End-to-End BreadBoard tools for Harmony mission: SW architecture and preliminary results

MULTISTATIC RADAR WORKSHOP 2025

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Date: 20th June 2025
Issue: 1.0
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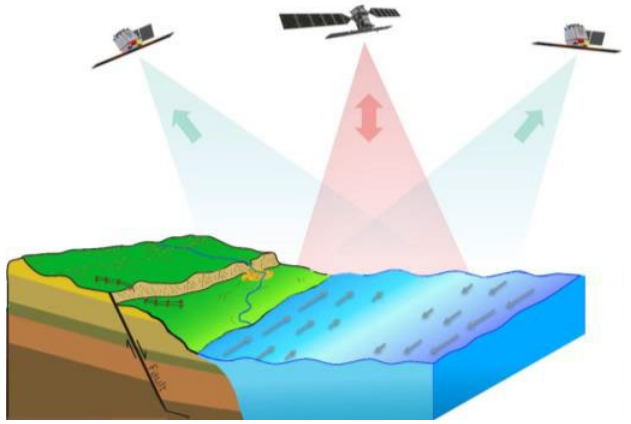
Overview

- Harmony mission and Breadboard simulator
- Challenges and Breadboard Simulator architecture
- Preliminary IRF results
- Conclusions

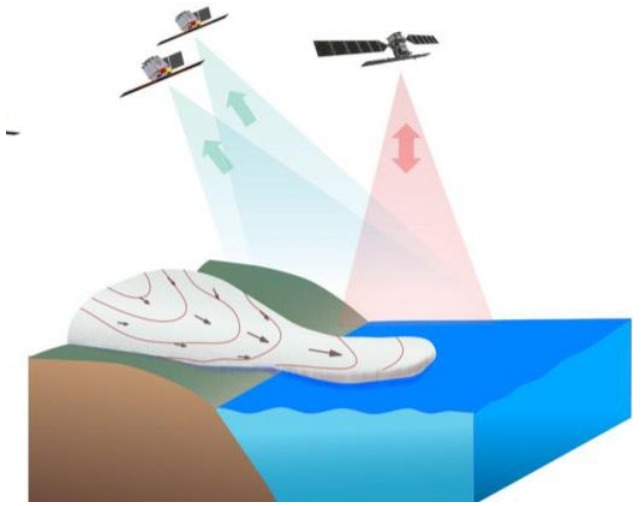
Harmony mission and Breadboard simulator

- Aresys is supporting Thales Alenia Space Italia with the ***Harmony SAR Instrument Data Breadboard Simulator L1 Breadboard Processor***



Key objectives:

- Validation of the L1 Algorithms for bistatic data
- Verification of compliance with SRD/UIRD Level-1 requirements for Level 0, Level 1A, and Level 1B products
- Support the HEEPS (Harmony End-to-End Performance Simulator) activities



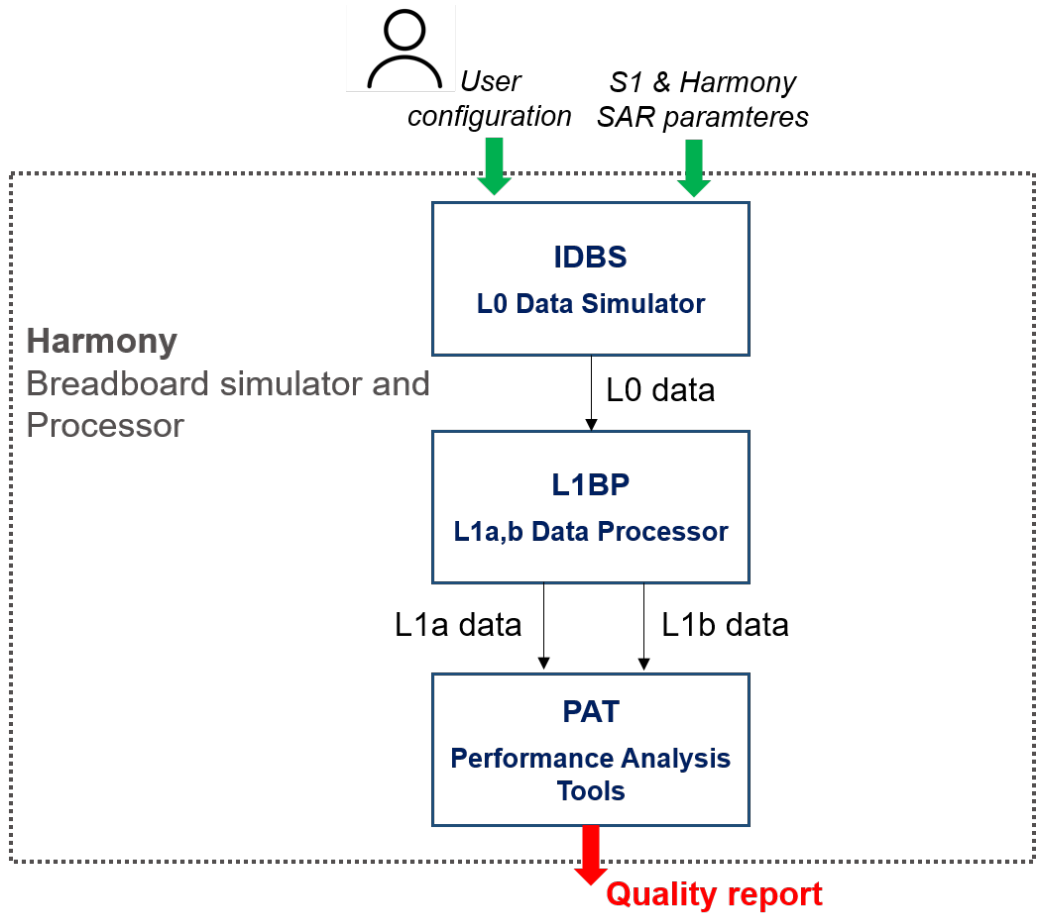
Challenges and Breadboard Simulator architecture

HARMONY brings specific challenges from the SAR simulation point of view:

- The along track angular separation between illuminator and receiver ≈ 350 km
- The illuminator and the passive receiver are independent SAR systems
- The antenna is split into three sub-assembly: two wings and one central panel

We propose a very flexible and accurate solution for the Harmony Breadboard Simulator based on:

- **IDBS** (SAR Instrument Data Breadboard Simulator): in charge of the generation of the SAR raw data
- **L1BP** (SAR Level 1 Breadboard Processor): in charge of the generation of the L1a and L1b Products
- **PAT** (Performance Assessment Tool): the set of tools that are used for assessment of the SAR data quality and SAR performance

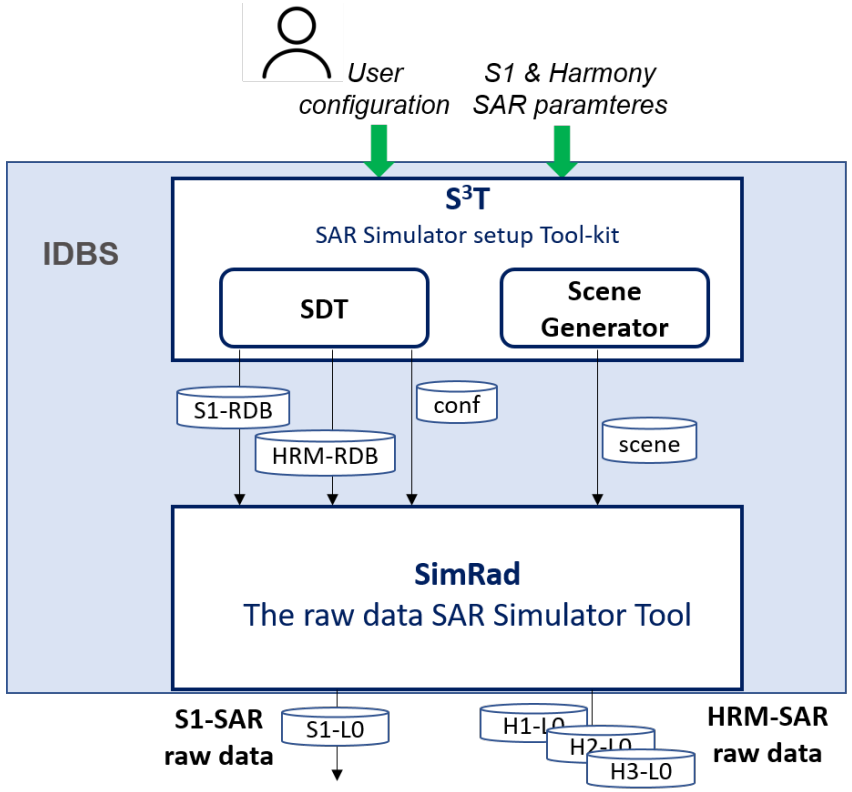


SAR Instrument Data Breadboard Simulator - IDBS (I)

The IDBS is composed by 2 main components:

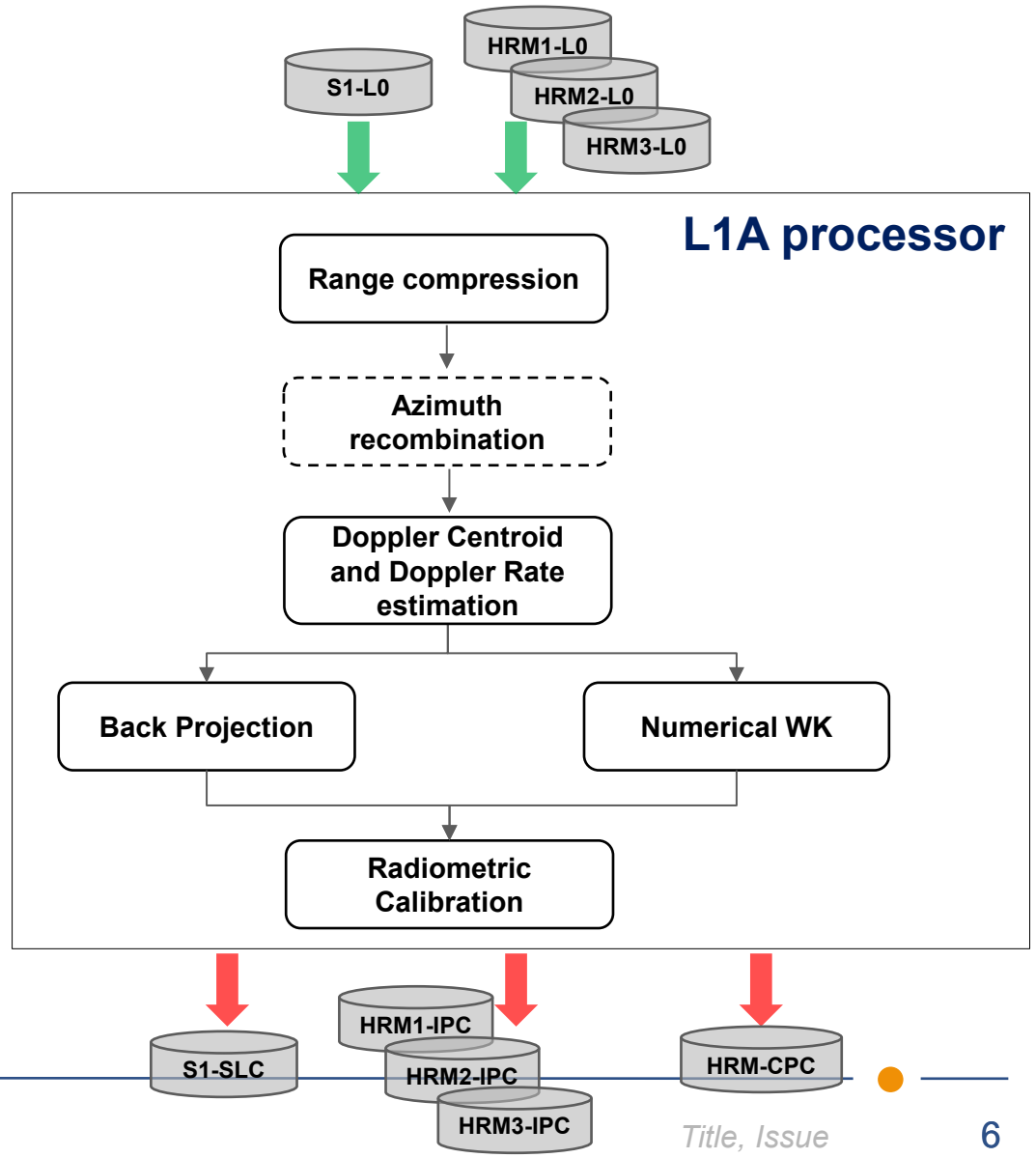
- **SAR simulator set-up tool-kit (S^3T):** dedicated to the setup of the simulation
  - SAR Design Toolbox (SDT): based on the user-defined SAR acquisition mode, this module creates the radar database (RDB) file containing all the information useful to the SAR simulation
  - Scene Generator: based on user's inputs, this module defines the scene to be simulated
- **The raw data simulator tool (SimRAD)**
  - It simulates the I/Q samples composing the simulated SAR RAW data
  - The core algorithm is based on the time-domain simulation approach, namely for each PRI and for each target computes the radar equation and generates the raw data accordingly

    ➡ *high fidelity simulation of SAR data*

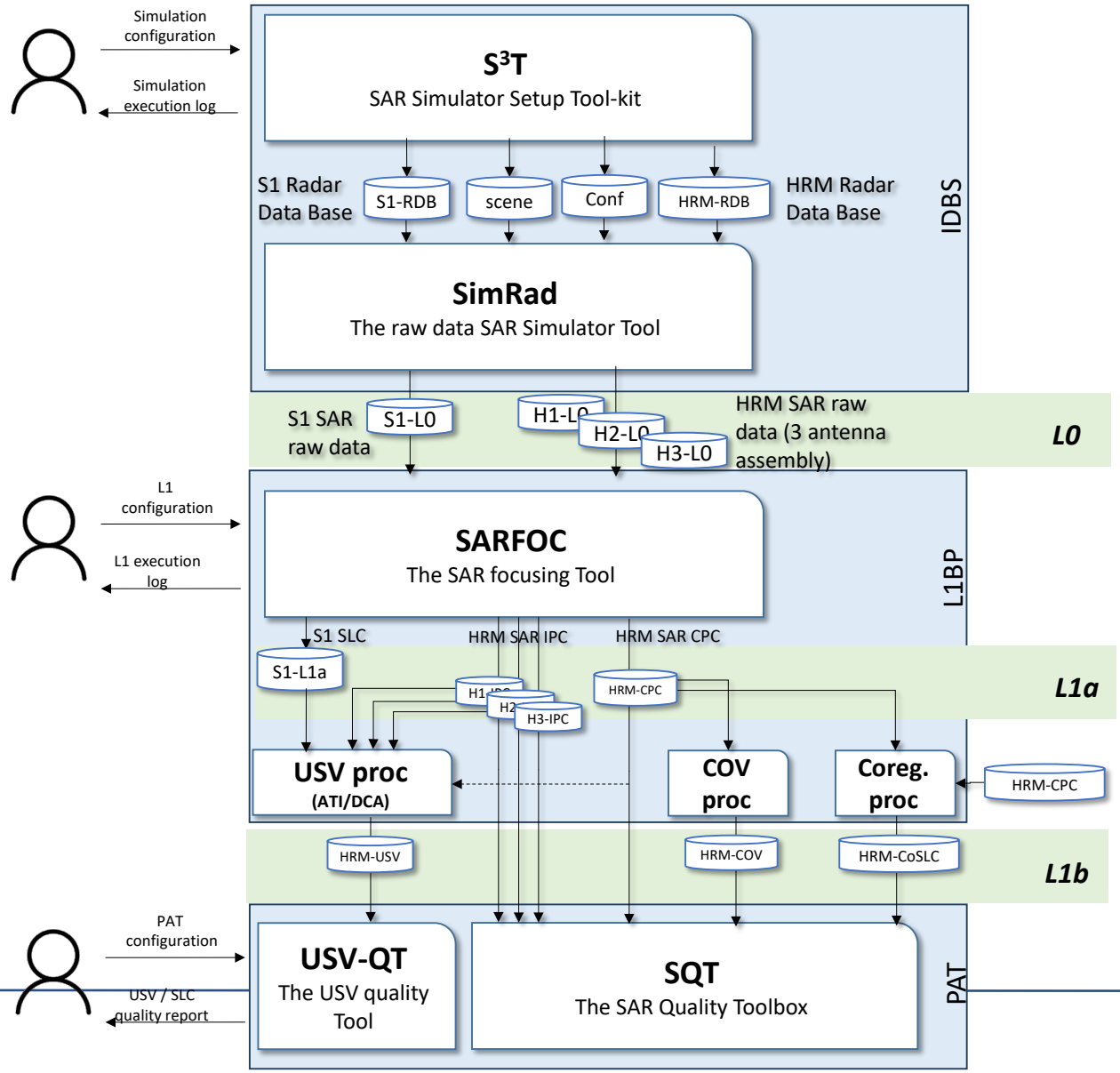


SAR Level 1 Breadboard Processor - L1A

- The main processing blocks of the L1A processors are:
  - **Range compression**: it implements the range compression
  - **Azimuth recombination**: the data from the three assembly are combined to then generate the SLC-CPC data
  - **Doppler Centroid and Doppler rate estimation:** it derives the Doppler Centroid and Doppler rate parameters
  - **Azimuth compression:** this block performs the azimuth compression. Possible options in the algorithm selection are the back projection or the numerical $\Omega - k$
  - **Radiometric calibration**: this block performs the relative radiometric correction on Single Look Complex data
- The SLC (IPC or CPC) data are written in output

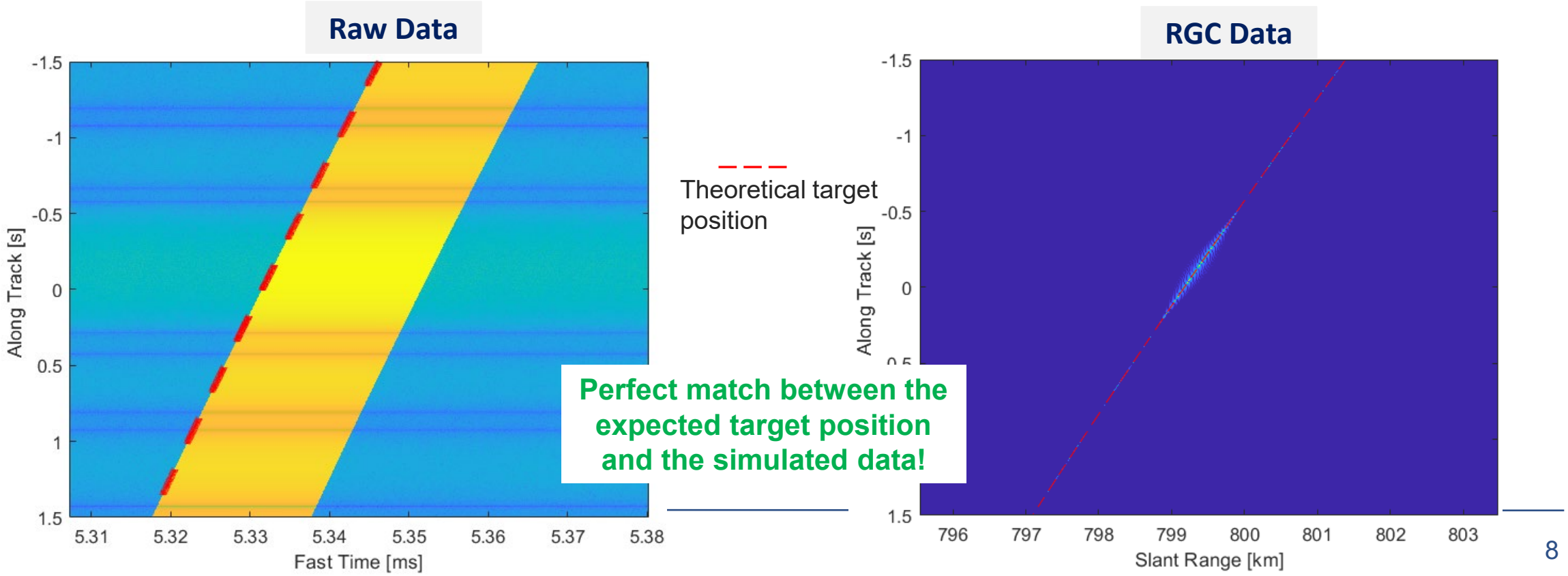


Complete simulator architecture

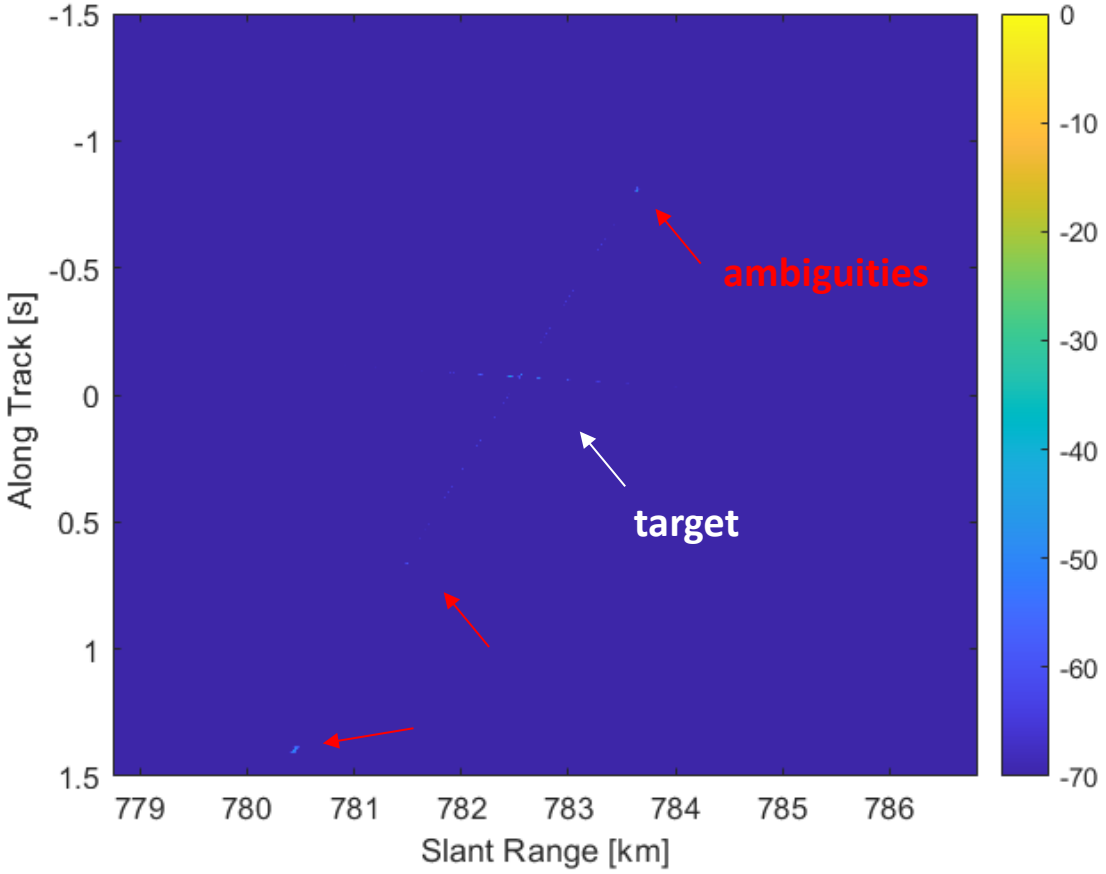


Simulated Scenario & Results

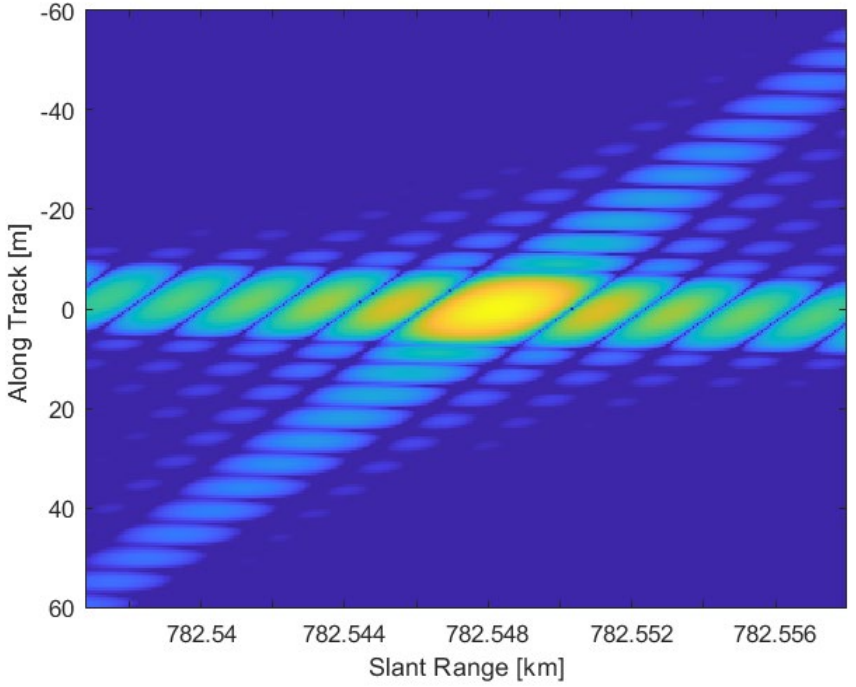
- Acquisition Mode: **STRIPMAP**
- Resolution [rg,az]: **1.782x5m**
- Scenario: **1 Point Target**
- Simulation length: **3 s**



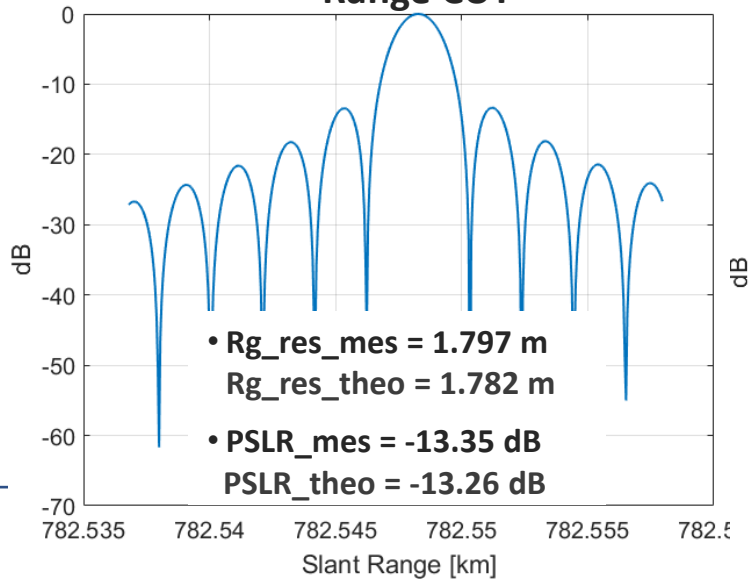
IRF results (BP)



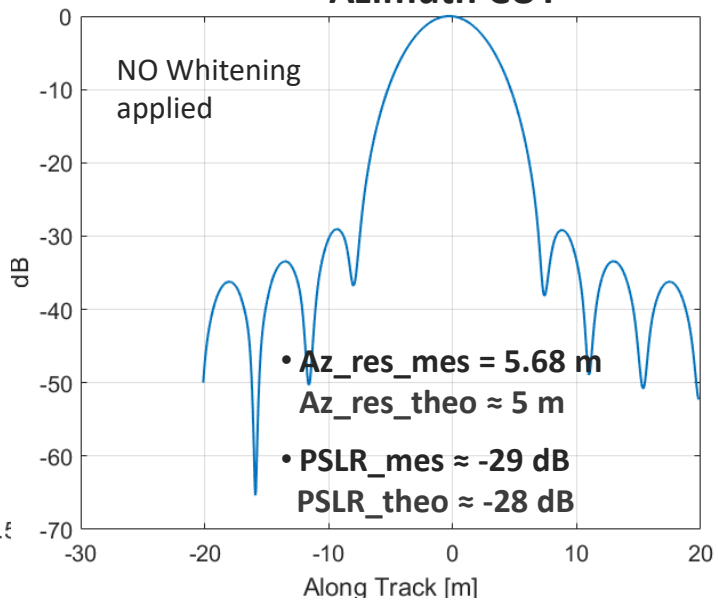
Zoom on target



Range CUT



Azimuth CUT



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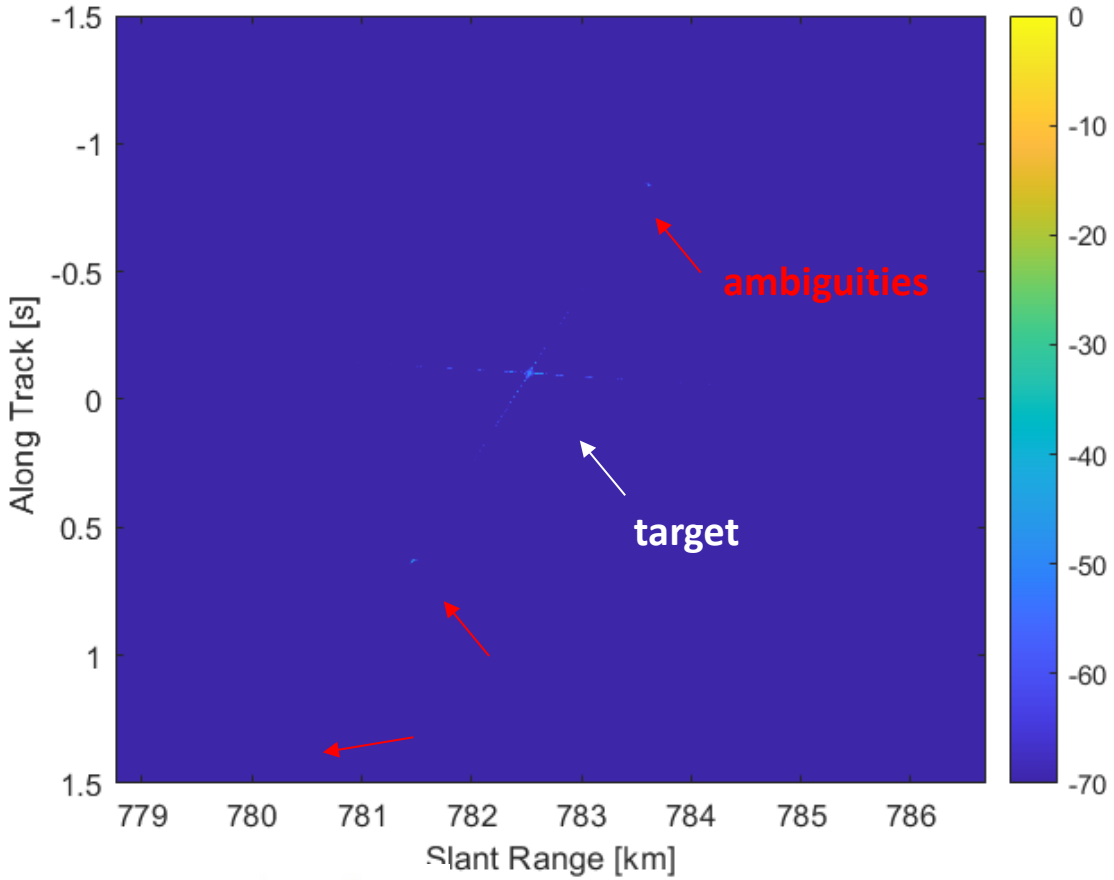
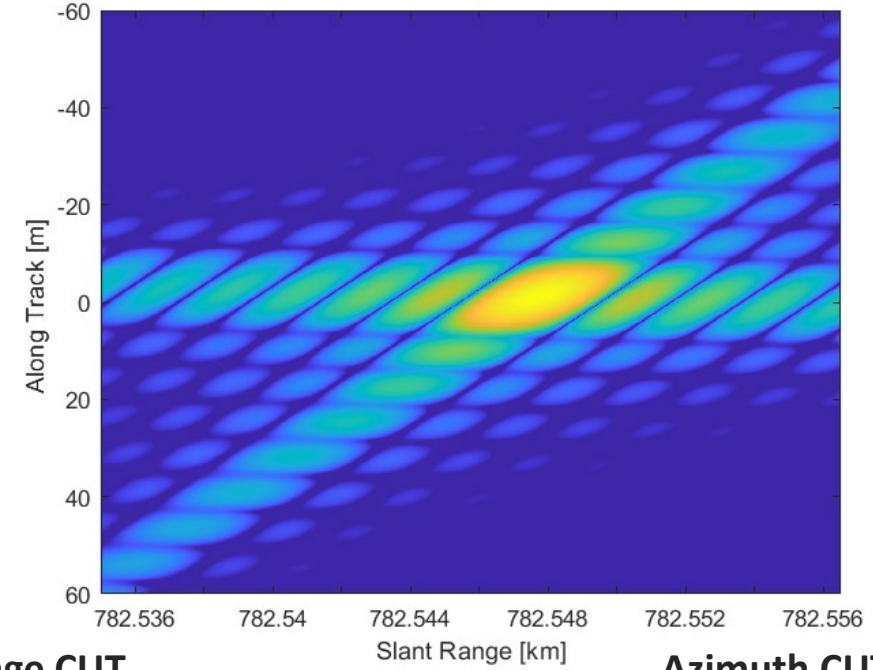
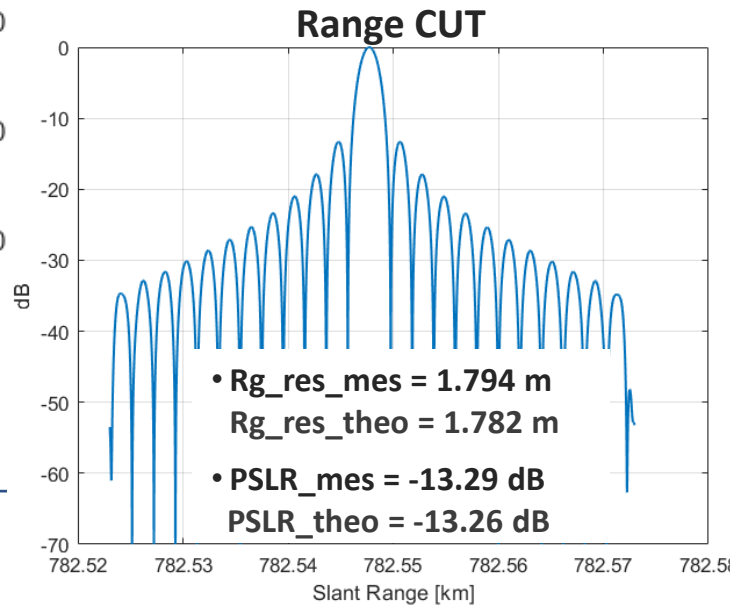
Preliminary numerical W-K results

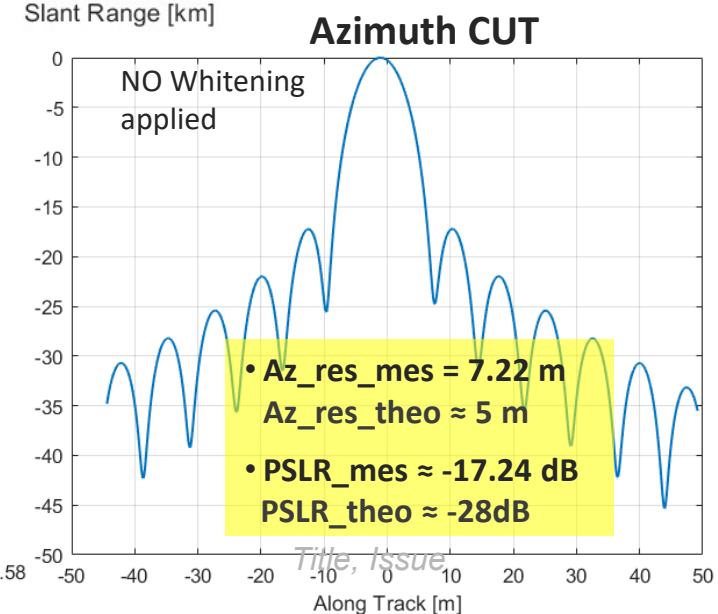


Zoom on target



Azimuth compression not yet perfect!





Conclusions

- The results show that an effective Harmony simulator architecture has been developed to face the challenges coming from the mission.
- Specifically, the main activities focused on:
  - The simulation of the L0 data
  - The simulation of the L1a data
  - The IRF analysis
- The preliminary results have shown a great match between the theoretical and the simulated performance.