RAISE

SPOKE 3

# Environmental Caring and Protection Technologies, towards a Zero Emission Environment

# Allegato A

## SUMMARY OF SPOKE 3 RESEARCH ACTIVITIES AND PROJECTS

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## General aims

Spoke 3 “Environmental Caring and Protection Technologies, towards a Zero Emission Environment” has the objective of creating an ecosystem of innovation to improve the strategy and methodologies for environmental monitoring dedicated to the three environmental scenarios (water, air, land) representative for the Ligurian territory.

Thanks to the skills of the Spoke Leader CNR and all affiliates (IIT, UniGe, ENEA, INGV, CIMA, AlgoWatt Spa, ETT Spa, Infosolution Spa e Ansaldo Green Tech), the potential of robotics and artificial intelligence are exploited to implement a process capable of modifying the current approach to environmental monitoring, which, although using high technology, suffers from the fact that the different monitoring systems (in fixed and/or mobile locations) are usually not connected to each other and return data to receiving stations dedicated to their integration (operational decoupling of monitoring systems). This approach determines, as a consequence, a low efficiency as early warning systems, a transfer and collection of partial data from different systems with limited integration between in situ observation and data management (punctual and/or disseminated and dynamic monitoring).

The main challenge of Spoke 3 is to change this paradigm thanks to the development of innovative robotic systems managed by artificial intelligence capable of making punctual and widespread monitoring coupled and synergistic by increasing the efficiency of data collection and their diffusion, duration and the energy savings of the monitoring missions and the quality and timing of the various forecasting systems (early warning systems) dedicated to the safeguarding and continuous monitoring of the aquatic, terrestrial and aerial sectors of our territory.

## 1. Research lines

Spoke 3 was built on four strategic lines of research and development (RL) which collect and represent the complementary technical-scientific skills of all the affiliates of the spoke organized into different Research Activities (RA).

| Research Line (WP) | | Research Activity (Task) | |
|---|---|---|---|
| RL1 | ECOROBOTICS & AI INNOVATIVE SYSTEMS (IIT, BARBARA MAZZOLAI) | RA1.1 | Innovative materials and sensors |
| | | RA 1.2 | AI driven environmental modelling |
| | | RA 1.3 | Robotic Intelligent Systems |
| RL2 | SMART TECHNOLOGIES FOR ENVIRONMENTAL MONITORING AND TERRITORY MANAGEMENT (UNIGE - Andrea Mazzino) | RA 2.1 | Forecasting models based on big data analysis approaches, AI and High-Performance Computing |
| | | RA 2.2 | Smart technologies for vulnerability analysis, risk assessment and territory safety |
| | | RA 2.3 | Smart technologies for the protection and management of the environment |
| RL3 | SMART ENERGY STORAGE AND DISTRIBUTION (UNIGE, STEFANO MASUCCO) | RA 3.1 | Technologies for intelligent energy distribution |
| | | RA 3.2 | Technologies for energy storage |
| | | RA 3.3 | Energy for autonomous systems, Task Leader |
| RL4 | SMART DATA MANAGEMENT AND COMMUNICATION - PLATFORMS AND PROCESSING PIPELINES FOR THE DATA LIFECYCLE (ETT, ANTONIO NOVELLINO) | RA 4.1 | Effective and efficient processing |
| | | RA 4.2 | Data collection, data wrangling and data interoperability |
| | | RA 4.3 | Data visualization |
| RL5 | Spoke Management & Development of innovative Technologically Assisted Citizen Science Systems - TACS (CNR - Marco Faimali) | RA 5.1 | Monitoring of activities and projects of spoke and affiliates |
| | | RA 5.2 | Creation and animation of spoke's advisory board |
| | | RA 5.3 | Development of innovative Technologically Assisted Citizen Science Systems (TACS) |

**Tab. 1:** Strategic lines of research and development (RL) and relative research activities (RA).

## Research Line_1 Ecorobotics & AI innovative systems

This RL develops sustainable monitoring systems, biomaterials, robotic platforms, early warning systems and AI-techniques to autonomously and synergically patrol large areas, acquiring data for hydrogeological risks prevention, damage mitigation, ecosystem restoration and garbage collection. We will consider classic robotic vehicles for sea, terrestrial and aerial navigation, as well as new bio-inspired, soft, and/or biodegradable robots, arms and manipulators. AI and ML techniques will be exploited to collect, analyse and make a smart use of the enormous data streams coming from different robots and sensors.

## Research Line_2 Smart technologies for environmental monitoring and territory management

The specific/innovative techniques and components developed in RL1 in relation to AI, robotics, smart sensors and their synergistic combination, will be capitalised in RL2 at the service of the territory, in relation to monitoring and risk assessment, safety and protection.

The technology transfer toward the territory will not supplant but rather blend into the traditional practices, bringing forward a real paradigm shift. This revolution will emerge both in terms of performance and reliability of the system as well as in terms of energy autonomy guaranteed by modern energy harvesting techniques developed in RL3, with a key role played by the availability in real time, modulated in space and time where needed, and with human intervention reduced to a minimum, of a huge amount of observed data.

**Research Line_3 Smart energy storage and distribution**

In this RL, AI and stochastic techniques will be applied as tools for automatic decision support at different spatial and temporal scales for the management, adaptive control and prediction of energy demand and production from renewable sources (wind, solar and geothermal). The scope of application ranges from the production from renewable sources (from the scale of milliwatts to supply distributed sensors to megawatts) up to management systems and building automation (home automation). The RL will also deal with the optimization of innovative systems for the management of the storage of energy through lithium storage systems, super cap and through electrochemical systems of electrolysis and co-electrolysis powered by renewable energy for the production of "green" hydrogen. Quality of Service (QoS) and safety in telecommunications networks for the control of electrical and industrial networks.

**Research Line_4 Smart data management and communication - platforms and processing pipelines for the data lifecycle**

The creation of "value" through the use of analytical tasks over large quantities of raw data is made effective and efficient thanks to a complex data life cycle that foresees, in the initial phases, data acquisition and wrangling (i.e., cleaning, transformation, and integration) and, before analytical tasks, a preliminary data exploration through data visualisation tools. This RL aims at providing such cross competencies by designing (i) large scale data processing platforms, (ii) data wrangling pipelines, and (iii) data visualisation approaches for data generated by RL1, considering the analytical tasks proposed in RL2 (and RL3).

**Research Line_5 Spoke Management & Development of innovative Technologically Assisted Citizen Science Systems (TACS)**

CNR and the research affiliates UniGe and IIT (with the participation of all the other affiliates) will coordinate the Spoke 3 activities to ensure the immediate set up of the work plans of previous RLs, and to continuously monitor the progress of activities, issuing the calls for projects and services (for external parties, in particular SMEs), establishing and animating an Advisory Board at Spoke level, scheduling advanced training initiatives, and interacting with the hub and spokes 4 and 5. The Spoke Advisory Board will meet every 3 months, also to address the competitive cascade calls that will be issued for the implementation of activities and the provision of services by external parties. Under this work-package, also the administrative tasks (mainly related to the reporting of costs and expenses) will be carried out. Furthermore, a task dedicated to the development of specific devices dedicated to Citizen Science is also planned. Citizen science is a growing field that involves the active participation of non-professional scientists in scientific research projects. It represents a

powerful tool for scientists to gather large amounts of data and observations, which would be difficult or impossible to obtain otherwise. In this context, the RL aims to promote and organize citizen science activities technologically assisted applied to environmental monitoring in order to collect valuable scientific data while maximising population engagement on environmental caring and protection. A selection of sensors and tools with potential compatibility in terms of target, size, use easiness and price, will be selected keeping as priority endpoint the sufficient precision and accuracy to ensure the scientific reliability of the data.
In order to overcome an excessive fragmentation of the activities reported in the RAISE Ecosystem proposal (RL and RA), make R&D activities and the deployment of their results more effective, increase the opportunities for collaboration between the participants of spoke 3, eleven specific projects have been defined. They gather all the competencies of the RL and RA of the proposal and introduce specific scientific and technological results in the fields of robotics and AI applied to the care and monitoring of the environment (Figure 1).

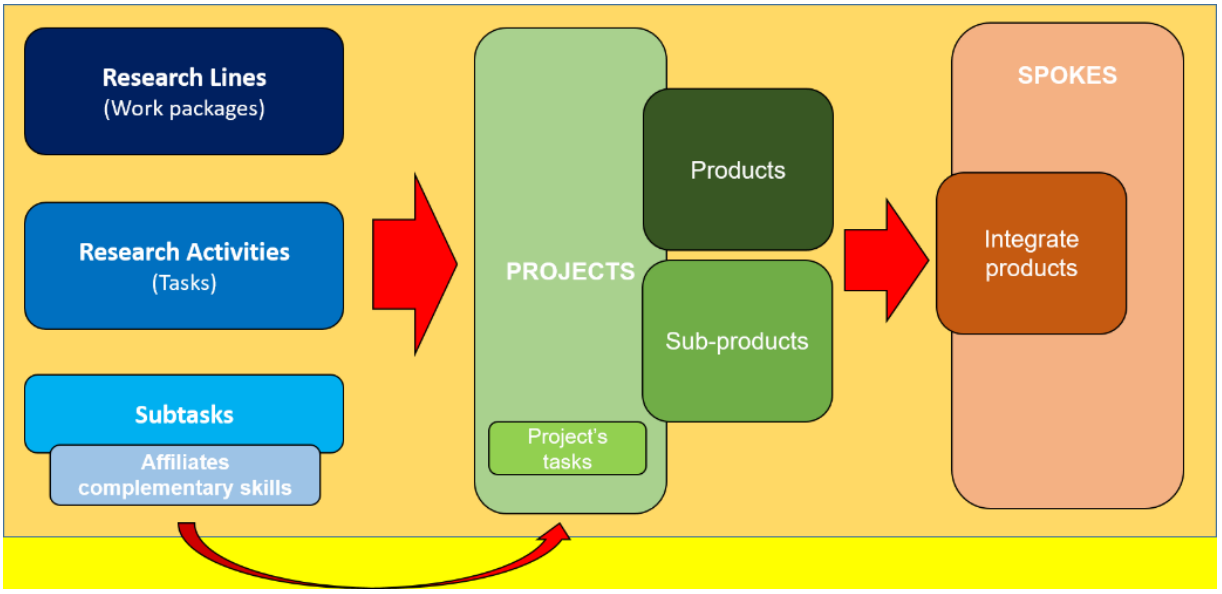


**Fig. 1:** From Strategic lines of Research and development Lines (RL) and relative Research Activities (RA) to products. Work Packages and Tasks reported in parenthesis and used in the submitted proposals have been now replaced with Research Lines (RL) and Research Activities (RA), respectively

## 2. Research projects

Within the Spoke 3, were defined 11 projects favoring the interaction between the activities of the different RLs. This rationalization activity has made it possible to achieve a high level of operational synergy between the various research groups involved (RLs and RA), able to guarantee the realization of the projects (11 projects planned) and of the different products and integrated products (prototypes and demonstrators) related to them which will potentially be the subject of a technology transfer process in synergy with Spoke 5.

Each project is dedicated to a specific theme and involves the realization of different results (Research & Development Products). The expected results are the creation of technologies, methodologies, complex systems, prototypes, demonstrators, proof of concepts which, in this report, will generally be referred to as "Products" which can be divided into three categories:

**By-products:** results of development and research that are fundamental for the creation of products but which do not have a reference application market;

**Products:** results of development and research that also individually have a reference market;

**Integrated products:** innovative complex systems deriving from the operational integration of sub-products and products created by the various projects.

In general, products created within each single project and resulting from synergies between projects (product and integrated product) of Spoke 3 can be expected.

The eleven projects are the following:

### 1 Advanced technological platforms for sea monitoring and forecasting

This project proposes the development of a new integrated system that combines single-point and diffused monitoring through the development of hardware and software modules that integrate traditional in-situ measurements with adaptive monitoring managed by AI solutions. This integrated system will enable more efficient data collection even in extreme conditions, reduce energy costs, improve the forecasting system and allow the realization of innovative early warning approaches and effective decision support systems.

### 2 Technologies for advanced air monitoring and forecasting

The aim of this project is to produce a U-turn by a synergistic approach capitalizing the huge technological progress achieved in the last a few years in the field of autonomous drone swarms, autonomous mobile robots, and cheap and accurate air-quality sensors. Exploiting in concert these technologies, a paradigm shift will be possible by transforming the classical 2d-notion of environmental measure (1d in space and 1d in time) into a frontier 4d-based acquisition strategy (3d in space and 1d in time).

### 3 Technologies for advanced environmental monitoring and seismic forecasting

Several technologies to be used to map and monitor earthquake and post-sismic conditions will be developed. An automatic procedure for the near real-time mapping

of earthquake shaking and associated consequences at the urban scale will be developed, thanks to AI and ML techniques. A procedure for the automatic interpretation of images acquired after seismic events at the scale of individual artefacts or urban areas for the purpose of attributing synthetic damage levels will be realized. Tele-guided or autonomously guided robots to survey of damage in post-seismic conditions in indoor or outdoor environments will be deployed.

## 4 Technologies for advanced environmental monitoring and hydrogeological instability

Project 4 concerns the development of technologies for the ground and environment monitoring, with particular reference to natural hazards. Intelligent monitoring systems for geo-hydrological risk forecasting - including landslides, extreme rainfall, extreme winds and other weather and climate variables of interest – will be developed. The products deriving from project 4 are aimed at monitoring meteorological, coastal and slope (landslide) hazards, also in the light of global change.

## 5 Advanced technologies and robotic solutions for precision agriculture and for reforestation

This project aims to develop technical solutions for two main domains: precision agriculture and land management. For precision agriculture applications, this project will focus on automating annual operations inside the vineyard, developing a soft gripper for gentle fruit grasping, and developing miniaturized devices for in-situ monitoring and drug delivery. In the land management part, the project will provide solutions to intervene in different terrestrial scenarios, e.g., releasing autonomous platforms to clean up beaches and small alleys or monitoring surface land parameters (such as humidity) and reforestation strategies in extended and difficult-to-reach areas

## 6 Advanced technologies for coastal erosion

AI and ML will be applied for the joint use of conventional and unconventional measurements for wave and meteo-marine propagation models with focus on data management and sharing platforms. Automatic procedure with ML and AI techniques for the realization of a storm surges warning system will be realized, as well as a combined 1D laser scanner webcam system for continuous monitoring of the marine storm events to be able to activate the alert system. The final aim of these products is to create an integrated early warning system of storm surges and apply it in a pilot site of the metropolitan city of Genoa.

## 7 Technologically assisted ecotoxicological kits

This project aims to develop innovative, automatic and smart technological solutions to be used directly in the field for environmental surveys, implementing biological testing during environmental monitoring actions. Three biological early warning systems will be developed (i.e. based on bacteria, and larval/adult aquatic

invertebrate's responses) as products of the project to monitor the aquatic health status, able to provide a real-time signal when pollution or other stress may occur in the natural environment.

## 8 AI-powered Management Systems for Resilient Networks with Coordination and Integration of Distributed Energy Resources

The project aims at delivering a comprehensive set of complementary AI-powered tools to support the optimized management of resilient electric/energy networks, taking into consideration the proper integration and coordination of Distributed Energy Resources (DER) and other assets (storage systems, electric vehicles, etc.), according to different yet synergic paradigms (spanning from smart grids up to Virtual Power Plants and Energy Communities).

## 9 Simulation, performance prediction and validation of energy-storage systems for renewable sources, exploiting AI, robotics and innovative materials

The project will develop innovative energy storage management technologies, materials and systems (robotics, simulation and digital twin), with possibility of experimental validation within JOINTLAB. Different aspects/tasks will be fronted like: operation data management and plant supervision; electrochemical storage prototypes and the electrolyzer for the JOINTLAB will be built and installed by Ansaldo Green Tech; the JOINTLAB will provide an opportunity to evaluate various storage systems and not only electrochemical solution.

## 10 Eco-sustainable Platform of Smart Systems for Efficient Energy Harvesting and Storage (ENHANCE)

Environmental monitoring in remote and harsh areas calls for autonomous vehicles, which for definition do not require on-board personnel. This new paradigm allows the development of small-scale technology (in terms of both size and weight) and opens the possibility of increasing the renewable energy availability on autonomous vehicles. An environmentally mindful platform secures the versatility of the device, which can then be deployed in pristine areas, such as Polar environments and marine protected areas, as well as in polluted and dangerous locations, e.g. oil spill sites. The reduced dimensions and weight of monitoring vehicles lowers the amount of energy required for scheduled missions. Furthermore, the on-board green quota should be increased in order to cover the whole energy requirements and drastically decrease pollution and Green House Gases (GHG) emissions, minimizing the carbon footprint of emerging technologies. The autonomous vehicle may transport and deploy smart drifting sensors for monitoring purposes. A smart processing unit would be available on the autonomous vehicle for data exchange with the smart sensors.

The project also aims at developing smart piezoelectric polymer-ceramics and thermoelectric polymer-Van der Waals dichalcogenides composite materials to be integrated in flexible PEH (piezoelectric harvester) and TE (thermoelectric) devices for producing sustainable electric energy by efficiently exploiting plentiful mechanical and thermal energy sources accessible all around us, such as natural (marine)

environment/human/machinery vibration, bending, and pressure for PEH and solar energy and waste heat sources for TE.

## 11 Technologically Assisted Citizen Science Systems (TACS)

Citizen science is a growing field that involves the active participation of non-professional scientists in scientific research projects. It represents a powerful tool for scientists to gather large amounts of data and observations, which would be difficult or impossible to obtain otherwise. In this context, the project aims to promote and organize citizen science activities technologically assisted by specific device applied to environmental monitoring in order to collect valuable scientific data while maximising population engagement on environmental caring and protection. A selection of sensors and tools with potential compatibility in terms of target, size, use easiness and price, will be selected keeping as priority endpoint the sufficient precision and accuracy to ensure the scientific reliability of the data.