Louise Yu, François Boy, Damien Desroches, Alejandro Bohe

Swath altimetry simulations with Radarspy in preparation of Copernicus mission Sentinel-3 Next Generation Topography

Acknowledgements

ESA	Alejandro Egido
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	Franck Demeestere
CLS	Pierre Dubois
CS group	Julien Bosman
	Guillaume Beauchamp

RADARSPY

EGU24 Wien – HS6.5
19 Apr 2024

Contents

1

The S3NG-T mission

Short introduction

S3NG-T mission

- ESA Copernicus, Sentinel series – launch 2033
- Objective
  - Sentinel-3 Enhanced Continuity: altimetry (50 km / 5 d oceans, 10 cm RMS inland waters)
  - Sea ice
- Phase A/B1 industrial study on swath altimetry concept
- Mission Gate Review 2 May → Swath Yes/No

S3NG-T mission

- ESA Copernicus, Sentinel series – launch 2033
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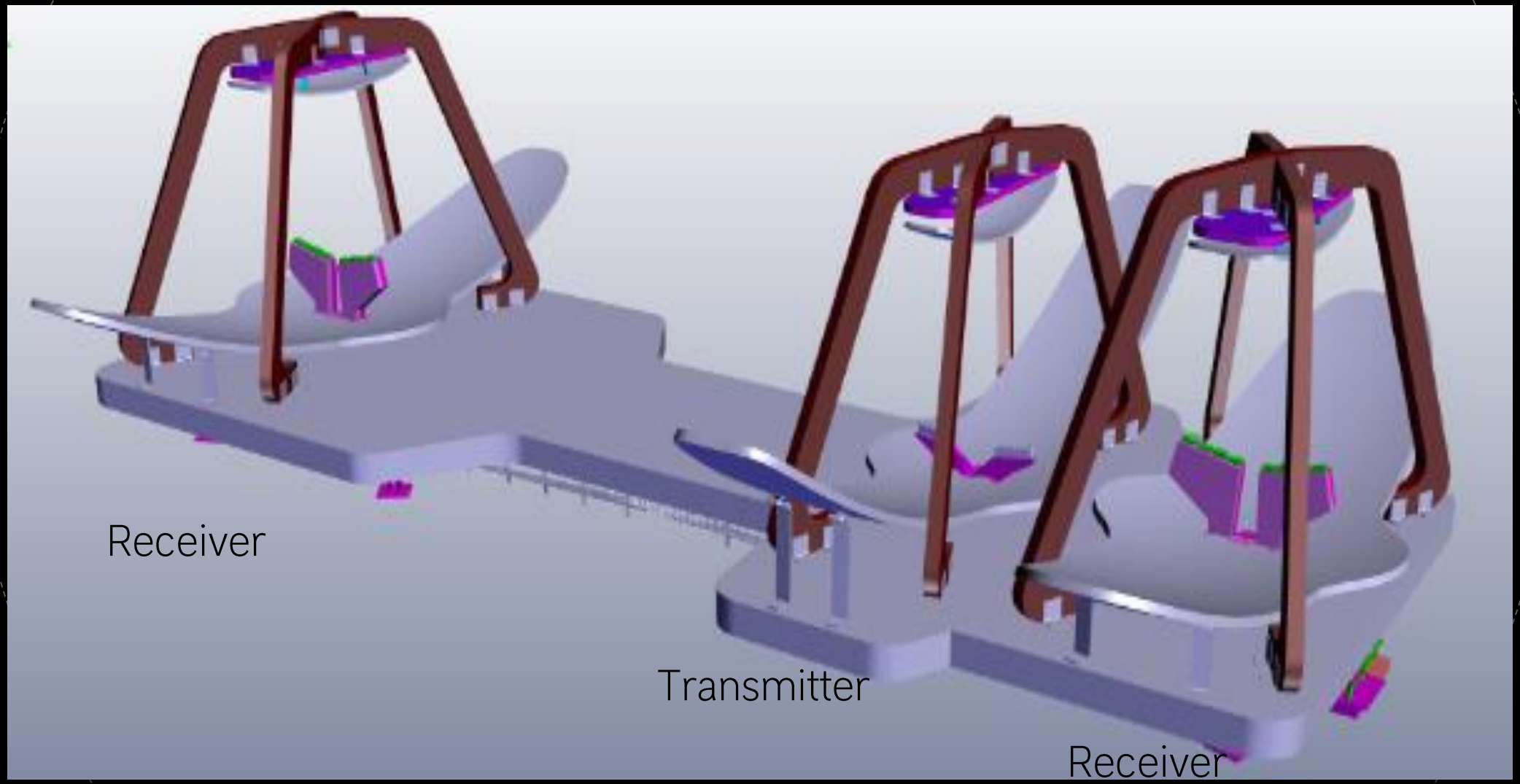
- Mission Gate Review 2 May → Swath Yes/No

CNES role: advisory (SWOT expertise)

- Provide news/updates about SWOT
- Run performance assessments with in-house simulator for cross-checking purposes
  - ➢ Up to now: HR chain OK, LR chain in progress

SAOOH[1]: swath instrument of S3NG-T



Courtesy of Thales Alenia Space, Toulouse

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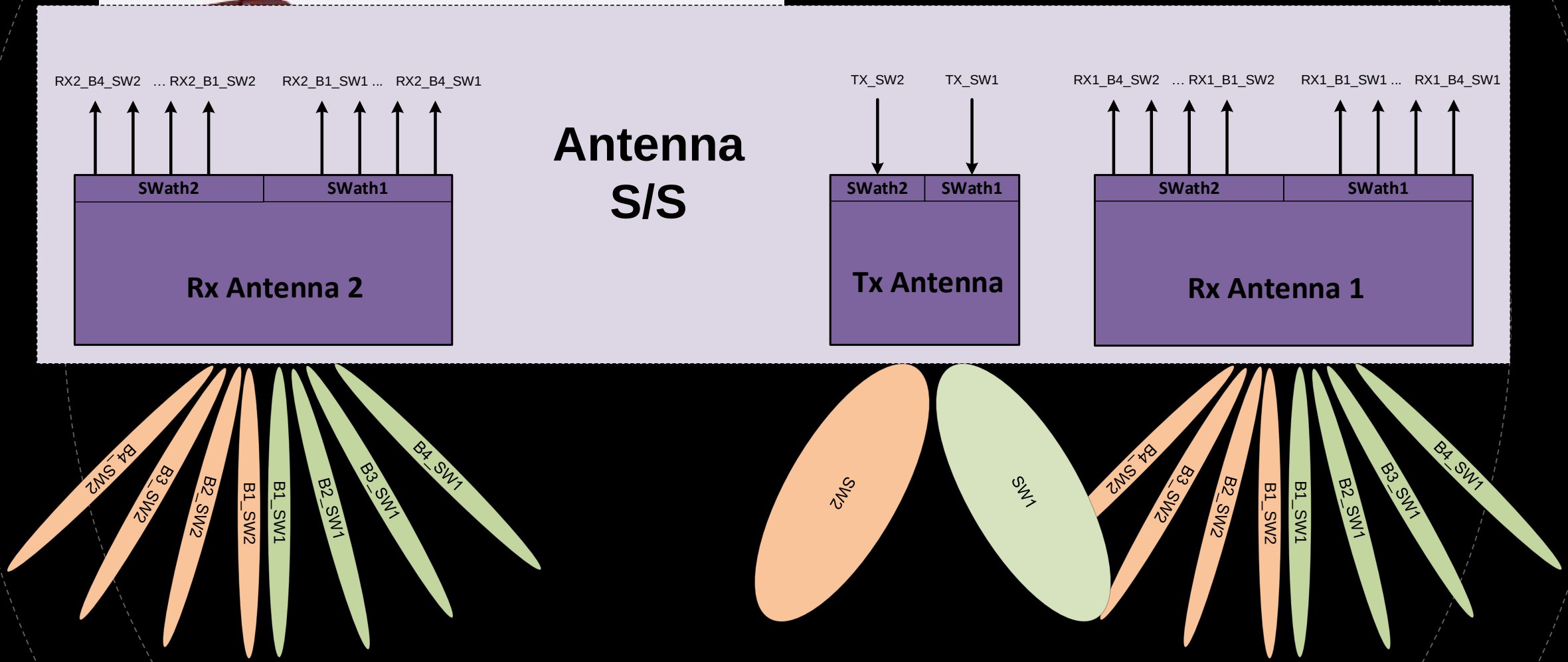

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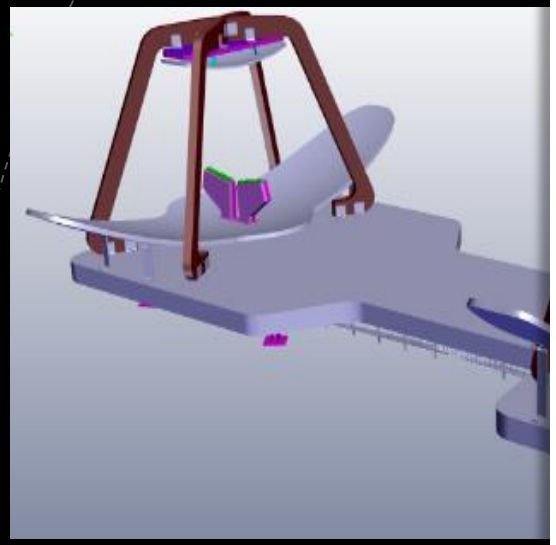

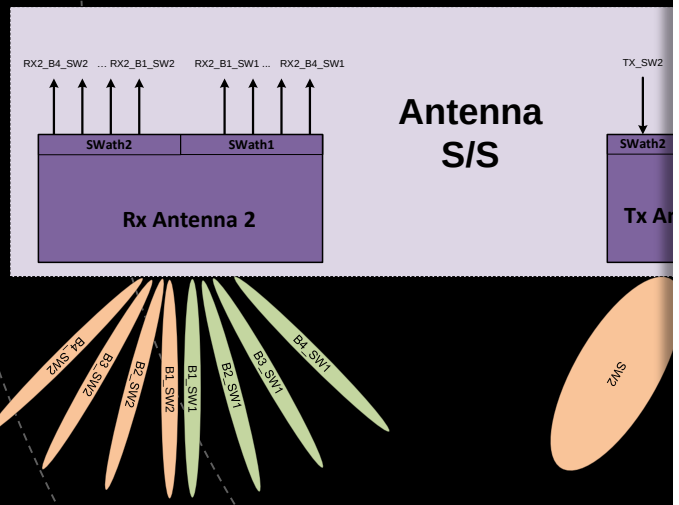

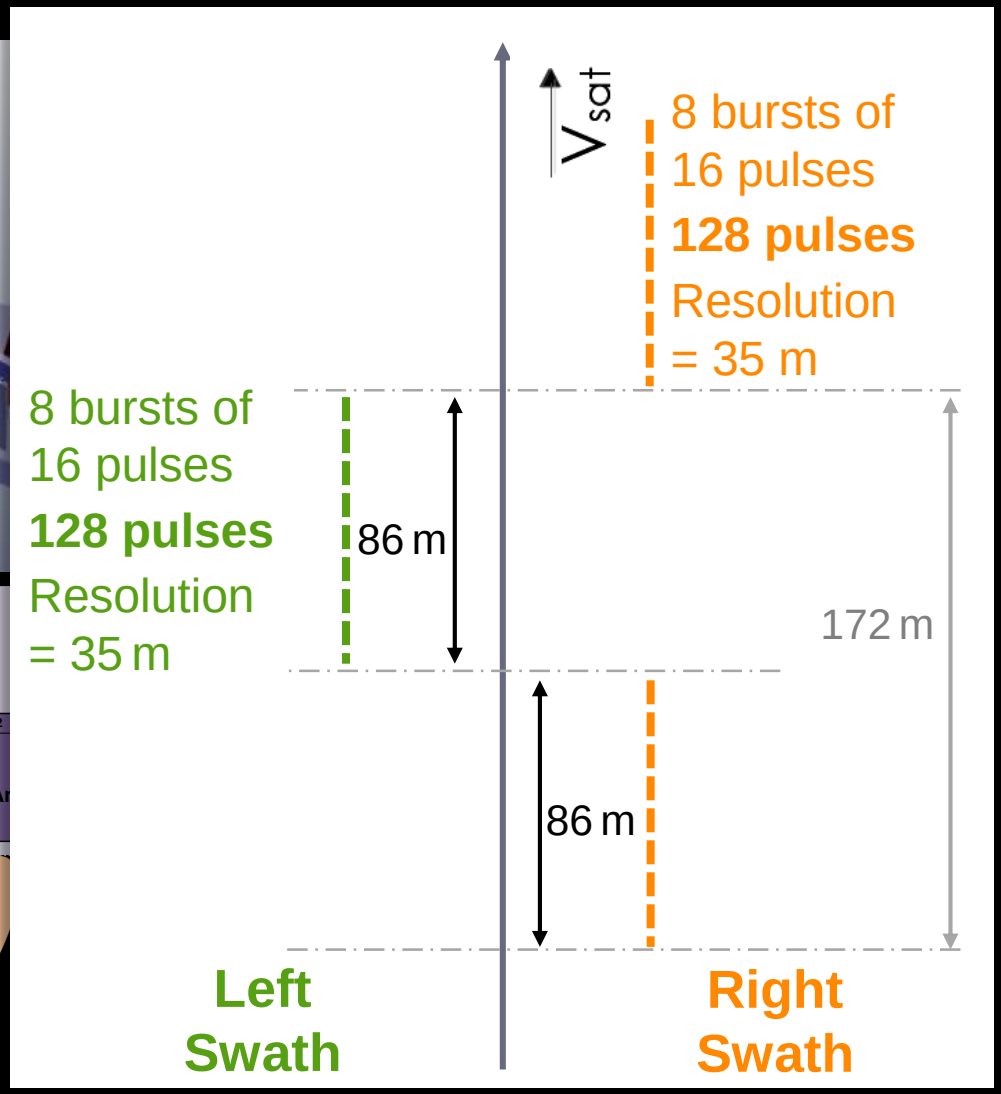

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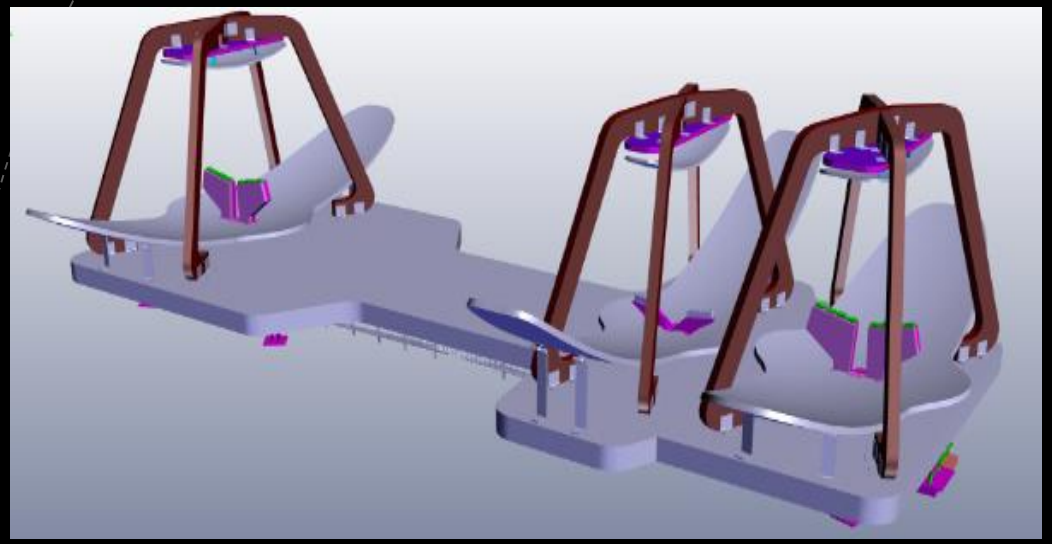

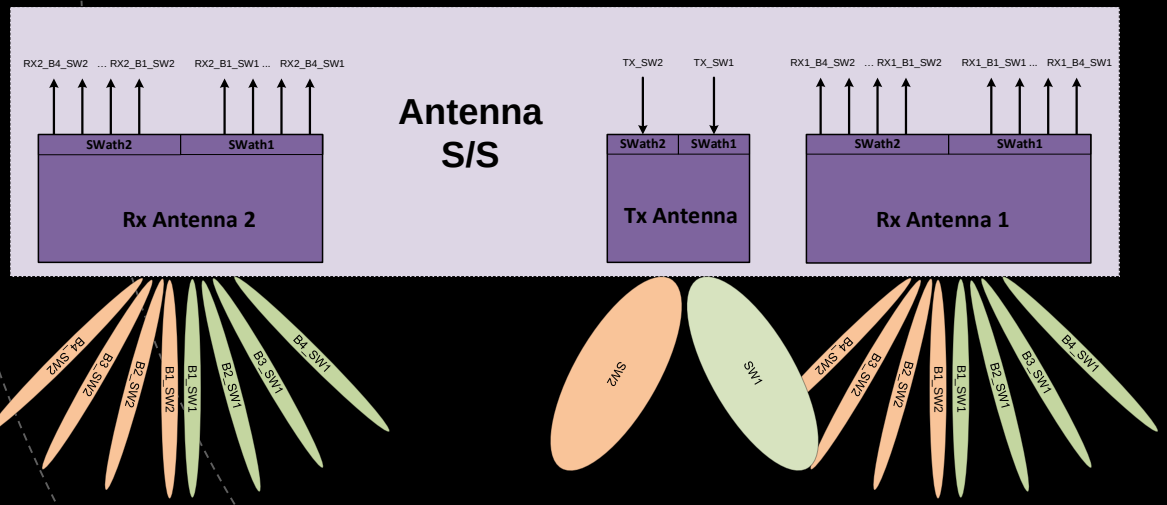

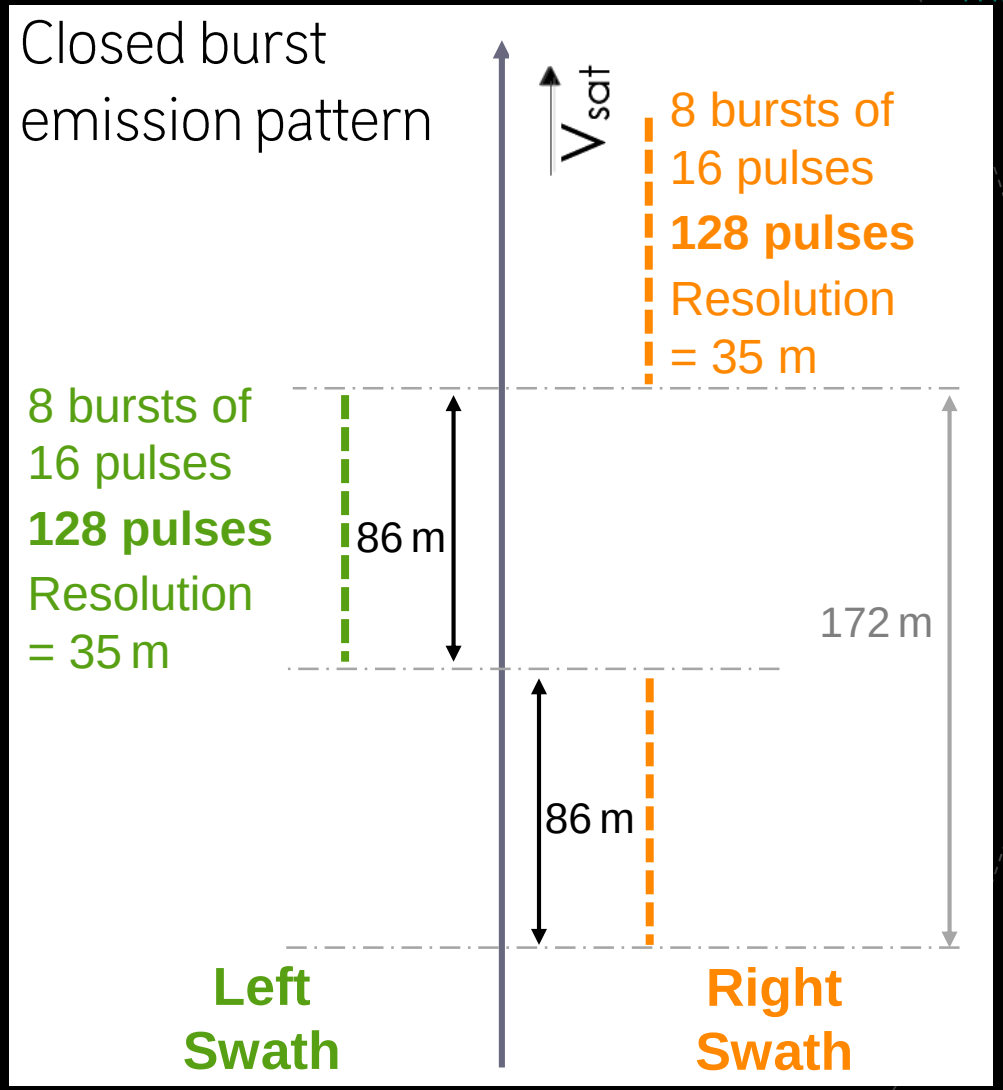

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Vs SWOT/KaRIn?

	SWOT/KaRIn	S3NG/SAOOH
Altitude	890 km	814.5 km
Baseline	10 m	3 m
SNR[1]	SAOOH current best estimate SNR ≈ KaRIn in-flight SNR	
PRF[2]	4.4 kHz	10 kHz
Emission pattern	Open burst	Closed burst (HR mode) Open burst (HRFF mode, 1-swath only)
Receivers	1 antenna / swath	4 antennas / swath

[1] Signal-to-Noise Ratio
[2] Pulse Repetition Frequency

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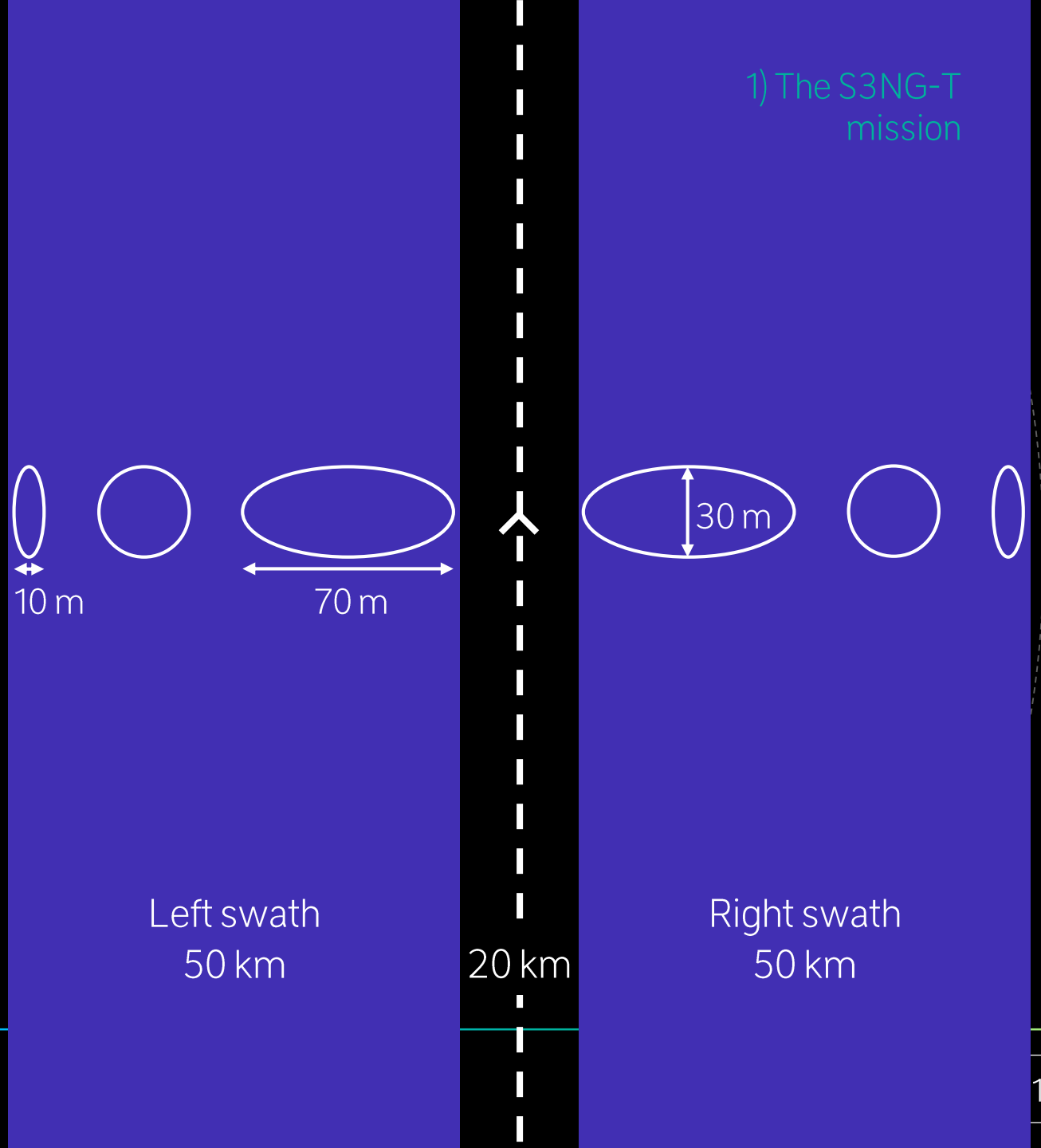

[1] Signal-to-Noise Ratio
[2] Pulse Repetition Frequency

2

The RADARSPY simulator

RADARSPY

Radarspy

RADAR Simulator in Python

- CNES internal development

RADARSPY

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RADARSPY

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RADARSPY

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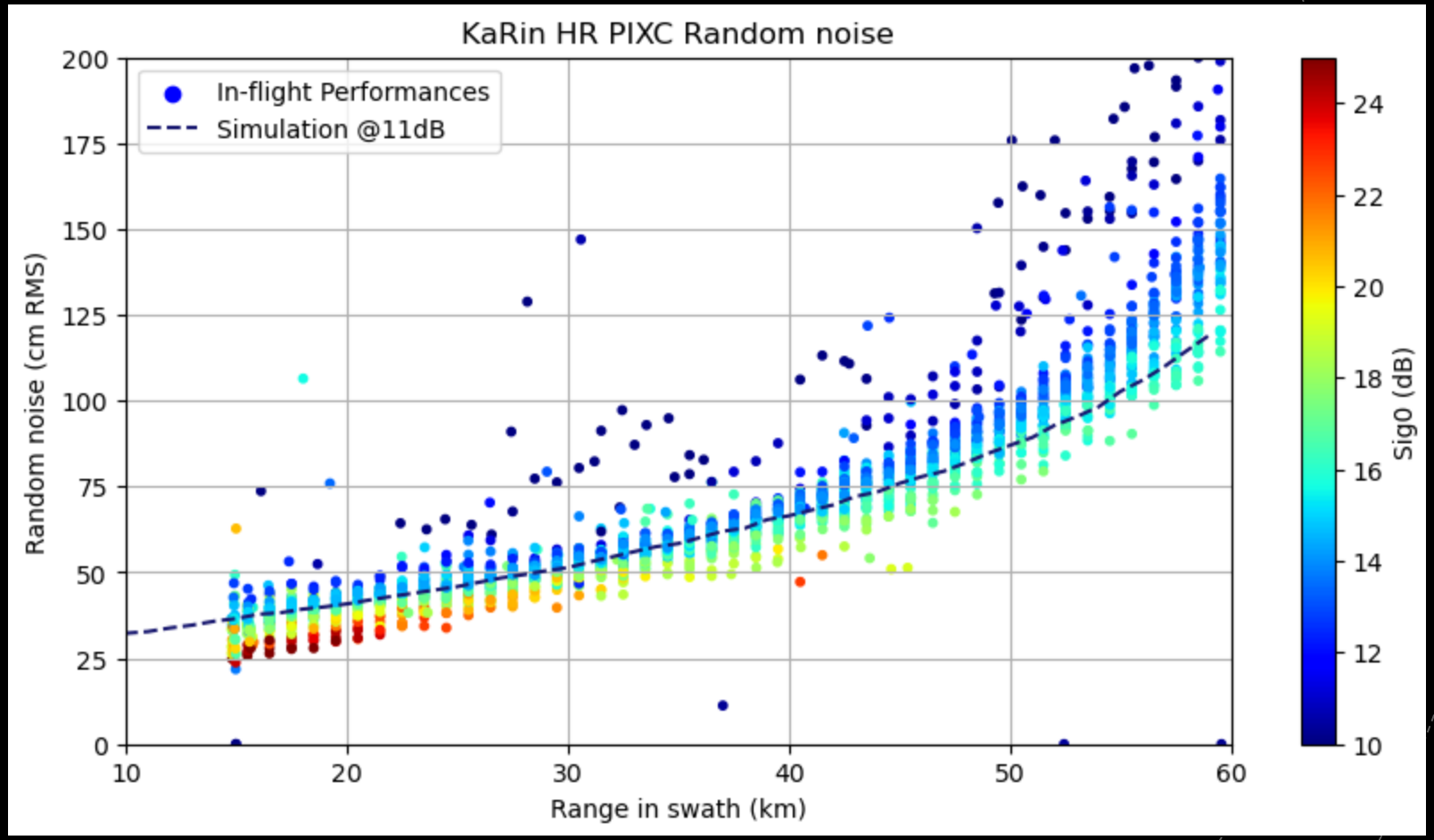
- Performances assessment

RADARSPY

Radarspy vs inflight data

Comparison between simulated and inflight performances on SWOT/KaRIn

Excellent match → high confidence in Radarspy implementation

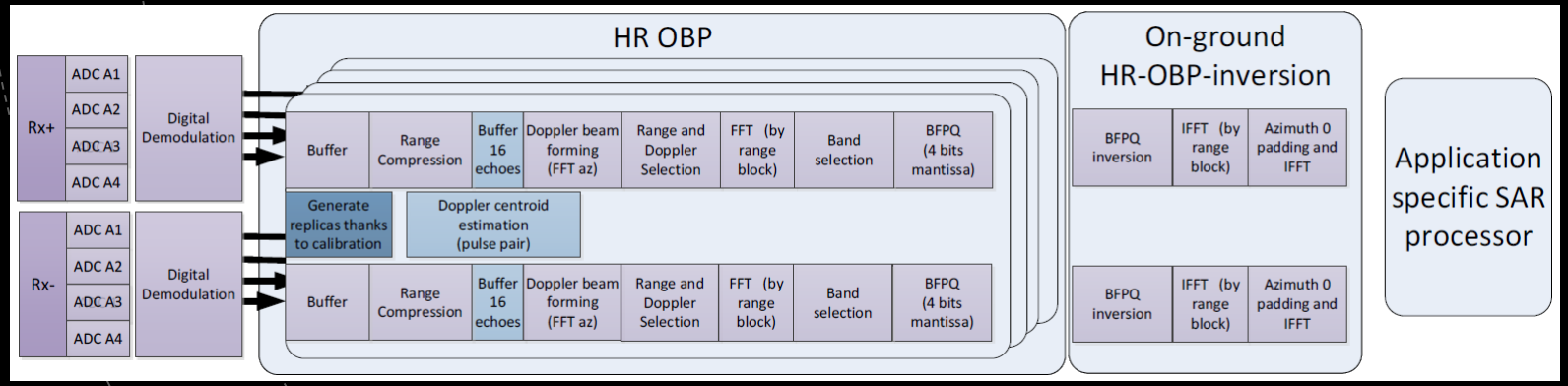


Measurements over Issykhul lake

SAOOH HR processing chain

Implemented TAS-F's "On-Board Processor ATBD v2"

- Few corrections (reported during project key-point)
- Simplifications
  - Tracker functions not implemented
  - Doppler centroid: zero for now



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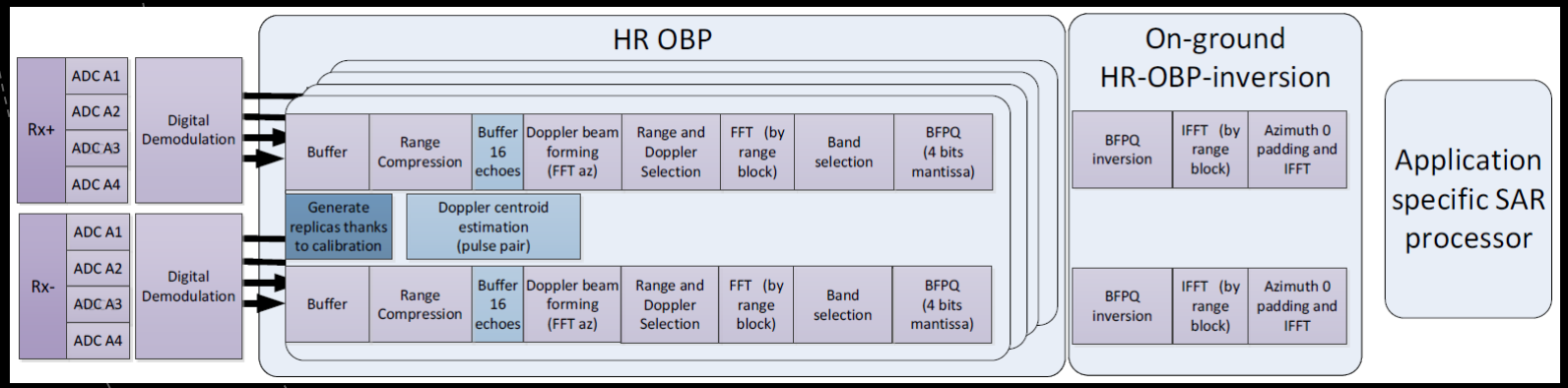
  - Quantization depth



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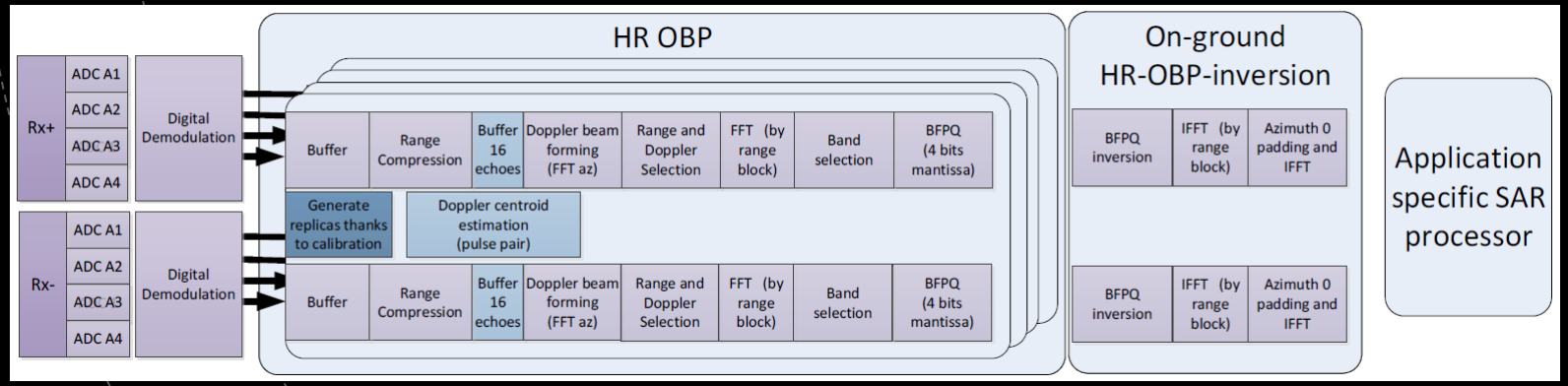
Ground processing chain inspired by SWOT processing chain

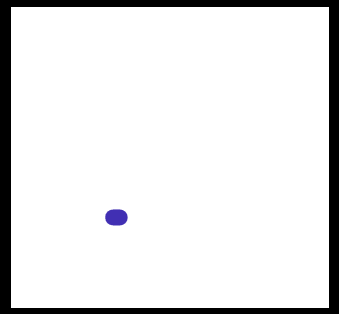
➢ Up to pixel clouds



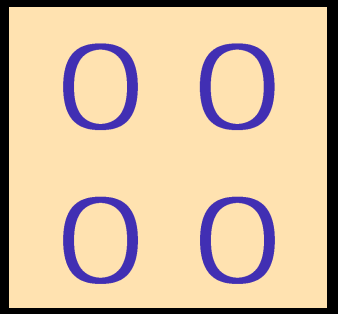
Simulation results

Test scenarii

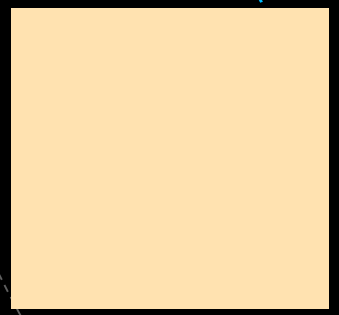
Point target analysis: azimuth resolution 30 m (cf. backup)



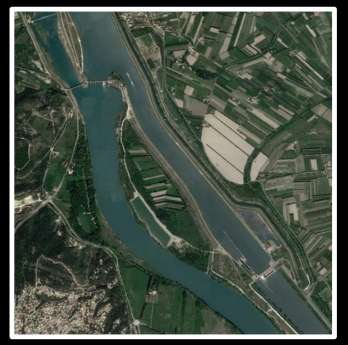
Circular rivers (water detection, …)



Random noise assessment w/ typical sig0 over inland waters (10-16 dB)



Realistic scene (Camargue)



SAOOH random noise

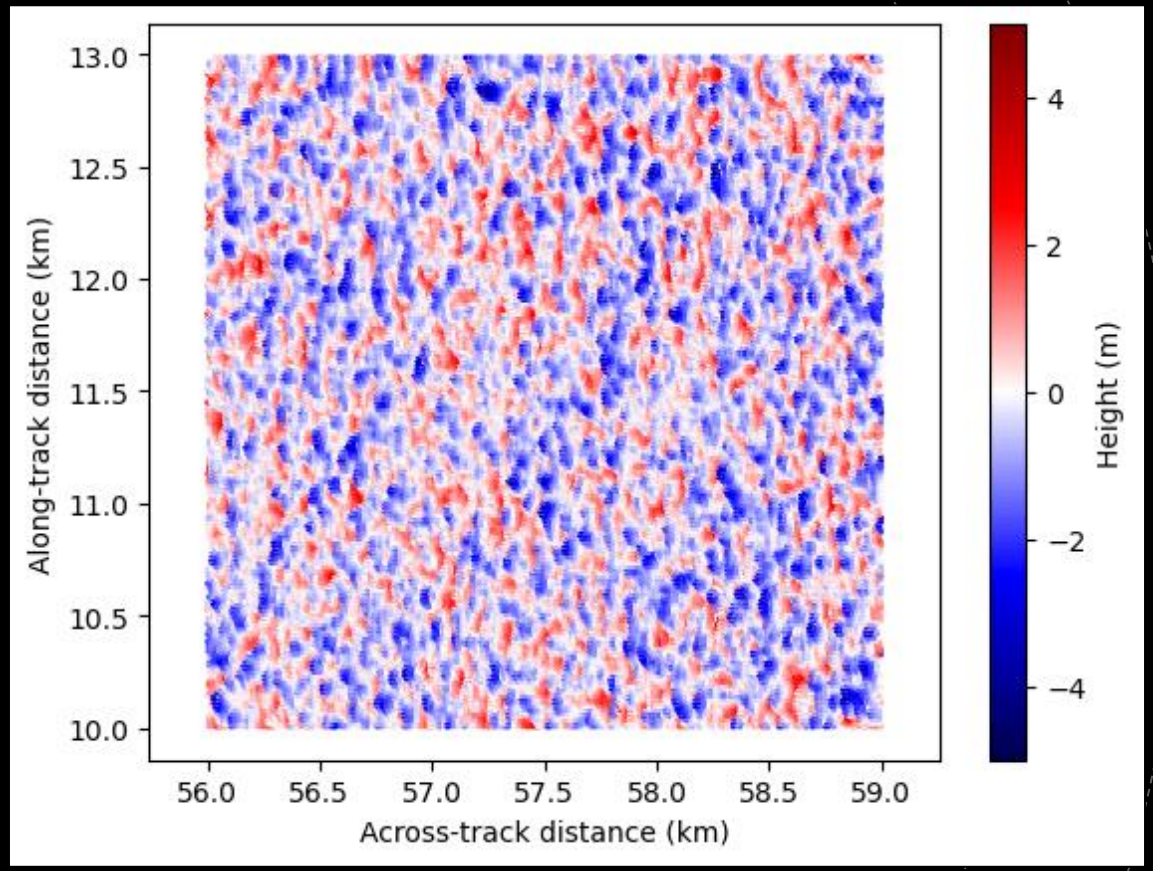
Radarspy vs TAS-F analytical model

No quantization, 5/16 Doppler beams, sig0 = 10 dB

Random noise = 5-7 cm (6 cm average in the swath)

→ Good agreement!

- analytical model random noise & simulations
- More confs to be tested to validate → great tool for quick analysis
- CLS simulations agree too



Pixel cloud

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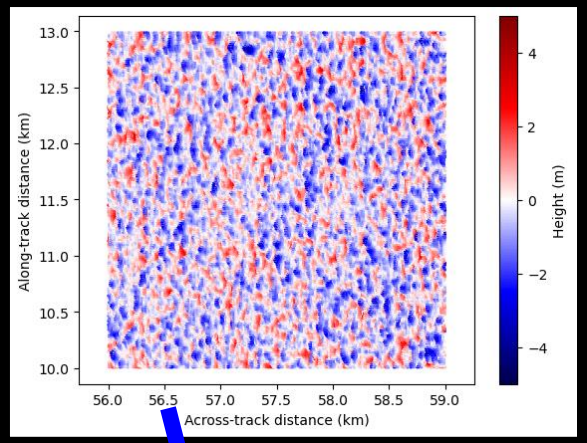

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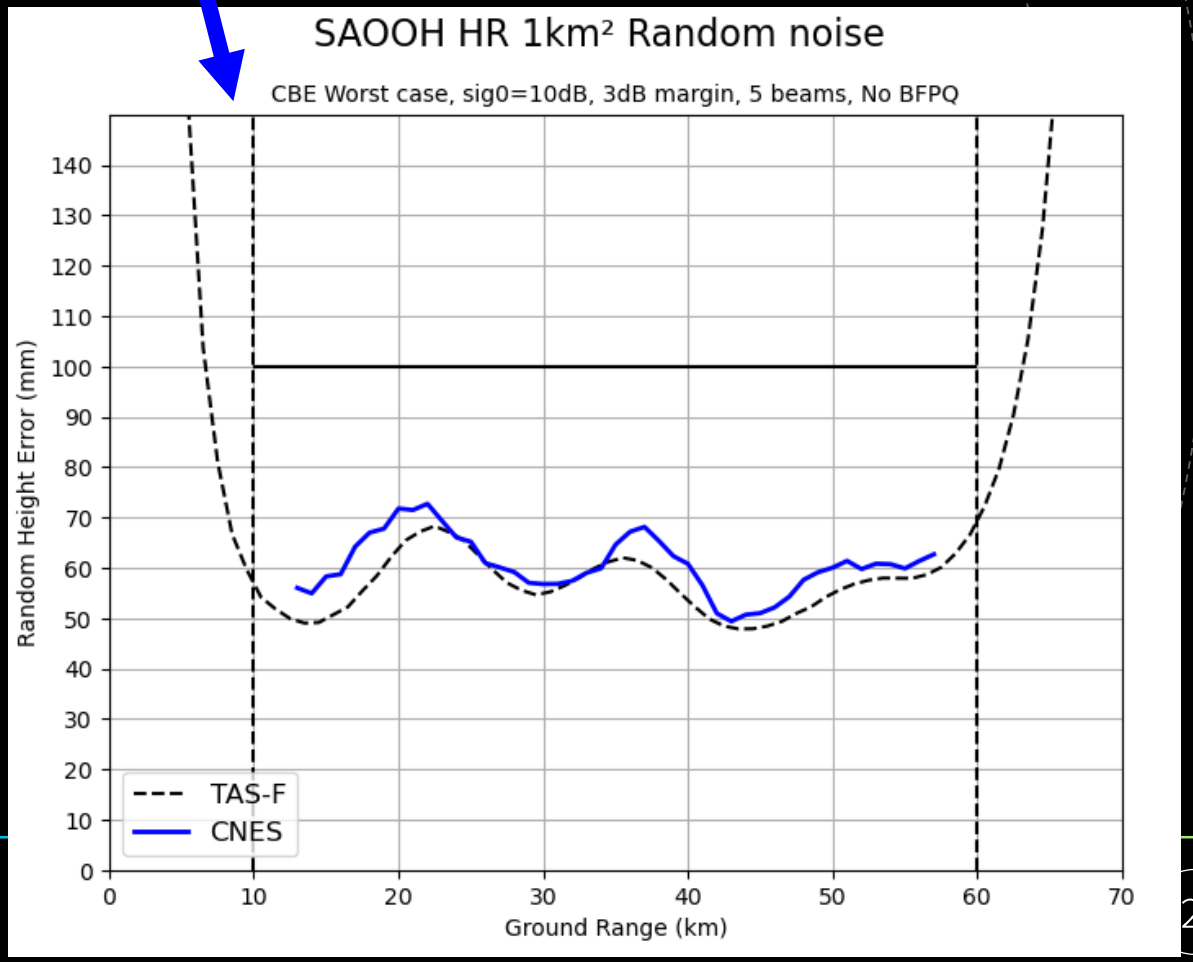
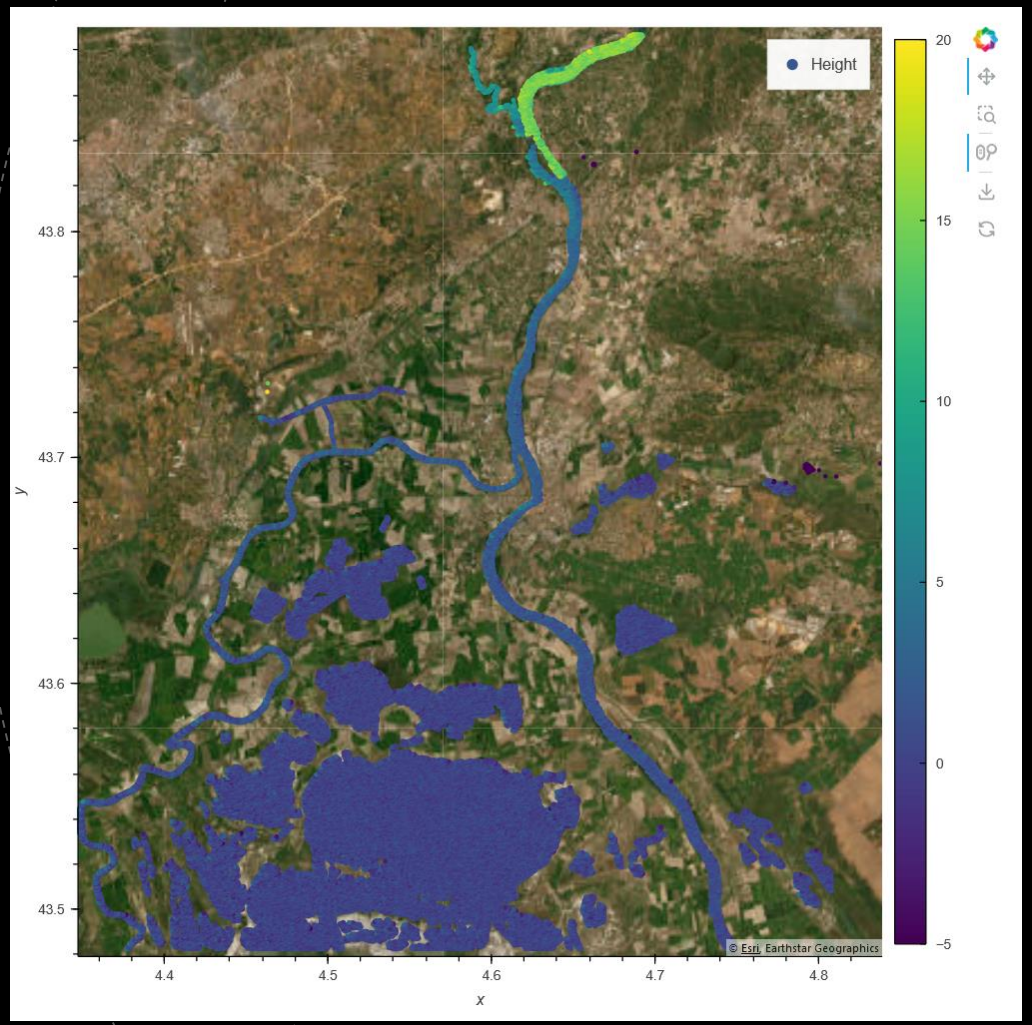
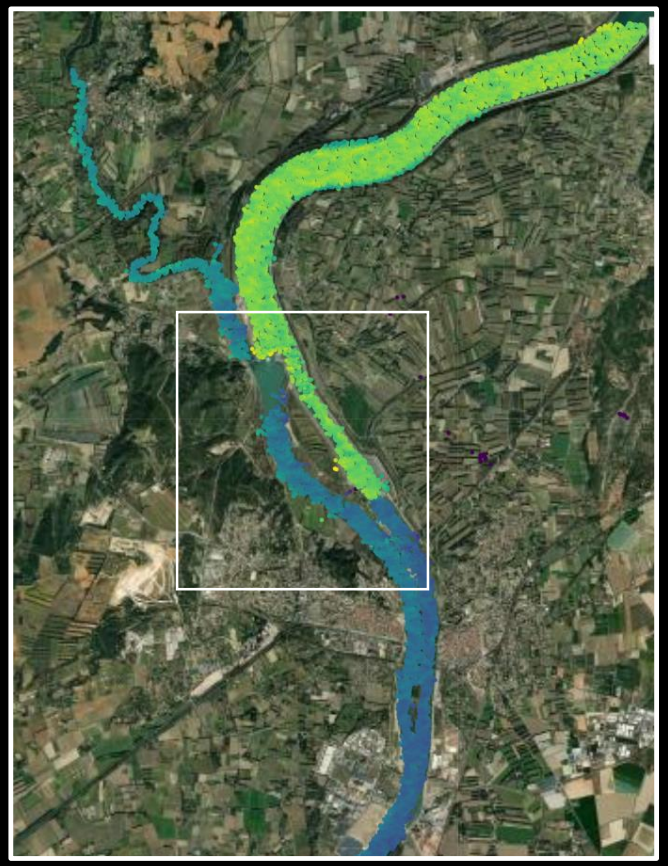


Realistic simulation in HR mode over Camargue (France)





HR mode requirement verification

Water Surface Elevation requirement

Total uncertainty of ≤ 10 cm

* This allocation was validated with a large margin during Phase A/B1 industrial study

The total uncertainty requirement is well verified.

Error Component	Height Error (cm)
SAOOH Random Error	7
Systematic Error after XCAL allocation	6.6*
Ionosphere	0.03
Dry Troposphere	0.7
Wet Troposphere	2
Radial Component	1
Non linear error	1.2
Total uncertainty allocation	10

Conclusions

- S3NG-T upcoming ESA/Copernicus altimetry mission w/ Swath concept (?)
- CNES w/ swath altimetry expertise (SWOT) ran performance analyses for S3NG/SAOOH – HR
- Good agreement btw/ Radarspy and inflight data / TAS-F analytical model
- Requirement on hydrology WSE uncertainty is verified

Future work

- Complete HR performance assessment (water detection perf., HRFF mode implementation…)
- LR chain implementation
- Attitude errors, navigation bulletins etc…

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RADARSPY

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Thank you!

BACKUP

slides

SAOOH vs KaRIn

	SAOOH	KaRIn
Altitude	815 km (S3)	890 km
Swath	2x50 km	2x50 km
Frequency	35.75 GHz	35.75 GHz
Bandwidth	200 MHz	200 MHz
Chronogram	Closed Burst	Open Burst
Mode(s)	HR & HRFF	HR
3dB Azimuth Aperture	0.24°	0.12°
3dB Range Aperture	2.8°	2.8°
PRF	~10 kHz	4 KHz

	SAOOH	KaRIn
Range Resolution	10-70 m	10-70 m
Azimuth Resolution (after averaging)	~30 m	~20 m
Nb Antenna Beams / swath	4	1
Baseline length	3 m	10 m
Random Noise @sig0=10dB	6 cm	1-1.5 cm

SAOOH current best estimate SNR is equivalent to KaRIn in-flight SNR.

Radarspy

RADAR Simulator in Python

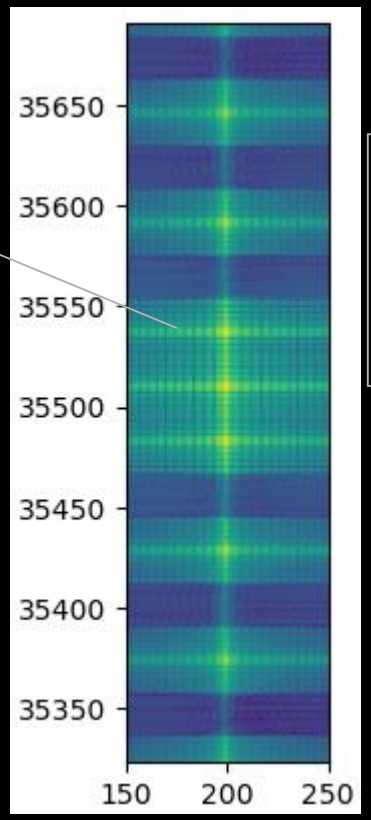
- CNES internal development
- Multi-missions radar simulator
- Python code
- Ocean static or dynamic scenes (from waves spectra, static or dynamic)
- Hydrology scenes from DEM and surface mask
- Point Target Responses and Synthetic scenes (for fundamental analysis)
- Instrument models (KaRIn, Poseidon)
- Satellite orbit & attitude
- Data processing (on-board & on-ground)
- Performances assessment
- High computation capability with +1,000 CPUs for one user (TREX)

RADARSPY

Single target simulation

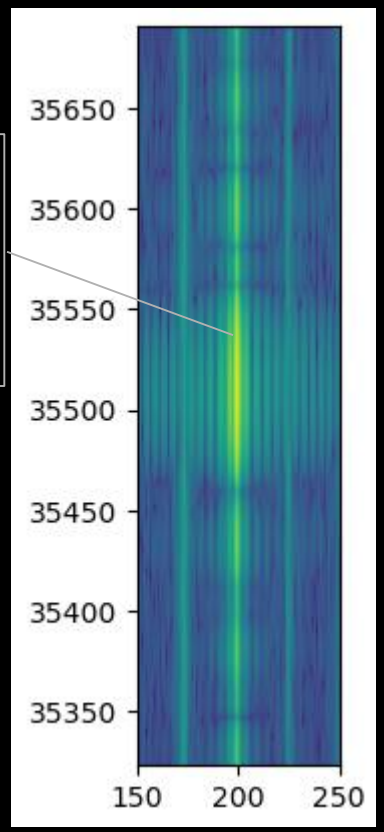
Grating side lobes due to the closed burst chronogram (known, expected)

HR



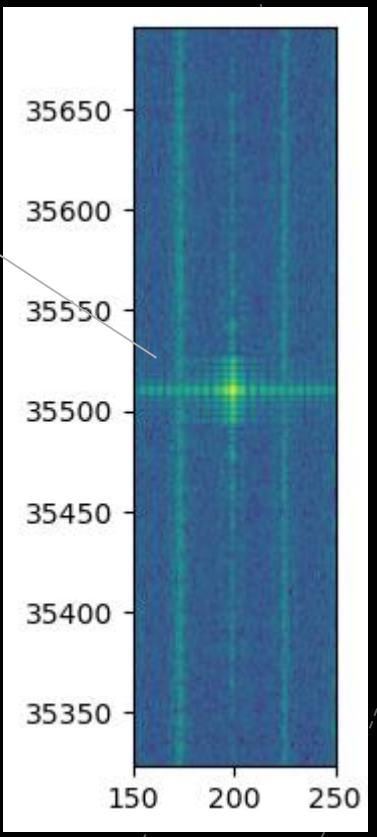
Side lobes filtering*: Azimuth resolution is degraded down to 30 m

HR + azimuth filtering



HRFF = single swath with open burst chronogram, no grating side lobes*

HRFF



* Low amplitude replicas in range are observed. Under investigation. Marginal impact on random noise computation.