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

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

PUBLIC AFFILIATES

unipg
UNIVERSITÀ DEGLI STUDI DI PERUGIA

INAF
ISTITUTO NAZIONALE DI ASTROFISICA

PRIVATE AFFILIATES

FONDAZIONE BRUNO KESSLER

ThalesAlenia Space

Finanziato dall'Unione europea
NextGenerationEU

Ministero dell'Università e della Ricerca

Italiadomani
PIANO NAZIONALE DI RIPRESA E RESILIENZA

VITALITY

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 2024.

Vitality, a territorial ecosystem to improve Italy's central regions

A real "ecosystem" for innovation, digitalization and sustainability, serving research as well as the economy of Italy's central regions. This is **Vitality,** a journey that started in 2023 and that will have its epilogue at the end of 2025. The partnership is made up of as many as 24 bodies, including 10 universities, 4 public entities and 10 private ones.

This is an ambitious project, one of 11 "territorial ecosystems" funded by the Ministry of Universities and Research (Mur), as part of the National Plan for Recovery and Resilience (NRPR). We are dealing with nearly 115 million euros that will be used for the purpose of strengthening the cooperation of important subjects and entities of three neighboring Italian regions: Abruzzo, Marche and Umbria.

It is no coincidence, in fact, that the universities of L'Aquila (which is also the proponent of the entire ecosystem), Chieti-Pescara, Teramo, and Gran Sasso Science Institute for Abruzzo, Perugia for Umbria, the Polytechnic University of the Marche, Urbino, Camerino and Macerata for the Marche, as well as the University of Molise, have already been working on this for some time.

Alongside the universities, there are other major public entities involved, such as the National Research Council, the National Institute of Astrophysics, the Teramo Zooprophylactic Institute, and the National Institute for Rest and Care for the Elderly, as well as several other private players which are important to the economy of our country.

Two phases for connected territories

The involved organizations operate in various ways and in different territories, **but at the same time are united by common socio-economic, historical and even morphological characteristics.** In fact, there are the Apennine areas but also the Adriatic coast, in each case non-metropolitan urban areas whose life historically stems from the symbiotic relationship between university, city and business. This is the case for Perugia as well as for L'Aquila, not to mention Camerino and Urbino (long called "the campus city of Italy"). The same goes for decentralized universities in their respective territories, such as the Polytechnic University of Marche and the University of Molise. In these regions, the productive fabric is substantially composed of small and medium-sized enterprises, although not in toto. In fact, there are also several large corporations, some of which are part of Vitality.

The overall objectives of the whole operation can be divided into two major phases. **On the one hand, research oriented toward the innovative development of the area.** In this sense, we are concerned with many areas, from digital technologies to engineering, psychosocial and medical sciences, from biotechnology to physics to, of course, the aerospace sector in which the Astra project is immersed. Then there are all the aspects related to the transmission of the research results, at the service of productive areas, always within the fields of action, and always guided by the three key concepts - innovation, digitalization and sustainability.

But what is the project about concretely? It is made up of ten "spokes," that is, the 10 macro-projects of which the Vitality ecosystem is composed. Four of these are coordinated by universities in the Marche region, two by the University of Perugia (the only Umbrian university) and four by universities in Abruzzo. These latter include the Gran Sasso Science Institute (Gssi), lead partner of Astra, the **spoke 2 of Vitality.**

Astra: a research alliance

Astra stands for *Advanced Space Technologies and Research Alliance*. In addition to the Gssi that leads it, the project can count on the affiliation of the University of Perugia and the National Institute of Astrophysics (Inaf). The private companies that are part of it are the Bruno Kessler Foundation and Thales Alenia Space SpA.

The Gssi is the most recently established and most internationalized university in the entire ecosystem: in fact, more than 40 percent of its students come from abroad. It is a postgraduate school, which offers doctoral programmes in various disciplines and is the only postgraduate university in the national university system that is located in southern Italy.

The **University of Perugia,** an Astra-affiliated university, is one of the oldest and most prestigious in the country and also the only one to coordinate two spokes in Vitality (9 and 10). Inaf is a research organization established in the late 1990s that brings together astronomical observatories distributed throughout Italy. In short, it deals with the study of the Universe, in close synergy with other entities in the field, such as the **National Institute of Nuclear Physics (Infn).**

Alongside these public entities, as mentioned, two private entities also participate in Astra. One is the **Bruno Kessler Foundation,** which has its base camp in Trento and is involved in scientific and technological research (with a focus on cybersecurity and artificial intelligence). The second is **Thales Alenia Space SpA,** an Italian-French multinational company in the space sector, specialized in the production of satellites, probes and observatories, and which has one of its plants in L'Aquila, one of the territories involved in the ecosystem and indeed the one where the University proponent of the entire Vitality ecosystem was born.

Astra's main goal is to develop technologies and devices that can help bridge the gap between **"pure" research and research destined to the industrial and commercial spheres, of course in the space sector.** Specifically, the research activities will cover both hardware (from space technologies to X-ray observation) and software (such as digital satellite twins or on-board software platforms), with a focus on technology transfer and the impact of the project on the territory and in the productive fabric.

These three angles (hardware, software and impact) also represent the three work packages that make up the project. In the next articles we will recount this latter, with the aim of narrating the relevance, design and results of Astra.

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
ONGOING	New IR telescope facility commissioning (December 2024)

WP2 Digital platforms for space industry

3 Task

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

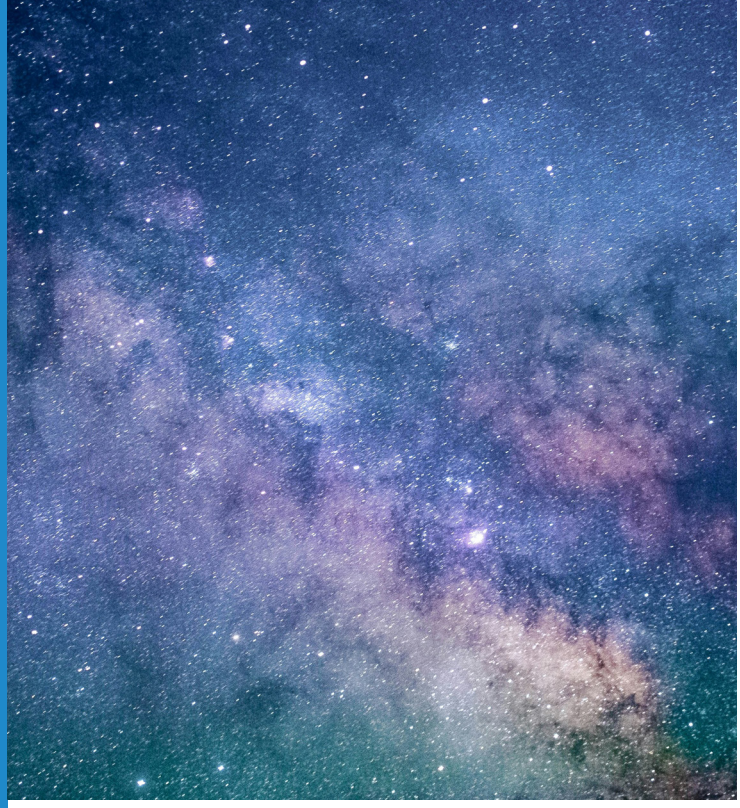
STATUS	UPCOMING EXPECTED DEADLINE
ONGOING	Initial validation of the V&V techniques on the Crystal Eye satellite (December 2024)

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
ONGOING	IP protection (December 2024)



Hardware development and space infrastructure

As we described in the previous pages, **Astra is a project divided into three macro-environments, called work packages, which in turn are divided into numerous tasks,** namely parts of the design process. The first work package addresses an essential element when it comes to the development of new space technologies: the hardware component.

Specifically, **it foresees the development of a series of advanced and innovative technological systems intended for the space industry.** At the roots of the project lies the idea of bridging between purely theoretical research and ready-to-use commercial applications, as well as of creating a diverse and international ecosystem to facilitate exchanges among the people and organizations involved.

The project is made up of four main activities. **The first revolves around the Crystal Eye,** a pioneering instrument in astronomy. It is a sensor capable of flying along low Earth orbits (between 300 and 1,000 kilometers above the Earth) and designed to be installed on satellites or space stations. The sensor has a very compact structure: a small 20-centimeter hemisphere, weighing about 50 kilograms. Within this task, the goal is specifically to develop new technologies that will improve the Crystal Eye and make it capable of intercepting X-rays and gamma rays. Such a project will have a major impact on future space missions.

The second task focuses on the technological advancement of the lunar antenna (Lgwa, acronym of Lunar gravitational-wave antenna). This instrument, developed a few years ago by the Gran Sasso Science Institute, currently allows the detection of gravitational waves directly from the Moon, thereby effectively turning the Moon itself into a detector. In this case, the activity aims at recreating a lunar environment so that the antenna can also function on Earth. Specifically, this is achieved through a cooling process that will bring temperatures down to lunar levels in the predominantly shaded areas (thus below -200 degrees Celsius).

Another activity in the first work package foresees the development of the Campo Imperatore telescope, specifically through the creation of an infrared optical system, that is, one capable of intercepting waves of a lower frequency than those visible to the human eye. As a matter of fact, infrared sensitivity is potentially a very innovative feature in astronomy because it allows telescopes to better observe the cosmos, detecting objects that are hidden from normal optical sensors. The Campo Imperatore Telescope is an astronomical observation center founded in the 1960s, at an altitude of more than two thousand meters, atop the Gran Sasso d'Italia, which is the highest peak in the Apennines.

Finally, a key activity in Astra's hardware work will be the development of multifunctional structures for space applications. Two in particular: commercially available Cubesat satellite platforms, or small, lightweight, cube-shaped satellites, and platforms for small loads under 20 kilograms (so-called payload technologies). With a focus not only on design and manufacturing, but also on mechanical structure. An example of a multifunctional structure is the Penetrating Particle Analyser (Pan), an instrument consisting of a magnetic spectrometer and capable of intercepting particles in space.

In short, a series of infrastructures to be developed within an ambitious project, involving people from both the industry and research institutions, with different backgrounds and skills. Moreover, this will occur in an international and intercultural context, open to mutual contamination, which is a fundamental stimulus for research and technological innovation.

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 mln di 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 ONGOING	12/2025
WP1.B	Cryogenic systems for the LGWA pathfinder ONGOING	12/2025
WP1.C	Infrared Adaptive-Optics facility at the AZT-24 telescope of Campo Imperatore ONGOING	12/2024
WP1.D	Multifunctional structures for space applications ONGOING	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	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 4,1 mln di 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	ONGOING
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	ONGOING
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	TO BE LAUNCHED
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	TO BE LAUNCHED

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	IN CORSO

Entities participating in the activities

GRAN SASSO SCIENCE INSTITUTE
SCHOOL OF ADVANCED STUDIES
Scuola Universitaria Superiore

Financial resources 4,1 mln di 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	TO BE LAUNCHED

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

Il work package mira a sfruttare le straordinarie capacità osservative dell'Osservatorio di Campo Imperatore (AQ) acquisendo un nuovo impianto di ottica adattiva infrarossa da montare sul telescopio AZT-24 e capace di affrontare le sfide astrofisiche previste nei prossimi decenni nei campi dell'Astronomia Multi-messaggero, Supernove e Cosmologia, Evoluzione Stellare e Sistemi Planetari Abitabili.

DEADLINE	STATUS
December 2024	ONGOING

Entities participating in the activities

INAF
ISTITUTO NAZIONALE DI ASTROFISICA

Financial resources 0,6 mln di 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	NEARING COMPLETION
Adaptive optics acquisition	Through different tenders and inhouse activities the adaptive optics system will be acquired.	INAF	June 2024	NEARING COMPLETION
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	ONGOING

Entities participating in the activities

Financial resources 0,3 mln di 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	ONGOING
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	ONGOING

Outputs

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

Software for space digitalisation

In parallel with the work on hardware, which we explored in detail in the previous pages, **Astra is also involved in the creation of software that is particularly innovative and relevant to the space sector.** This is what the second work package is dedicated to.

Again, **an asset of the project is the involvement of personnel with cross-cutting characteristics, from both the research and industry sectors, international and with diverse skills.** The idea behind this entire part of the spoke is that the space sector, like other fields, needs to be digitized in a widespread manner. The work package is structured into three activities, focusing on as many key aspects of digital software innovation.

The first activity deals with the construction of an infrastructure that will make the entire life cycle of certain devices used in the space industry digital and virtual. It focuses in particular on the technology of the so-called digital twins, of which two different versions will be implemented during the course of this project. **Digital twins** are virtual replicas of physical resources (which can be systems, devices, processes as well as people, depending on the specific case). A number of useful interventions can be made through them. For example, the digital twin is able to make predictions about possible future malfunctions of the physical component and thus do predictive maintenance, that is, maintenance based on this anticipation.

Other functions that digital twins can perform are virtual risk assessments and even team training. **This way they could replace some structures that are currently very expensive but necessary for the supply,** maintenance and skills acquisition. Another interesting potentiality of this technology is to "decouple" software elements from hardware elements. This distinctive operation has advantages because, by being able to treat the two elements separately, possible integration problems can be anticipated at an early stage.

The second activity is structured around an absolutely crucial issue regarding intelligent and autonomous systems. That is reliability, which also includes software resilience and security. These cross-cuttingly important elements are critical in spacecraft because of their particularly stringent certification requirements. In particular, the action includes the introduction of machine learning and artificial intelligence systems, as well as various additional on-board services, also made possible by the computational power of the Gran Sasso Science Institute's space processors. In order to increase software reliability, various possible methods and approaches will be tested. The ultimate goal is to integrate the inherently essential aspect of machine autonomy and intelligence: it is necessary, in fact, that at the same time ground control is guaranteed. The machine, in other words, cannot be intelligent and autonomous but at the same time not be reliable, safe and controllable from a human perspective. The validation will be carried out with the Crystal Eye, the space sensor we have already talked about while recounting the activities planned in the first work package.

Finally, **the last of the three activities is geared toward innovating the relationship between platform and payload, in terms of software.** Payload refers to the load capacity of the spacecraft, that is, the mass it can carry, be it cargo, passengers, or equipment. Thus, the central goal is to combine these two aspects and work on a single software platform that encompasses both simultaneously.

Thus, the resulting platform will have a hybrid character and will also be capable of operating in orbit. Many different methodologies and technologies will be employed to carry out these operations, particularly those related to the aforementioned artificial intelligence.

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	74	3	ONGOING

UPCOMING EXPECTED DEADLINE

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

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 3,1 mln di 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	ONGOING	12/2025
WP2.B	Trustworthiness of smart and autonomous system	ONGOING	12/2025
WP2.C	Onboard SW platform for New Space Applications	ONGOING	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	ONGOING

Entities participating in the activities

Financial resources 1,9 mln di 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	ONGOING
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	ONGOING
Digital Twin end of Validation	The digital twin is validated with the real case of study.	GSSI, TAS-I	December 2025	TO BE LAUNCHED

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	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 0,7 mln di 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	NEARING COMPLETION

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	ONGOING
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	ONGOING

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	ONGOING

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 mln di 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	COMPLETED
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	TO BE LAUNCHED
Final testing and qualification	Final acceptance review	GSSI, TAS-I	December 2025	TO BE LAUNCHED

Astra's research results and their impact on the economic fabric

In the previous articles **we began to dissect two fundamental axes of which Astra is composed:** the development in terms of infrastructure and hardware on the one hand and in terms of digitization and software for space on the other. The third work package is no less important because it is dedicated to a crucial issue: the impact of the project on research, economic actors and the communities in general.

In this sense, **there is a twofold stated objective: first, to protect and valorize the results of the research carried out during the project and second, to assess its economic, social and environmental sustainability.** The creation of a Center for Ethical Technology Transfer and Impact Management is in fact a key step in this work phase.

The first action of this project revolves around two fundamental concepts: that of intellectual property and that of valorization. They are two sides of the same coin. In fact, recognizing the importance of the work done means, on the one hand, protecting the heritage of ideas and the original and innovative outcome of research, and on the other hand, it also means extrapolating the elements of interest derived from it, to then put this work at the service of the community.

At the output level, these two directions will result in patents, registrations, licenses, exploitation agreements and collaboration with various organizations, entities and institutes.

The natural consequence of valorization is **knowledge transfer: the second action of this third work package of Astra is dedicated to this aspect.** This transfer will take place through collaboration deals with various research institutions but also with industries (with a special focus on small and medium-sized enterprises) that will be able to make the most of the knowledge acquired by Astra's researchers. Numerous relationships, collaborations on research projects and training processes will be formalized in this context.

In addition, **spin-offs will be established by Astra's affiliates,** namely the University of Perugia, the National Institute of Astrophysics (Inaf), the Bruno Kessler Foundation and Thales Alenia Space SpA, to accelerate and make knowledge transfer more direct. It is no coincidence that qualified personnel will be hired specifically for this purpose.

Finally, **an action of this spoke is dedicated to evaluating and monitoring the social, economic and environmental impact of the technologies developed during the project.** This will be done through publications, seminars and evaluation reports on the topic, as well as through the generation of appropriate ethical use licenses. The evaluation is done both by reconstructing ex ante the impact of individual projects and by reporting ex post.

The latter strand of Astra thus also represents a public recounting by the key players in the spoke-primarily the Gssi, which is responsible for it, and, in general, of the restitution to the community of the results achieved through Pnrr funding to the Vitality ecosystem.

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	ONGOING

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 mln di 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		Scadenza prevista
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 mln di 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

Financial resources 0,1 mln di 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	TO BE LAUNCHED
SMEs graduation	Completion of acceleration programs.	GSSI, FBK	December 2025	TO BE LAUNCHED

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 mln di 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

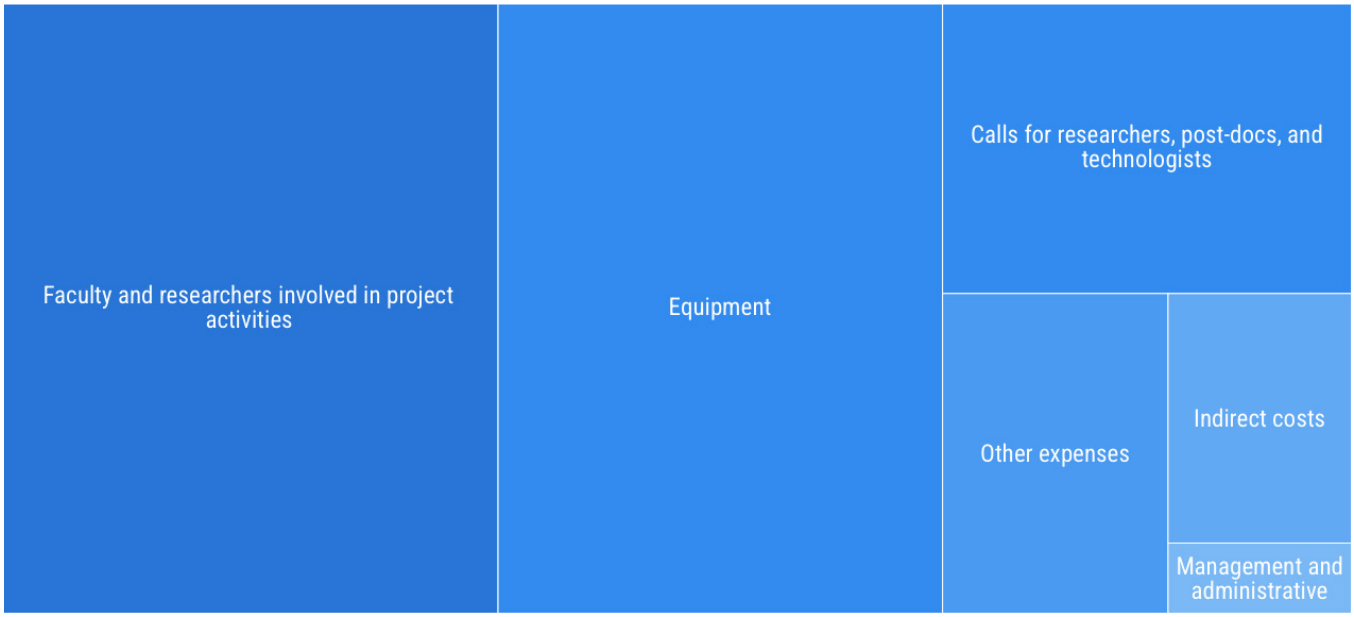
Here you can find all the information about the project's financing and track the progressive transfer of funds and the allocation of resources based on their use and entity within the Astra partnership.

10,4 Million euro » **3,8** Million euro

Project's total cost | Transferred to the project so far

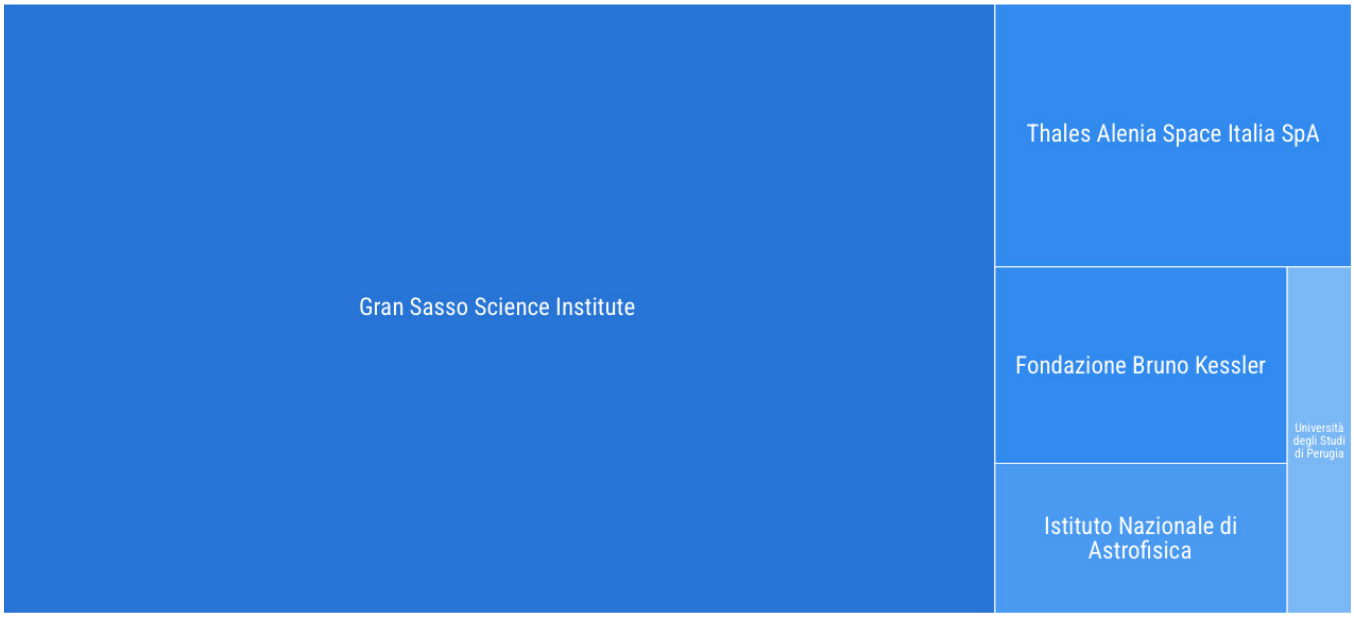
Resources divided by item

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

Role of People in a Highly Technological Project

More than 70 people from 5 organizations working in three different territories of the country.

In summary, this is the synergy of human resources and interdisciplinary skills that drive Astra. Here, you can find a substantial group of people who make a difference, beyond the technological peculiarities of the project.

While the development of innovative space technologies inevitably requires sophisticated infrastructures to implement them, the role of people and their skills is crucial. For this reason, **some of Astra's milestones concern the recruitment of qualified staff who can contribute to achieving intermediate and final goals.**

We are talking about 7 milestones within as many tasks, covering all three work packages of the project. These goals have been completed to date, with the hiring of high-profile personnel from Italy and abroad, essential for the initiation and development of the project.

Fifteen people have been hired specifically for Astra, including **8 post-doc holders, 4 researchers, and 3 technologists.** All these professionals have been hired by GSSI, adding to the institute's own staff, as well as other partners, employing between 10 and 15 professionals in Astra. Approximately, this team is composed by 70 people in total who dedicate all or part of their skills and responsibilities to the project.

"Although it may seem almost trivial to say, it is essential to emphasize the importance of the team - says **Roberto Aloisio,** scientific director of Astra, as well as professor and director of the Astroparticle Physics Area of GSSI - human contribution to research activities, including applied research, represents the true added value".

For this reason, **the personnel dedicated to Astra are crucial:** "Creating specific research teams with precise focus allows to hire ad hoc figures - adds the GSSI professor - this creates a peculiar professional expertise, which then becomes fundamental for achieving the project's goals".

This also applies to groups working remotely, as in this case. In L'Aquila are based those contracted by **GSSI** and the private partner **Thales Alenia.** Beyond Gran Sasso d'Italia, also located in Abruzzo, there is the **Abruzzo Astronomical Observatory,** which is part of the National Institute of Astrophysics (INAF).Then there are the human resources activated for Astra in Umbria (linked with the **University of Perugia**) and in the province of Trento, at the **Bruno Kessler Foundation.** This is a networked system, an aspect that is in line with the spirit of all the spokes of the Vitality ecosystem.

All the 15 professionals hired to contribute to Astra were selected through public competitions based on titles and interviews: "We received applications from various parts of the world," says Roberto Aloisio "As an example, Professor Herman Lima Pessoa, moved from Brazil to Abruzzo with his family. The skills that our staff has are very rare; he, for instance, is making an excellent contribution to the design and optimization of electronic subsystems". These are also professional paths that involve significant life choices, like those of Professor Pessoa We will discuss these aspects in future insights.

The internationalization of research represents a potential asset for everyone because having the opportunity to attract human resources from abroad increases the quality of the people working on the project.

But it is not always possible to find the right figures: "The **Italian National Plan of Recovery and Resilience (PNRR)** has produced an enormous availability of highly specialized positions - highlights the scientific director of Astra - just think of Vitality, which has 10 spokes coordinated by 9 different universities. This is obviously an opportunity but it can become a problem: because sometimes calls for applications receive little response. Fortunately, even aside from Astra, GSSI has an international projection, so we are experiencing these issues less than others".

In highly technological projects, another risk is represented by a potential lack of attention to human aspects. Aloisio seems to avert this: "**I have found many enthusiastic people.** This is a quality I consider essential because to do this work you need enthusiasm and a love for knowledge".

Astra is not only a cold technology and design project for space. It is made up by dozens of men and women who work closely together every day in a network that **generates results and innovation and contributes to the technological and cultural development of the country.**

ACCOUNT OF ACTIVITIES

Herman Lima, from Brazil to Abruzzo to Develop Astra's Research

Let's continue our journey into the human resources of the project by re-reading the words of **Roberto Aloisio,** Astra's scientific director: "Human contribution to research activities, both theoretical and applied, represents the true added value".

These words, although simple, hide many nuances:stories of people and organizations, large international collaborations and daily life, as well as technical skills, **relationships within a multidisciplinary team and the ability to balance technological and human value.**

Among the people called to fill numerous roles in Astra, we have talked to Herman Lima. Originally from Brazil with an education in electronics, Professor Lima worked in his country until last year. He was holding a permanent position at the Brazilian Center for Research in Physics (CBPF), where he coordinated a laboratory dedicated to the design and construction of position detectors. He also took part in neutrino detection experiments.

In December 2023, **Lima won a scholarship as a Visiting Scientist with the NUSES space mission group at the Gran Sasso Science Institute.** Later, in April of this year, he began a stable collaboration with Astra through a temporary research contract. The researcher, who hails from Rio de Janeiro, said: "My activities are linked to the development of customized electronic reading systems and data acquisition applied to space missions, particularly the NUSES mission. But I also have academic duties, such as supervising PhD students and faculty members in the GSSI PhD program".

Like many other foreign researchers working on the project, Lima embodies one of Astra's main goals: **fostering interaction between scholars and scientists from different parts of the world with institutions and industrial partners in central Italy.**

"I believe that Vitality and its Astra spoke represent an important opportunity to support space science projects based in Italy - says the Brazilian scientist - Space science is an expensive field of research, and it is impossible to progress efficiently without solid and stable financial support".

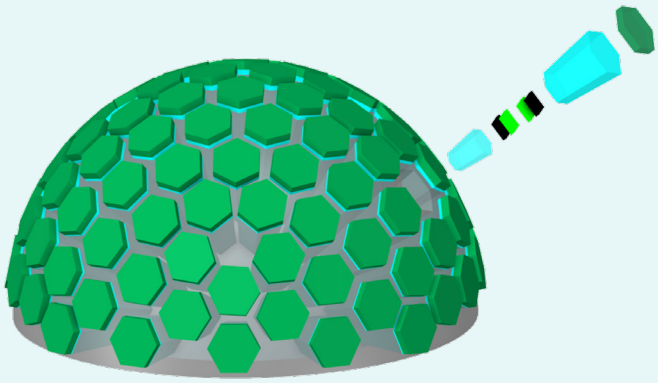
Strong internationalization allows local systems and methodologies to permeate each other through continuous exchange. But what are the main differences between Brazil and European countries in this research field? "Although there is a solid and highly qualified body of researchers in Brazil, as here in Italy, I think the main difference is the amount of financial support provided by Brazilian government agencies. It is not enough. Due to scientific policies that often change along with governments, there is a lack of long-term continuity", Lima highlights.

His situation is emblematic of Astra's team story, even for extra-scientific reasons. **This is one of those cases where a researcher moves with is family to Italy in the city of L'Aquila.** Here is where the GSSi headquarters are located. This change didn't happen without any difficulty: "Moving to Italy with the family, including two children, is not an easy task," he admits. "There is an excess of bureaucracy. It took more than six months to stabilize our situation, and we are still waiting for a few documents, which should arrive shortly".

Aside from the cumbersome bureaucracy, Lima seems to be doing well in the mountains of central Italy: "**But the Italians, mainly in L'Aquila where we live, as well as the GSSI staff, have been very kind to us.** This has certainly been a pleasant experience. Not to mention the excellent food and rich culture that we find in this country. So far, the balance is quite positive".

Improving both professional and human systems related to an international research project is crucial to its success. As we have pointed out many times, human resources are the most important asset even for high-tech projects.

Allowing such advanced profiles to leave their home country, even temporarily, and come to Italy to enrich space research is, in some way, an already accomplished goal for the "ecosystem" that Astra is part of.



ACCOUNT OF ACTIVITIES

New Horizons for Observing the Universe with the Crystal Eye

Crystal Eye is an innovative space detector for X and gamma rays that could significantly impact the study of the cosmos and the design of future space missions.

In simplified terms, this is a cutting-edge instrument that is central to an important activity within Astra's Work Package 1 - developing new space hardware technologies. **Crystal Eye is a highly sophisticated hemispherical device** designed to detect intense gamma-ray bursts It aims to uncover the mechanisms that generate them. Roughly the size of a basketball, it is made of crystals that emit small flashes of light when gamma radiation is detected.

The project began in 2018 at the University of Naples Federico II, where **Felicia Barbato,** received the initial pilot funding to develop the idea. Now she is a Type B researcher at the Gran Sasso Science Institute.

During that period, such projects gained new relevance due to the surfacing of what is now known as **multimessenger astronomy.** Projects such as gravitational wave experiments represented a massive breakthrough in astrophysics. "Crystal Eye may play a crucial role in the multimessenger approach - says Barbato - we will attempt to observe the same point in the sky from different perspectives, gathering information from as many messengers as possible. In doing so, we aim to reconstruct phenomena such as the origin of gamma rays as if solving a puzzle".

The challenge arises when detecting specific energy ranges of gamma rays, as few operational satellites are currently capable of this. This is where the idea of the Crystal Eye comes in. As explained by Barbato: "On the one hand, there are ground-based and space-based telescopes that offer high-resolution observations but within very narrow fields of view. In contrast, the Crystal Eye provides low-resolution images but has a hemispherical field that covers a much wider range. This allows it to signal gamma-ray sources to instruments with higher resolution but more limited observation fields".

The Astra team is currently working on a prototype of Crystal Eye with a few pixels. They aim to launch it into space aboard the European Space Agency's (ESA) Space Rider in 2026. If the launch and the reentry are successful, the experiment's data will be recovered, and potential damage to the instrument—whether from radiation or the stresses of launch and reentry—will be assessed.

Developing the prototype helps technological research: it allows space testing of technologies that work on Earth but must be adapted to the unique conditions of the space. "For instance" Barbato shares "while previous detectors were larger and more fragile, the Crystal Eye will feature Silicon Photomultipliers (**SiPMs**), similar to the parking sensors on cars, which have never been tested in space."

This represents a significant opportunity for future investments in space technology, as the current weakness of detectors lies in their susceptibility to radiation damage. The research aims to discover how to protect these devices once in orbit. Reducing sensor size while improving flight durability leads to lower energy consumption and more efficient experiments. In other words, if the Astra experiment succeeds, it could represent a major technological progress.

The energy range that Astra's Crystal Eye aims to explore is particularly intriguing, as it remains relatively unknown from an experimental data perspective. **This part of the project has received €4.1 million in funding,** which will also support the setup of laboratories.

The data collected by the Crystal Eye, combined with information from other gamma-ray detection instruments, will allow researchers to study the sources of these powerful electromagnetic radiations. This will enrich scientific knowledge and fulfill humanity's "**curiosity abouthow the universe works,**" says the GSSI researcher.

In short, Crystal Eye will be another eye, **gazing into the depths of the universe.**

ACCOUNT OF ACTIVITIES

Digital Platforms for the "Factory of the Future" in the Space Industry

One of the three main pillars of Astra is its second work package, dedicated to **digital platforms serving the aerospace industry.** While the first work package primarily emphasizes hardware technology development, the second pillar of Astra centers on the software industry.

The ultimate goal is to create digital platforms that drive innovation in research and optimize supply chains already active in the space sector, such as Thales Alenia, one of Astra's two private partners.

Digitalizing production is key to what has been called the "Factory of the Future" within the framework of the **Fourth Industrial Revolution,** commonly known as Industry 4.0. At its core, this paradigm focuses on industrial automation. The virtual and digital replication of industrial processes—from early engineering stages to full-scale production—has the potential to revolutionize cost efficiency, productivity, and effectiveness. One of the first sectors where these methods have been implemented is the automotive sector.

A key focus of Astra's researchers is the implementation of digital twins, a concept gaining traction across industries. A **digital twin** is not merely a digital model but a virtual representation of an object or system that evolves alongside the physical entity throughout its lifecycle. **It is updated in real time through simulation and learning mechanisms,** often augmented by artificial intelligence, which will be explored in the next articles.

Production equipment is integrated into a centralized system for data storage and management. **Real-time data processing enables the monitoring of production processes in alignment with the digital twin framework.** This virtualization and modeling of processes enable optimal production planning. Such advancements are being applied to a case study involving the Crystal Eye, a flagship product in Astra's roadmap, that we've explored in previous articles.

Challenges of Implementing Digital Twins for Space Applications

Developing reliable digital simulation systems for space applications is a formidable challenge. Space technologies demand extraordinary reliability, as they must operate in physical conditions vastly different from those on Earth. This discrepancy necessitates robust simulation systems capable of handling these unique environmental constraints.

Astra is committed to meeting these stringent quality standards. "We are working on scheduling tasks for a satellite developed by Thales Alenia," explains **Patrizio Pelliccione,** Full Professor at the Gran Sasso Science Institute (GSSI), where he leads the Computer Science area and oversees Astra's second work package.

"What we are attempting to do with our project partners," Pelliccione continues, "is to define a mechanism for optimizing the operation and exploitation of a satellite already in orbit. We are achieving this through the digital twin paradigm."

This approach encompasses multiple dimensions, ranging from the satellite's physical operations — such as rotation, observation and avionics — to its role in scientific research and service delivery.

Simulation and Prototyping Through Digital Twins

Practically, this involves creating a software representation in a highly sophisticated simulator. **Astra's research team uses this simulator to validate the organization of tasks and temporal functionality of the satellite.** "Through digital twins, we can assess computational usage, determine if adjustments are needed, and even add or remove functionalities," emphasizes the GSSI professor.

This process fosters the generation of knowledge, the creation of customized research prototypes, and the simulation of potential problem-solving scenarios for in-orbit challenges. It represents pure research experimentation conducted on Earth, always with an eye toward the skies.

ACCOUNT OF ACTIVITIES

Working on trust and reliability of autonomous and intelligent systems

The second work package of the Astra project **has a budget of € 3.1 million.** This funding will support the creation of a state-of-the-art digital environment, not only for terrestrial technologies but also for the aerospace sector, as highlighted in previous articles.

A key aspect underpins this effort: reliability. This is the focus of the second task in WP2, aptly named "Trustworthiness of Smart and Autonomous Systems".

The introduction of machine learning and artificial intelligence (AI) technologies entails stringent reliability requirements. This is especially critical in the context of space applications, where the operating environment is inherently distinct from the familiar conditions on Earth.

Researchers at Astra are experimenting with integrating AI techniques into onboard software for of the **Crystal Eye** satellite. To this end, they are developing innovative methods to ensure that these intelligent and autonomous systems meet safety requirements and quality standards.

Addressing the reliability of AI systems is no trivial matter. "The work package I am responsible for is structured into several tasks, covering the digitalization of the production process," explains **Patrizio Pelliccione,** Director of the Computer Science area at the Gran Sasso Science Institute. "This ranges from the development of onboard software platforms to the satellite's digital architecture".

Building trust and reliability in autonomous space systems also involves refining the satellite's architecture. The research team is exploring how to implement "software watertight compartments" within the satellite, ensuring each component operates independently while contributing to the satellite's overall functionality. This approach aims to minimize potential issues and associated costs.

"Sometimes, the focus on AI is exaggerated", admits Professor Pelliccione. Currently, while AI can be applied to so-called "critical systems," **the ultimate decision-making responsibility for critical events** still resides with human engineers.

Critical systems have **varying degrees of criticality depending on their controllability,** which may be low (potentially leading to problematic or catastrophic impacts, as in the aerospace domain) or high, where controllability mitigates potential negative consequences. The reliability level, therefore, spans this spectrum.

"We are steadily moving towards a new era of AI, where it's more controllable than in the past," highlights Pelliccione. "High-quality software technology must not only be efficient and maintainable but must also adhere to **explainability** criteria".

Explainable AI (XAI) is a concept that has recently gained prominence in the field of machine learning. Its goal is to shed light on what occurs inside the "black box" of data and algorithms used to train AI models.

This topic extends beyond mere technological considerations, touching upon philosophical and ethical dimensions of AI. "Recently, I contributed to an article on how to engineer systems to truly serve humanity. While this goes beyond Astra's specific scope, it is crucial for our contributions—enabling satellite systems to articulate the rationale behind decisions made by AI", states Pelliccione.

Similarly, the recently enacted European AI Act emphasizes **transparency, accountability, and explainability in automated actions.** "When you deeply understand the reasoning behind an action, you begin to build trust between humans and machines," concludes the professor.

Peer-reviewed journal papers - 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. 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 , Article number 012024. (Conf. Ser.)

3. 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. (Conf. Ser.)

Peer-reviewed journal papers - Digital platforms for space industry

Milestone 24 - Digital platforms for space industry

A. Peer-reviewed journal papers

1. 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.* (Journal Paper)

2. Roger Nazir, Alessio Bucaioni, Patrizio Pelliccione (2023) *Architecting ML-enabled systems: challenges, best practices, and design decisions Journal of Systems & Software (JSS).* (Journal Paper)

3. 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). (Journal Paper)

4. Samira Silva, Patrizio Pelliccione, Antonia Bertolino (2023) *Self-Adaptive Testing in the Field, ACM Transactions on Autonomous and Adaptive Systems.* (Journal Paper)

5. Franco Barbanera, Ivan Lanese, Emilio Tuosto: *Composition of synchronous communicating systems. J. Log. Algebraic Methods Program.* 135: 100890 (2023). (Journal Paper)

6. Franco Barbanera, Ivan Lanese, Emilio Tuosto: *A Theory of Formal Choreographic Languages. Log. Methods Comput. Sci.* 19(3) (2023). (Conf. Paper)

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

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

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

10. 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.* (Conf. Paper)

11. 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.* (Journal Paper)

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

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16. 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)

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22. 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 (Conf. Ser.)

23. 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)

Atti dei convegni

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. 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)**

3. 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)**

4. 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)**

5. 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)**

6. 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)**

7. 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)**

8. 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 and Planetary Science Conference, held 11-15 March, 2024 at The Woodlands, Texas/Virtual. LPI Contribution No. 3040, id.2202 (2024). **(INTERNATIONAL)**

9. 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)**

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