

Smart On-Board Processing for Next-Generation SAR Systems: Achievements and Final Results of the SOPHOS Project

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The number of satellites launched into orbit is rising rapidly each year, and their complexity and capabilities are increasing significantly. Today, near-global Earth coverage by optical sensors is achieved daily by civilian spacecraft, and soon civilian SAR (Synthetic Aperture Radar) systems are expected to provide similar coverage. The growing volume of spaceborne data will require new solutions for transferring it to the ground, as downlink remains a key bottleneck. Advances in onboard processing and storage will enable higher performance in smaller spacecraft, but current systems are still limited by computational power, memory capacity, and data reliability, especially in very compact designs. Smart on-board processing for Earth observation systems (SOPHOS) was a 3-year EU Horizon Europe project. The main goal of SOPHOS was to design and implement enabling technology for high-end data products produced on board spacecraft via the implementation of power-efficient high-performance space processing chains for various Low-Earth Orbit (LEO) missions, with a focus on Synthetic Aperture Radar (SAR), which is one of the most data intensive space applications currently used. This paper presents the final results and achievements of the project.

The SOPHOS demonstrator is designed to validate the advanced on-orbit processing and data management capabilities developed within the SOPHOS project. Its primary purpose is to showcase high-performance payload data handling, flexible routing, and efficient SAR image formation and compression. The demonstrator integrates three key components: (i) the Payload Processing Module (PPM), (ii) the Mass Memory Module (MMM), and (iii) the Electronic Ground Support Equipment (EGSE).

The on-board processing algorithms selected for on-board implementation cover two central mission scenarios: the derivation of High-Quality as well as Low-Latency SAR information products. High-quality SAR images are assumed to be single-look (i.e., at full resolution) to serve advanced applications, such as SAR interferometry. They are usually processed on ground without any approximation. For this purpose, a novel performance-optimized block-adaptive quantization (PO-BAQ) is introduced, which extends the concept of the state-of-the-art BAQ and allows for an optimization of the resource allocation by controlling the resulting SAR image degradation [4]. Since quantization errors are significantly influenced by the local distribution of the SAR image intensity, such an optimization is achieved by exploiting the a priori knowledge about the SAR backscatter

statistics of the imaged scene. On the other hand, low-latency products may be processed on board up to the stage of a multi-looked SAR image, making use of the time between data acquisition and the next available downlink opportunity. At the same time, the data volume required for downlink can be reduced compared to raw data.

In this paper, we present the concept and main achievements of the SOPHOS project, with a particular focus on the implementation and optimization of SAR processing algorithms for on-board execution. The paper discusses the challenges and solutions adopted to enable efficient real-time processing, including algorithm adaptation, optimization strategies, and their integration into the SOPHOS demonstrator. Furthermore, the design of the demonstrator and the interfacing activities between the EGSE, Mass Memory, and Payload Processing Module are presented.