SURPRISE

SUPER-RESOLVED COMPRESSIVE INSTRUMENT IN THE VISIBLE AND MEDIUM INFRARED FOR EARTH OBSERVATION APPLICATIONS

SURPRISE Kick Off

Project Summary and Work Plan – Month 1

SURPRISE Factsheet

Title: SURPRISE - SUper-Resolved comPRessive InStrument in the visible and medium infrared for Earth observation applications

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Coordinator: "Nello Carrara" Institute of Applied Physics (IFAC) - National Research Council - Italy

Partners: Swiss Centre for Electronics and Micro-techniques (CSEM) – Switzerland; Politecnico di Torino (POLITO) – Italy; ACRI-ST S.A.S- France; SAITEC Srl- Italy; RESOLVO Srl – Italy; Fraunhofer Institute for Photonic Microsystems (IPMS) – Germany; LEONARDO S.P.A - Italy

1. The Project

1.1. Project Overview

SURPRISE is built around 9 work packages, listed below and with the interactions illustrated in Figure 1:

WP1 - Ethics requirements (IFAC)

WP2 - EO applications and user requirements (ACRI_ST)

WP3 - SLM design, assembly and test (IPMS)

WP4 - System specifications and design (IFAC)

WP5 - System modelling and algorithm development (POLI-TO)

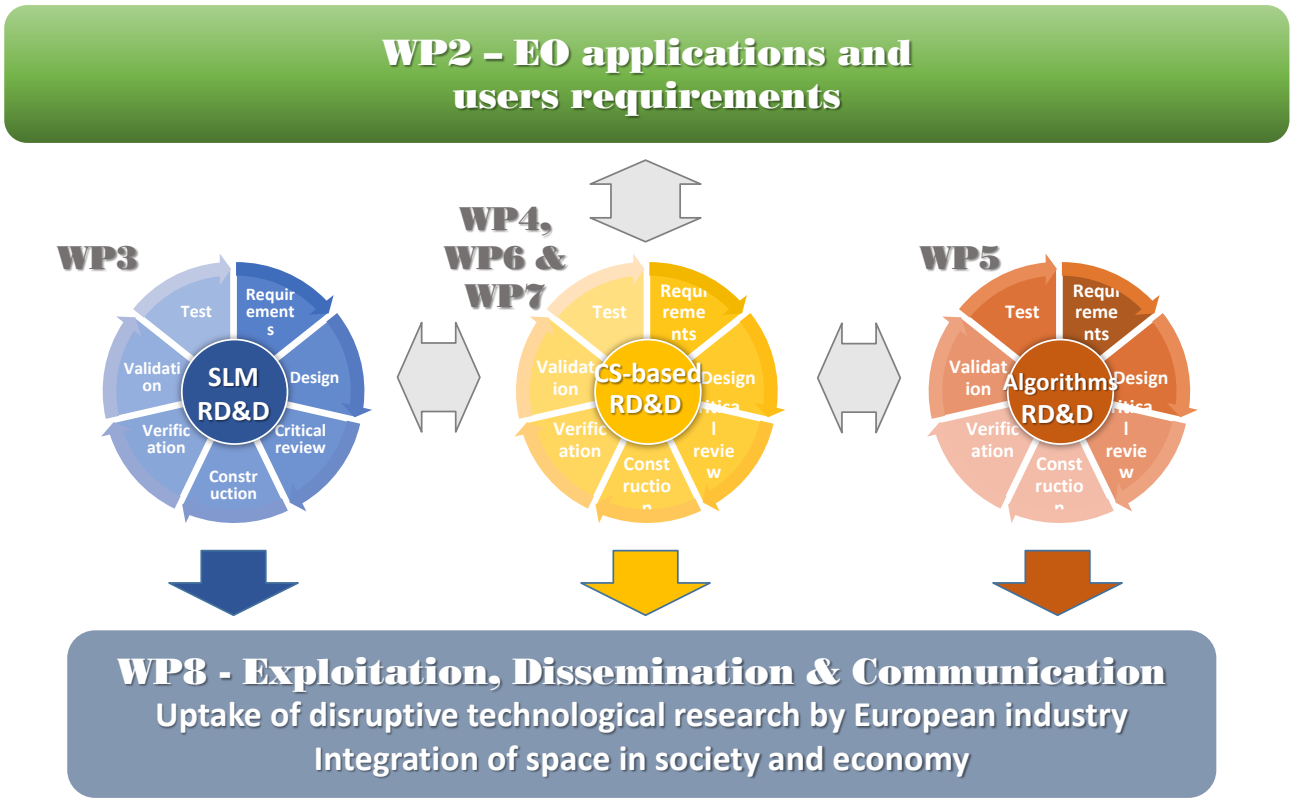
WP6 - Subsystems procurement, construction and test (CSEM)

WP7 - System assembly, test and final assessment (IFAC)

WP8 - Reaching society and the market (RESOLVO)

WP9 - Management (IFAC)

Figure 1: SURPRISE WP Interactions



1.2. Objectives, approach and innovation

SURPRISE is designed to enhance performance of future Earth Observation (EO) payloads in terms of spatial resolution, on-board data processing and encryption capabilities. This will be achieved by using Compressive Sensing (CS) technology implemented via Spatial Light Modulators (SLM). SURPRISE's objectives are to:

- demonstrate the functioning of Spatial Light Modulator (SLM) technology in relevant environment, with particular reference to its operation in the Medium InfraRed (MIR);
- implement a demonstrator of a super-spectral EO payload in the Visible-Near InfraRed (VNIR) and Medium InfraRed (MIR) with enhanced performance in terms of at-ground spatial resolution, on-board data processing and encryption functionalities;
- analyse the impact of enhanced performance on EO application products and services;
- uptake of disruptive technological research by EU industry.

SURPRISE is innovative in terms of:

- Advances in Compressive Sensing technology, thanks to the implementation of a space-targeted VNIR-MIR demonstrator – and relevant reconstruction algorithms - integrating super-resolution and single pixel camera concepts;

- Advances in SLM technology, by adapting COTS DMD to operation in the MIR and by studying the first European SLM, micromirror array-type, with electronics oriented to space application;
- Advances in on-board processing and encryption capabilities by addressing the innovation potential of Compressive Sensing;
- Advances in EO application products and services by addressing the impact on them of enhanced EO systems capabilities and by investigating innovative EO application products.

1.3. Partner roles in SURPRISE

CNR-IFAC is the project coordinator and brings to the project their extensive experience in EO instrumentation and data processing. The partner also brings specific knowledge on optical design (WP4), data simulation of optical instrumentation for Earth Observation (hyperspectral, multispectral, panchromatic images), Star Tracker systems and Astronomy (WP5) and system prototyping (assembly, verification, validation and test), calibration and validation (WP7)

CSEM supports work on a COTS solution for the SLM matching the SURPRISE instrument specifications and on a European solution for a space qualified SLM (WP3). They contribute to instrument subsystem specifications (WP4) and manage procurement, construction and testing of some parts of the electronic and data handling (WP6). They support assembly and verification in the complete instrument (WP7).

FRAUNHOFER IPMS contributes to SURPRISE as SLM expert. IPMS supports adaption of a COTS SLM by Texas Instruments, its system verification and testing in relevant environment. They also provide an own SLM, an analogue micromirror array, including address electronics and control software for 1) elaborating a detailed specification for a European custom micromirror arrays and 2) testing alternative imaging principles for the SURPRISE instrument (WP2).

POLITO provides input in terms of image compression and onboard data handling architecture, looking at quality evaluation of reconstructed images (WP4). They use expertise in compressed sensing to develop image reconstruction algorithms, expertise in encryption and authentication to define a CS-based Cryptosystem and expertise in image analysis to define and implement data analysis functionalities (WP5).

ACRI-ST contributes with their strong background on Earth observation missions. ACRI-ST uses their experience in requirements analysis and support to mission specifications, Ground Segment development and operation, data communication/access and ground processors prototypes to lead on activities related Earth Observation applications and user requirements (WP2).

SAITEC's provides the scanning system and the OGSE for assembly and test of the instrument demonstrator. In this role, they contribute to defining the specifications and designing this part of the system (WP4), deal with activities regarding the procurement, construction and test of the two subsystems (WP6) and support system assembly, test and final assessment (WP7).

RESOLVO brings extensive communication and exploitation experience to the project in order to support activities bringing results to society and to the market (WP8). Resolvo also brings there knowledge of

responsible research and innovation practices into the design and running of the Innovation and Risk Management system (WP9).

LEONARDO supports with expertise in electro-optical space instruments, in particular imaging spectrometer, addressing issues related to component selection and compatibility of design choices with Space standards (WP3). They support development of the Roadmap for space qualification of sensitive electronics (WP6) and are responsible for the CS-based EO payload development plan, in its space grade configuration (WP7).

2. The Kick Off

SURPRISE kicked off in Florence in 16th January 2020. All partners attended the meeting, together with the European Commission Project Officer and the members of the User Community Panel from ESA, ESA-ESTEC and EUMETSAT.

2.1. Main outcomes and conclusions from the Kick Off

The Kick Off meeting was the chance for participants to discuss in detail the project R&D activities and the synergies between them.

Fraunhofer IPMS shared their initial proposals for the design of an MMA (Micro Mirror Array), which is envisaged as the European alternative to Digital Micromirror Device (DMD®) produced by Texas Instrument and should work in the VIS-NIR and in the MIR spectral range. Fraunhofer IPMS, working in collaboration with other partners and particularly CSEM and CNR-IFAC, will produce a roadmap to build a SLM – with its electronics – compatible with space qualification.

CNR-IFAC shared an overview and background on Compressive Sensing (CS) techniques and the work plan designed to build a laboratory demonstrator of a multispectral imager working in VIS-NIR and MIR spectral range based on CS technique and SR. CNR-IFAC will be responsible for the consolidation of the demonstrator's specifications, its design -with an emphasis on its optical section.

Politecnico di Torino (POLITO) is responsible for the CS algorithms and demonstrated how it is possible, using CS technique, to have data compression, signal encryption and MTF compensation. POLITO will use deep learning techniques to obtain an optimal reconstruction of the acquired data.

CSEM will have the role of procuring and testing all of the subsystems of the SURPRISE instrument and preparing them for assembly. CNR-IFAC will then be responsible for the final assembly, test and overall assessment. During the kick off, CSEM and partners discussed the significant engineering challenges related to subsystem testing.

CSEM will work in collaboration with partners to identify compliant components and modules, design, construct and assemble modules/subsystems, commission the modules and, finally, verify, validate and test individual subsystems. After the successful test of the subsystems, they will be ready to be assembled.

A range of tests and calibration measurements will be carried out on the reworked DMD and relevant electronics, in relevant environment and different operating conditions. These tests will cover thermal tests, vacuum tests and vibration tests, with a focus on the electronics.

In parallel to these updates on the R&D and technical components of the project, partners discussed the important role of defining User Requirements providing key inputs for the consolidation of the future demonstrator specifications and the essential integration of concepts of Responsible Research of Innovation in all phases of work.

The impact of SURPRISE will be seen on the long term, but the potential is huge. Within the EO field, we can see potential for the state of the art SLM to grow on EU markets. The project can also influence ground segment applications, through the optical ground segment equipment (OGSE) system. There could also be potential use outside the EO field, looking at the design of new European SLMs and ad hoc CS algorithms and even small satellites for astrophysics (though less commercial than EO).

2.2 The European Commission and the User Community Panel

SURPRISE fits into a wider framework of investments into Earth Observation. The European Commission currently has 6 projects working on Earth Observation and space related topics will be included under Pillar 2 – Global Challenges of the Horizon Europe programme.

EUMETSAT is responsible for satellite missions for meteorological applications on LEO and geostationary satellites and is investing in future missions and R&D projects with important data retrieval implications. Continuing of information coming from different missions is essential and EUMETSAT is interested in results from SURPRISE project, in particular on the possible reduction of data rate with increased resolution using CS technology and super resolution approach.

ESA is increasing funding R&D trends related to small satellite and compact optical payloads. Freeform optics and freeform gratings are envisaged in the design of such compact payloads. Future missions based on Cube Satellites (*Cubesats*) would require specific characteristics for each optical payload. ESA-ESTEC is particular interested in SURPRISE, for the potential of the CS technique to produce compact optical payloads.

User Community Panel members are interested in discussing future applications of a super resolved instrument based on CS techniques. It is important to remember that the project concerns cutting edge techniques, so it is impossible to know what the outcomes will be. This bottom-up approach in R&I is encouraged: such techniques can optimise what we already have, but we need to do the development and then search for potential applications.

However, ESA will only use proven technologies on its missions. As such, during the project, it will be important to define which applications (looking at future generations of Sentinel satellites) could benefit from the use of CS, taking into account the expected TRL.

3. Next Steps

Following the Kick Off, a series of working groups will be set up to take forward the various elements of the project: Roadmap analysis;; COTS DMD vs. system requirements; System model and data simulation; System Concept, Preliminary Specs and Application Products; SLM development

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