
ESA studies related to cryosphere altimetry
AltiCryo User Meeting – Feb 3rd 2017
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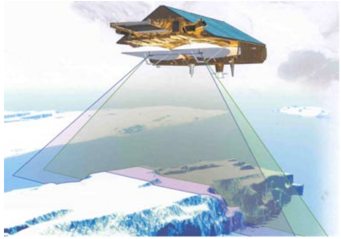
European Space Agency

Overview

1) cryosat enhanced continuity
   - Concepts for Cost-effective Cryosat Enhanced Continuity
   - extension: Addition of Ka-Band for Cryosat Follow-On
   - extension: (Ku+Ka)-Band Antenna for Cryosat Follow-On
   - *Cryosat Fast-Track Follow-On*
2) wide swath
   - extension: Measurement performances of wide swath altimetry missions
   - Interferometric antennas at Ku and Ka band with modest baselines for wide swath altimetry
   - Swath Altimeter for Operational Oceanography - Feasibility Study
   - *coming up: Feasibility Study into Multibeam Wide Swath Altimetry*
3) Arctic+
4) Polaris

1.1 Concepts for Cost-effective Enhanced Cryosat Continuity



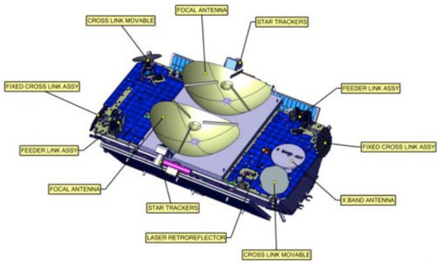
Status:

Final Review was on 30/11/16

Contractor: TAS

Objectives:

- Analyse and discuss the Iridium-PRIME offer (and constraints)
- Assess mission enhancements over the oceans by adding functions for improved ionosphere and troposphere delay corrections
- Analyse the feasibility of adding a wide swath mode
- Define the whole altimetry payload



Conclusion:

- Iridium prime technical feasibility confirmed, with acceptable performance
- Payload: Ku+Ka radar interferometer (POS-4 architecture) as promising option
- Enhancements constrained
    - Swath capabilities (multi-beam) not feasible
    - Accommodation of radiometer not possible
- Programmatic challenges

Error type	Ku	Ku+Ka	Ka	Comments
Altimeter range noise	0,80 cm	0,80 cm	1,50 cm	Based on SAR mode in Ku- and Ka-Band.
Sea state bias	2,00 cm	2,00 cm	2,00 cm	
Ionospheric error	2,00 cm	0,50 cm	0,30 cm	Ku, Ka : Correction with ionosperic models Ku+Ka : Correction with dual frequencies Ku & Ka (scale = 100 km)
Dry tropospheric error	0,70 cm	0,70 cm	0,70 cm	
Wet tropospheric error	3,00 cm	3,00 cm	3,00 cm	Correction with tropospheric model
TOTAL RMS	**4,26 cm**	**3,79 cm**	**3,98 cm**	
(GPS+LRR) POD	2,50 cm	2,50 cm	2,50 cm	
Total RMS with POD	**4,94 cm**	**4,54 cm**	**4,70 cm**	

1.2 Extension: Addition of Ka-Band for Cryosat Follow-On

Status:

Proposal received 19/01/17, Under approval

Contractor: TAS

Objectives:

- Consolidate the design of the SIRAL Follow-On instrument
- Study Ku/Ka dual band instrument option
- System performance consolidation + programmatic elements
- Specification for the Ka-band amplifiers

1.3 Extension: (Ku+Ka)-Band Antenna for Cryosat Follow-On

Status:

Proposal received 19/01/17, Under approval

Contractor: TAS

Objectives:

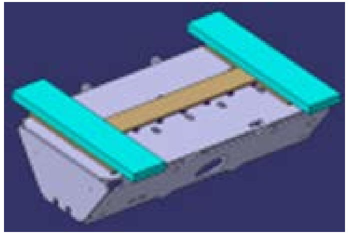
- Analyse RF performances of dual-band antenna in Ku and Ka band
- Subsystem consolidation (feedhorn design)
- Study stability and calculate angle-of-arrival error budget
- Study industrial capabilities and programmatic elements

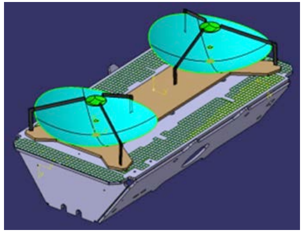
2.1 Extension: Measurement performances of wide swath altimetry missions

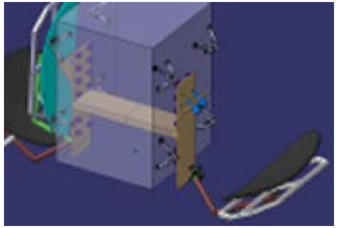
Status:

Final Review was on 30/11/16

Contractor: TAS





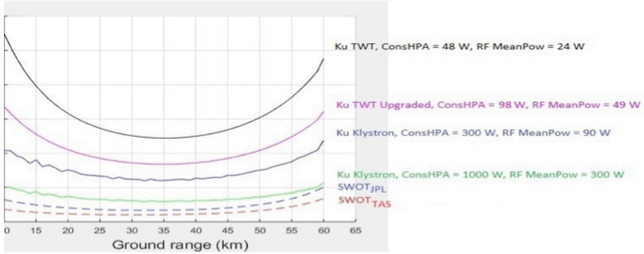


Objectives:

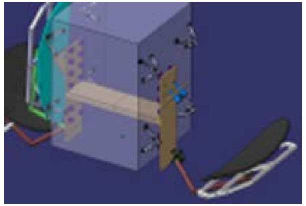
- Preliminary definition of a parametric wide swath payload
- Calculate associated instrument performances and provide these to Mercator as inputs into OSSE activities

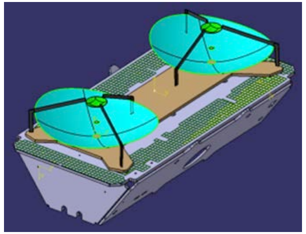
Conclusion:

- Set of performance curves supplied to Mercator
- Simulation at Mercator ongoing



2.2 Interferometric antennas at Ku and Ka band with modest baselines for wide swath altimetry





Status:

System Requirements Review completed in Sept 2016

Concept Selection Review planned for Feb 2017

Contractor: TAS

Objectives:

- Survey of state-of-the-art and requirements
- Trade-off analysis of the antenna and selection of 2 antenna architectures
- Detailed Design and Analysis of the 2 selected antenna architectures
- Conclusion and development roadmap

2.3 Swath Altimeter for Operational Oceanography - Feasibility Study

Status:

Ongoing procurement, Kick-Off expected in the next month, duration 12 months

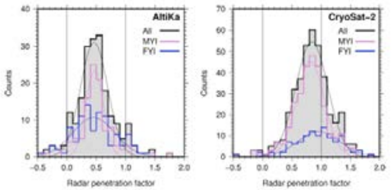
Objectives:

- Formulate user requirements
- Trade off system elements and payload complement
- Selection and detailed analysis of mission concept
- Study calibration concepts
- Development plan

3. Arctic+ Activities

Programme started following the ESA/CliC scientific consultation meeting on Earth Observation and Arctic Research Priorities held on 20 January 2015 in Tromsø.

1. Improving observations and understanding of snow on Arctic sea ice



Objectives:

- Explore, develop and validate different approaches to retrieve snow thickness over sea ice
- Develop a new prototype processor
- Produce and validate an experimental dataset of snow thickness over the Arctic.

Team: isardSAT PL (prime contractor), University College London (UCL), York University (YU) and Finish Meteorological Institute (FMI).

Status: The project kicked off 5th of October 2016. The work during first quarter has been focused on the consolidation of the scientific requirements, collection of the required datasets

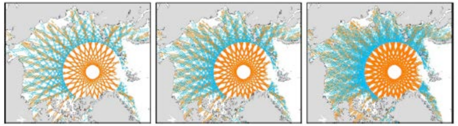


Figure 1-14 The coverage of CS2 (orange) and AltiKa (blue) for over 7 days (left), 10 days (middle) and 14 days (right) in February 2014.

2. Towards a reconciled estimate of Arctic sea ice mass

Objectives:

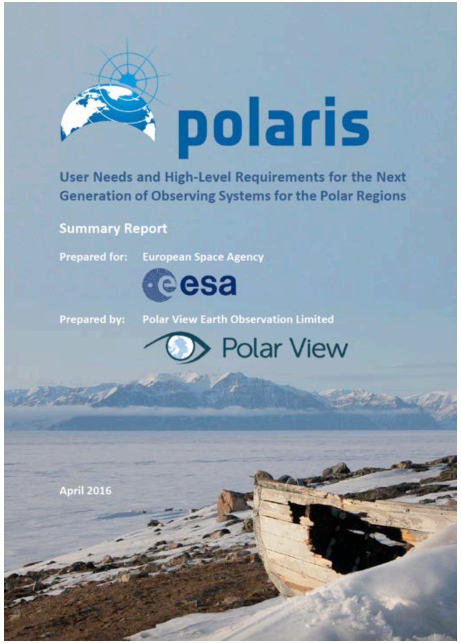
- Derive a reconciled sea ice mass estimate
- Intercomparison of ice mass balance estimates from different remote sensing approaches and models
- Develop recommendations for future research and EO missions

Team: isardSAT PL (prime contractor), York University, University College London (UCL), Finish Meteorological Institute (FMI) and Alfred Wegener Institute (AWI).

Status: The project kicked off 5th of October 2016

4. Earth Watch / Polaris Programme

- Polaris User Requirement Study
  - multi-frequency SAR ranked highly
- Working with EC on evolution of Copernicus Space Segment
  - Polar and Snow Cover User Requirements Workshop
- System Design Studies
  - Hosted Arctic Imager (HAI)
  - L-band SAR in tandem with S-1 (Polar train)
  - PAP: platform study for CS2 enhanced continuity



Altimetry in the age of operational Remote Sensing

Erik De Witte - January 2017

Purpose

- To stimulate discussion, and gather inputs/feedback that will feed into:
    - Shared vision for future altimetry roadmap
    - Improved inter-agency coordination
    - Guidance to new activities
    - Timeline for future altimetry mission concepts
    - Basis to develop technology roadmaps
    - Converging on a vision for the future observation system of systems that is shared among different communities (ocean and cryosphere)

The 4 Components of the Current Altimetry Observation System

Reference Component


Jason-2


Sentinel-6 (Planned)

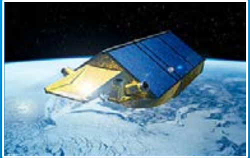

Jason-3


Haiyang-2

Submesoscale Component


SWOT (planned)

Cryosphere Component


Cryosat-2

Mesoscale Component


Sentinel-3


SARAL

Source: “The Next 15 Years of Satellite Altimetry”: http://www.ceos.org/images/OST/SatelliteAltimetryReport_2009-10.pdf

Applications by Altimetry Observation System Component

Reference Component	Cryosphere Component	Submesoscale Component	Mesoscale Component

mean sea level trend

mean global circulation

large scale variability

tides

ice sheets

mesoscale oceanography

sea ice

coastal domain

mountain glaciers

inland waters / hydrology

geodesy / bathymetry

marine meteorology

What are the Core Requirements for the Cryosphere Component?

Cryosphere Component

- ice sheets
- sea ice
- mountain glaciers

- Orbit / Constellation / No of satellites?
- Multi-band Ku/Ka
  - Sea ice
  - What are the benefits for land ice?
- Interferometric capability (Ku+Ka / Ku / Ka)
- Improve observations at finer scales & coastal areas
  - Interferometric swath processing
    - How does this trend drive design of future systems?
  - Full SAR processing?

Timeline of Current & Planned Missions

Current and Planned Missions				2017-2019	2020-2029	2030-2039
Reference Component						
JASON-2/OSTM	POS-3	nadir altimeter	1336km/66°			
JASON-3	POS-3	nadir altimeter	1336km/66°			
S-6A	POS-4	nadir altimeter	1336km/66°			
S-6B	POS-4	nadir altimeter	1336km/66°			
HY-2C(*)	ALT	nadir altimeter	1336km/66°			
HY-2D(*)	ALT	nadir altimeter	1336km/66°			
HY-2F(*)	ALT	nadir altimeter	1336km/66°			
HY-2G(*)	ALT	nadir altimeter	1336km/66°			
Cryosphere Component						
Cryosat-2	SIRAL-2	ISAR altimeter	717km/92°			
Mesoscale Component						
SARAL	AltiKa	nadir altimeter	SSO (800km)			
S-3A	SRAL	nadir altimeter	SSO (814km)			
S-3B	SRAL	nadir altimeter	SSO (814km)			
S-3C	SRAL	nadir altimeter	SSO (814km)			
S-3D	SRAL	nadir altimeter	SSO (814km)			
HY-2A	ALT	nadir altimeter	SSO (964km)			
HY-2B	ALT	nadir altimeter	SSO (973km)			
HY-2E	ALT	nadir altimeter	SSO (973km)			
Sub-Mesoscale Component						
SWOT	KaRIN	swath altimeter	891km/78°			
COMPIRA	SHIOSAI	swath altimeter	TBD			
HY-2H		swath altimeter	SSO (973km)			

?

How to Evolve the Observation System?

Current and Planned Missions				2017-2019	2020-2029	2030-2039
Reference Component						
JASON-2/OSTM	POS-3	nadir altimeter	1336km/66°			
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HY-2G(*)	ALT	nadir altimeter	1336km/66°			
Cryosphere Component						
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Mesoscale Component						
SARAL	AltiKa	nadir altimeter	SSO (800km)			
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S-3C	SRAL	nadir altimeter	SSO (814km)			
S-3D	SRAL	nadir altimeter	SSO (814km)			
HY-2A	ALT	nadir altimeter	SSO (964km)			
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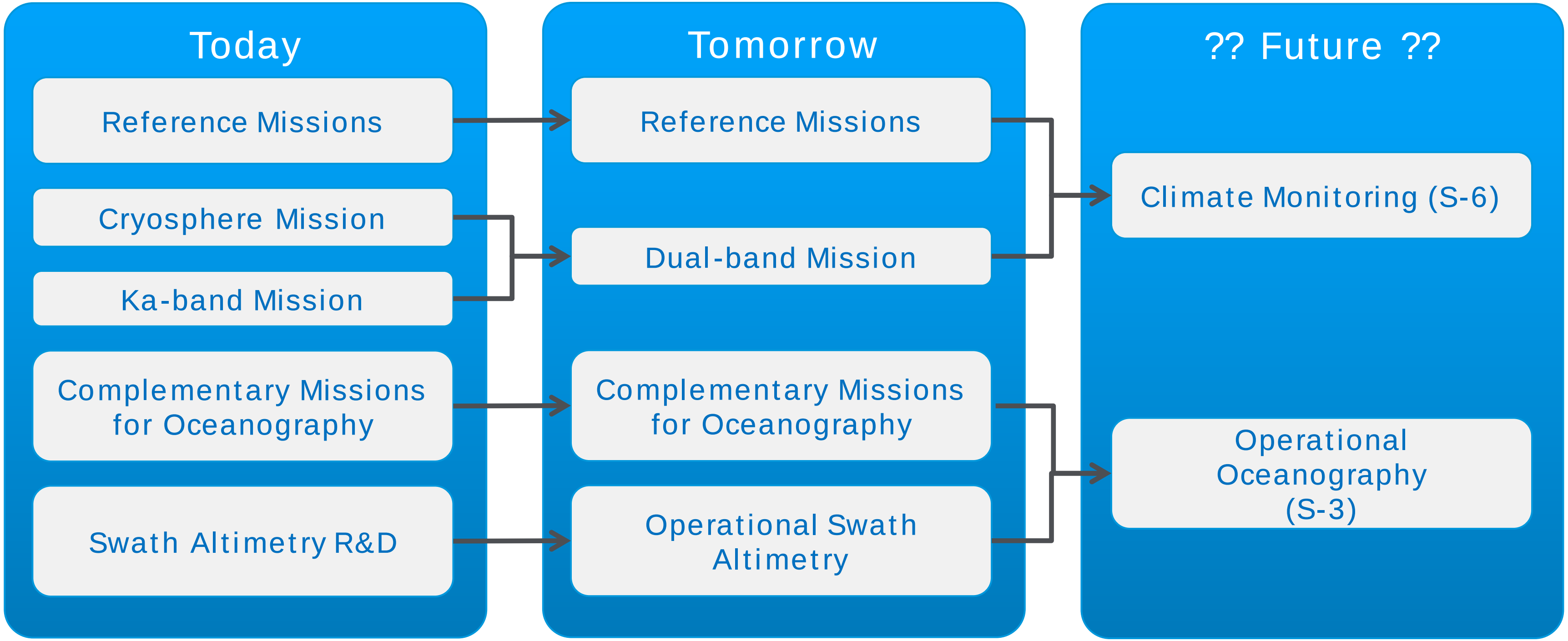
HY-2E	ALT	nadir altimeter	SSO (973km)			
Sub-Mesoscale Component						
SWOT	KaRIN	swath altimeter	891km/78°			
COMPIRA	SHIOSAI	swath altimeter	TBD			
HY-2H		swath altimeter	SSO (973km)			

- Reference and mesoscale components are in Copernicus
- What about the other two?
- Can we consolidate the observation system architecture to address all altimetry applications with a perpetually operational system?
- What would that look like and how do we get there?
- What will be the role of Europe in this?

Future Trends?

- In the near term future we will see continuation of high-precision nadir-looking "reference missions" (Sentinel-6) and additional missions that provide denser sampling (S-3 and others).
- Will Cryosat-2 be followed by an operational mission (maybe even a two-satellite constellation) within Copernicus, serving all the user communities that can be served by precise dual-band altimetry (cryosphere, oceanography, inland water and snow,..)?
- Could it be possible in the future to merge reference and cryosphere components?
    - Could have multiple satellites phased around non-tide-resonant CS orbit.
    - What might enable this?
    - Or do we need to keep 1 satellite on reference orbit?
    - Role of international partners?
- Could it be possible in the future to merge mesoscale and sub-mesoscale components?
    - Will CS and wide swath altimeter evolve towards very similar payloads, if not identical, with the main difference the orbit and the platform?

One possible Scenario...



Same …in a bit more detail

on-going/planned | speculative

Future Missions (hypothetical)				2017-2019	2020-2029	2030-2039
Reference & Cryo missions / Climate monitoring						
S-6A	POS-4	nadir altimeter	1336km/66°			
S-6B	POS-4	nadir altimeter	1336km/66°			
Cryosat-2	SIRAL-2	ISAR altimeter	717km/92°			
SARAL	AltiKa	nadir altimeter	SSO (800km)			
Cryosat-3	Ku+Ka	ISAR altimeter	717km/92°			
S-6C/D/…	?	?	?			
Operational Oceanography Missions / mesoscale dynamics						
S-3A	SRAL	nadir altimeter	SSO (814km)			
S-3B	SRAL	nadir altimeter	SSO (814km)			
S-3C	SRAL	nadir altimeter	SSO (814km)			
S-3D	SRAL	nadir altimeter	SSO (814km)			
SWOT	KaRIN	swath altimeter	drifting			
S-3E		swath altimeter	drifting			
S-3F		swath altimeter	drifting			

CSC Evolution | CSC-NG

Other Unknowns

- Emerging technologies that may change the future of altimetry
  - Constellations of miniaturised altimeters
    - Denser sampling obtained by constellation of small nadir altimeters
    - GNSS/R
  - Role of direct current measurements for (sub-)mesoscale
    - ATI or DCA
    - Dedicated active mission or passive followers
    - Could be implemented as passive followers flying together with swath altimetry mission
- International cooperation
  - China has plans for
    - Reference missions (HY-2C/C/F/G) (*)
    - Complementary missions (HY-2A/B/E)
    - Wide swath mission (HY-2H)
  - Which of those are firmly confirmed? What will their policy be on data sharing?
- Further away in the future, what – if any – will be the role of laser altimetry?

Some more questions to finish off...

- Which scientific challenges and applications are not yet well addressed by the current altimetry observation system? What should be the next priorities?
- In the long-term, will we be able to streamline the altimetry constellation into fewer components? How?
- Will swath altimetry take a place in an operational altimetry constellation? What scientific challenges and operational needs should it address?
- How can we coordinate the future altimetry constellation at national, European and Global levels?
- As we move to finer scales, what auxiliary technologies do we need to develop in order to support the altimetry roadmap? (e.g. high resolution radiometers)