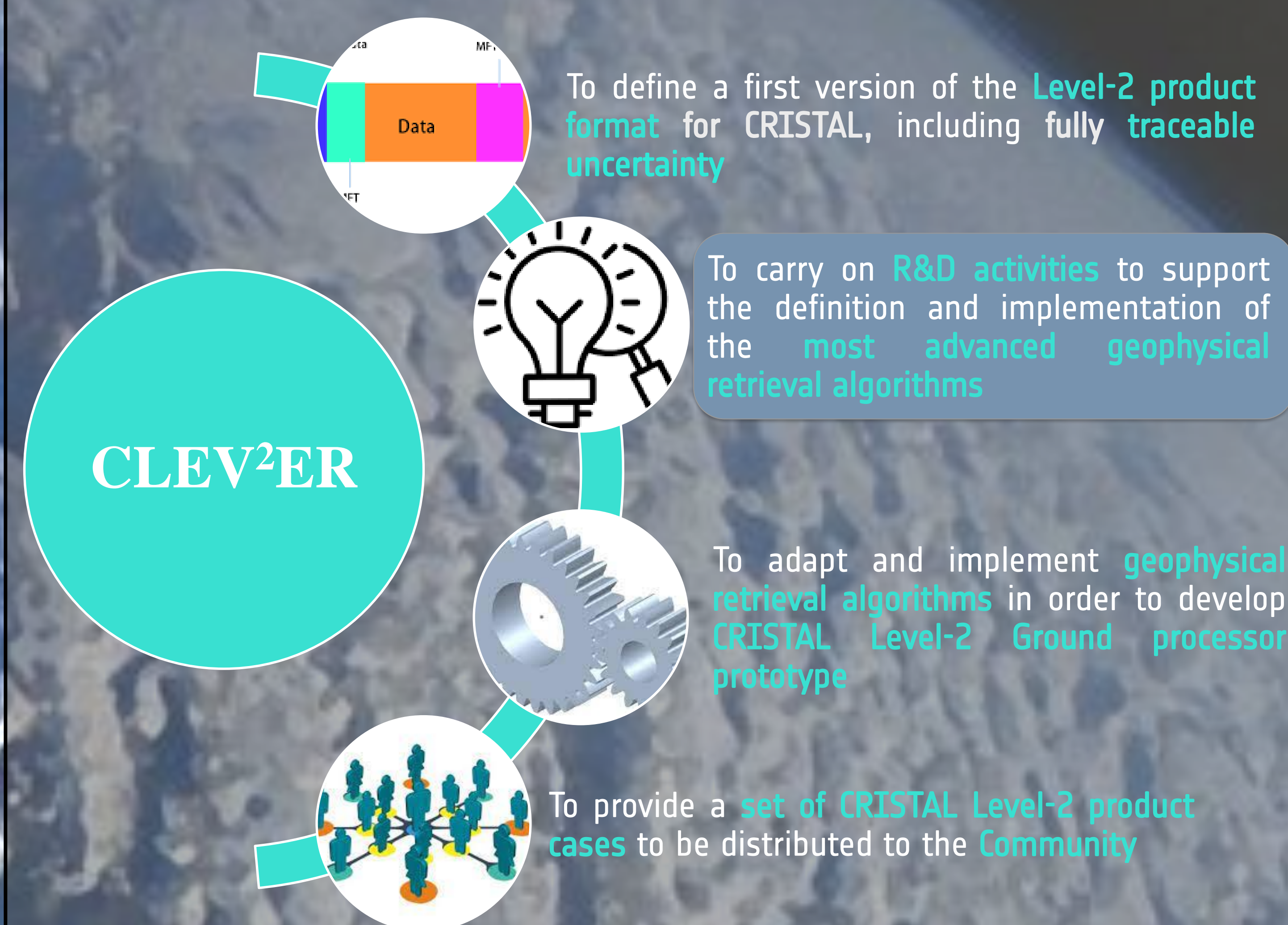1. A Level-2 ground processor prototype (L2 GPP) will be designed and developed in a first stage
2. The Level-2 operational processor will be developed in a second stage
3. In-Flight validation plan will be prepared to define methods and protocols for the validation of the CRISTAL Level-2 products versus Fiducial Refence Measurements (FRM)

2023 2024 2025 2026 2027 2028

CLEV2ER — L2 GPP

CRISTAL IN-PROVA — L2 In-Flight Validation Plan

CRISTAL L2 Operational Processor — L2 OP

→ CLEV2ER Sea Ice and Iceberg

CRISTAL LEVel-2 procEssor prototype and R&D (CLEV2ER) is the project that is aimed at
- define a first version of the Level-2 product format for CRISTAL over the Sea Ice and Iceberg domains
- develop CRISTAL Level-2 Ground processor prototype
- carry on R&D activities to support the definition and implementation of the most advanced geophysical retrieval algorithms for sea ice and icebergs

CLEV²ER

To define a first version of the Level-2 product format for CRISTAL, including fully traceable uncertainty

To carry on R&D activities to support the definition and implementation of the most advanced geophysical retrieval algorithms

To adapt sed implement geophysical retrieval algorithms in order to develop CRISTAL Level-2 Ground processor prototype

To provide a set of CRISTAL Level-2 product cases to be distributed to the Community

Impact of snow properties on penetration (e.g. as density, salinity, roughness, etc.)

Performance in iceberg detection and volume estimation

Depth of penetration into the snow pack at Ku and Ka bands

Operational summer sea ice

Exploiting off-nadir leads from both interferometric acquisitions [1] and from multiple adjacent ground tracks [2]

FFSAR and interferometry exploitation

Single track
Multiple tracks

[1] A. Di Bella, R. Kwok, T. W. K. Armitage, H. Skourup and R. Forsberg, "Multi-peak Retracking of CryoSat-2 SARIn Waveforms Over Arctic Sea Ice," in IEEE Transactions on Geoscience and Remote Sensing, vol. 59, no. 5, pp. 3776-3792, May 2021, doi: 10.1109/TGRS.2020.3022522

[2] Landy, J. C., Bouffard, J., Wilson, C., Rynders, S., Aksenov, Y., & Tsamados, M. (2021). Improved Arctic sea ice freeboard retrieval from satellite altimetry using optimized sea surface decorrelation scales. Journal of Geophysical Research: Oceans, 126.