ASTRA

ADVANCED SPACE TECHNOLOGIES AND RESEARCH ALLIANCE

An alliance between public and private bodies, aiming to bridge between pure research and its numerous applications, in order to implement innovative technologies in the space sector.

SPOKE

GRAN SASSO SCIENCE INSTITUTE
SCHOOL OF ADVANCED STUDIES

PUBLIC AFFILIATES

unipg
UNIVERSITÀ DEGLI STUDI DI PERUGIA

INAF
ISTITUTO NAZIONALE DI ASTROFISICA

PRIVATE AFFILIATES

FONDAZIONE BRUNO KESSLER

ThalesAlenia Space

Finanziato dall'Unione europea
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Ministero dell'Università e della Ricerca

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VITALITY

December 2025 Report

ASTRA ADVANCED SPACE TECHNOLOGIES AND RESEARCH ALLIANCE

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The project

Astra is the acronym of Advanced Space Technologies and Research Alliance. Its objective is to contribute to technological innovation in the space sector, by bridging the gap between pure research and its application.

It sees the participation of three public research centers and two private entities. The former are the Gran Sasso Science Institute (GSSI), the University of Perugia and the National Institute of Astrophysics (INAF). The private bodies are the Bruno Kessler Foundation and Thales Alenia Ltd.

Astra is a “spoke” (namely, a macro-project) of Vitality (Innovation, digitization and sustainability ecosystem for the economy in central Italy), a project launched in 2023 and financed by the Recovery and Resilience Facility (RRF). Vitality is made up of 10 spokes, including Astra.

Astra’s main objective is to develop technologies and devices that can help bridge the gap between research in its “pure” form and that intended for industrial and commercial applications, in the space sector. Its research activities will specifically concentrate on both hardware and software, with special attention to technological transfer and to the project’s impact on the territory and its productive fabric.

This report outlines the state of Astra during its first two years of activity. Data on the following pages is updated to December 2025.

MONITORING OF ACTIVITIES

Work packages

The project is organized into three work packages, each consisting of various tasks. Each task includes milestones and outputs.

WP1 Advanced technologies for space industry

4 Task

LENGHT	LAUNCH	DEADLINE	AVAILABLE RESOURCES	STRUCTURED PERSONNEL	RECRUITED RESEARCHERS
35 months	January 2023	December 2025	5.318.922,74 €	60	5

STATUS	UPCOMING EXPECTED DEADLINE
NEARING COMPLETION	Preliminary engineering study of LGWA Soundcheck (December 2025)

WP2 Digital platforms for space industry

3 Task

LENGHT	LAUNCH	DEADLINE	AVAILABLE RESOURCES	STRUCTURED PERSONNEL	RECRUITED RESEARCHERS
35 months	January 2023	December 2025	3.117.822,01 €	74	3

STATUS	UPCOMING EXPECTED DEADLINE
NEARING COMPLETION	Final version of V&V techniques for smart systems, final version of AI software for space, and final validation with the Crystal Eye satellite (December 2025)

WP3 Technology Transfer and Impact Management

3 Task

LENGHT	LAUNCH	DEADLINE	AVAILABLE RESOURCES	STRUCTURED PERSONNEL	RECRUITED RESEARCHERS
35 months	January 2023	December 2025	864.837,50 €	31	3

STATUS	UPCOMING EXPECTED DEADLINE
NEARING COMPLETION	Landscape Analysis (December 2025)

WP1

Advanced technologies for space industry

In the framework of this WP1, the Spoke and Spoke affiliates will develop innovative technologies of great interest for the Space industry, covering both innovations in payloads technologies and satellite platforms, bridging the gap that separates pure research ("curiosity driven") from the industrial and commercial application of new technologies.

Innovative sensors for space observations in different frequency bands will be realized, spanning from X and gamma rays down to ultraviolet and visible, bringing their space qualification to the highest level. Innovative solutions for Cubesat platforms will be developed aiming at integrating payload and platform functionalities, by thinking of the mechanical structure as an integral part of the payload/platform serving additional purposes other than structural integrity.

The activities of WP1 will allow to train and attract human resources from industry and research institutions, who will acquire design, innovative, management and leadership skills, in an international context, flexible and open to contamination between different backgrounds, cultures, technologies and skills.

Long term sustainability will be ensured by the fact that the space sector is undergoing a re-thinking of the supply chain, especially when low TRL is involved, which requires opening and making accessible the supply chain to new partners particularly in the sector of advanced research, where innovative technological solutions are typically developed.

In order to allow access to the space sector to research centers and industries, TAS-I, an affiliate of this spoke, has resolved that their new satellite AIT factory under development will include an area open to those subjects (including SMEs) which do not yet have facilities such as Clean room, environments and test machines. It should be emphasized that these facilities have within them the competent human resources not only to make them work, but also to assist and guide any guests.

LENGHT	LAUNCH	DEADLINE	STRUCTURED PERSONNEL	RECRUITED RESEARCHERS	STATUS
35 months	January 2023	December 2025	60	5	ONGOING

UPCOMING EXPECTED DEADLINE

New IR telescope facility commissioning (December 2024)

Entities participating in the activities

GRAN SASSO SCIENCE INSTITUTE – SCHOOL OF ADVANCED STUDIES – Scuola Universitaria Superiore

unipg – UNIVERSITÀ DEGLI STUDI DI PERUGIA

INAF – ISTITUTO NAZIONALE DI ASTROFISICA

FONDAZIONE BRUNO KESSLER

ThalesAlenia Space – a Thales / Leonardo company

Financial resources — 5,3 Million euro

Faculty and researchers involved in project activities	1,821,690.66 €
Calls for researchers, post-docs, and technologists	500,000.00 €
Equipment	2,723,978.49 €
Buildings/land	0.00 €
Calls for companies	0.00 €
Consultancies	0.00 €
Indirect costs	273,253.59 €

Task 4

The work package consists of the following tasks listed.

Task			Foreseen deadline
WP1.A	Crystal Eye: novel technologies for X and gamma ray observation	NEARING COMPLETION	12/2025
WP1.B	Cryogenic systems for the LGWA pathfinder	NEARING COMPLETION	12/2025
WP1.C	Infrared Adaptive-Optics facility at the AZT-24 telescope of Campo Imperatore	COMPLETED	12/2024
WP1.D	Multifunctional structures for space applications	NEARING COMPLETION	12/2025

Expected impact

- New technologies and prototypes developed
- Human resources from industry and research institutions trained on-the-job through joint projects
- Highly qualified human resources and PhD students attracted, especially from other EU and non-EU countries
- Supply chains industries and SMEs involved in WP activities

WP1.A Crystal Eye: novel technologies for X and gamma ray observation

Crystal Eye (CE) is an innovative hemispherical space-based X-ray and gamma-ray detector based on the use of LYSO crystals read by Silicon Photomultipliers (SiPM).

The CE project will have a strong impact on the design of future space missions. The pioneering design of CE in fact is possible thanks to the use of new materials (LYSO, windform), sensors (Silicon Photo Multiplier, SiPM) and platform technologies (additive manufacturing, modern SoC).

Important technological outputs are expected on both sides of new sensors development, in terms of improved radiation hardness and platform innovations. In the framework of this task new laboratories for scientific payload development and assembly will be realized in the GSSI and GSSI- LNGS compounds.

DEADLINE	STATUS
December 2025	NEARING COMPLETION

Entities participating in the activities

GRAN SASSO SCIENCE INSTITUTE – SCHOOL OF ADVANCED STUDIES – Scuola Universitaria Superiore

FONDAZIONE BRUNO KESSLER

ThalesAlenia Space – a Thales / Leonardo company

Financial resources 4,1 Million euro

Faculty and researchers involved in project activities	1,056,853.70 €
Calls for researchers, post-docs, and technologists	500,000.00 €
Equipment	2,355,340.50 €
Buildings/land	0.00 €
Calls for companies	0.00 €
Consultancies	0.00 €
Indirect costs	158,528.05 €

Milestones

Title	Description/objectives	Entities	Expected month of completion	Status
Electronics and mechanical optimization	Requisites definition, design and optimization of the mechanical and electronic setups of the Crystal Eye instrument. Preparation of the executive project of the Crystal Eye payload.	GSSI, FBK, TAS-I	August 2023	COMPLETED
Testing and assembly laboratory completion	The first phase of the activities has started with the definition and design of the laboratories for scientific payload development and assembly. The foreseen location is in the compound of the National Gran Sasso Laboratories of INFN (Assergi, L'Aquila).	GSSI	December 2023	COMPLETED
CE payload qualification model realization and test	Through different tenders and inhouse activities, three models of the Crystal Eye payload will be realized (structural model, qualification model and flight model). Engineering tests of the models and space qualification of the payload.	GSSI, FBK, TAS-I	June 2025	ONGOING
In-lab payload delivery	Final tests on the flight model of the Crystal Eye payload, in lab delivery of the complete assembly.	GSSI, FBK, TAS-I	December 2025	ONGOING

Outputs

Title	Description/objectives	Entities	Expected month of completion	Status
Satellite Payload		GSSI, FBK, TAS-I		
Task final report		GSSI		

WP1.B Cryogenic systems for the LGWA pathfinder

The Lunar Gravitational-wave Antenna (LGWA) was recently proposed to measure surface vibrations induced by passing gravitational waves from astrophysical and cosmological sources.

Inertial sensors are under development with sub-picometer to femtometer precision in the decihertz band. It requires an emulator of the seismic and thermal environment to test and operate these sensors on Earth as part of a TRL6 requirement.

Building on a research facility at INFN-LNGS for the development of a seismic isolation system, we propose to augment the facility by a cryogenic system to emulate the <40K ambient temperature of a lunar permanently shadowed region. Furthermore, we propose to carry out a preliminary engineering study of LGWA and its pathfinder mission “LGWA Soundcheck”.

DEADLINE	STATUS
December 2025	● NEARING COMPLETION

Entities participating in the activities

GRAN SASSO SCIENCE INSTITUTE
SCHOOL OF ADVANCED STUDIES
Scuola Universitaria Superiore

Financial resources 4,1 Million euro

Faculty and researchers involved in project activities	234,000.00 €
Calls for researchers, post-docs, and technologists	0.00 €
Equipment	148,637.99 €
Buildings/land	0.00 €
Calls for companies	0.00 €
Consultancies	0.00 €
Indirect costs	35,100.00 €

Milestones

Title	Description/objectives	Entities	Expected month of completion	Status
Cryogenic system production	The first phase of the activities has started with the definition of requirements, design and optimization of the cryogenic system. The forthcoming phase will be devoted to the executive project of the cryostat. In the final phase the cryostat will be produced through external tenders and inhouse activities.	GSSI	December 2023	● NEARING COMPLETION

Title	Description/objectives	Entities	Expected month of completion	Status
Cryogenic facility commissioning	Commissioning of the complete infrastructure of the cryogenic system.	GSSI	December 2024	NEARING COMPLETION
Preliminary engineering study of LGWA Soundcheck	Engineering tests of the cryogenic facility and study of the system capabilities.	GSSI	December 2025	ONGOING

Outputs

Title	Description/objectives	Entities	Expected month of completion	Status
Engineering study		GSSI		
Task final report		GSSI		

WP1.C Infrared Adaptive-Optics facility at the AZT-24 telescope of Campo Imperatore

The task aims at exploiting the extraordinary observational capabilities of the Campo Imperatore Observatory (AQ) by acquiring a new Infrared, adaptive optics facility to be mounted at the AZT-24 telescope and capable of tackling the astrophysical challenges expected in the next decades in the fields of Multi-messenger Astronomy, Supernovae and Cosmology, Stellar Evolution and Habitable Planetary Systems.

DEADLINE	STATUS
December 2024	COMPLETED

Entities participating in the activities

INAF
ISTITUTO NAZIONALE DI ASTROFISICA

Financial resources 0,6 Million euro

Faculty and researchers involved in project activities	287,250.00 €
Calls for researchers, post-docs, and technologists	0.00 €
Equipment	220,000.00 €
Buildings/land	0.00 €
Calls for companies	0.00 €
Consultancies	0.00 €
Indirect costs	43,087.50 €

Milestones

Title	Description/objectives	Entities	Expected month of completion	Status
Realization of the executive project for the IR optics system	Definition of requirements, design and executive project of the IR optics system.	INAF	August 2023	COMPLETED
Adaptive optics acquisition	Through different tenders and inhouse activities the adaptive optics system will be acquired.	INAF	June 2024	COMPLETED
New IR telescope facility commissioning	Commissioning and engineering tests of the new IR telescope facility.	INAF	December 2024	ONGOING

Outputs

Title	Description/objectives	Entities	Expected month of completion	Status
IR telescope facility		INAF		
Task final report		GSSI, INAF		

WP1.D Multifunctional structures for space applications

The task will be dedicated to study innovative solutions for multifunctional structures for cubesat platforms and small (< 20 Kg) payloads, as the Penetrating particle Analyzer (PAN), currently developed with standard solutions.

Mechanical design for space application traditionally provides structural support to the payload/platform with particular attention to the choice of materials and geometry to match the stringent requirements on masses/volumes.

The objective of this activity is to go further in the design and production of support structures, by thinking of the mechanical structure as an integral part of the payload/platform serving additional purposes other than structural integrity.

DEADLINE	STATUS
December 2025	NEARING COMPLETION

Entities participating in the activities

Financial resources 0,3 Million euro

0.3 Million euro	243.586,96 €
Faculty and researchers involved in project activities	243,586.96 €
Calls for researchers, post-docs, and technologists	0.00 €
Equipment	0.00 €

Buildings/land	0.00 €
Calls for companies	0.00 €
Consultancies	0.00 €
Indirect costs	36,538.04 €

Milestones

Title	Description/objectives	Entities	Expected month of completion	Status
Design	Definition of design requirements and translation of mathematical models to numerical simulations. Analysis and optimization of design parameters, choice and characterization of materials and processes, selection of components.	UNIPG	December 2024	NEARING COMPLETION
Prototype	Component-level testing, design optimization though a breadboard functional analysis in a laboratory environment. Manufacturing of a complete prototype, characterization and testing of the prototype in a relevant environment under possible operative conditions (launch and on-orbit associated mechanical and thermal loads).	UNIPG	December 2025	NEARING COMPLETION

Outputs

Title	Description/objectives	Entities	Expected month of completion	Status
Prototype		UNIPG		
Task final report		GSSI, UNIPG		

WP2

Digital platforms for space industry

WP2 aims at the realization of shared digital platforms to support innovation in research institutions and industrial supply chains operating in the space sector.

As already pioneered in the automotive sector, the factory of the future will be digitally enabled, from the early stages of engineering to production, and will benefit from digital continuity between the various elements of the supply chain. All production equipment will be connected to a centralized system for data storage and management.

The real-time processing of these data will allow the monitoring of the production process according to the logic of the Digital Twin. The virtualization and modeling of production processes will allow an optimization of the planning, reducing the lead times and the necessary stack in the various phases. WP2 will implement this new paradigm, and will include a case study connected with the development of the Crystal Eye satellite covered in WP1, allowing the development scientific satellite to be fully compatible with new industry approaches of software defined satellites.

In the Crystal Eye satellite, we aim at making use of AI techniques in the on-board software. Thus, WP2 will also investigate new techniques for guaranteeing the trustworthiness of smart and autonomous systems to guarantee that the behavior of these systems will not violate safety requirements and will reach the expected quality.

The trustworthiness problem is exacerbated by the adoption of AI techniques. The use of AI techniques in the on-board software requires also to investigate innovative software architecture and software platform enabling the use of AI on board and, in general, addressing the needs of new space applications. WP2 is structured in three tasks that cover the digitalization of productive process, onboard SW platform, and trustworthiness and explainability of AI applications, and onboard SW platform.

To ensure long term sustainability, TAS-Italia will connect its own R&D laboratories with those used by the spoke's activities, integrating tools and processes, possibly leading to the actual creation of an Open Concurrent Engineering Facility available also to SMEs.

LENGHT	LAUNCH	DEADLINE	STRUCTURED PERSONNEL	RECRUITED RESEARCHERS	STATUS
35 months	January 2023	December 2025	76	3	● NEARING COMPLETION

UPCOMING EXPECTED DEADLINE

Initial validation of the V&V techniques on the Crystal Eye satellite (December 2024)

Entities participating in the activities

Financial resources — 3,1 Million euro

Faculty and researchers involved in project activities	1,679,826.52 €
Calls for researchers, post-docs, and technologists	500,000.00 €
Equipment	686,021.51 €
Buildings/land	0.00 €
Calls for companies	0.00 €
Consultancies	0.00 €
Indirect costs	251,973.98 €

Task 3

The work package consists of the following tasks listed.

Task			Foreseen deadline
WP2.A	Automatic tuning, analysis, and optimization of systems using digital twins	COMPLETED	12/2025
WP2.B	Trustworthiness of smart and autonomous system	NEARING COMPLETION	12/2025
WP2.C	Onboard SW platform for New Space Applications	NEARING COMPLETION	12/2025

Expected impact

- New tools, techniques, software and platforms developed
- Human resources from industry and research institutions trained on-the-job through joint projects
- Highly qualified human resources and PhD students attracted, especially from other EU and non-EU countries

WP2.A Automatic tuning, analysis, and optimization of systems using digital twins

The task aims at realizing an integrated, end-to-end, infrastructure for the digitalization and virtualization of the operational life cycle of one or more devices used in Space industry, including methodologies and tools allocated to the on-board SW platform production process.

Through the realization of digital twins, several goals can be achieved like predictive maintenance, virtual risk assessment and training processes both for the production and operational teams. Furthermore this digital infrastructure can simplify the access to space manufacturing to new actors by removing current barriers related to expensive (procurement, maintenance and know-how) facilities and to the complexity of the quality assurance process.

The digital twin could be shared or licensed for use to new partner that are in this way easily introduced to the Space SW industry processes. Moreover, a digital virtualization infrastructure comprehending a platform simulator, permits to decouple the SW production process from the HW production manufacturing time anticipating, inside the platform overall planning, possible HW SW integration issues.

DEADLINE	STATUS
December 2025	COMPLETED

Entities participating in the activities

Financial resources 1,9 Million euro

Faculty and researchers involved in project activities	580,239.78 €
Calls for researchers, post-docs, and technologists	500,000.00 €
Equipment	686,021.51 €
Buildings/land	0.00 €
Calls for companies	0.00 €
Consultancies	0.00 €
Indirect costs	87,035.97 €

Milestones

Title	Description/objectives	Entities	Expected month of completion	Status
Digital process Preliminary design review	Identification of development, HW and SW needed to realize the digital twin for the specific spacecraft architecture/component.	GSSI, TAS-I	March 2023	COMPLETED
Digital Twins first prototype	Digital Twin process and tools chain prototype with preliminary Validation and Test facility.	GSSI, TAS-I	September 2023	COMPLETED
Digital Twin V1	Digital Twin Process and tools chain V1, including AI/ML techniques for automatic tuning of systems.	GSSI, TAS-I	June 2024	COMPLETED
Digital Twin V2	Digital Twin Process and tools chain V2, including AI/ML techniques for automatic tuning and optimization of customizable systems.	GSSI, TAS-I	Juno 2025	COMPLETED
Digital Twin end of Validation	The digital twin is validated with the real case of study.	GSSI, TAS-I	December 2025	COMPLETED

WP2.B Trustworthiness of smart and autonomous systems

To be used in everyday life, smart and autonomous systems must be trustworthy. Besides of guaranteeing quality, in many application domains smart and autonomous systems need to obey to certification of software properties.

Spacecraft systems have highly demanding reliability and resilience requirements. The introduction of Machine Learning and Artificial intelligence technologies among on-board SW applications will bestow even greater importance to requirements of reliability and resilience.

The additional computational power supplied by new space processors, eventually combined with dedicated coprocessors, will allow on-board additional services to enhance the spacecraft autonomy and the system reliability and resilience following a predictive maintenance approach. and by exploiting V&V techniques.

A specific aim of this task is the seamless integration of current software development practices of autonomous systems with precise verification flows for achieving trustworthiness. Examples of techniques that we plan to investigate are static analysis techniques, model-based and (semi)automatic approaches to software verification, software testing both in production and in the field.

DEADLINE	STATUS
December 2025	NEARING COMPLETION

Entities participating in the activities

GRAN SASSO SCIENCE INSTITUTE – SCHOOL OF ADVANCED STUDIES – Scuola Universitaria Superiore

FONDAZIONE BRUNO KESSLER

ThalesAlenia Space – a Thales / Leonardo company

Financial resources 0,7 Million euro

Faculty and researchers involved in project activities	579,418.04 €
Calls for researchers, post-docs, and technologists	0.00 €
Equipment	0.00 €
Buildings/land	0.00 €
Calls for companies	0.00 €
Consultancies	0.00 €
Indirect costs	86,912.71 €

Milestones

Title	Description/objectives	Entities	Expected month of completion	Status
Requirements of V&V techniques and of AI techniques for space	Identification of the requirements of both V&V techniques for smart and autonomous systems and AI techniques for space (also considering the specific HW architecture of the use case).	GSSI, FBK, TAS-I	June 2023	COMPLETED
AI for space design review	Main design decisions for AI software for space. We will specifically refer to the Crystal Eye satellite.	GSSI, FBK, TAS-I	December 2023	COMPLETED
First version of V&V techniques for smart systems and prototype of AI software for space	First version of V&V techniques for smart and autonomous system and their specialization to AI techniques for space. Delivery of the first working prototype of AI software for space.	GSSI, FBK, TAS-I	June 2024	COMPLETED

Title	Description/objectives	Entities	Expected month of completion	Status
Initial validation of the V&V techniques on the Crystal Eye satellite	Initial validation of V&V techniques for smart and autonomous systems with the Crystal Eye satellite representative example.	GSSI, FBK, TAS-I	December 2024	COMPLETED
Final version of V&V techniques for smart systems, final version of AI software for space, and final validation with the Crystal Eye satellite	Final version of V&V techniques for smart and autonomous systems and their initial validation with industrial examples. Final version of the AI software for space. Final validation with the Crystal Eye satellite use case.	GSSI, FBK, TAS-I	December 2025	NEARING COMPLETION

WP2.C Onboard SW platform for new space applications

This task aims at developing innovative SW architectures, with SW relevant technologies, that go beyond the current concept of platform and payload disjoint processing, converging into a single SW platform for New Space Applications.

The SW platform sought is based on a hybrid and parallel computing concept, embedding SW Files System concentrators and memories paradigms such those used into ground data centers. For the processing there will be scalar, vectorial IP's and accelerators derived from programmable logics.

This computing grid based on HW COTS, will be orchestrated with systems based on open sources standards (such as Open MP - Open CL) to maximize efficiency in the allocation of computation for IP's resources and memories.

The idea is to develop an In-orbit framework with DevSecOps technologies that allows the development, testing and deployment of FLIGHT SW even when the SW platform is in orbit.

The framework engines will be designed to host accelerators for artificial intelligence, capable a very high level of autonomy on board, integrating the most modern AI libraries developed on the new space market (as a reference Tensor Flow, Klepsydra, etc).

This technology will allow AI maneuvers, AI reconfigurations and on-board diagnostics-based AI, with a virtual AI operator that will limit the management costs of complex software from the ground stations.

DEADLINE	STATUS
December 2025	NEARING COMPLETION

Entities participating in the activities

GRAN SASSO SCIENCE INSTITUTE – SCHOOL OF ADVANCED STUDIES – Scuola Universitaria Superiore

ThalesAlenia Space – a Thales / Leonardo company

Financial resources 0,6 Million euro

Faculty and researchers involved in project activities	520,168.70 €
Calls for researchers, post-docs, and technologists	0.00 €
Equipment	0.00 €
Buildings/land	0.00 €
Calls for companies	0.00 €
Consultancies	0.00 €
Indirect costs	78,025.30 €

Milestones

Title	Description/objectives	Entities	Expected month of completion	Status
Critical design review	Critical design review of new OnBoard SW approach.	GSSI, TAS-I	June 2023	NEARING COMPLETION
Procurement of commercial HW and SW	All the commercial equipment required shall be available within this milestone.	GSSI, TAS-I	October 2023	ONGOING
Integration and Test Readiness review	The focus of this review is to accept the Integration and Test approach.	GSSI, TAS-I	June 2025	ONGOING
Final testing and qualification	Final acceptance review	GSSI, TAS-I	December 2025	ONGOING

WP3

Technology transfer and impact management

This work package will implement an innovative approach to technology transfer for the spoke activities. Thanks to the creation of a Center for Ethical Technology Transfer and Impact Management, which will leverage expertise from the spoke's affiliates, protection and valorization of results will be managed from early stages of R&D together with an evaluation of downstream economic, social, and environmental sustainability.

Collaboration between research institutions and industries will be strengthen through an innovation network linking stakeholders of the innovation ecosystem. In order to maximize impact, specific resources will be allocated to strengthen the capacity of supply chains (especially SMEs) to incorporate and market innovations, thanks to acceleration and spin-off creation tasks.

LENGHT	LAUNCH	DEADLINE	STRUCTURED PERSONNEL	RECRUITED RESEARCHERS	STATUS
35 months	January 2023	December 2025	31	3	NEARING COMPLETION

UPCOMING EXPECTED DEADLINE

IP protection (December 2024)

Entities participating in the activities

GRAN SASSO SCIENCE INSTITUTE – SCHOOL OF ADVANCED STUDIES – Scuola Universitaria Superiore

INAF – ISTITUTO NAZIONALE DI ASTROFISICA

ThalesAlenia Space – a Thales / Leonardo company

Financial resources — 0,9 Million euro

Faculty and researchers involved in project activities	317,250.00 €
Calls for researchers, post-docs, and technologists	500,000.00 €
Equipment	0.00 €
Buildings/land	0.00 €
Calls for companies	0.00 €
Consultancies	0.00 €
Indirect costs	47,587.50 €

Task 3

The work package consists of the following tasks listed.

Task		Status
WP3.A	Protection and Valorization of Intellectual Property ONGOING	12/2024
WP3.B	Supply chain development and spin- off creation ONGOING	12/2025
WP3.C	Ensuring the ethical use of new technologies ONGOING	12/2025

Expected impact

- Strengthening collaboration between research institutions and industries
- Exploit R&D results
- Strengthening of supply chain
- Ensure economic, social and environmental sustainability of new technologies, also thanks to the Inclusion of specific clauses in exploitation agreements

WP3.A Protection and valorization of intellectual property

This task will provide scouting, evaluation and protection of all the intellectual property developed as part of R&D projects of the Spoke. Additionally, it will provide consulting and legal services aimed at the valorization of IP through licensing and collaborative agreements. To this end, the spoke will hire highly qualified staff, which will be supported by academic and professional resources of Spoke affiliates (GSSI, FBK, TASI) and the know-how from their respective networks. The GSSI, for instance, is part of JoTTo (the Joint Technology Transfer Office of Scuola Normale of Pisa, Scuola Sant'Anna of Pisa, IMT of Lucca, IUSS of Pavia, SISSA of Trieste, GSSI) whose skills in the transfer and exploitation of research results could be leveraged. In order to ensure long term sustainability of these activities, the above services can potentially be extended to companies and SMEs within the extended industrial supply chains.

DEADLINE	STATUS
December 2025	ONGOING

Entities participating in the activities

GRAN SASSO SCIENCE INSTITUTE – SCHOOL OF ADVANCED STUDIES – Scuola Universitaria Superiore

FONDAZIONE BRUNO KESSLER

ThalesAlenia Space – a Thales / Leonardo company

Financial resources 0,5 Million euro

Faculty and researchers involved in project activities	36,000.00 €
Calls for researchers, post-docs, and technologists	500,000.00 €
Equipment	0.00 €
Buildings/land	0.00 €
Calls for companies	0.00 €
Consultancies	0.00 €
Indirect costs	5,400.00 €

Milestones

Title	Description/objectives	Entities	Expected month of completion	Status
Initial Agreements	Predisposition of Non-Disclosure Agreements and collaborative agreements within the spoke.	GSSI	March 2023	COMPLETED
Preliminary survey	Preliminary survey of potential IP.	GSSI, FBK, TAS-I	December 2023	COMPLETED
IP protection	Completed filing of all patents and registrations for the results of the spoke activities.	GSSI	December 2024	ONGOING
Exploitation	Signing of exploitation agreements and licensing.	GSSI, FBK		ONGOING

Outputs

Title	Description/objectives	Entities	Expected month of completion	Status
Patents and registrations	Patents and registrations filed.			
Exploitation agreements and licensing	Exploitation agreements and licensing signed.			

WP3.B Supply chain development and spin- off creation

This task will support and complement the collaborations between research institutions and industries that will take place within the R&D work packages in order to maximize the exploitation of technology transfer and the development of industrial supply chains. The task starts with the definition of the supply chains landscape related to the spoke's activities in order to arrange R&D project collaborations and on the job education within the ecosystem. Additionally, SMEs interested in the spoke's activities will be openly selected to receive tailored acceleration services, including funding and investor research. Finally, the spoke will facilitate the incorporation and establishment of spin-offs from the affiliates of the spoke, in order to exploit directly IP and know how. The spoke will provide these services through highly qualified staff hired for this purpose, supported by academic and professional resources of Spoke affiliates (GSSI, FBK, TASI) and the know-how from their respective networks. Part of the accelerator services (e.g. internationalization, entrepreneurship, etc..) will be outsourced through external tenders to highly qualified external accelerators, selected on the basis of international excellence and local capacities.

DEADLINE	STATUS
December 2025	ONGOING

Entities participating in the activities

GRAN SASSO SCIENCE INSTITUTE – SCHOOL OF ADVANCED STUDIES – Scuola Universitaria Superiore

FONDAZIONE BRUNO KESSLER

ThalesAlenia Space – a Thales / Leonardo company

Financial resources — 0,1 Million euro

Faculty and researchers involved in project activities	117,000.00 €
Calls for researchers, post-docs, and technologists	0.00 €
Equipment	0.00 €
Buildings/land	0.00 €
Calls for companies	0.00 €
Consultancies	0.00 €
Indirect costs	17,550.00 €

Milestones

Title	Description/objectives	Entities	Expected month of completion	Status
Staffing	Completed hiring of a financing expert/grant writer and of an innovation promoter to support task 4.b.	GSSI	March 2025	NEARING COMPLETION
Landscape Analysis	Completion of supply chains landscape analysis and identification of funding sources.	GSSI, FBK, TAS-I	December 2025	ONGOING
Innovation Network	Formalization of the innovation network (including SMEs, third party providers of acceleration services, Venture Capital Funds, etc,,) and beginning of acceleration activities.	GSSI	December 2025	ONGOING
Spin-off incorporation	Spin-off incorporation.	GSSI, FBK	December 2025	ABORTED
SMEs graduation	Completion of acceleration programs.	GSSI, FBK	December 2025	ABORTED

Outputs

Title	Description/objectives	Entities	Expected month of completion	Status
Innovation network	Establishment of Innovation Network.			
Spin-off creation	Spin-off incorporation.			

WP3.C Ensuring the ethical use of new technologies

The Spoke, also thanks to the specific skills of the Social Studies area of the GSSI and its existing collaborations, such as that with Openpolis Foundation, will assess and monitor the social and environmental impact of new technologies developed.

The Intellectual Property rights deriving from technological development activities of the spoke will then be exploited while maximizing social and environmental sustainability, through licenses that require ethical applications.

This task will include ex-ante evaluation of the impact of single technological development projects, collection and analysis of KPI, identification of meliorative actions and strategies for project activities and valorization of results, dissemination of best practice through publications and seminars.

DEADLINE	STATUS
December 2025	ONGOING

Entities participating in the activities

GRAN SASSO SCIENCE INSTITUTE
SCHOOL OF ADVANCED STUDIES
Scuola Universitaria Superiore

FONDAZIONE BRUNO KESSLER

Financial resources 0,2 Million euro

Faculty and researchers involved in project activities	164,250.00 €
Calls for researchers, post-docs, and technologists	0.00 €
Equipment	0.00 €
Buildings/land	0.00 €
Calls for companies	0.00 €
Consultancies	0.00 €
Indirect costs	24,637.50 €

Milestones

Title	Description/objectives	Entities	Expected month of completion	Status
Intended Impact	Definition of the Intended economic, social, environmental Impact and individuation of KPI for each Technology Development project.	GSSI, FBK	December 2025	ONGOING
Dissemination Workshops	Organization of workshops aimed at both the public and the private sector to disseminate best practices and techniques for impact evaluation and management.	GSSI, FBK	December 2025	ONGOING
Interim report	Sharing with each project P.I. of an Interim report on Impact trajectory and forecast, identifying possible meliorative actions to implement in the following 12 months.	GSSI	December 2025	ONGOING
Final report	Publication of a case study on the economic, social, and environmental Impact of each technology development project.	GSSI	December 2025	TO BE LAUNCHED

Outputs

Title	Description/objectives	Entities	Expected month of completion	Status
SMEs accelerated	Completion of acceleration program by SMEs.			
Impact case studies	Publication of a case studies.			

Financial resources

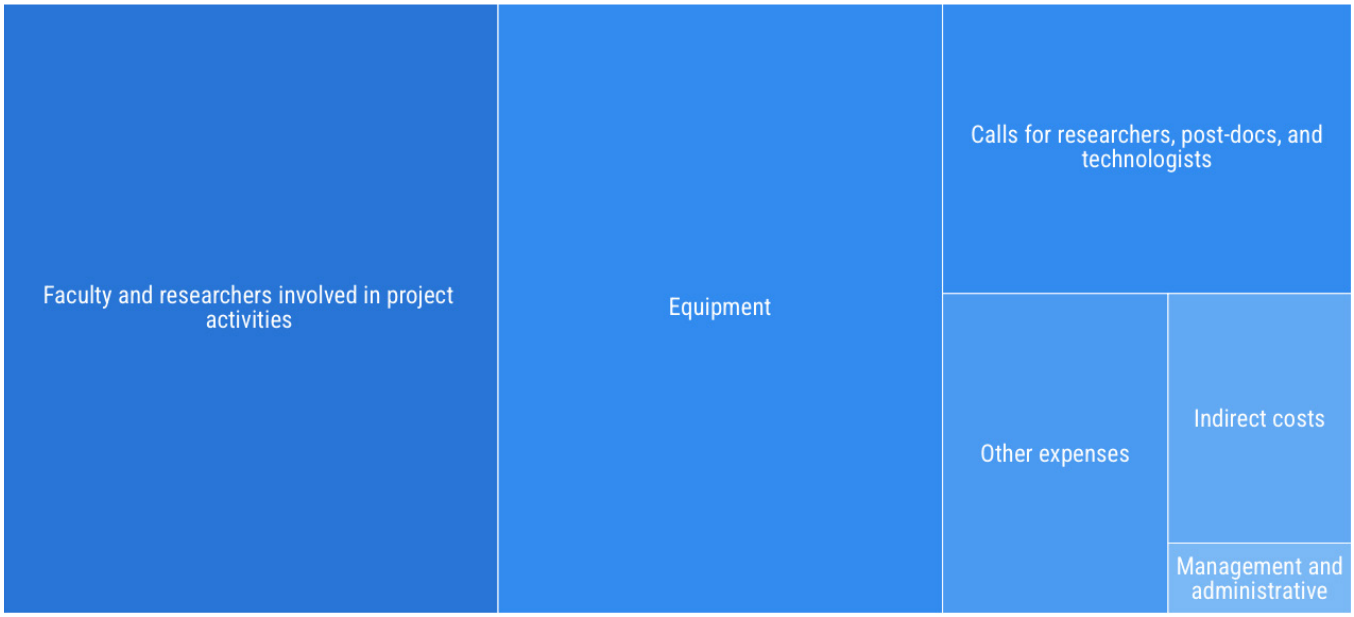
Here you can find all the information about the project's financing and track the progressive transfer of funds and the allocation of resources based on their use and entity within the Astra partnership.

10,4 Million euro
Project's total cost

10,4 Million euro
Transferred to the project so far

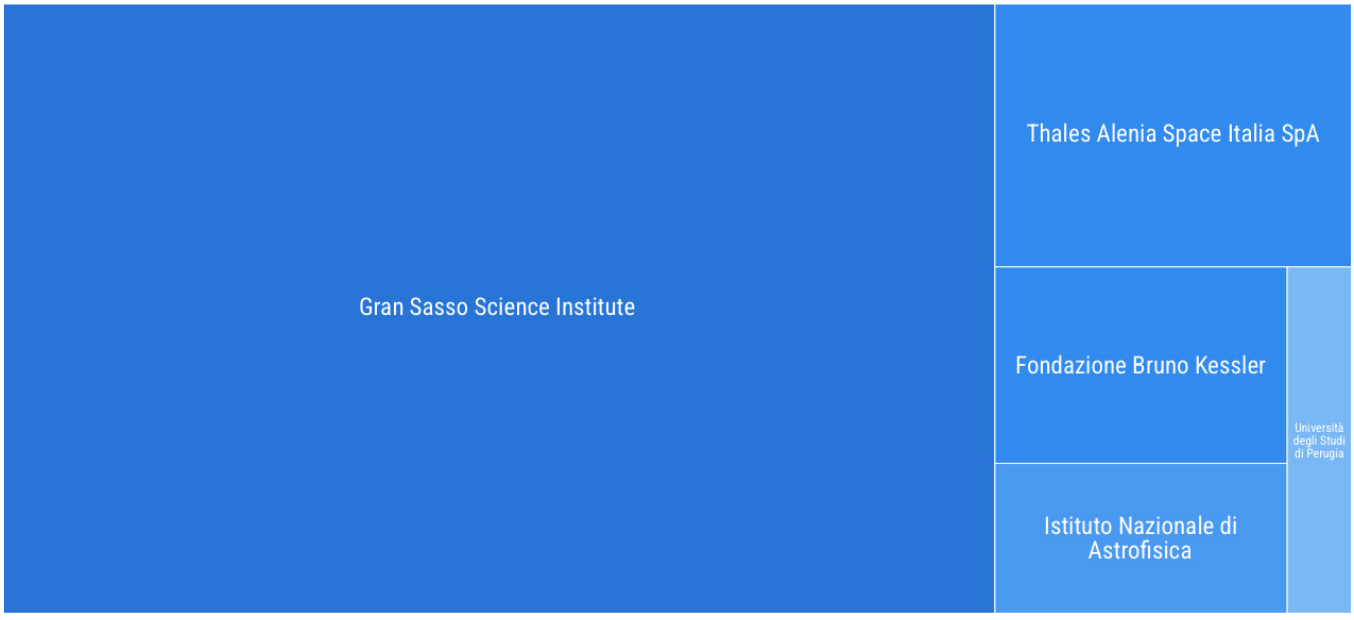
Resources divided by item

Here you can find out how the financial resources are divided based on the type of cost. By clicking on the items, you can see the funds' distribution by work package and task for each typology of cost.



Breakdown by entity

Astra sees the participation of five public and private institutions from the industry and academia. Here you can see how the financial resources have been distributed among the alliance's partners.



La ripartizione delle risorse gestite da ogni partner

La tabella mostra come sono state distribuite nel dettaglio le risorse da ogni singolo soggetto dell'alleanza.

	Faculty and researchers involved in project activities	Calls for researchers, post-docs, and technologists	Equipment	Buildings/ land	Calls for companies	Consultancies	Management and administrative	Other expenses	Indirect costs
Gran Sasso Science Institute	1.630.125,00 €	1.500.000,00 €	3.190.000,00 €	0,00 €	0,00 €	0,00 €	163.012,50 €	903.248,55 €	244.518,75 €
Università degli Studi di Perugia	243.586,96 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0 €	0 €	36.538,04 €
Istituto Nazionale di Astrofisica	287.250,00 €	0,00 €	220.000,00 €	0,00 €	0,00 €	0,00 €	0 €	0 €	43.087,50 €
Fondazione Bruno Kessler	623.728,70 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0 €	0 €	93.559,30 €
Thales Alenia Space Italia SpA	1.034.076,52 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0 €	0 €	155.111,48 €
Totale	3.818.767,18 €	1.500.000,00 €	3.410.000,00 €	0,00 €	0,00 €	0,00 €	163.012,50 €	903.248,55 €	572.815,07 €

ACCOUNT OF ACTIVITIES OF 2025

Technology transfer is a part of Astra's path

In narrating Astra's activities, we have focused so far on overviews related to two work packages: the first one centered on hardware technologies and the second one that is more oriented towards software.

There is a third work package, as important as the first two, called "Technology Transfer and Impact Management". **It encompasses the strategies designed to manage the transfer of technology, the impact of Astra on the space industry and the possible economic outcomes for the cities involved in the project.**

This work package has a budget of 900,000 euros, primarily used to ensure the involvement of highly specialized professionals. **Three staff members have been specifically hired for this purpose, in addition to over 30 employees already working within the organizations involved in the partnership.**

The work package is structured along three main directions: *Protection and Valorization of Intellectual Property, Supply chain development and spin- off creation e Ensuring the ethical use of new technologies.*

According to **Kiran Prestia**, a legal expert hired within Astra to coordinate the protection, management, and valorization of intellectual and industrial property, technology transfer of expertise is essential to fostering innovation and economic development, particularly in high-tech projects such as those in the space sector.

This process goes beyond the mere transfer of technology. It includes the definition of licensing conditions and the protection of intellectual and industrial property. It also represents a growth opportunity for universities, research institutes, businesses, and investors, stimulating progress and economic innovation.

As Prestia affirms, "At an initial stage, it is crucial to identify and analyze the technologies developed, determine their ownership, creation process, and intended use. Within Astra, confidentiality agreements and conventions have been signed among project partners to ensure alignment with the objectives, timelines, and reporting of the technologies produced."

Prestia continues, "Following this phase, specific implementation agreements will be signed, detailing roles, responsibilities, and operational procedures for the exploitation and protection of the developed technologies. This ensures compliance with current regulations and guarantees maximum transparency in the management and transfer of results."

Another key aspect is the development and protection of the results generated by the produced technologies. These are referred to as foreground, meaning the outcomes obtained through research activities, particularly those of original nature that qualify for intellectual property protection. In other words, they represent the intellectual property results achieved during project execution.

These results can be transferred or licensed, either for a fee or free of charge. "It is essential for each project affiliate to promote the valorization of research outcomes and the associated data, ensuring open access as quickly as possible and with minimal restrictions, in accordance with the principles of Open Science and FAIR Data, as well as the specific agreements established among the parties regarding intellectual property management" says Prestia.

In the context of the project, **free access to intellectual property results is not merely a formality but a crucial element in fostering synergy among partners.** It allows them to integrate their respective expertise and accelerate the development of innovative products.

Formalizing intellectual property management is fundamental to ensuring the proper and transparent transfer of ownership or, alternatively, free access to the results. "If implemented effectively, technology transfer acts as a bridge between research and innovation, transforming scientific results into innovative products and services." Concludes Prestia, "This process not only generates tangible value for the organizations involved but also strengthens the entire ecosystem, promoting economic growth, sustainability, and competitiveness on a systemic scale."

The objectives of fostering technological and socio-economic development are among the defining features of the *Vitality ecosystem*, of which Astra is one of ten spokes. With measurable results and well-defined goals, Astra's path is still long, but the determination and vision to navigate it are firmly in place.

ACCOUNT OF ACTIVITIES OF 2025

From research to business: networks and agreements driving Astra's technology transfer

In the previous weeks, we've explored how Astra plays a key role within the **Vitality ecosystem, particularly in coordinating research and industry efforts around technology transfer.**

This commitment also takes shape through the *JoTTO* **network, short for Joint Technology Transfer Office** - an inter-university initiative launched in 2015 by Italy's Ministry of Education, University and Research to foster the exchange of knowledge and innovation between academia and the production sector. The network includes six elite institutions: IMT School for Advanced Studies Lucca, Scuola Normale Superiore, Sant'Anna School of Advanced Studies in Pisa, IUSS University School for Advanced Studies Pavia, SISSA in Trieste, and the Gran Sasso Science Institute (GSSI) in L'Aquila, which also serves as a spoke in the Astra project.

"The goal is to provide a shared service to the six schools, cutting across various scientific domains, and focusing on research valorization and the so-called 'third mission' of universities", explains lawyer **Kiran Prestia**, who coordinates intellectual and industrial property management within Astra.

stia, a member of JoTTO's scientific committee, also took part in JoTTO FAIR 2025 – **Where Research Meets Industry, held in Lucca this past February** (as seen in the photo). This was a key event designed to build bridges between the academic world and business.

Technology transfer also hinges on a crucial component in projects like Astra: preliminary agreements between the spoke (GSSI) and affiliated organizations, such as the University of Perugia, INAF, Thales Alenia Space, and the Bruno Kessler Foundation. **These agreements are essential for clearly defining roles**, responsibilities, and operational frameworks—ensuring the project stays on track with its goals and timelines.

"These agreements," Prestia explains, "provide a clear regulatory framework for fund disbursement, adherence to timelines, activity monitoring, and the achievement of milestones and targets. Without them, the risk of inefficiencies or non-compliance increases, potentially undermining the required level of transparency".

Another key issue governed by these agreements is the management and exploitation of intellectual and industrial property generated through the collaborative work of Astra's spokes and affiliates. As previously reported, the project aims to generate scientific and technological results whose ownership and usage terms are clearly defined from the outset.

"The concepts of **background** (pre-existing knowledge and rights), **foreground** (results achieved during project execution), and **sideground** (knowledge developed in parallel but not directly linked to the project) help delineate these categories," notes Prestia, who joined Astra to oversee these matters.

This overall approach is designed to protect the rights of each partner, while also encouraging open access to data in accordance with FAIR principles (**Findable, Accessible, Interoperable, Reusable**). It aims to prevent potential disputes while ensuring a fair distribution of benefits.

Astra is at present in the early stages regarding its Technology Readiness Level (TRL). "Our goal is to reach a sufficient level of maturity by 2026 to begin commercializing the results—such as through licensing," Prestia concludes.

ACCOUNT OF ACTIVITIES OF 2025

The challenge of Crystal Eye to gamma ray bursts

Last year, we discussed one of Astra's key components: **the development of Crystal Eye**, a crucial instrument within Astra's *Work Package 1*, the one dedicated to advancing new *hardware technologies*.

The work on the experiment has continued over the past few months. Naturally, the development of such a prototype involves a complex journey. *Crystal Eye* relies on innovative technology that incorporates new materials and sensors. "We are creating a compact and highly sensitive scientific instrument designed to operate in orbit, constantly monitoring the entire sky to detect gamma ray bursts," says **Ivan De Mitri** (picture), Professor of Experimental Physics at the Gran Sasso Science Institute (GSSI) and *Work Package 1* Leader within the Astra project.

Gamma ray bursts are events that occur at enormous distances from the observer. Deep understanding of them remains an ambitious goal for science, as it is still among the most mysterious and powerful phenomena in the universe.

The key feature of the prototype lies in the use of scintillating crystals, which emit a flash of light each time they are hit by ionizing radiation, such as that produced by gamma bursts. "These crystals, when impacted by high-energy radiation, produce flashes of light that are captured by silicon photomultipliers, compact and efficient devices", adds the professor from GSSI. **This approach allows for reducing the size of the device without compromising its detection capability.**

Gamma-ray bursts were discovered by chance during the Cold War by small satellites launched into orbit by the US Air Force, whose purpose was to detect possible nuclear tests by observing bursts of X-rays and gamma rays. After several years of data collection, scientific analysis revealed the existence of gamma-ray flashes lasting only a few seconds, with both Earth and the Sun ruled out as their origin. These results were published in 1973, and the phenomena were named Gamma Ray Bursts (GRBs). "Today we know that gamma-ray bursts are caused by events such as the death of massive stars or the merger of binary systems of neutron stars, which occur in distant galaxies and release enormous amounts of energy", says De Mitri.

The device is designed to capture these light signals with an accuracy of about one degree. Once detected, the system can immediately send an alert to the scientific community, indicating the precise location of these radiation events in the sky. "The speed at which we can localize such an event is crucial to allow other instruments to study it in a complementary way, and to improve its localization in the sky in order to identify the source", says the researcher, referring to the ability to leverage the project within a multimessenger approach, which we have discussed in the past.

The ability to detect gamma ray bursts in real time has applications not only in astrophysics but also in other fields of science. For example, the crystals used could also be employed to monitor terrestrial atmospheric phenomena, such as Terrestrial Gamma-ray Flashes (TGFs), which occur during very powerful storms. "Although these events do not originate in space, they are similar to cosmic gamma bursts and provide us with important data on atmospheric physics," explains De Mitri.

A Crystal Eye prototype will be tested aboard the **European Space Agency's (ESA) Space Rider mission**: "For us, Space Rider represents a crucial phase of the project, as it will allow us to verify the functioning of the devices and gather data on their behavior during flight," says De Mitri. The launch is expected for the end of 2026, with the payload returning to Earth for post-mission analysis.

With Crystal Eye, we are poised to open a new frontier in observing the most extreme events in the cosmos. This is made possible through international collaborations, demonstrating how research can be applied in interdisciplinary contexts, combining astrophysical expertise, advanced technologies, and a clear **focus on the future of space exploration.**

ACCOUNT OF ACTIVITIES OF 2025

The multiplying effect of Astra and ESA's "Mini-Fast" call

The challenge launched by the Astra partnership goes beyond the experimental phase defined by the project itself. In fact, **Astra is designed to pave the way for new opportunities in aerospace research.**

It follows a logic similar to the **National Recovery and Resilience Plan (PNRR)**, which funded the creation of the Vitality ecosystem and its Astra spoke: enabling new capabilities and skills that not only foster cutting-edge research but are also meant to grow and last independently over time.

This is the context in which a new opportunity is emerging around the Crystal Eye project, one of the main pillars of Astra's first work package (WP1). The European Space Agency (ESA) has recently launched a call that fits this framework. "ESA regularly issues calls for proposals for future space missions, which vary depending on the type and size of the scientific instruments involved," explains *Ivan De Mitri*, professor of experimental physics at the Gran Sasso Science Institute (GSSI) and head of WP1 in Astra.

Some missions are long-term and highly complex, with launches planned by 2040—GSSI itself is involved in several of them. But ESA also runs quicker, more focused initiatives known as "Mini-Fast" calls.

The Mini-Fast call is specifically designed for "agile," **low-cost scientific missions that can be developed and launched within five years.** Its aim is to assess both the interest in and feasibility of new types of missions under ESA's scientific program. "Mini-Fast is meant for innovative technologies that are already well-tested, so they can be ready to fly on a shorter timeline," De Mitri says.

This is exactly where Crystal Eye fits in. Backed by a network of scientific and industrial institutions, **the project is developing an advanced technological prototype that could eventually be launched into space.** The Mini-Fast program offers up to €50 million in funding—over ten times more than the €4.1 million currently allocated to Crystal Eye. This would allow the project to evolve far beyond the prototype phase.

"The whole Astra journey has been essential to even apply for this call," De Mitri emphasizes. "The funding allowed us to reach a level of readiness that would have been very hard to achieve otherwise. The costs involved in building the sensor, launching it, and operating it in orbit are extremely high. No single institution could handle them alone. The involvement of agencies like the Italian Space Agency or ESA is absolutely crucial."

In short, **international agencies play a key role in amplifying the impact of initiatives like Astra**, generating a positive ripple effect within the Vitality ecosystem. "The ultimate goal isn't just to launch a space mission," concludes De Mitri, "but to build a system that keeps producing innovation well beyond any single project."

ESA will announce the results of the Mini-Fast call next autumn. If selected, Crystal Eye will be ready to move forward on its own—powered by the momentum created by Astra.

ACCOUNT OF ACTIVITIES OF 2025

Assessing the value of a research project

As we follow the unfolding story of ASTRA through its many activities, we return to the third work package (WP3), which focuses on the impact and technology transfer of the project. **Unlike the first two work packages, WP3 investigates the broader socio-economic consequences of scientific research.**

WP3 is structured around three core tasks. The third (WP3C) is titled *Ensuring the Ethical Use of New Technologies*. With a dedicated budget of around €200,000, it is led by *Adriana Carolina Pinate*, a researcher in Applied Economics at the Gran Sasso Science Institute (GSSI).

At the heart of this research lies a simple but crucial principle: the value of a scientific project cannot be measured solely by academic publications or technological outcomes. Broader, often harder-to-answer questions also come into play- ones that accompany many public investments: What is the actual societal impact? Is the project sustainable, useful, fair or all of the above?

"WP3C aims to measure the economic and social impact of ASTRA's activities," says Pinate. "We've set ourselves the ambitious goal of applying a cost-benefit analysis (CBA) to a scientific research infrastructure that is modest in scale compared to the large-scale public works - such as highways or subway systems - that typically undergo this kind of evaluation."

Traditionally, cost-benefit analysis has been reserved for massive infrastructure projects or, within scientific research, initiatives of major economic significance like CERN. In ASTRA's case, however, the analysis is being applied to a project with limited duration, experimental nature, constrained resources, and a strong focus on knowledge production and the adoption of innovative technologies.

This is where the novelty of the approach lies: "We are working to build an evaluation model that can be applied to small- or medium-scale research projects, which are often excluded from conventional assessment tools. In this sense, our work also serves as a case study for both the scientific community and public funders," explains Pinate.

Another distinctive feature of ASTRA's methodology is its emphasis on in itinere evaluation—that is, assessment during the project's implementation rather than only upon its completion. This real-time approach allows the team to capture effects and transformations as they happen, including those that are less visible. It's a complex task that requires tracking inputs, outputs, and intermediate outcomes from personnel costs to academic output, from new collaborations to impacts on researcher training.

The challenge is to measure the value of knowledge itself—the ability of ASTRA to generate intangible wealth and inspire scientific innovation. To do so, the team uses tools such as the shadow price, an economic concept often employed in cost-benefit analysis. A shadow price estimates the value of a good or resource—in this case, the outcomes of ASTRA's research—that does not have a direct market price. In other words, the team constructs indirect estimates of the social value of goods that lie outside traditional market mechanisms.

Ultimately, **the WP3C analysis also embraces an innovative perspective that aims to foster a broader discussion within research communities**: How are projects funded, and who truly benefits? The goal is to bring greater transparency and accountability to public investments in science—to demonstrate not only what is being done, but why it matters.

ACCOUNT OF ACTIVITIES OF 2025

The scientific output generated by the Astra project

Dozens of scientific publications have explored the ongoing research carried out within the Astra project.

The many researchers involved in the project's activities have already achieved significant results — outcomes that have been presented in academic journals and at international conferences.

To make this work accessible to everyone, we've created a *dedicated section* on this website listing all publications, organized by the project's three work packages (WPs), which we've been reporting on since the very beginning: WP1 (*Advanced Technologies for the Space Industry*); WP2 (*Digital Platforms for the Space Industry*); WP3 (*Technology Transfer and Impact Management*).

Each list is updated as of July 2025, and publications are grouped into three categories: Peer-reviewed journal papers; Conference proceedings; Monographs and other works.

As new publications are released, the section will continue to grow and be updated regularly until the end of the project.

The value of Astra through citizen engagement

As discussed in a previous article, the Astra project places significant emphasis on evaluating its impact not only on scientific research but also on the broader community. While traditional cost-benefit analyses remain part of the process, Astra introduces an innovative, experimental approach aimed at answering a deceptively simple yet largely unexplored question: **What is the value of such a scientific research project for Italian citizens?**

To address this, the Astra research team is preparing a nationwide survey targeting a statistically representative sample of the Italian population, accounting for factors such as age, gender, geographic location, education, and income. Participants will be asked using recognized experimental methods, such as **Willingness To Financially Participate (WTFP)**, as well as tailor-made approaches on how important Astra is to them as individuals and as members of a wider community.

The goal is to determine whether, and to what extent, the scientific research and technological innovations produced by Astra hold value in the eyes of the public. "We aim to collect primary data to estimate the so-called 'existence value' of research not its direct utility, but the perceived value of knowledge itself, regardless of any personal benefit" explains **Adriana Pinate**, head of the task Ensuring the Ethical Use of New Technologies within the project's third work package.

This concept, what economists refer to as non-use value, is complex and rarely measured empirically using economic incentives. Yet that is precisely what the Astra team intends to do: assess the public's willingness to pay for basic research, even in the absence of direct involvement or tangible outcomes.

"People often ask how much research costs, but rarely how much it is worth to those who aren't conducting it" Pinate adds, "And yet, simply knowing that projects like Astra exist that they develop technologies and generate knowledge with far-reaching impact can have intrinsic value, even for those with no direct ties to academia".

The method employed is contingent valuation, a well-established tool in behavioral economics typically used to evaluate public goods, such as natural parks or protected rivers. In Astra's case, however, the public good in question is scientific knowledge itself.

By analyzing the data gathered through this experiment, researchers will explore how perceptions of science's value vary across different segments of the population. This demographic insight could also highlight which communities geographically and socially feel most connected to scientific advancement.

The experimental data will be nationally balanced and demographically representative. Moreover, its implications go beyond academia: the results are expected to feed into broader public discussions on the societal role of science. **The findings will be published in leading international journals and made publicly available on the Astra website**, in compliance with data privacy laws, to ensure transparency and credibility both for participants and the general public.

Through this impact assessment, the Astra team is not only evaluating outcomes, but also aiming to turn a technical exercise into a tool for civic engagement and public reflection. "Research doesn't just produce results it can generate meaning, perspective, and future policy" Pinate concludes "Finding ways to communicate its value is, in itself, an act of innovation."

The Astra survey, the lottery, and participant choices

In the previous in-depth article, we left off with a question that was both simple and complex: how much is a scientific research project based on space science and technology like Astra worth to Italian citizens? This is one of the main questions underlying the work of the project's third work package, WP3 ("Technology Transfer and Impact Management"). An interdisciplinary working group, coordinated by **Adriana Pinate** of the Gran Sasso Science Institute (head of WP3C, *Ensuring the ethical use of new technologies*), conducted a nationwide survey using experimental methods, involving a representative sample of the Italian population.

The objective was precisely to try to answer the question about the general perception of the project's impact. Specifically, we are talking about an online survey distributed in the second half of September to one thousand adults residing in Italy and recruited by a company specializing in surveys.

A pilot phase had also involved an additional 40 participants. Below we present the results of the experimental section relating to a lottery launched on the occasion of the survey, designed specifically to estimate the value (including economic value) that participants placed on Astra after learning about its characteristics.

It should be emphasized that all information complies with privacy and participant anonymity regulations, and participants are not identifiable even by the research team itself.

The Experiment

The questionnaire was divided into four sections, the second of which was experimental. Adopting a **revealed preference approach** (a method that deduces respondents' preferences from their actual choices rather than from direct questions), participants first learned about Astra. The main features of the project were presented through images, words, and renderings.

Subsequently, they were offered the opportunity to win a real sum of money through a lottery. Finally, they were asked to donate (in part, in whole, or not at all) their winnings to science, and specifically to Astra.

This mechanism made it possible to estimate the project's value for Italian residents, a crucial piece of data for developing the **cost-benefit analysis (CBA)**, one of the main tools in impact assessment. In addition to the 4 euros provided for participating in the survey, it was possible for each respondent to win an additional sum of money. Participants were randomly assigned to one of two prize groups:

Group A: 80 euros, 25 winners (1 in 20 people)
Group B: 40 euros, 50 winners (1 in 10 people)

After receiving information about Astra, participants received the following information on which they had to make choices. At the end of the survey, a unique random number (from 1 to 500) was assigned to each participant for entry into the lottery.

Here the video of the lottery and the winning numbers (group A), recorded live.

Here the video of the lottery and the winning numbers (group B), recorded live.

The Pilot Survey

Finally, as we have already highlighted, an initial pilot survey was conducted which included 20 participants per group, for a total of 40 people surveyed. Below you can see the videos of the pilot survey lottery winners, with the results related to the third choice (on the average of the donations).

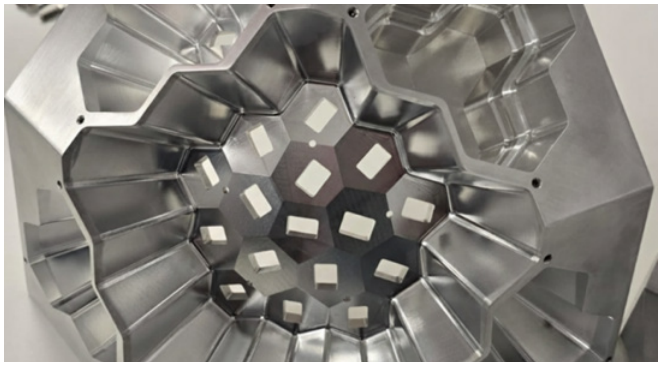
Group A – 80 euros (1 winner out of 20 participants)
Group B – 40 euros (2 winners out of 20 participants)

ACCOUNT OF ACTIVITIES OF 2025

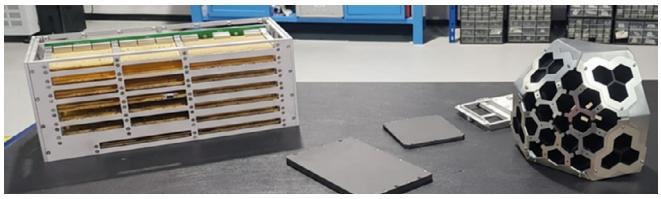
The Structural Model of Crystal Eye takes shape

Before a new scientific instrument can venture into space, it must successfully pass a long series of trials. It's not enough for it to simply function well: it must also survive the launch, which is notoriously a "traumatic moment" in the "life" of any object destined for space. This is where the Structural Model of Crystal Eye enters the scene—a "silent twin" of the detector, built specifically to undergo the essential testing that prepares it for subsequent launch activities.

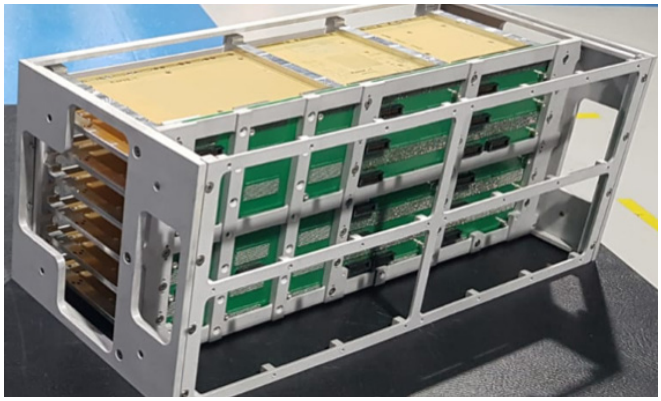
This rigorous **"stress test"** will serve to understand exactly how the future instrument will react to the vibrations of the launch and to identify any potential structural weak points. The team from Astra's WP1 (Advanced technologies for Space industry) has completed the assembly — the joining of parts — of the Crystal Eye structural model. "Given the nature of the tests to be carried out," states GSSI researcher **Felicia Barbato**, "not all the standards and requirements typically adopted for the production of qualification and/or flight components were strictly applied to the manufacturing of these parts. However, the materials used are of an equivalent nature to those that will be employed in the subsequent versions of the detector." The structural model, therefore, is nothing more than a non-functional but completely identical copy of the real Crystal Eye, as can be seen from the photo below (referencing the original article), which shows the internal structure.



In the next photo, however, we can identify the two principal parts: the load-bearing structure, which will contain the crystals destined to detect gamma rays, and the Electronics Box, the operational hub that interprets the signals received by the detector and communicates with the satellite to send data back to us.



The detector's support structure is made entirely of aluminum and is composed of main sub-parts, represented by internal and external semi-sphere sections. The load-bearing structure is composed of two hemispheres, one internal and one external. Within it are the crystals and electronics which, in the operational version, will record particles and radiation-related phenomena. In the structural model, all of this is simulated, but the support structure is, of course, identical to the flight structure. There is also the **"Electronics Box"**, also made of aluminum, which will host the circuit boards and systems that process the data.



Once completed, **numerous accelerometric sensors will be positioned on the model.** During the vibration test, these sensors record precisely how the instrument moves and reacts to shocks and movements. This real-world data will then be compared with computer-generated simulations. In short, these are fundamental test steps designed to guarantee the ultimate reliability and trustworthiness of the actual Crystal Eye, which represents one of the key pillars of the Astra project.

Photo: the headquarters of the Gran Sasso Science Institute Rectorate in L'Aquila (Italy)

ACCOUNT OF ACTIVITIES OF 2025

The latest updates on Astra's progress

Almost 7 million euros transferred, many tasks completed, and the project's progress status is well underway.

This is how the data update on the Astra portal, one of the Vitality ecosystem projects, can be summarized.

The data, updated as of November 2025, reports a total of 6.7 million euros transferred, to which the final project balances will be added, reaching the overall allocated amount of 10.4 million euros.

Within the three project work packages, there are 39 milestones, all of which can be navigated through this portal. Of these, 14 are already completed, 8 are in the process of **completion**, 14 are ongoing, and 3 have been cancelled due to some in-progress modifications to the project activities.

Work Package number 2 (*Digital platforms for Space industry*) **has the highest number of completed objectives: 8.**

It must also be added and highlighted that the "completion date" is used to consider a milestone finished. For almost half of the milestones (16 out of 39), the completion date is the same as the project end date, which is December 2025.

These are just a few figures, but they are emblematic of how a research project funded with public resources has been monitored, even through this portal. In fact, **it is not common for such monitoring to be publicly presented,** especially within the scope of the National Recovery and Resilience Plan (PNRR).

ACCOUNT OF ACTIVITIES OF 2025

Astra: three years of milestones to guarantee continuity

By the end of the year, the Astra project will formally conclude. Over the past three years, this initiative has seen a **collaborative effort between public and private entities in space research** to develop new hardware and software technologies. As one of the ten spokes of the Vitality ecosystem, the project has achieved highly satisfactory results, confirming the exceptional quality of the professionals involved and the standard of Italian aerospace research.

We spoke with Roberto Aloisio—Full Professor at the Gran Sasso Science Institute (GSSI) and project coordinator—to review this journey and better understand the results achieved and their future potential. "On the hardware and research infrastructure front (**Work Package 1**), the results are tangible," explains Aloisio. "The team successfully completed testing on the Engineering Model (EQM) of the **Crystal Eye** scientific payload, passing every trial."

"In these weeks, we are finalizing the **Proto-Flight Model (PFM)**, the version of the payload intended for satellite integration and subsequent launch," the Italian physicist says. Furthermore, a new light-detection technology developed by the Bruno Kessler Foundation, one of the project's private partners, was refined and qualified for space use.

Concurrently, research efforts have also yielded fruit in the **second work package** ("Digital Platforms for Space Industry"), leading to the creation of a new Digital Twin model for satellites and their orbital management. "In this area," Aloisio states, "we worked closely with Thales Alenia Space Italy to develop advanced Digital Twins that will be engineered for industrial use, demonstrating the success of technological development between academia and industry."

These significant results from collaborations with private entities demonstrate that one of Astra's primary objectives—constructive public-private cooperation in the space sector—has been met.

The picture is completed by **structural innovations achieved through the project**, such as the activities managed by the National Institute for Astrophysics (INAF). INAF carried out a significant upgrade of the Campo Imperatore Observatory on the Gran Sasso d'Italia, making it suitable for infrared measurements. These measurements are essential for cosmological studies, such as the observation of supernovae. This work places the Campo Imperatore infrastructure among the world's leading centers for this type of research.

Regarding the **third and final work package** — dedicated to technology transfer and monitoring the project's impact — the Astra team will release the final results of an innovatively conducted survey in the coming weeks.

As previously noted, Astra is part of the Vitality ecosystem, funded by the **National Recovery and Resilience Plan (PNRR)** and ranked among Italy's top-funded innovation ecosystems. However, beyond research excellence and documented results, a structural issue remains at the level of national public policy: a lack of continuity.

Aloisio himself highlights this: "The PNRR was fundamental and played a crucial role by promoting the creation of new research infrastructures. The critical issue lies in the fact that no financial coverage has been planned beyond 2026, especially regarding the professional future of many researchers who have been instrumental to the success of these projects."

At the national level, the emerging scenario could jeopardize the continuation of many projects like Astra. The challenge ahead is to guarantee the resources necessary to secure the benefits derived from structural collaborations between the public and private sectors. Doing so means protecting pathways that contribute to both the **national economic system and the country's cultural fabric.**

Articles peer-reviewed - Technology Transfer and Impact Management

Milestone 25 - Technology Transfer and Impact Management

A. Peer-reviewed journal papers

1. Pinate, A., Cattani, L., Dal Molin, M., & Faggian, A. (2024). *'Get back to where you once belonged?' Effects of skilled internal migration on Italian regional green growth". Papers in Regional Science*, 103(4), 100036. (Q1)

2. Brandano, M. G., & Pinate, A. C. (2025). Smart Specialisation Strategy in a Tourist Country: A new path of development in Italian regions?. Journal of Policy Modeling. (Q1) This work has been funded by the European Union - NextGenerationEU under the Italian Ministry of University and Research (MUR) National Innovation Ecosystem grant ECS00000041 - VITALITY – CUP: D13C21000430001.

C. Peer-reviewed journal papers

1. Pinate, A. C., Dal Molin, M., & Brandano, M. G. (2024). The Geography of Green Innovation in Italy. In CONFLICT SCENARIOS AND TRANSITIONS. Opportunities and Risks for Regions and Territories. (Book Chapter)

Articles peer-reviewed - Digital platforms for space industry

Milestone 24 - Digital platforms for space industry

A. Peer-reviewed journal papers

1. Moretti, M., Rossi, A., & Senin, N. *"Optical tomography by laser line scanning and digital twinning for in-process inspection of lattice structures in material extrusion."* Additive Manufacturing (2024): 104424. Doi.org/10.1016/j.addma.2024.104424. (Q1)

2. Anh Ho, Anh M. T. Bui, Phuong T. Nguyen, Amleto di Salle, Bach Le (2025) EnseSmells: Deep ensemble and programming language models for automated code smells detection The Journal of Systems & Software. (Q1). [2502.05012] EnseSmells: Deep ensemble and programming language models for automated code smells detection. This work has been funded by the European Union–NextGenerationEU, under the Italian Ministry of University and Research (MUR) National Innovation Ecosystem grant ECS00000041–VITALITY–CUP J97G22000170005.

3. Samira Silva, Ricardo Caldas, Patrizio Pelliccione, Antonia Bertolino (2025). *Different Approach for Testing Body Sensor Network Applications Journal of Systems & Software (JSS) to appear.* (Q1). This work has been funded by the European Union–NextGenerationEU, under the Italian Ministry of University and Research (MUR) National Innovation Ecosystem grant ECS00000041–VITALITY–CUP J97G22000170005.

4. A. Avritzer, A. Janes, A. Marin, C. Trubiani, A. Van Hoom, M. Camilli, D. S. Manasche, A. B. Bondi "Software aging Detection and Rejuvenation Assessment in Heterogeneous Virtual Networks" IEEE Transactions on Emerging Topics in Computing (TETC), to appear. (Q1). This work has been funded by the European Union–NextGenerationEU, under the Italian Ministry of University and Research (MUR) National Innovation Ecosystem grant ECS00000041–VITALITY–CUP J97G22000170005.

5. Rebelo Luciana, Basciani Francesco, Pelliccione Patrizio (2025) Applications of AI in Space Domain ACM Computing Surveys. To appear. (Q1). This work has been funded by the European Union–NextGenerationEU, under the Italian Ministry of University and Research (MUR) National Innovation Ecosystem grant ECS00000041–VITALITY–CUP J97G22000170005.

B. Conference proceedings

1. Simone Fioravanti, Michele Flammini, Bojana Kodric, Giovanna Varricchio: "*PAC Learning and Stabilizing Hedonic Games: Towards a Unifying Approach*", 37th AAAI Conference on Artificial Intelligence (AAAI), Washington, D.C., USA, AAAI Press, Palo Alto, California, USA, pp. 5641-5648, February 2023. **(INTERNATIONAL)**

2. Enxhi Ferko, Alessio Bucaioni, Patrizio Pelliccione, Moris Behnam (2023) *Analysing Interoperability in Digital Twin Software Architectures for Manufacturing In: ECSA 2023.* **(INTERNATIONAL)**

3. Angelella S., Albi E., Dionigi M., Logozzo S., Valigi M.C. *Proposal and Modeling by Simscape Multibody of a Mechatronic Device for Breast Cancer Cells Experiments (2024) Mechanisms and Machine Science*, 164 MMS **(INTERNATIONAL)**

4. Roland Kuhn, Hernán C. Melgratti, Emilio Tuosto: Behavioural Types for Local-First Software (Artifact). Dagstuhl Artifacts Ser. 9(2): 14:1-14:5 (2023). *Behavioural Types for Local-First Software (Artifact). Dagstuhl Artifacts* **(INTERNATIONAL)**

5. Roland Kuhn, Hernán C. Melgratti, Emilio Tuosto: *Behavioural Types for Local-First Software*. ECOOP 2023: 15:1-15:28. **(INTERNATIONAL)**

6. Alkida Balliu, Sebastian Brandt, Fabian Kuhn, Dennis Olivetti, Gustav Schmid (2023): "*On the Node-Averaged Complexity of Locally Checkable Problems on Trees*", in 37th International Symposium on Distributed Computing (DISC 2023). **(INTERNATIONAL)**

7. Ngoc-Thanh Nguyen, Keila Lima, Astrid Marie Slålvik, Rogardt Heldal, Eric Knauss, Tosin Daniel Oyetoyan, Patrizio Pelliccione, Camilla Sætre, Lars Michael Kristensen (2023) *Synthesized data quality requirements and roadmap for improving reusability of in-situ marine data in: 31st IEEE International Requirements Engineering Conference (RE23)*. **(INTERNATIONAL)**

8. Francesca Arcelli Fontana, Matteo Camilli, Davide Rendina, Andrei Gabriel Taraboi, Catia Trubiani: *Impact of Architectural Smells on Software Performance: an Exploratory Study. International Conference on Evaluation and Assessment in Software Engineering* (EASE), 2023: 22-31. **(INTERNATIONAL)**

9. Riccardo Pinciroli, Raffaela Mirandola, Catia Trubiani: *Modular Quality-of-Service Analysis of Software Design Models for Cyber-Physical Systems. International Conference on Advanced Information Systems Engineering (CAiSE)* 2023: 88-104. **(INTERNATIONAL)**

10. Kenneth Johnson, Samaneh Madanian, Catia Trubiani "*Patterns of Applied Control for Public Health Measures on Transportation Services under Epidemic*", in the Proceedings of the International Conference on Software Engineering for Adaptive and Self-Managing Systems (SEAMS), 2024. **(INTERNATIONAL)**

11. A. Staffa, M. Palmieri, G. Morettini, F. Cianetti and C. Braccesi. Integration of Piezoresistive Sensors into AM Structural Components: *Evaluation of Sensor Properties and Its Impact on Component Mechanical Performance, 2024*. **(NATIONAL)**

12. D'Incecco, P., Gorinov, D. A., Dolci, M. et al., "*The INAF Campo Imperatore Observatory in Abruzzo (Italy) as an Earth Observation Facility for the Study of Venus Night Airglows (VNAs), Proceedings of the 55th Lunar, Planetary Science Conference*", held 11-15 March, 2024 at The Woodlands, Texas/Virtual. LPI Contribution No. 3040, id.2202 (2024). *https://ntrs.nasa.gov/citations/20240000324* **(INTERNATIONAL)**

13. M. Dolci, E. Brocato, G. Rodeghiero et al., "*Upgrading the AZT24 telescope at the Campo Imperatore high-altitude observatory: design and installation of a new, seeing-enhanced NIR imager*", Proceedings of the SPIE Astronomical Telescopes + Instrumentation 2024 Conference, id. 13096-336 (2024). **(INTERNATIONAL)**

14. Rodeghiero, G., Valentini, A., Dolci, M. et al., "*A new near-IR imager for the 1.1m infrared telescope of the Campo Imperatore Observatory*", Proceedings of the 6th Chianti Topics, held 26-29 February, 2024 in Florence. Video Mem. SAIt, under publication (2024). **(NATIONAL)**

15. Luciana Rebelo, Érica Souza, Gian Berkenbrock, Gerson Barbosa, Marlon Silva, André Endo, Nandamudi Vijaykumar, Catia Trubiani (2023) "*Prioritizing test cases with Markov Chains: a Preliminary Investigation*", in 35th International Conference on Testing Software and Systems (ICTSS 2023). **(INTERNATIONAL)**

16. Samira Silva, Ricardo Caldas, Patrizio Pelliccione, Antonia Bertolino (2025) *An adaptive testing approach based on field data In: 6th ACM/IEEE International Conference on Automation of Software Test (AST)*. **(INTERNATIONAL)**

17. Alberto Avritzer, Andrea Janes, Catia Trubiani, Helena Rodrigues, Yuanfang Cai, Daniel Sadoc Menasché and Álvaro José Abreu de Oliveira, "*Architecture and Performance Antipatterns Correlation in Microservice Architectures*", International Conference on Software Architecture (ICSA), 2025. **(INTERNATIONAL)**

18. Alessio Bucaioni, Amleto Di Salle, Ludovico Iovino, Patrizio Pelliccione, Franco Raimondi (2025) *Architecture as Code In: 22nd International Conference on Software Architecture* (ICSA 2025). **(INTERNATIONAL)**

19. Compagnucci Ivan, Pinciroli Riccardo, & Trubiani Catia. *Performance Analysis of Architectural Patterns for Federated Learning Systems. 22nd IEEE International Conference on Software Architecture*. ICSA 2025. **(INTERNATIONAL)**

20. Di Frischia, S., Dolci, M. 2024: AI detection of S/N<1 *Sources in infrared images: a deep learning algorithm developed for the AZT24 facility at Campo Imperatore Observatory, Proceedings of the SPIE*, id. 13101, p. 131012Y **(INTERNATIONAL)**

21. Tiziano Santilli, Marco De Luca, Domenico Amalfitano, Anna Rita Fasolino, Patrizio Pelliccione (2024) *Characterizing Software Architectural Metrics for Continuous Compliance in the Automotive Domain* In: 21st IEEE International Conference on Software Architecture (ICSA 2024). **(INTERNATIONAL)**

22. Keila Lima, Ngoc-Thanh Nguyen, Rogardt Heldal, Lars Michael Kristensen, Tosin Daniel Oyetoyan, Patrizio Pelliccione, Eric Knauss (2024) *A data-flow oriented software architecture for heterogeneous marine data streams* In: 21st IEEE International Conference on Software Architecture (ICSA 2024). **(INTERNATIONAL)**

23. Alessio Bucaioni, Amleto Di Salle, Ludovico Iovino, Leonardo Mariani, Patrizio Pelliccione (2024) *Continuous Conformance of Software Architectures* In: 21st IEEE International Conference on Software Architecture (ICSA 2024). **(INTERNATIONAL)**

24. A. Aloisio, M. Flammini, C.Vinci: "*Generalized Distance Polymatrix Games*", Proc. of the 49th International Conference on Current Trends in Theory and Practice of Computer Science (SOFSEM), Cochem, Germany, Lecture Notes in Computer Science 14519, Springer, Basel, Switzerland, pp. 25-39. **(INTERNATIONAL)**

25. V. Bilò, M. Flammini, G.Monaco, L.Moscardelli, C.Vinci: "*On Green Sustainability of Resource Selection Games with Equitable Cost-Sharing*", Proc. of the 23rd International Conference on Autonomous Agents and Multiagent Systems (AAMAS), Auckland, New Zealand, IFAAMAS, Richland, South Carolina, USA. **(INTERNATIONAL)**

26. Gianlorenzo D'Angelo, Esmaeil Delfaraz: *Approximation Algorithms for Node-Weighted Directed Steiner Problems*. In 35th International Workshop on Combinatorial Algorithms (IWOCA 2024). **(INTERNATIONAL)**

27. D'Incecco, P., Gorinov, D. A., Dolci, M., Tartaglia, L., De Luise, F., Valentini, G., Cantiello, M., Filiberto, J., Bhiravarasu, S. S., Brocato, E., Rodeghiero, G., Valentini, A., Benedetti, S., Di Carlo, M., Di Cianno, A., Di Frischia, S., Napoleone, N., Piersimoni, A., Portaluri, E., Raimondo, G., Spanò, P., Di Achille, G. 2024: *The INAF Campo Imperatore Observatory in Abruzzo (Italy) as an Earth Observation Facility for the Study of Venus Night Airglows* (VNAs), Proceedings of the 55th Lunar, Planetary Science Conference, id. 3040, p. 2202 **(INTERNATIONAL)**

28. Dolci, M., Brocato, E., Rodeghiero, G., Di Frischia, S., D'Incecco, P., Canzari, M., Benedetti, S., De Luise, F., Di Carlo, M., Di Cianno, A., Napoleone, N., Piersimoni, A. M., Portaluri, E., Raimondo, G., Tartaglia, L., Valentini, A., Valentini, G. 2024: *Upgrading the AZT24 telescope at the Campo Imperatore high-altitude observatory: design, installation of a new, seeing-enhanced NIR imager, Proceedings of the SPIE*, id. 13096, p. 130968W, *https://ui.adsabs.harvard.edu/abs/2024SPIE13096E..8WD* **(INTERNATIONAL)**

29. J. Afonso, E. Konjoh Selabi, M. Murgia, A. Ravara, E. Tuosto. *TRAC: a tool for data-aware coordination. COORDINATION 2024 (To appear)* **(INTERNATIONAL)**

30. C. G. Lopez Pombo, P. Montepagano, E. Tuosto. *SEArch: an execution infrastructure for service-based software systems. COORDINATION 2024 (To appear)* **(INTERNATIONAL)**

31. C. Bartolo Burlò, A. Francalanza, A. Scalas, E. Tuosto. *COTS: Connected OpenAPI Test Synthesis for RESTful Applications. COORDINATION 2024 (To appear)*. **(INTERNATIONAL)**

32. Carlos G. Lopez Pombo, Agustín E. Martinez-Suñé, Emilio Tuosto: Automated Static Analysis of QoS Properties of Communicating Systems. To appear at FM 2024. **(INTERNATIONAL)** This work has been funded by the European Union - NextGenerationEU under the Italian Ministry of University and Research (MUR) National Innovation Ecosystem grant ECS00000041 - VITALITY – CUP: D13C21000430001

33. Yechuan Xia, Alessandro Cimatti, Alberto Griggio, Jianwen Li: *Avoiding the Shoals - A New Approach to Liveness Checking*. CAV (1) 2024: 234-254. **(INTERNATIONAL)**. This work has been funded by the European Union–NextGenerationEU, under the Italian Ministry of University and Research (MUR) National Innovation Ecosystem grant ECS00000041–VITALITY–CUP C63C22000560006

34. P. Haller, A. Hussein, H. Melgratti, A. Scalas, E. Tuosto: *Fair Join Pattern Matching for Actors*. To Appear at ECOOP 2024 **(INTERNATIONAL)**. This work has been funded by the European Union - NextGenerationEU under the Italian Ministry of University and Research (MUR) National Innovation Ecosystem grant ECS00000041 - VITALITY – CUP: D13C21000430001.

35. Omar Inverso, Emerson Sales, Emilio Tuosto: *Accurate Static Data Race Detection for C*. To Appear at FM 2024 **(INTERNATIONAL)** This work has been funded by the European Union - NextGenerationEU under the Italian Ministry of University and Research (MUR) National Innovation Ecosystem grant ECS00000041 - VITALITY – CUP: D13C21000430001.

36. G. D'Angelo and E. Delfaraz. Approximation Algorithms for Connected Maximum Coverage. In 24th International Conference on Autonomous Agents and Multiagent Systems (AAMAS 2025). **(INTERNATIONAL)**. *Approximation Algorithms for Connected Maximum Coverage*. This work has been funded by the European Union–NextGenerationEU, under the Italian Ministry of University and Research (MUR) National Innovation Ecosystem grant ECS00000041–VITALITY–CUP J97G22000170005.

37. J. Andres Diaz-Pace, C. Trubiani, D. Garlan, "Data-driven Understanding of Design Decisions in Pattern-based Microservices Architectures", European Conference on Software Architecture (ECSA), 2025, to appear. **(INTERNATIONAL)**. *Replication package for: "Data-driven Understanding of Design Decisions in Pattern-based Microservices Architectures"*. This work has been funded by the European Union - NextGenerationEU under the Italian Ministry of University and Research (MUR) National Innovation Ecosystem grant ECS00000041 - VITALITY – CUP: D13C21000430001.

C. Monographs/others

1. Franco Barbanera, Ivan Lanese, Emilio Tuosto: *A Theory of Formal Choreographic Languages. Log. Methods Comput. Sci. 19(3) (2023). A Theory of Formal Choreographic Languages. Log. Methods Comput. Sci.* (Journal Paper without Q, but with DOI)

2. Ngoc Thanh Nguyen, Rogardt Heldal, Keila Lima, Tosin Daniel Oyetoyan, Patrizio Pelliccione, Lars Michael Kristensen, Kjetil Waldeland Høydal, Pål Asle Reiersgaard, Yngve Kvinnsland (2023) *Engineering Challenges of Stationary Wireless Smart Ocean Observation Systems IEEE Internet of Things Journal*. DOI: 10.1109/JIOT.2023.3283252. Journal Paper without Q, but with DOI

3. Roger Nazir, Alessio Bucaioni, Patrizio Pelliccione (2023) Architecting ML-enabled systems: challenges, best practices, and design decisions Journal of Systems & Software (JSS). https://doi.org/10.1016/j.jss.2023.111860. *Architecting ML-enabled systems: challenges, best practices, and design decisions Journal of Systems & Software (JSS)*. (Journal Paper without Q, but with DOI)

4. Gianlorenzo D'Angelo, Debashmita Poddar, Cosimo Vinci: Better bounds on the adaptivity gap of influence maximization under full-adoption feedback. Artif. Intell. 318: 103895 (2023). https://doi.org/10.1016/j.artint.2023.103895. *Cosimo Vinci: Better bounds on the adaptivity gap of influence maximization under full-adoption feedback.* (Journal Paper without Q, but with DOI)

5. Samira Silva, Patrizio Pelliccione, Antonia Bertolino (2023) *Self-Adaptive Testing in the Field, ACM Transactions on Autonomous and Adaptive Systems*. https://doi.org/10.1145/3627163. Self-Adaptive Testing in the Field, ACM Transactions on Autonomous and Adaptive Systems. (Journal Paper without Q, but with DOI)

6. Franco Barbanera, Ivan Lanese, Emilio Tuosto: *Composition of synchronous communicating systems. J. Log. Algebraic Methods Program*. 135: 100890 (2023). https://doi.org/10.1016/j.jlamp.2023.100890. Composition of synchronous communicating systems. J. Log. Algebraic Methods Program (Journal Paper without Q, but with DOI)

7. Giovanni Quattrocchi, Emilio Incerto, Riccardo Pinciroli, Catia Trubiani, Luciano Baresi", Autoscaling Solutions for Cloud Applications under Dynamic Workloads", accepted for IEEE Transactions on Services Computing (TSC), to appear. DOI:10.1109/TSC.2024.3354062 *Autoscaling Solutions for Cloud Applications under Dynamic Workloads", accepted for IEEE Transactions on Services Computing (TSC), to appear.* (Journal Paper without Q, but with DOI)

8. P. Krupa, O. Inverso, M. Tribastone, A. Bemporad. "Certification of the proximal gradient method under fixed-point arithmetic for box-constrained QP problems". Elsevier Automatica 2024. *https://doi.org/10.1016/j.automatica.2023.111411* (Journal Paper without Q, but with DOI)

9. Rossi, A., Pescara, T., Gambelli, A. M., Gaggia, F., Asthana, A., Perrier, Q., Basta, G., Moretti, M., Senin, N., Rossi, F., Orlando, G. & Calafiore, R. *"Biomaterials for extrusion-based bioprinting and biomedical applications"*. Frontiers in Bioengineering and Biotechnology, 12 (2024): 1393641. doi.org/10.3389/fbioe.2024.1393641 (Journal Paper without Q, but with DOI)

10. Srajan Goyal, Alberto Griggio, Stefano Tonetta: *System-level simulation-based verification of Autonomous Driving Systems with the VIVAS framework and CARLA simulator. Sci. Comput. Program.* 242: 103253 (2025) (Journal Paper without Q, but with DOI)

11. Samira Silva, Ricardo Caldas, Patrizio Pelliccione, Antonia Bertolino (2025) *Different Approaches for Testing Body Sensor Network Applications Journal of Systems & Software (JSS). (Journal Paper without Q, but with DOI)*. This work has been funded by the European Union - NextGenerationEU under the Italian Ministry of University and Research (MUR) National Innovation Ecosystem grant ECS00000041 - VITALITY – CUP: D13C21000430001

12. Luciana Brasil Rebelo dos Santos, Érica Ferreira de Souza, André Takeshi Endo, Catia Trubiani, Riccardo Pinciroli, Nandamudi Lankalapalli Vijaykumar. "Performance regression testing initiatives: A systematic mapping". Information and Software Technology, Volume 179, 2025, 107641, ISSN 0950-5849 (Journal Paper without Q, but with DOI). This work has been funded by the European Union - NextGenerationEU under the Italian Ministry of University and Research (MUR) National Innovation Ecosystem grant ECS00000041 - VITALITY – CUP: D13C21000430001

13. João Paulo Costa de Araujo, Genáina Nunes Rodrigues, Marc Carwehl, Thomas Vogel, Lars Grunske, Ricardo Caldas, Patrizio Pelliccione (2024) Explainability for Property Violations in Cyber-Physical Systems: An Immune-Inspired Approach IEEE Software (Journal Paper without Q, but with DOI). This work has been funded by the European Union - NextGenerationEU under the Italian Ministry of University and Research (MUR) National Innovation Ecosystem grant ECS00000041 - VITALITY – CUP: D13C21000430001

14. Ricardo Caldas, Juan Antonio Piñera Garcìa, Matei Schiopu, Patrizio Pelliccione, Genaína Rodrigues, Thorsten Berger (2024) *Runtime Verification and Field-based Testing for ROS-based Robotic Systems IEEE Transactions on Software Engineering (TSE)* (Journal Paper without Q, but with DOI). This work has been funded by the European Union - NextGenerationEU under the Italian Ministry of University and Research (MUR) National Innovation Ecosystem grant ECS00000041 - VITALITY – CUP: D13C21000430001

15. A Petrucci, F Basciani, P Pelliccione: "AI/ML for safety-critical software: the case of the space domain", IEEE Software. (Journal Paper without Q, but with DOI). This work has been funded by the European Union - NextGenerationEU under the Italian Ministry of University and Research (MUR) National Innovation Ecosystem grant ECS00000041 - VITALITY – CUP: D13C21000430001

16. Lorenzo Bettini, Amleto Di Salle, Ludovico Iovino, Pierantonio. *Supporting reusable model migration with Edelta. The Journal of Systems & Software (JSS)*. (Journal Paper without Q, but with DOI). This work has been funded by the European Union - NextGenerationEU under the Italian Ministry of University and Research (MUR) National Innovation Ecosystem grant ECS00000041 - VITALITY – CUP: D13C21000430001

17. Andrea Bombarda, Silvia Bonfanti, Martina De Sanctis, Angelo Gargantini, Patrizio Pelliccione, Elvinia Riccobene, Patrizia Scandurra (2024) *Evaluation framework for autonomous systems: the case of Programmable Electronic Medical Systems IEEE Transactions on Software Engineering (TSE).* (Journal Paper without Q, but with DOI). This work has been funded by the European Union - NextGenerationEU under the Italian Ministry of University and Research (MUR) National Innovation Ecosystem grant ECS00000041 - VITALITY – CUP: D13C21000430001

18. Tiziano Santilli, Patrizio Pelliccione, Rebekka Wohlrab, Ali Shahrokni (2024) Continuous Compliance in the Automotive Industry IEEE Software. (Journal Paper without Q, but with DOI). This work has been funded by the European Union - NextGenerationEU under the Italian Ministry of University and Research (MUR) National Innovation Ecosystem grant ECS00000041 - VITALITY – CUP: D13C21000430001

19. Davide Bilò, Gianlorenzo D'Angelo, Luciano Gualà, Stefano Leucci, Mirko Rossi: *Blackout-tolerant temporal spanners. J. Comput. Syst. Sci. 141: 103495 (2024)*. (Journal Paper without Q, but with DOI). This work has been funded by the European Union - NextGenerationEU under the Italian Ministry of University and Research (MUR) National Inno

vation Ecosystem grant ECS00000041 - VITALITY – CUP: D13C21000430001

20. Carlos Gustavo López Pombo, Agustín E. Martinez Suñé, Emilio Tuosto: *A Dynamic Temporal Logic for Quality of Service in Choreographic Models*. ICTAC 2023: 119-138 (Journal Paper without Q, but with DOI). This work has been funded by the European Union - NextGenerationEU under the Italian Ministry of University and Research (MUR) National Innovation Ecosystem grant ECS00000041 - VITALITY – CUP: D13C21000430001

21. Srajan Goyal, Alberto Griggio, Stefano Tonetta: *System-level simulation-based verification of Autonomous Driving Systems with the VIVAS framework and CARLA simulator. Science of Computer Programming Sci.* 242: 103253 (2025). *https://doi.org/10.1016/j.scico.2024*.103253 (Journal Papers without Q, but with DOI). This work has been funded by the European Union–NextGenerationEU, under the Italian Ministry of University and Research (MUR) National Innovation Ecosystem grant ECS00000041–VITALITY–CUP C63C22000560006

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23. Sven Peldszus, Davide Brugali, Daniel Strüber, Patrizio Pelliccione, Thorsten Berger (2024) *Software Reconfiguration in Robotics. To appear at Empirical Software Engineering journal.* (Journal Paper without Q, but with DOI). This work has been funded by the European Union - NextGenerationEU under the Italian Ministry of University and Research (MUR) National Innovation Ecosystem grant ECS00000041 - VITALITY – CUP: D13C21000430001

24. Filippo Fabiani, Bartolomeo Stellato, Daniele Masti, Paul J. Goulart - *A neural network-based approach to hybrid systems identification for control (2024 maybe 2025) To appear in Automatica*. (Journal Paper without Q, but with DOI). This work has been funded by the European Union - NextGenerationEU under the Italian Ministry of University and Research (MUR) National Innovation Ecosystem grant ECS00000041 - VITALITY – CUP: D13C21000430001

25. Ngoc-Thanh Nguyen, Rogardt Heldal and Patrizio Pelliccione, *Concept-drift-adaptive Anomaly Detector for Marine Sensor Data Streams. Internet of Things journal, Elsevier. To appear. 2024.* (Journal Paper without Q, but with DOI). This work has been funded by the European Union - NextGenerationEU under the Italian Ministry of University and Research (MUR) National Innovation Ecosystem grant ECS00000041 - VITALITY – CUP: D13C21000430001

26. Carnevale, D., D'Angelo, G., & Olsen, M. (2025). *Approximating Optimal Labelings for Temporal Connectivity. Proceedings of the AAAI Conference on Artificial Intellingence*, 39(25), 26490-26490-26497. (Journal Paper without Q, but with DOI). Approximating Optimal Labelings for Temporal Connectivity | Proceedings of the AAAI Conference on Artificial Intelligence. This work has been funded by the European Union - NextGenerationEU under the Italian Ministry of University and Research (MUR) National Innovation Ecosystem grant ECS00000041 - VITALITY – CUP: D13C21000430001.

Articles peer-reviewed - Advanced technologies for space industry

Milestone 23 - Advanced technologies for space industry

A. Peer-reviewed journal papers

1. Barbato F., Abba A., Anastasio A., Barbarino G., Boiano A., De Mitri I., Di Giovanni A., Ferrentino L., Garufi F., Guida R., Papa S. Renno F., Vanzanella A., Wu L. - *CRYSTAL EYE: A new X and gamma ray all-sky-monitor for space missions - Nuclear Instruments and Methods in Physics Research, Section A: Accelerators, Spectrometers, Detectors and Associated Equipment*, Volume 1049, April 2023, Article number 168045. (Q1)

2. Remani, A., Rossi, A., Peña, F., Thompson, A., Dardis, J., Jones, N., ... Senin, N, ... & Leach, R. (2024). *In-situ monitoring of laser-based powder bed fusion using fringe projection. Additive Manufacturing*, 90, 104334. (Q1). This work has been funded by the European Union–NextGenerationEU, under the Italian Ministry of University and Research (MUR) National Innovation Ecosystem grant ECS00000041–VITALITY–CUP J97G22000170005.

B. Conference proceedings

1. R. Colalillo, F. C. T. Barbato, I. De Mitri, A. DiGiovanni, M. Fernandez Alonso, G. Fontanella, F. Garufi, F. Guarino, I. Siddique, A. Smirnov, L. Valore, and Libo Wu - *Crystal Eye: a wide sight on the Universe for X and gamma-ray detection* - Proceedings of Science, PoS (ICRC2023) 1538, 2023. **(INTERNATIONAL)**

2. Garufi F., Abba A., Anastasio A., Barbarino, Barbato F.C.T., G., Boiano A., De Asmundis R., De Mitri I., Ferrentino L., Guarino F., Guida R., Vanzanella A. - The Crystal Eye X and gamma-ray detector for space missions - Journal of Physics: Conference Series Open Access Volume 2429, Issue 1, 2023. **(INTERNATIONAL)**

3. A. Staffa, M. Palmieri, G. Morettini, F. Cianetti and C. Braccesi. Integration of Piezoresistive Sensors into AM Structural Components: Evaluation of Sensor Properties and Its Impact on Component Mechanical Performance. DOI:10.1088/1757-899X/1306/1/012021. This work has been funded by the European Union - NextGenerationEU under the Italian Ministry of University and Research (MUR) National Innovation Ecosystem grant ECS00000041-VITALITY. We acknowledge Università degli

Studi di Perugia and MUR for support within the project Vitality. **(NATIONAL)**

4. Achilli G.M., Angelella S., Dionigi M., Logozzo S., Valigi M.C. *Preliminary Development of a Fluidic Device for Astrobiology Missions (2024) Mechanisms and Machine Science*, 160 MMS, pp. 287 - 295. Authors kindly acknowledge the project ASTROCUBE: Esperimenti e payload miniaturizzati per piattaforme CubeSat. **(INTERNATIONAL)** This work has been funded by the European Union-NextGenerationEU under the Italian Ministry of University and Research (MUR) National Innovation Ecosystem grant ECS00000041-VITALITY. Authors acknowledge Università degli Studi di Perugia and MUR for support within the project Vitality.

5. Angelella S., Albi E., Dionigi M., Logozzo S., Valigi M.C. *Proposal and Modeling by Simscape Multibody of a Mechatronic Device for Breast Cancer Cells Experiments* (2024) Mechanisms and Machine Science, 164 MMS, pp. 546 - 554, Cited 0 times. **(INTERNATIONAL)** This work has been funded by the European Union - NextGenerationEU under the Italian Ministry of University and Research (MUR) National Innovation Ecosystem grant ECS00000041 - VITALITY. We acknowledge Universit\u00E0 degli Studi di Perugia and MUR for support within the project Vitality. And for contamination, this research was also partially funded by the University of Perugia, both Fondo progetti di ateneo WP 4.3 by means of Progetto Astrocube and Progetto Colonize\u201D.

6. Virginia Burini, Silvia Logozzo, Maria Cristina Valigi, A new SMART gripper with soft fingers and integrated force sensors for adaptive robotic tasks, Robotics and Autonomous Systems, Volume 195,2026,105218,ISSN 0921-8890. This work has been funded by the European Union - NextGenerationEU under the Italian Ministry of University and Research (MUR) National Innovation Ecosystem grant ECS00000041-VITALITY. We acknowledge Università degli Studi di Perugia and MUR for support within the project Vitality. (NATIONAL)

C. Monographs/others

1. Michele Moretti, Arianna Rossi, Nicola Senin, *"Optical tomography by laser line scanning and digital twinning for in-process inspection of lattice structures in material extrusion." Additive Manufacturing (2024)*, Volume 93, 2024, 104424, https://doi.org/10.1016/j.addma.2024.104424. This work has been funded by the European Union–NextGenerationEU, under the Italian Ministry of University and Research (MUR) National Innovation Ecosystem grant ECS00000041–VITALITY–CUP J97G22000170005. (Journal Papers without Q, but with DOI)

2. Rossi A, Pescara T, Gambelli AM, Gaggia F, Asthana A, Perrier Q, Basta G, Moretti M, Senin N, Rossi F, Orlando G and Calafiore R. *"Biomaterials for extrusion-based bioprinting and biomedical applications". Frontiers in Bioengineering and Biotechnology* 12 (2024): 1393641. DOI: 10.3389/fbioe.2024.1393641. This work has been funded by the European Union–NextGenerationEU, under the Italian Ministry of University and Research (MUR) National Innovation Ecosystem grant ECS00000041–VITALITY–CUP J97G22000170005. (Journal Papers without Q, but with DOI)

3. Bertolini, V.; Faba, A.; Dionigi, M.; Cardelli, E. *Frequency Domain Model of a Resonant LCC-S Converter for High-Frequency Wireless Power Transfer Applications Considering Switching Losses in MOSFETs Bridge.* Appl. Sci. 2025, 15, 5878. (Journal Papers without Q, but with *DOI*). This work has been funded by the European Union–NextGenerationEU, under the Italian Ministry of University and Research (MUR) National Innovation Ecosystem grant ECS00000041–VITALITY–CUP J97G22000170005

4. Angelella, S.; Burini, V.; Logozzo, S.; Valigi, M.C. *Characterization and Optimization of a Differential System for Underactuated Robotic Grippers.* Machines 2025, 13, 717. (Journal Papers without Q, but with DOI). This work has been funded by the European Union - NextGenerationEU under the Italian Ministry of University and Research (MUR) National Innovation Ecosystem grant ECS00000041-VITALITY. We acknowledge Università degli Studi di Perugia and MUR for support within the project Vitality.

5. *Three-Dimensionally Printed Temperature Sensors Based on Conductive PLA Materials.* A Staffa, G Krivic, M Tocci, M Palmieri, F Cianetti, J Slavič Sensors 25 (20), 6348. (Journal Papers without Q, but with DOI). This work has been funded by the European Union - NextGenerationEU under the Italian Ministry of University and Research (MUR) National Innovation Ecosystem grant ECS00000041-VITALITY. We acknowledge Università degli Studi di Perugia and MUR for support within the project Vitality.

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