Engagement Webinar

Presenting SURPRISE to National Space Organisations

DATE 10 September 2020 / TIME 10.00 – 11.30 (CET)

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 – Switzerland, Politecnico di Torino – 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

Web page: h2020surprise.eu

Introduction

Earth Observation (EO) data is increasingly important to our understanding of the planet and to how we address socio-environmental challenges. Currently, applications for data collection and handling are limited by long revisit time and low spatial resolution.

Thanks to the use of two disruptive technologies, spatial light modulators and compressive sensing, the EU-funded project SURPRISE is developing a demonstrator of a super-spectral EO payload (sensor) with enhanced capability in spatial resolution, on-board data processing and encryption functionalities. By introducing for the first time the concept of a payload with medium spatial resolution and near continuous revisit – by the hour – SURPRISE can lead to a major EO breakthrough and complement existing operational services.

SURPRISE started on 01 January 2020 and runs for 3 years. This webinar was designed to introduce and discuss the project and its initial results with the national space agencies and offices of the countries represented in the Consortium. It welcomed the active participation of the SURPRISE partners and User Community Panel members, together with the national space agencies/offices.

Meeting Report

The meeting was opened by Jessica Huntingford from Resolvo Srl, SURPRISE project partner in charge of Communication and Dissemination. As part of SURPRISE's objectives, partners wish to engage with other stakeholders operating in the space / Earth Observation (EO) field. To this end, they carried out a stakeholder mapping exercise to identify whom they thought should be involved. Unsurprisingly, all partners identified their national space agencies and offices as key players. The engagement webinar is born from that mapping, in order to provide national space agencies and offices with initial information about the project. It is hoped that this can be the start of further contact and cooperation over the coming years.

Valentina Raimondi, SURPRISE Principle Investigator (CNR-IFAC), took the floor to provide an initial introduction to the project and its main innovations. SURPRISE integrates super-resolution and single pixel camera concepts into a single architecture, to develop a super-spectral demonstrator working in the VIS-NIR and MIR. The project's objective is to enhance the performance of future EO payloads in terms of spatial resolution, on-board data processing and encryption capabilities. Ms Raimondi presented the two key technologies used by SURPRISE to achieve this goal – Compressive Sensing (CS) and Spatial Light Modulators (SLM) – and how these interact in the SURPRISE approach. She concluded by describing the project working methodology and the initial research steps undertaken by the SURPRISE partners over the first 8 project months. The full presentation can be found in annexe below.

Sara Francés González from Fraunhofer Institute for Photonic Microsystems then discussed the research work being carried out on the micromirrors for the Spatial Light Modulator. Subsequently, Alexandre Pollini from the Swiss Centre for Electronics and Micro techniques provided further information on the work they are undertaking to support and test development of the space qualified SLM. Due to an unexpected last minute problem, Nicolas Lamquin, from ACRI-ST, could not deliver his presentation on activities related to User Requirements. However, a summary of the relevant project deliverable is available for consultation onto the SURPRISE website (http://www.h2020surprise.eu/materialandoutputs/).

At the end of the round of presentations, the first Q&A round was opened.

Raffaele Vitulli from ESA-ESTEC (member of the SURPRISE User Community Panel) asked Fraunhofer Institute for Photonic Microsystems if the typical requirements for space (radiation, temperature range, operations in vacuum, etc.) were taken into account during the tests of SLM solutions. Sara Francés González confirmed that temperature will be considered in tests and that the possibility to include vacuum tests is also being taken into account.

Valentina Raimondi highlighted that SURPRISE partner Leonardo will also support the study for SLM development, with several test environments already envisaged. Most tests on the various technologies and MMA (Micro Mirror Array) devices useful for SLM development, will be carried-out at CSEM, which has all the necessary test facilities.

The second question came from Roberto Bonsignori from EUMETSAT (member of the SURPRISE User Community Panel), who asked CSEM about the advantage in terms of data points acquired through the CS methodology, compared to other image acquisition methods. Alexandre Pollini confirmed that tests showed a massive increase in data points thanks to CS.

Focus then turned to the SURPRISE User Community Panel (UCP). The panel is the project external Advisory Board: a group of experts that have volunteered to support the project, providing advice and guidance. The UCP consists of 3 permanent members: Roberto Bonsignori, from EUMETSAT and Raffaele Vitulli and Alessandro Zuccaro Marchi from ESA. Additional members with specific expertise are currently being involved.

The session began with a video message sent by Alessandro Zuccaro Marchi, from the optics department of ESA-ESTEC (Netherlands). He followed previously funded ESA projects on CS, run by SUPRRISE Lead Partner IFAC and partner CSEM. He believes that CS may be part of the answer to current EO limitations in terms of long revisit time and low spatial resolution and data downing capabilities. Through SURPRISE, Mr Zuccaro Marchi hopes to see progress towards a space qualified, European produced SLM. With SURPRISE's developments in CS, he also sees potential for many space related initiatives, initially within the framework of in orbit demonstrations and, longer term, for future Copernicus-like missions.

Raffaele Vitulli (ESA-ESTEC) followed up, agreeing with the potential areas of interest described by his colleague. Mr Vitulli is a senior data processing engineer in ESA. He highlighted the synergies between the ESA-ESTEC optics and data acquisition departments, where he works, and their relevance for SURPRISE. As one of the first researchers who introduced the CS concept into ESA's work, he believes in the potential of this disruptive technology for future space applications and he is keen to follow SURPRISE's work to this aim.

Roberto Bonsignori (EUMETSAT) offers his point of view on the project and potential synergies with EUMETSAT's ongoing activities. As an operational agency, EUMETSAT is interested in exploiting advanced technologies that can make their services and activities more reliable and efficient. In this sense, SURPRISE is interesting for them, as it focuses on disruptive technologies for perspective applications. Not only they are interested in how SURPRISE technologies could help reduce data acquisition complexity, but also in trade-offs among various features (e.g. data amount, resolution, data security, etc.).

At the end of this second session, the room was opened again for discussion.

Sara Francés González stressed that data amount is a very important aspect to be considered for all space applications and asked Roberto Bonsignori whether it is easy to define a optimum for the image size and target for resolution for a future payload with CS architecture. Mr Bonsignori replied that it is not an easy task. This type of definition is not only about the image itself, but also the quantitative measurements of the image. Therefore, the essential prerequisite to defining the most suitable architecture, is to identify the best data reduction method. In this context, it is necessary to achieve an optimal compromise among the various tasks to be performed by the payload. He stressed that, to this end, the different and complimentary expertise of the SURPRISE partners can bring a high added-value to the research work.

The last session left space for questions and comments from the National Space Agencies and Offices.

Valerie Koller from the Swiss Space Office stressed that, as an Office (not an Agency) they do not take forward their own development activities. On the contrary, they support Swiss research institutions to develop their studies. Their work is characterised by a strong bottom-up approach, with a high attention being paid to the interests of their reference user community. They would be interested in being informed about the progress of SURPRISE activities, in order to understand where the research work leads and what are the possible exploitation opportunities.

Julien Michel from the French Space Agency (CNES) explained that CS was first approached by CNES in 2012. Research was carried-out and a paper published, which can be found here: https://ieeexplore.ieee.org/abstract/document/6351550. CNES would be interested in learning how CS has evolved and what the SURPRISE approach is.

Anko Börner from the Institute of Optical Sensors of DLR (German National Aeronautics and Space Research Centre) presented the Institute's work on optical instruments for applications in space, security and other sectors. Their instruments have a high technology readiness level, meaning their research has a strong end-user orientation.

DLR agrees that SLM and CS could be two core technology to improve remote sensing and they are actively working on relevant initiatives. Some research activities of potential relevance for SURPRISE are geometrical calibration of cameras based on diffractive optical elements, single pixel cameras based on CS approach and AI sensors. The latter is considered a particularly interesting technology that could speed-up breakthrough innovation in the field. Therefore, they would be happy to be involved actively in SURPRISE activities.

Tiziano Bianchi from Politecnico di Torino (PoliTo) confirmed that their work on the reconstruction algorithm in SURPRISE also adopts an AI approach, using deep learning methods compressive imaging reconstruction. Therefore, there is room for exchange and collaboration on this field.

Valentina Raimondi confirmed that results from a previous ESA funded project, in which IFAC worked with PoliTo, highlighted that CS based on an information-driven approach can bring much higher advantages than “classical” CS. Therefore, information driven architecture is an important element to be addressed by SURPRISE.

Valentina Raimondi closed the webinar by thanking all participants and confirming that the national partners will maintain contact and provide updates on SURPRISE progress and on opportunities for further contact and exchange. She invited participants to visit the SURPRISE website (http://www.h2020surprise.eu/) for project materials and updates.

The SURPRISE project
An overview

Valentina Raimondi *and the SURPRISE Consortium*

The EU H2020 call and the SURPRISE proposal

- EU H2020 RIA call: EU H2020 LC-SPACE-14-TEC-2018-2019 - *Earth observation technologies*
- Sub-topic 3: *Disruptive technologies for remote sensing*

→ **SUper-Resolved comPRessive InStrument in the visible and medium infrared for Earth observation applications (SURPRISE)**

Start date: 1 January 2020 – duration: 3 year

The challenge and the goal

- Mature disruptive space technologies for novel Earth Observation (EO) payloads
- Enhance performance of future EO payloads in terms of spatial resolution, on-board data processing and encryption capabilities
- Strengthen the competitiveness of European research and industry

This goal will be achieved
by using **Compressive Sensing (CS)** technology implemented
via **Spatial Light Modulator (SLM)**.

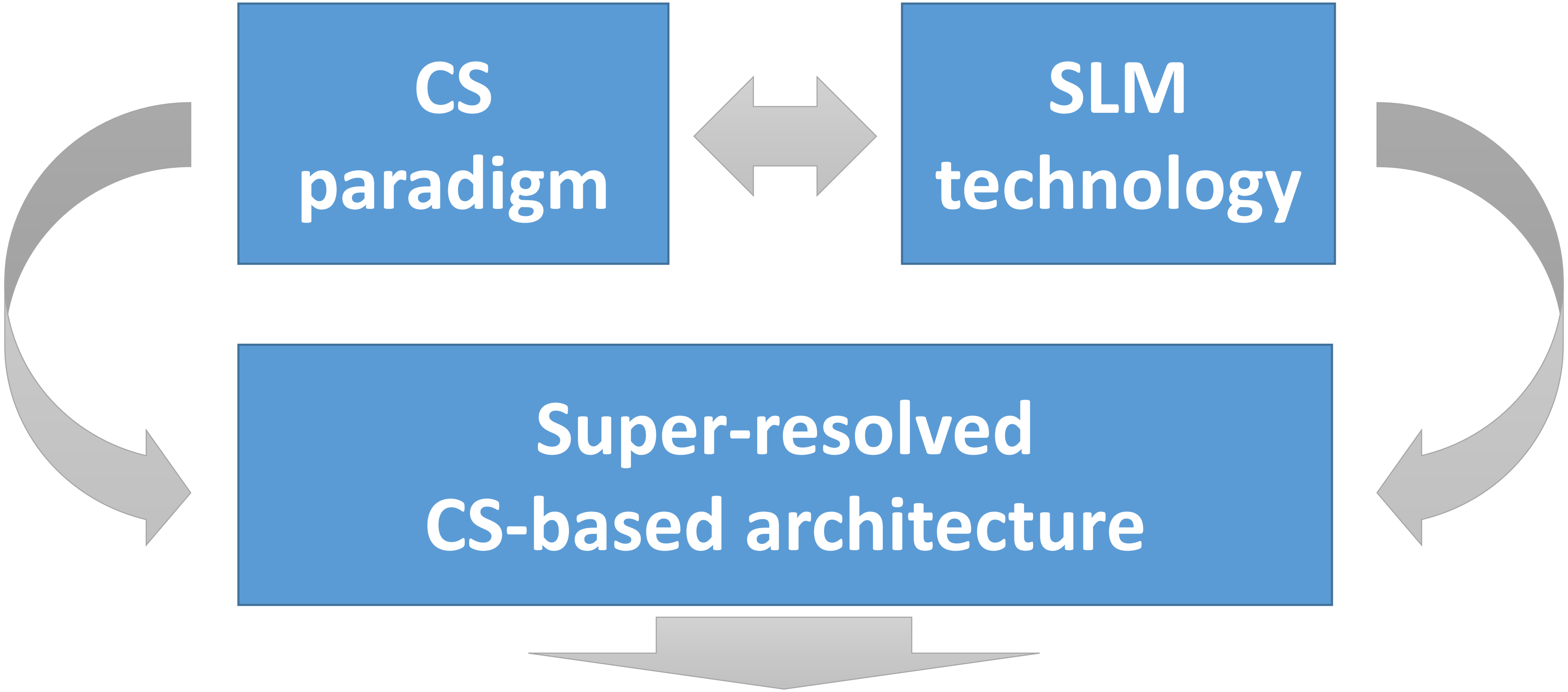
Main objectives

- 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.
- Demonstrate the functioning of SLM technology in relevant environment, with particular reference to its operation in the MIR.
- Analyse the impact of enhanced performance on EO application products and services.
- Uptake of disruptive technological research by EU industry.

The partnership

- **CNR-IFAC:** 'Nello Carrara' Institute of Applied Physics - National Research Council of Italy (IT) – *Lead Partner*
- **CSEM**: Centre Suisse d'electronique et de microtechnique SA - Recherche et Developpement (CH)
- **POLI-TO**: Politecnico Di Torino (IT)
- **ACRI-ST** SAS (FR)
- **SAITEC** SRL (IT)
- **RESOLVO** SRL (IT)
- **IPMS**: Fraunhofer Gesellschaft Zur Foerderung Der Angewandten Forschung E.V. (DE)
- **LEONARDO** SpA (IT)

The approach



EO super-spectral payloads
with enhanced spatial resolution, on-board data processing and encryption capabilities

Compressive Sensing

- **Classical sampling**: acquisition of N samples; after the N acquisitions, during compression, only K<<N significant coefficients (typically in a transform domain) are retained.
- **Compressive Sampling (CS)**: acquisition of K<<N measurements, no further compression is needed.

In practice, a basic CS instrument can be developed by using:

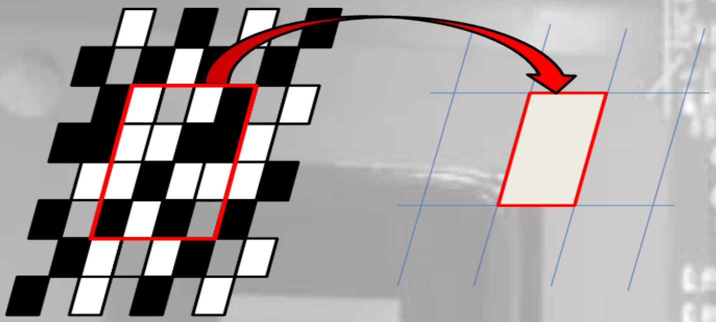
- **Collection optics** to collect the light.
- **2-D Spatial Light Modulator (SLM)** that physically performs the scalar product between the coding mask and the incoming image.
- **Condenser lens** that concentrates the radiation on a single photodetector.
- **Single-element detector** that “measures” the signal.

✓ ***Images can be reconstructed from the set of measurements by using “ad-hoc ” algorithms.***

Compressive sensing instrumentation

- Core components: Collection optics, Spatial Light Modulator (SLM), detector with a low number of pixels (down to one single-pixel).
- If the SLM has N pixels, it is possible to reliably reconstruct the original image acquiring K<<N measurements, each one corresponding to a different modulation mask coded on the SLM.
- Integration time of the single acquisition is reduced with respect to a traditional system, while total acquisition time is generally increased.
- Images acquired with compressive sensing techniques need to be decoded subsequently.

SLM technology and super-resolution

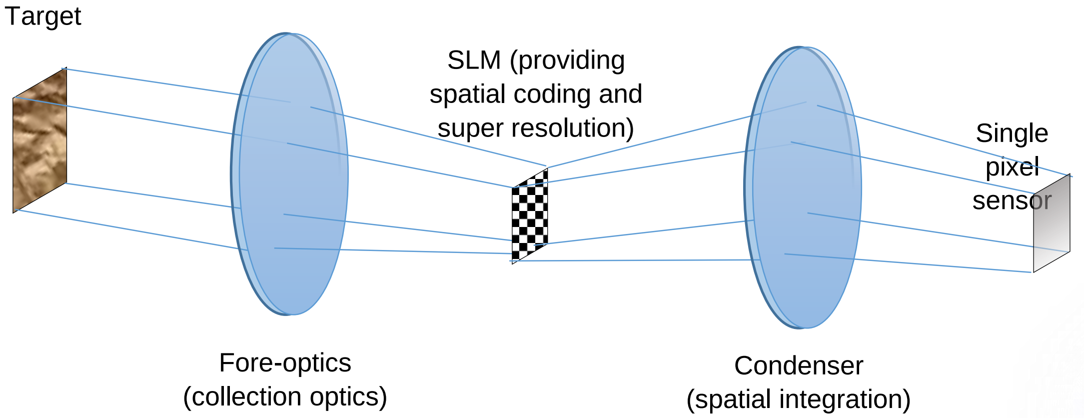


SLM (high resolution + masking) *Low-resolution detector*

A super-resolution imaging system is an imaging system whose resolution is enhanced with respect to the one dictated by the number of pixel of the detector.

- A super-resolution optical system can be implemented by using **an SLM with a high number of micromirrors** (NxN larger than the number of detector's pixels).
- **At each pixel of the detector is associated an NxN group of elements of the SLM**. In this way, each pixel of the detector integrates the light coming from NxN SLM elements.
- The series of measurements acquired while applying a different coding mask for each measurement, is used to **recostruct** –by means of an *ad-hoc* algorithm - **an image with a resolution equal to that on image plane** at the SLM.
- If during acquisition, the number of measurements (and corresponding modulation masks coded on the SLM) are less than NxN, we obtain an **inherent data compression** (*CS paradigm*).

The SURPRISE demonstrator: the concept



Acquisition mode	2D Target scanning system
Target size	30 mm x 30 mm
Super-resolution factor	2 to 32
SLM	1024 x 768 micromirrors, 13.68 μm pitch
VIS-NIR channels	>10 channels, 400-900 nm spectral range
MIR channels	3.3± 0.2 μm; 4± 0.2 μm;

- **Integration of the super-resolution and single pixel camera concepts** into a single architecture
- Super-spectral demonstrator working in the VIS-NIR and MIR

✓ SURPRISE demonstrator architecture will be designed to be **scalable** to an EO instrument on board a geostationary satellite

✓ A first iteration on the main specifications of the SURPRISE demonstrator - based on **COTS** for optical elements, SLM and detectors – was already carried out, leading to a preliminary design of the demonstrator.

Innovation and impact

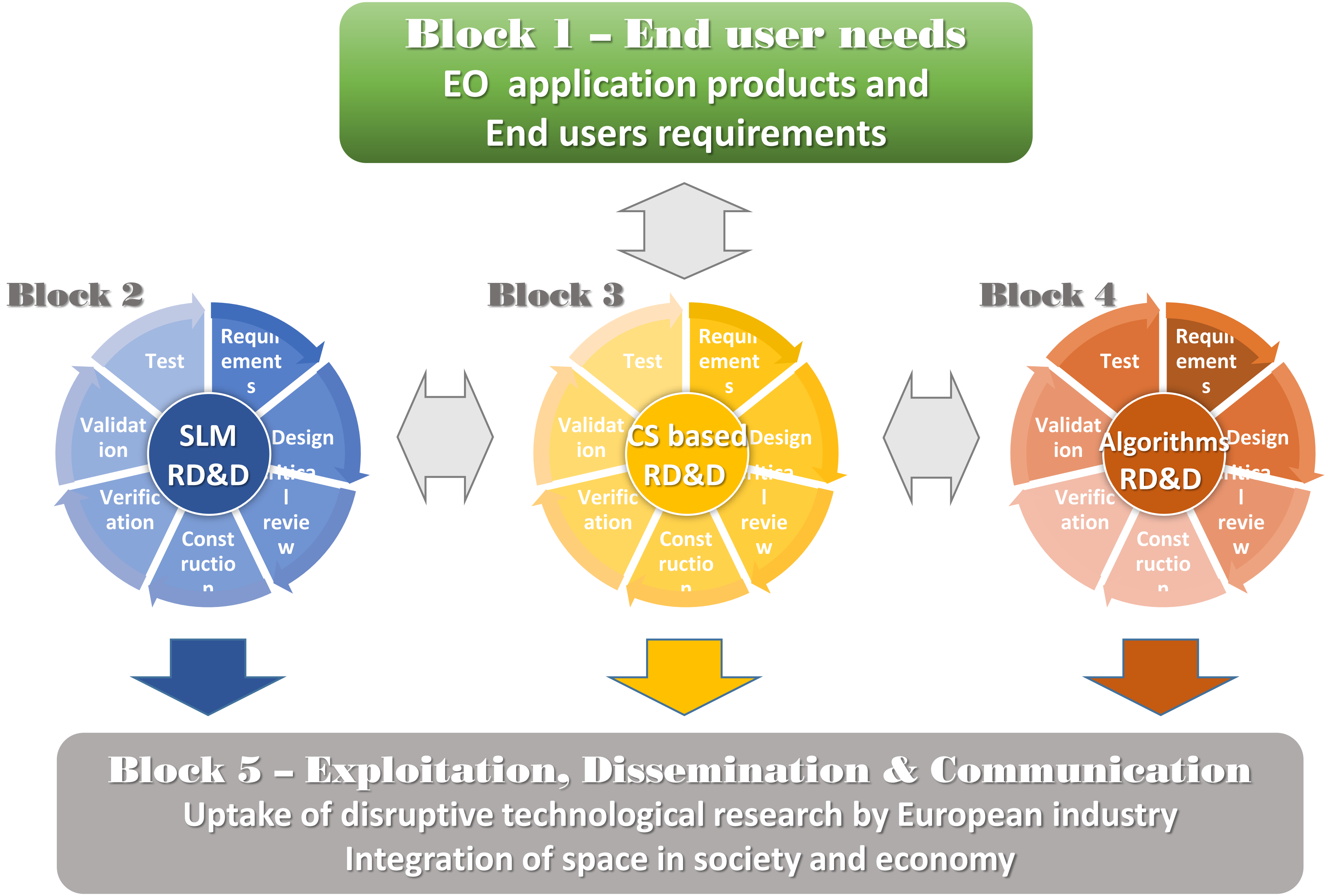
- **Novel generation of optical systems in the IR.** The CS technology will introduce a new approach – disruptive for space instrumentation – integrating super-resolution and single pixel camera concepts.

- **A new approach to data acquisition, compression and encryption.** The CS technology merges data acquisition and compression into a single measurement step, with benefits in terms of bandwidth requirements, payload’s budgets and native encryption.

- **Data processing and computational burden.** The CS technology will pave the way to information-oriented data analysis and on board processing at little computational cost.

- **Industrial competitiveness in cutting-edge technologies.** The SLM technology will lead to the first SLM, MMA-type, fully based on European technology and specifically designed for space applications.

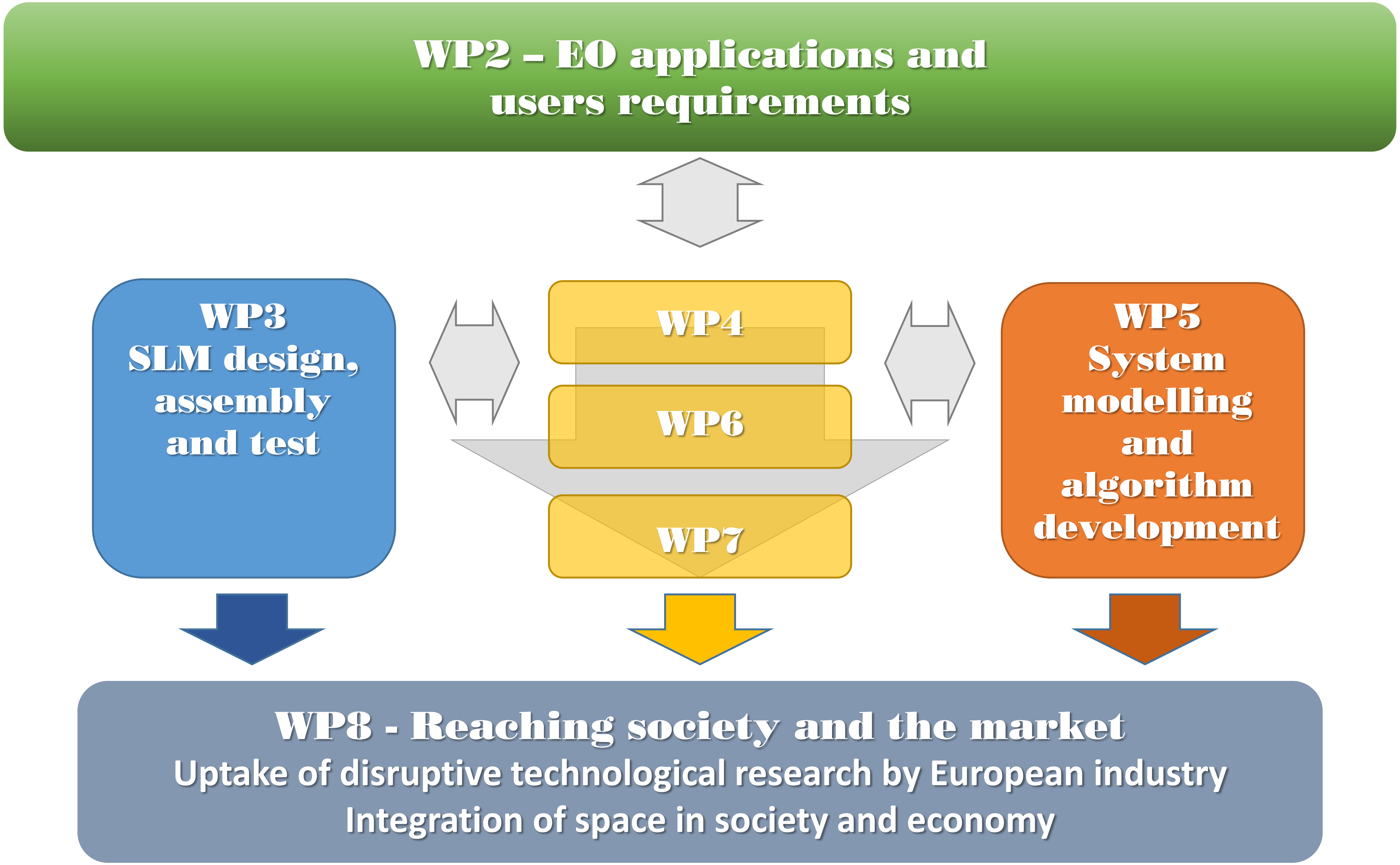
Methodology



Implementation

- WP1 - Ethics requirements (CNR-IFAC)
- WP2 - EO applications and user requirements (ACRI-ST)
- WP3 - SLM design, assembly and test (IPMS)
- WP4 - System specifications and design (CNR-IFAC)
- WP5 - System modelling and algorithm development (POLI-TO)
- WP6 - Subsystems procurement, construction and test (CSEM)
- WP7 - System assembly, test and final assessment (CNR-IFAC)
- WP8 - Reaching society and the market (RESOLVO)
- WP9 - Management (CNR-IFAC)

Workflow and synergy among WPs



Thanks for the attention!

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