Horizon Europe Programme

Application Form EIC PATHFINDER OPEN

Project proposal – Technical description (Part B)

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SOLARIA
AI-DRIVEN SPACE DEBRIS MITIGATION

Proposal template Part B: technical description

TITLE OF THE PROPOSAL

A REVOLUTIONARY SYSTEM FOR DETECTION AND DISPOSAL OF SPACE DEBRIS IN LOW EARTH ORBITS USING LASER RADIATION CONTROLLED BY ARTIFICIAL NEURAL NETWORKS

SOLARIA: TEACHING SPACE SYSTEMS TO PROTECT THEMSELVES

#@APP-FORM-HEEICPAOP@#

Participant No. *	**Participant organisation name**	**Short Name**	**Country**
1 (Coordinator)	Durante Space Tech	D4S	Spain
2	Politecnico di Milano	POLIMI	Italy
3	International Institute of Applied Research and Technology	I2ART	Germany
4	University of Strathclyde	STRATH	UK
5	IRIS s.r.l.	IRIS	Italy

1. Excellence #@REL-EVA-RE@#

1.1 Long-term vision #@PRJ-OBJ-PO@#

‘***The light bulb was not invented by continuously improving the candle’Oren Harari***

The SOLARIA project envisions a future where sustainable, autonomous and intelligent management of space debris becomes an integral part of orbital infrastructure operations.

Through the development of the science and underpinned AI-driven, laser-based systems that are to be deployed on agile CubeSat platforms, SOLARIA aims to revolutionize space debris mitigation — shifting from the passive avoidance to proactive, in-situ orbital environment controls. The long-term ambition is to establish a new operational paradigm in which **distributed, self-adaptive systems autonomously detect, characterize, and eliminate orbital debris.** These systems will operate collaboratively to ensure the resilience of critical orbital layers, safeguarding satellite-based services that are essential for global communications, Earth observation, societal resilience, and climate monitoring.

By initiating a fundamental rethinking of space infrastructure, SOLARIA contributes to the creation of a **sustainable orbital commons,** reinforcing Europe’s strategic autonomy in space security and laying the groundwork for next-generation **Space Situational Awareness (SSA) and Space Traffic Management (STM)** frameworks. The project’s vision extends beyond technological demonstration. **SOLARIA serves as a scientific and technological pathfinder**, catalyzing new markets for intelligent orbital services, advancing the theoretical and applied basis for autonomous debris interaction, and supporting international efforts toward long-term orbital sustainability.

SOLARIA builds upon conceptual foundations explored in a previous Pathfinder submission (LASBOOM, 2024), which received a positive evaluation but was not selected for funding. The current project reflects a significant scientific and structural evolution: deeper modelling of laser-material interaction, improved AI control logic, expanded treatment of orbital dynamics, and refined risk mitigation protocols. The consortium, methodology, and work packages have been redesigned to address the critical feedback received, particularly in relation to scientific depth and technical feasibility. SOLARIA now integrates a complete low-TRL approach (2–4) aligned with Pathfinder’s ambition for systemic, high-gain breakthroughs.

By operating at the intersection of **early-stage scientific exploration (TRL 2–3)** and system-level architectural innovation, **SOLARIA positions Europe as a frontrunner in the governance of the near-Earth space environment**.

1.2 Science-towards-technology breakthroughs

The SOLARIA project introduces a radical shift on how orbital debris is addressed — not as a hazard to avoid, but as a system-level problem to be **autonomously monitored, engaged, and resolved**. Rather than relying on passive observation or costly heavy infrastructure, SOLARIA proposes a distributed architecture of **agile CubeSats** equipped with **AI-controlled**, **low-power laser systems**, capable of **detecting, tracking, and altering the trajectories of debris objects directly in orbit**.

The uncontrolled proliferation of space debris — a phenomenon known as the **Kessler Syndrome** — underscores the urgent need for in-situ, intelligent mitigation strategies. NASA estimates over 100 million particles smaller than 1 cm and more than 21,000 objects around 10 cm currently orbit Earth. A single 1 cm fragment at orbital velocity (~7 km/s) is enough to disable a satellite, threatening the continuity of services essential to communication, security, and Earth monitoring.

Despite ongoing international initiatives, **ground-based optical tracking systems remain limited in resolution, scalability, and responsiveness** — particularly for debris in the **critical 1–10 cm range**. These objects are virtually undetectable from Earth, yet account for the majority of collision risks. ***This technological blind spot represents a scientific challenge that SOLARIA directly targets.***

Scientific foundations and breakthrough logic

SOLARIA addresses this gap with a multi-layered strategy that combines **early-stage scientific exploration (TRL 2–3) with a novel system-level architecture**. Each breakthrough will be made by meeting some specific, significant scientific and/or technological challenges:

- **Multi-pass laser ablation** across two orbital shells (600 km and 2000 km) requires new models of cumulative impulse delivery over time, constrained by laser power, orbital dynamics, and material-specific response to photonic energy.
- **AI-controlled targeting** needs adaptive algorithms capable of learning debris patterns under extreme variability — fusing trajectory prediction with optical and thermal feedback under ModelOps/AIOps frameworks.The AI system is trained using synthetic orbital environments generated through debris-field simulators and laser-debris interaction datasets. The training pipeline combines supervised learning for trajectory recognition with reinforcement learning for mission-level adaptation under uncertainty. Retraining occurs continuously through cloud-edge orchestration, allowing adaptation to new debris classes and orbital anomalies.
- **Low-energy tunable lasers** must balance energy efficiency with precision impulse control. This requires innovation in laser modulation, energy storage, and debris surface modeling under varying incident angles.
- **Adaptive CubeSat logic** needs to address novel questions of decentralized decision-making, swarm autonomy, and in-orbit fault resilience — a field still in its infancy in dynamic orbital conditions.
- **Dual-mode sensing/engagement** logic pushes the boundary of switching latency, onboard perception-action cycles, and mission prioritization in non-deterministic orbital environments.

Scientific modelling of photonic energy transfer under low-divergence laser emission is currently being developed using coupled thermal–mechanical simulations to predict orbital Δv impact per pulse. This supports the adaptive tuning of pulse parameters based on debris spin rate, angle of incidence, and surface material feedback.

At the core of SOLARIA's intelligence lies a distributed network of **cooperative AI agents**, embedded within each CubeSat as self-learning mission assistants.

These agents operate at the edge, performing real-time orbit analysis, target prioritization, laser control, and in-situ decision making.

They interact asynchronously with the cloud-based mission platform, allowing for:

- local autonomy
- system-wide knowledge propagation
- adaptive mission planning
- and intelligent fallback in case of network fragmentation.

These AI agents are not hard-coded — they evolve mission by mission, leveraging edge learning and cloud retraining via ModelOps pipelines. This creates a **swarm of intelligent units** capable of collaborating, adapting, and optimizing debris mitigation strategies in a dynamic orbital environment.

Breakthrough	SOLARIA Scientific Advance	Breakthrough Nature	Addresses The Barriers
Multi-pass laser ablation (600–2000km)	Time-resolved impulse modeling integrating photonics, thermodynamics, and orbital mechanics under low-energy conditions	Enables precise debris trajectory modification via micro-ablation across multiple passes	Solves lack of safe, scalable engagement method for 1–10 cm debris; avoids fragmentation risk
AI-controlled targeting	Onboard AI fusing trajectory prediction, thermal/visual feedback, and control logic within a ModelOps/AIOps architecture	First in-orbit adaptive targeting AI that learns and updates without ground-based intervention	Overcomes latency and scalability limits of ground-controlled systems
Tunable low-energy laser sources	Pulse modulation and energy coupling techniques for controlled momentum transfer with minimal thermal stress	Enables safe impulse delivery with CubeSat-level energy budgets	Removes need for bulky, high-power laser systems; compatible with small platforms
Adaptive CubeSat architecture	Distributed autonomy and resilience modeling for fault-tolerant, self-reconfigurable satellite constellations	Introduces collective behavior and mission awareness to microsatellite swarms	Eliminates dependency on central control; supports scalable constellation deployment
Dual-mode sensing/ engagement	Real-time switching logic between sensing and targeting functions with onboard prioritization	Fuses perception and action in a single, self-aware system	Eliminates response lag between detection and mitigation; increases operational fluidity

Each of these elements opens a scientific pathway towards an engineering solution — supporting Pathfinder-level ambition while maintaining coherence with experimental validation. These scientific advances are complemented by clear operational advantages, which will confirm high potential of the systematic approach:

- **Immunity to atmospheric distortion**, enabling precision targeting that is unachievable from ground-based platforms;
- **Modular, energy-efficient laser payloads**, minimizing launch mass and thermal load;
- **Autonomous CubeSat constellations**, enabling scalable and cost-effective deployment across orbital

layers;

- **Inherent upgradeability,** with architecture designed to accommodate future improvements in AI logic, laser control algorithms, and target classification systems.

By embedding resilience, adaptivity, and onboard learning into the core of its architecture, ***SOLARIA defines a new class of orbital infrastructure: mission-aware, self-correcting, and collectively intelligent.***

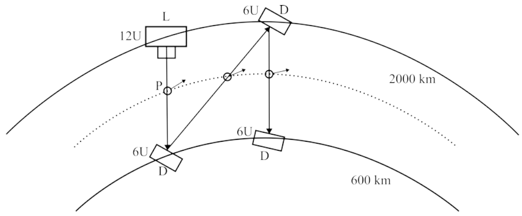


Fig1: SOLARIA Dual-Orbit CubeSat

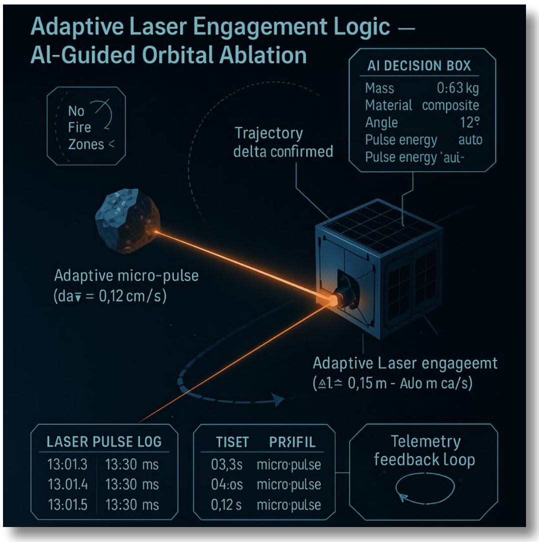
This paradigm shift does not merely enhance debris mitigation — it lays the scientific and architectural foundation for next-generation Space Situational Awareness (SSA) and Space Traffic Management (STM) capabilities. These systems will no longer rely solely on centralized, ground-driven command chains, but evolve toward distributed intelligence at the edge of space.

SOLARIA also embraces the inherent risks of semi-autonomous systems in dynamic orbital environments. Rather than eliminating uncertainty, the system is designed to learn from it — embedding adaptive control loops, probabilistic reasoning, and fail-safe decision-making directly within the in-orbit AI Box infrastructure.

Compared to traditional debris mitigation strategies, SOLARIA initiates a **fundamental rethinking of orbital operations**:

- Higher targeting accuracy, independent of weather or atmospheric distortion
- Persistent coverage via dual-orbit architecture
- Scalable and lightweight deployment using miniaturized platforms
- Full autonomy, eliminating dependency on ground-based telemetry or intervention

Laser operation is not hard-coded. Each CubeSat executes an adaptive energy deployment strategy based on real-time feedback: AI agents analyze debris velocity, mass, and material response, adjusting pulse energy and angle accordingly. Control loops manage incremental impulse transfer over multiple passes.



The system includes thermal load forecasting, trajectory deviation confirmation logic, and no-fire protocols under uncertainty or degraded telemetry.

This logic represents a mission architecture breakthrough — enabling satellites to act proactively, adapt intelligently, and evolve mission by mission. SOLARIA becomes a foundational enabler for a new era of orbital sustainability, fully aligned with Europe's vision for strategic autonomy and scientific leadership in space.

SOLARIA's innovation lies not in a single component, but in the orchestration of a new mission logic: **CubeSats that observe, decide, act, and learn — autonomously.** The system integrates self-learning AI algorithms for trajectory prediction and engagement optimization, reinforced through in-orbit feedback. These AI agents evolve mission by mission, leveraging both local computation and cloud-based retraining via a hybrid ModelOps/AIOps framework. By embedding resilience, autonomy, and adaptability directly into its architecture, SOLARIA defines a new class of orbital infrastructure: **mission-aware, self-correcting, and collectively intelligent**. This paradigm enables not only debris removal, but a foundation for future Space Situational Awareness (SSA) and Space Traffic Management (STM) services — fully aligned with the EU's vision for secure, sustainable, and strategically autonomous operations in space.

Breakthrough	Key Scientific Challenges to be Met	Starting TRL	Target TRL
Multi-pass laser ablation	Modeling cumulative impulse delivery across multiple shallow ablations in varying orbital layers	2 TRL	4 TRL
AI-controlled targeting	Enabling real-time adaptive learning under dynamic, uncertain orbital environments	2 TRL	4 TRL
Low-energy tunable lasers	Balancing impulse precision with energy efficiency under tight mass/ thermal constraints	2 TRL	4 TRL

Adaptive CubeSat architecture	Designing decentralized onboard autonomy and coordination within satellite constellations	2 TRL	4 TRL
Dual-mode functionality	Managing low-latency switching between sensing and targeting under operational uncertainty	2 TRL	4 TRL

SOLARIA fully embraces the risks inherent in operating semi-autonomous systems in dynamic orbital conditions. Rather than avoiding uncertainties, the system is designed to learn from them — embedding mission-level resilience, real-time adaptation, and intelligent fault handling directly into its architecture.

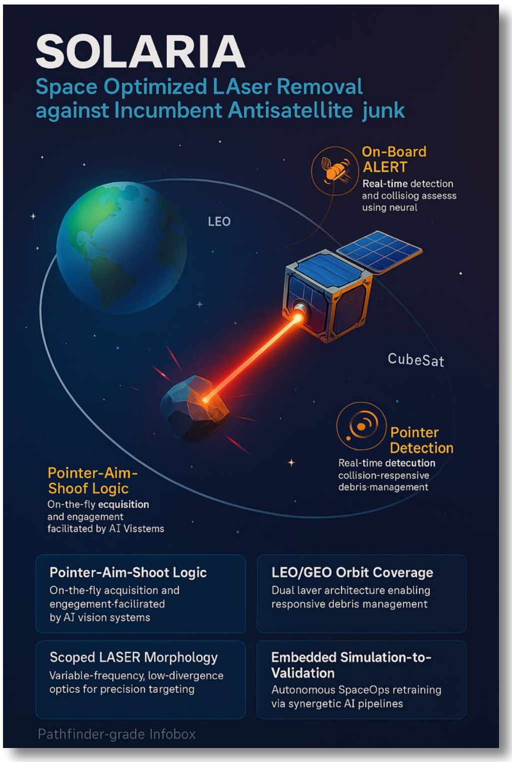
Together, these scientific and architectural breakthroughs position SOLARIA as a unique Pathfinder initiative: grounded in fundamental research, validated through experimental models, and capable of shaping a new operational logic for orbital autonomy.

We are not merely proposing hardware integration — we are building new science on laser–debris dynamics, adaptive autonomy, and in-orbit AI learning under uncertainty. This is the core value of SOLARIA as a Pathfinder initiative.

1.3 Objectives

The overarching objective of the SOLARIA project is to revolutionize space debris mitigation through the development of a fully autonomous, AI-controlled laser system, deployed on agile CubeSats and operating in low Earth orbits (LEO) up to 2000 km.

Rather than relying on passive observation or costly infrastructure, **SOLARIA introduces a new paradigm: distributed, self-adaptive orbital systems that engage, modify, and ultimately prevent debris accumulation through intelligent, in-situ actions**.



The project's scientific and technical objectives

ST1: System methodology and design of an integrated CubeSat platform equipped with tunable laser systems and adaptive optical sensors for real-time debris detection, targeting, and ablation.

ST2: Development of multi-pass detection and engagement strategy operating across two orbital shells (600 km and 2000 km) to maximize coverage, learning, and system resilience.

ST3: Development of self-learning AI algorithms for dynamic adaptation to evolving debris environments — combining trajectory prediction, uncertainty handling, and energy-aware decision-making.

ST4: Development of a modular and scalable system architecture, enabling decentralized operation, swarm coordination, and future upgrades of hardware and AI modules.

ST5: Lab prototype development and system performance validation, including thermo-vacuum simulations, thermal/mechanical stress analysis, and microgravity experiments.

ST6: Method, theory and prototype of a cloud-based decision-support platform (SaaS) for mission planning, AI model retraining, and real-time system management.

The developments will **ensure compliance with EU safety frameworks (WP5)**, particularly SSA and STM regulations, paving the way for responsible orbital deployment. The effort will also be made to establish a solid foundation for the future new market and services in AI-driven orbital operations, including smart debris removal, traffic management, and autonomous satellite support (**WP5**).

These objectives collectively support the project's dual ambition:

- Advance the scientific frontier of laser-aided orbital debris control through low-TRL experimentation
- Catalyze a shift in operational logic — from reactive risk mitigation to proactive, intelligent orbital stewardship.

In doing so, SOLARIA initiates a new class of mission architecture: self-governing, resilient, and mission-adaptive constellations, capable of protecting the orbital environment while creating tangible scientific and economic value for Europe and beyond.

Objective	Expected Outcome	Lead Partner(s)	WP
ST1	Functional CubeSat design with integrated tunable laser system	D4S / IRIS	WP2 / WP3

ST2	Operational plan covering 600–2000 km LEO layers with repeatability	POLIMI	WP2
ST3	AI models capable of learning and adapting to evolving debris scenarios	I2ART	WP2
ST4	Distributed architecture scalable across multiple CubeSats	POLIMI / I2ART	WP2 / WP3
ST5	Experimental results validating ablation, AI accuracy, system robustness	IRIS / D4S / STRATH	WP4
ST6	Cloud-based interface enabling decision-making and control	I2ART / POLIMI / STRATH	WP2 / WP3

1.4 Interdisciplinarity

SOLARIA is fundamentally interdisciplinary, combining scientific disciplines and engineering domains that, when tightly integrated, enable the emergence of a new technological paradigm in space debris mitigation.

Each core component of the system is anchored in early-stage scientific exploration (TRL 2–3), requiring the convergence of distinct but interdependent research efforts.

Discipline	Role in SOLARIA	Lead Partner(s)
Laser Physics & Optical Engineering	Design of tunable low-power lasers, modulation control, material-energy interaction modeling	D4S / IRIS
Artificial Intelligence & Machine Learning	Self-learning models for debris detection, probabilistic reasoning under uncertainty, cloud-edge ModelOps	I2ART
Aerospace Systems Engineering	Orbital dynamics modeling, multi-orbit mission design, CubeSat control algorithms	POLIMI / STRATH
Autonomous Systems Theory	Decentralized decision-making, resilience modeling, fault-tolerant mission logic	I2ART / POLIMI
Space Policy and Regulatory Science	Alignment with SSA/STM standards, safety compliance logic, legal foresight	STRATH
Materials Science and Thermal Engineering	Stress behavior under orbital conditions, shielding, AI housing vibration control	IRIS / D4S

This structure ensures that scientific discoveries in one domain (e.g. laser-material interaction) can immediately influence the progress in others (e.g. AI targeting behavior or mission planning). AI algorithms are developed in parallel with orbital simulations and sensor dynamics — not abstractly, but under realistic space-derived constraints. Similarly, decisions about autonomy or laser energy efficiency are grounded in experimental material performance data and resilience models.

The consortium's interdisciplinarity is not additive — it is generative. Each domain extends and challenges the others, creating the conditions for breakthroughs that no single field could deliver alone. By embedding this level of scientific convergence at low TRL, SOLARIA ensures that its innovation is not just the result of integration, but of co-creation across disciplines — fully aligned with the Pathfinder Open's ambition for high-risk, high-gain, paradigm-shifting research.

1.5 Methodological Approach & Cross-cutting Scientific Practices

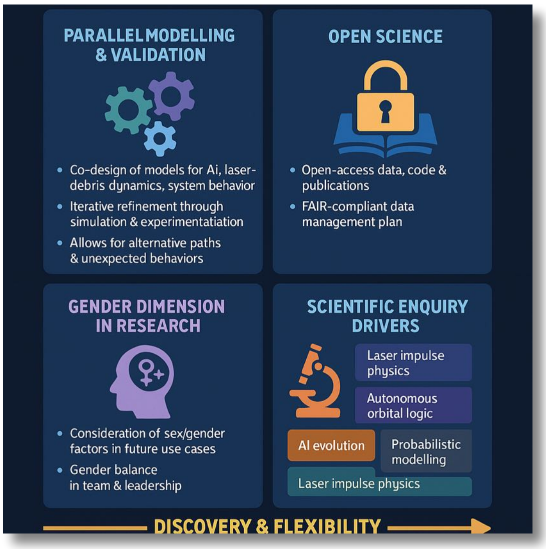
The SOLARIA project is built upon an exploratory, modular methodology designed to advance fundamental scientific understanding while enabling high-risk, high-gain technology integration at low TRL levels (2–4). The methodology addresses both the complexity of the orbital debris environment and the architectural innovations proposed, through iterative refinement and cross-domain validation.

Overall methodology and modelling rationale

The core approach follows a co-design and parallel modeling logic across key domains:

- **AI subsystem design** is grounded in semi-Markov temporal models, fuzzy logic, and reinforcement learning under non-deterministic orbital conditions.
- **Laser-debris interaction** is modeled using multi-physics simulations, accounting for energy transfer, material response, impulse propagation, and orbital perturbation.
- **System-level behavior** is shaped by adaptive CubeSat swarm autonomy, with distributed AI agents evolving via

real-time feedback and cloud-edge retraining pipelines.



These models are jointly developed and refined through WP2 and WP4, using experimental validation, simulation environments, and controlled testing. Uncertainties are actively embraced through a **fail-learn-improve strategy**, incorporating tolerance for mission variability and support for alternative paths (e.g., adjustment of laser pulse configuration, switching between engagement logics).

This flexible structure enables SOLARIA to **respond to unexpected behaviors**, while systematically exploring both scientific boundaries and technical feasibility.

Open science and research data management

SOLARIA is fully aligned with Horizon Europe's Open Science principles. The consortium will:

- Publish findings in **open-access journals**
- Release **non-sensitive datasets**, AI decision logs, and simulation scripts through platforms such as **Zenodo** or **OpenAIRE**
- Provide metadata and repositories compliant with **FAIR principles**, enabling reproducibility and cross-project collaboration

A dedicated **Data Management Plan (D1.2)** will cover the full research data lifecycle, including governance, security, anonymization (where relevant), and long-term preservation.

Gender dimension in research content

While SOLARIA's systems operate autonomously in a non-human environment, the AI architecture is designed to be **extensible to future human-centered space applications**. Where relevant — such as in future use cases involving proximity operations or on-orbit servicing — the system can incorporate datasets reflecting **sex/gender differences in ergonomic profiles,** reflexive control, or mission interface design.

The project governance also ensures **gender balance in leadership**, recruitment, and public-facing activities (see section 3.2).

Summary of methodological innovation

SOLARIA's methodology is not limited to system integration — it is a scientific inquiry into:

- The physics of impulse transfer in low-energy laser engagement
- The logic of distributed autonomy in orbital constellations
- The evolution of AI agents in unpredictable environments
- The interface between mission-level behavior and probabilistic modeling

This structured but flexible approach ensures that **scientific discovery is not a byproduct**, but a primary driver of the project's value — fully aligned with the Pathfinder Open ambition.

Each subsystem (laser, AI, control) is designed for modularity and in-mission upgradeability. AI agents are housed in thermally isolated shields, integrated with multi-sensor arrays, and linked to cloud-based orchestrators via secure communication. The CubeSat architecture supports adaptive mission profiles: detection-only, engage-on-pass, or full active mitigation.

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2. Impact #@IMP-ACT-IA@#

SOLARIA directly addresses the objectives of the EIC Pathfinder Open by fostering high-risk, high-gain scientific exploration, leading to the creation of new scientific paradigms and future markets in sustainable space operations.

The project embodies disruptive innovation beyond the current state-of-the-art, contributing to Europe's strategic autonomy, technological leadership, and environmental stewardship in space.

2.1 Long-term impact

SOLARIA is designed to make a transformative contribution to the future of orbital infrastructure protection, starting from low TRL scientific exploration and culminating in the definition of a new operational logic for sustainable space systems.

By enabling autonomous, in-situ debris removal at the early TRL stages (TRL 2–3 → TRL 4), SOLARIA opens a new pathway for orbital infrastructure protection — not based on incremental upgrades to ground systems, but on the creation of a novel operational paradigm in space.

By targeting the uncontrolled 1–10 cm debris population with autonomous, AI-driven, laser-equipped CubeSats, the project aims to unlock a new model of orbital governance: distributed, adaptive, and proactive.

Why SOLARIA is a Pathfinder-Grade Innovation	
Dimension	**Breakthrough Value**
Scientific Risk & Ambition	AI-controlled laser ablation in LEO — combining real-time detection, prediction and active mitigation in orbital conditions never tackled autonomously before.
Systemic Innovation	From standalone CubeSats to a cooperative, self-learning constellation for orbital debris engagement. SOLARIA is not a product, it's an operational paradigm.
EU Strategic Impact	Enabling the foundations for European autonomous STM/SSA services, reinforcing sovereignty in space governance, and supporting secure commercial access to orbit.

SOLARIA's long-term impact extends across technological, scientific, and strategic dimensions:

- **Technological and operational impact**

  Development of cost-effective, environmentally responsible debris removal capabilities, deployable on scalable CubeSat platforms

  Foundation for distributed, mission-aware constellations, capable of detecting, tracking, and acting independently within dynamic orbital environments

  Transition from passive risk mitigation to autonomous, proactive orbital maintenance, reducing dependency on Earth-based infrastructure

- **Scientific and ecosystem impact**

  Advancement of fundamental understanding of laser–debris interaction, multi-pass ablation dynamics, and real-time orbital modeling

  Enabling early experimentation with AI-powered decision-making in non-deterministic, physics-constrained environments

  Creation of reusable experimental and simulation models for future research on autonomy, energy delivery, and orbital swarm coordination

- **Strategic and policy impact**

  Direct contribution to the EU's vision for Space Situational Awareness (SSA) and Space Traffic Management (STM)

  Reinforcement of European leadership in orbital sustainability, both technologically and in global policy frameworks

  Preparation of a future ecosystem of intelligent orbital services, aligning technological innovation with regulatory foresight and security imperatives

By embedding autonomy, adaptability, and learning at the heart of its architecture, SOLARIA not only addresses today's debris challenge — it helps shape tomorrow's logic for operating in space.

Its legacy will not be a product, but a paradigm: space systems that protect themselves, collaborate across missions, and ensure the long-term sustainability of the orbital environment.

2.2 Innovation Potential

SOLARIA proposes a disruptive technological innovation that transcends current approaches to space debris mitigation, addressing a critical need with transformative potential across multiple dimensions.

Where existing systems primarily rely on **passive observation**, **avoidance manoeuvres**, high-cost mechanical removal platforms, SOLARIA introduces a new logic: distributed, real-time, autonomous debris engagement, powered by AI and laser-based impulse delivery.

Core innovation axes

- Autonomous, real-time debris mitigation via ***AI-driven targeting*** algorithms and tunable laser ablation systems
- ***Dual-orbit multi-pass engagement***, allowing continuous interaction with debris across 600 km and 2000 km orbital layers

- ***Miniaturized CubeSat platforms***, drastically reducing launch costs and enabling modular constellation deployment
- ***Low-power laser systems***, designed for safe impulse transfer without fragmentation or debris multiplication

These innovations address key limitations in the current state of the art, namely:

- Lack of scalable, autonomous in-orbit remediation technologies
- Inability to track or interact with 1–10 cm debris — the most threatening and unobservable class
- Operational complexity and cost of traditional debris management solutions

Scientific and technological breakthroughs of SOLARIA

- Multi-pass laser ablation logic, optimized for orbital dynamics and time-resolved impulse modeling
- Hybrid cloud-edge AI architecture, supporting in-orbit learning, model adaptation, and uncertainty management
- Integrated CubeSat autonomy, with decision layers capable of local optimization and coordinated mission adjustment

Feature	Ground-based Radar	Space Tug	SOLARIA
Target 1–10cm debris	❌	✅	✅✅
Real-time adaptation	❌	❌	✅✅
Energy efficiency	✅	❌	✅✅
Cost per intervention	High	Very high	Low
Deployment flexibility	❌	❌	✅✅

Expected outcomes and innovation potential

- Demonstration of a novel, distributed, low-mass, self-adaptive orbital remediation architecture
- Advancement in AI explainability, photonic precision control, and orbital response strategies
- Creation of new technical standards and use cases for STM/SSA operational services
- Establishment of Europe as a leader in intelligent orbital infrastructure innovation

Spillover potential

- Transferable methods to Earth observation, formation flying, AI-based swarm control, and adaptive robotics
- Methodological contributions to physics-informed AI, model retraining in mission-critical scenarios, and space-grade autonomy

SOLARIA's innovation does not lie in a single subsystem — but in the co-design of AI, laser physics, orbital mechanics, and system autonomy to create a new operating model for orbital interaction.

It transforms debris from a risk to a signal, from a hazard to a source of mission learning — redefining what it means to operate in Earth orbit.

SOLARIA\u2019s AI systems are designed with technical resilience and ethical robustness, ensuring real-time fault detection, system adaptability, and responsible decision-making. The architecture prioritizes sustainability, security, and social responsibility, fully aligning with EU principles on trustworthy AI and environmental protection.

Disruption Potential:

By enabling self-regulating, resilient orbital environments, SOLARIA fundamentally alters how space sustainability is achieved, opening pathways for future intelligent orbital infrastructures and supporting Europe's role as a global leader in space governance and technology.

By integrating resilient AI architectures inspired by ModelOps and AIOps principles, SOLARIA envisions an orbital ecosystem capable of dynamic self-healing, decentralized control, and continuous in-orbit learning. This disruptive approach redefines the management of orbital environments, paving the way for sustainable, autonomous space governance in the European and global context.

Regulatory Alignment:

SOLARIA proactively engages with evolving European space law frameworks to ensure responsible, secure, and compliant laser operations in orbit, aligning its innovations with the EU's vision for sustainable and secure space activities.

Through its disruptive operational logic, SOLARIA establishes a foundational platform for the next generation of Space Situational Awareness (SSA) and Space Traffic Management (STM) services, enabling a sustainable, secure, and intelligent orbital ecosystem for Europe and beyond.

*All AI modules are designed under the principle of "**security by design**". SOLARIA implements multi-layered protection for all mission-critical data — including end-to-end encryption (TLS 1.3), access-controlled data pipelines, and integrity checks for AI model updates. All data used for AI training or online learning are subject to traceability, version control, and validation to prevent data poisoning or adversarial manipulation. These safeguards ensure that autonomous actions remain reliable, explainable, and ethically aligned with EU AI policy and cybersecurity standard (**AI Act**).*

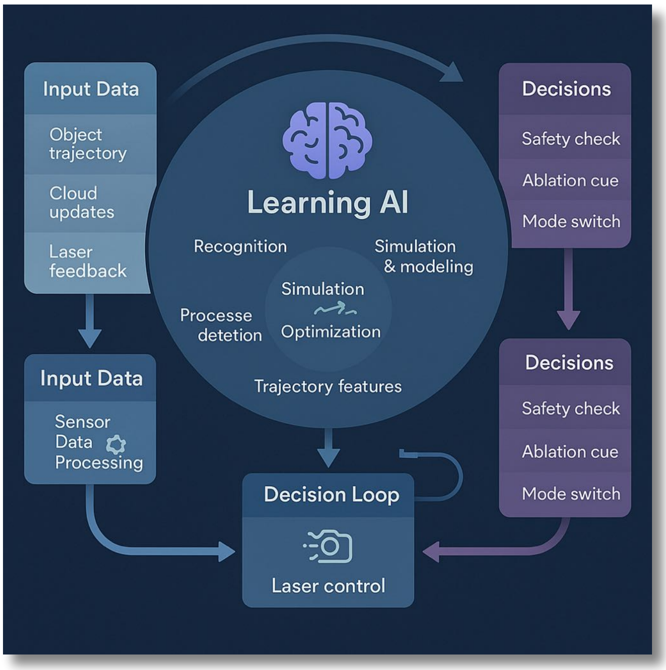

Fig2: SOLARIA Autonomous AI-Based Orbital Debris Mitigation Architecture.

CubeSat platforms autonomously detect, track, and engage space debris via real-time laser ablation, continuously interacting with the AI cloud for adaptive model retraining, decision support, and dynamic mission control across multiple orbital layers.

2.3 Communication, Dissemination and Exploitation

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The SOLARIA project adopts a proactive strategy for communication, dissemination, exploitation, and intellectual property management, ensuring that the scientific and technological breakthroughs achieved are fully valorised within Europe and beyond.

Communication and Dissemination Strategy

A comprehensive Communication and Dissemination Plan will be developed at project start (D5.1) and maintained throughout the project.

Key activities include:

- Open-access scientific publications in high-impact journals.
- Presentation of results at international conferences, space technology fairs, and policy dialogues.
- Public engagement through project websites, newsletters, webinars, and media campaigns.
- Targeted outreach to industry stakeholders, satellite operators, policy makers, and the broader scientific community.

All communication and dissemination activities will not only promote SOLARIA's objectives and findings, but will also accelerate scientific cross-fertilisation at low TRL — enabling other researchers and projects to build upon early-stage breakthroughs in AI-driven debris mitigation and orbital autonomy.

Target	Tool	Impact goal
Research community	Open-access publications	Accelerate AI and laser research at TRL 2–4
SMEs & space industry	Technology briefs & workshops	Enable downstream exploitation and spin-off
Policy makers (EU/ESA)	Webinars, white papers, clustering	Inform SSA/STM integration & regulation
General public	Media campaigns, visual demos	Promote awareness on orbital sustainability

Exploitation and Innovation Management

The exploitation strategy focuses on maximizing the societal and economic value of SOLARIA's results, in line with EU strategic interests.

Key exploitation measures include:

- **Protection of foreground Intellectual Property (IP)** through patents, design rights, and confidential know-how strategies.
- **Development of preliminary exploitation plans** for key technologies, particularly the AI-driven predictive targeting system and the modular laser CubeSat architecture.
- **Facilitation of technology transfer** towards European industrial players, SMEs, and potential spin-off initiatives.
- A**lignment with EU sustainability objectives**, ensuring that SOLARIA's technologies support long-term environmental and economic benefits.

Clustering and Cooperation with EU Initiatives

SOLARIA will actively engage in clustering activities with other Horizon Europe projects related to Space Situational Awareness (SSA), Space Traffic Management (STM), and space sustainability.

Joint workshops, policy dialogues, and cross-project dissemination activities will be organized to amplify the project's impact and ensure strategic synergies within the European innovation landscape.

Clustering activities will specifically target joint SSA/STM roadmapping with Pathfinder, EIC Transition, and ESA-supported initiatives, positioning SOLARIA as a reference architecture for intelligent, decentralized orbital safety systems.

Intellectual Property Rights (IPR) Management

A dedicated IPR management plan will:

- Monitor innovations emerging during the project.
- Support partners in protecting key outcomes through appropriate legal instruments.
- Ensure a clear framework for IP ownership and exploitation among partners, based on the consortium agreement.
- Prioritize exploitation within Europe to reinforce European technological leadership.

In addition to traditional IP protection routes, the project will explore open licensing models for simulation data, edge-AI architectures, and laser-material interaction datasets, enabling uptake by early-stage research initiatives and space tech SMEs across Europe.

Cross fertilisation

By actively involving early-career researchers, *high-tech SMEs, and innovation-driven stakeholders,* SOLARIA ensures not only technology transfer, but also the cultivation of the next generation of space technology pioneers within the European innovation ecosystem.

Stakeholder and Public Engagement:

SOLARIA will organize stakeholder workshops, webinars, and public outreach events targeting satellite operators, aerospace agencies, policymakers, and the general public. A dedicated website will host open-access publications, project updates, and interactive visualizations of debris mitigation activities. Regular newsletters, media outreach, and educational videos will support continuous engagement throughout and beyond the project lifecycle.

These actions will ensure that SOLARIA's results are not only disseminated, but actively translated into scientific acceleration, industrial readiness, and European strategic leadership in autonomous orbital operations.

#§COM-DIS-VIS-CDV§#

3. Quality and efficiency of the implementation #@QUA-LIT-QL@# #@CON-SOR-CS@# #@PRJ-MGT-PM@#

The SOLARIA project is structured into five interlinked work packages (WPs), organized across three key phases to ensure a coherent progression from system design to final validation and exploitation.

WP1 – Project Management (Leader: Durante Space Tech)

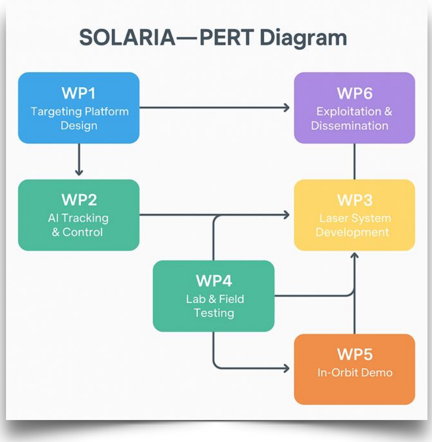
This WP ensures effective coordination, financial management, risk mitigation, and compliance with project milestones. It establishes efficient internal communication and monitors progress to guarantee that the project remains on schedule and within budget.

WP2 – System Design, Analysis, and Modeling

This phase focuses on the comprehensive design of SOLARIA's core components: laser modules, AI control systems, and CubeSat platforms. Detailed simulations of orbital dynamics, laser ablation processes, and system integration will be performed, producing a fully validated system architecture.

WP3 – Implementation and Integration

Transitioning from design to real-world implementation, WP3 covers the manufacturing of CubeSats, integration of optical systems and tunable laser sources, and setup of AI algorithms for autonomous debris detection and targeting. Subsystem validation in controlled environments will ensure compliance with performance specifications.



WP4 – Experimental Validation and Data Collection

This phase involves the deployment of SOLARIA modules in simulated space environments, conducting rigorous experimental tests to evaluate laser ablation efficiency, AI targeting precision, and overall system robustness. Data gathered will refine operational models and feed into post-mission analysis.

WP5 – Communication, Dissemination, and Exploitation

WP5 will maximize the impact of SOLARIA by disseminating scientific results, promoting open access publications, and engaging industry stakeholders. The WP will drive technology transfer initiatives, manage IP (including patents and licensing), and prepare the project for market translation through targeted outreach and strategic partnerships.

Implementation Strategy

The phased structure ensures a systematic and efficient progression:

- Year 1: Design validation and subsystem simulations (WP2).
- Year 2: Manufacturing, integration, and controlled environment testing (WP3).
- Year 3: Full experimental validation and data exploitation (WP4 and WP5).

Resource allocation and task distribution are carefully balanced to support technical excellence, minimize risks, and deliver the project's ambitious objectives on time.

3.1 Work plan and allocation of resources

#@WRK-PLA-WP@#

The SOLARIA consortium unites five leading institutions from Spain, Italy, Germany, and the United Kingdom, strategically combining excellence in aerospace engineering, laser physics, materials science, artificial intelligence, and space environment management.

This multidisciplinary synergy ensures the consortium's ability to address high-risk, high-gain challenges and pioneer disruptive innovations for active space debris mitigation.

Consortium Composition and Expertise:

- Durante Space Tech (Spain): Project coordinator with expertise in laser systems, optical integration, and CubeSat engineering for space applications.
- Politecnico di Milano (Italy): World-class leader in orbital mechanics and mission optimization for multi-orbit debris targeting.
- IRIS (Italy): Specialist in high-efficiency space-grade laser technology, ensuring robustness and adaptability in operational environments.
- I2ART (Germany): Developer of cutting-edge AI algorithms for autonomous debris detection, tracking, and targeting optimization.
- University of Strathclyde (UK): Expert in space policy, traffic management compliance, and environmental impact governance.

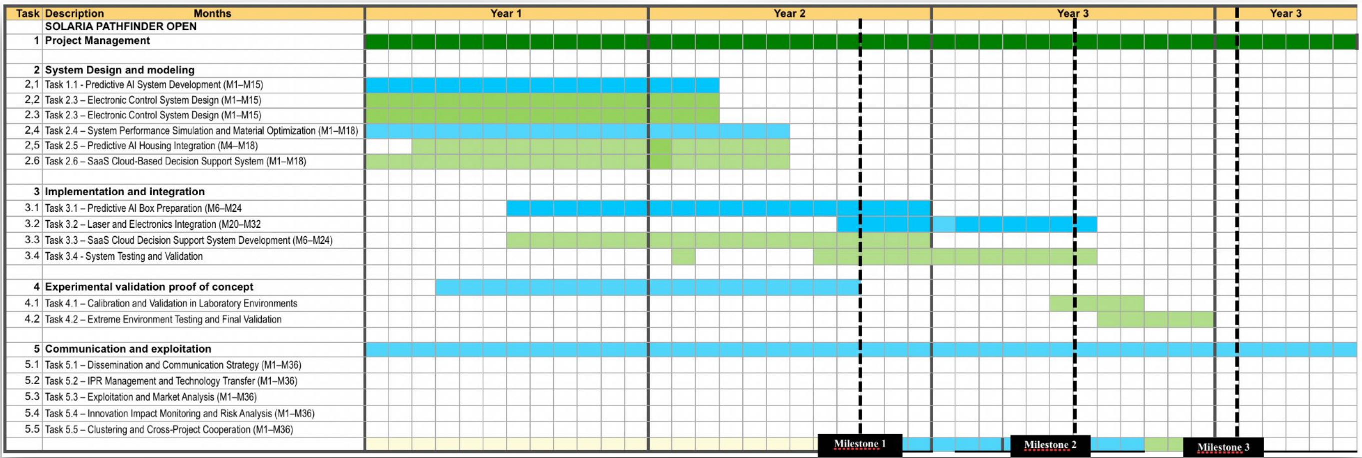
Complementarity and Agility:

- The consortium's structure ensures seamless collaboration across technology domains.
- Strong cross-disciplinary integration enables rapid iteration and risk mitigation during technology development.
- Agile project management allows flexibility in adapting to evolving research findings and operational constraints.

Resource Allocation and Work Plan Structure:

Resources are proportionally allocated across five Work Packages (WPs) to align technical leadership with critical tasks:

- WP1: Project Management (D4S lead)



- WP2: System Design and Modelling (IRIS lead)
- WP3: Integration and Implementation (I2ART lead)
- WP4: Experimental Validation (POLIMI lead)
- WP5: Dissemination and Exploitation (STRATH lead)

Table 3.1a: List of work packages

WP No	Title	Lead Part. N.	Lead Partner	Name & surname of Work package leader	Gender of Work package leader	Start Month	End Month
WP1	Project Management	1	D4S	Sergio Durante	M	M1	M36
WP2	Detailed Design, Analysis, and Modeling	2	IRIS	Giulia Molinari	F	M1	M18
WP3	Implementation and Integration	3	I2ART	Tatiana Levchenko	F	M6	M32
WP4	Experimental Testing and Data Collection	4	POLIMI	Luca Magagnin	M	M28	M36
WP5	Communication, Dissemination, and Exploitation	5	STRATH	Yi Qin	F	M4	M36

This structured yet agile work plan ensures that SOLARIA remains scientifically ambitious, technically feasible, and strategically aligned with the Pathfinder Open vision for pioneering breakthrough technologies.

Table 3.1b: Work package description

Work Package Number	1		Lead	POLIMI	
Work Package Title	***Project management***				
	Start Date	1	End Date	36	

Objectives:

This work package ensures the overall legal, contractual, financial, administrative, and operational coordination of SOLARIA. POLIMI will manage the communication with the European Commission, oversee risk monitoring, ensure the timely delivery of milestones and deliverables, and foster effective collaboration among all partners.

Description of work

Task 1.1 – Coordination and Project Monitoring (POLIMI) M1–M36

• Coordination of consortium activities, supporting the development of concepts, methodologies, and technologies.
• Management of internal and external communications, ensuring alignment with complementary projects and standardization initiatives.
• Organization of regular virtual meetings to optimize efficiency and cost-effectiveness, complemented by physical meetings

Task 1.2 – Financial and Administrative Management (POLIMI) M1–M36

• Full management of financial and administrative processes, including collection and submission of cost statements, coordination of payments, and liaison with the Commission's financial offices.
• Oversight of deliverable submission and contractual compliance.

Task 1.3 – Development of Periodical Progress Reports (POLIMI) M1–M36
• Preparation of annual progress reports summarizing achievements, methodologies, hardware developments, and demonstration outcomes.
• Delivery of a mid-term evaluation at Month 18 and a final project report at project completion.
Task 1.4 – Data Management Plan for Open Research Data (POLIMI) M1–M36
• Implementation of an Open Data Management strategy in line with EC recommendations.
• Protection of sensitive partner-generated data and definition of the full data management lifecycle for project datasets.

Work Package Number	2		Lead	I2ART	
Work Package Title	**Detailed Design, Analysis, and Modeling**				
	Start Date	1	End Date	18	

Objectives:
To develop, refine, and optimize the SOLARIA system, ensuring that all hardware and software components meet performance, reliability, and operational autonomy requirements for space debris detection and removal.

Description of work
Task 2.1 – Predictive AI System Development (M1–M15)
• Design and virtual simulation of a self-learning predictive AI box for debris detection and trajectory prediction.
• Optimization of AI algorithms for autonomous adaptive learning in dynamic orbital environments.
Task 2.2 – Laser System and Multi-Pass Detection Design (M1–M15)
• Engineering of a dual-orbit laser targeting system with multi-pass detection capability.
• Integration of AI control systems with tunable optical modules.

Task 2.3 – Electronic Control System Design (M1–M15)
• Development of electronic architectures for real-time data acquisition, laser targeting control, and dynamic system adaptation.
Task 2.4 – System Performance Simulation and Material Optimization (M1–M18)
• Multi-physics simulations of mechanical stress, thermal behavior, and dynamic interactions.
• Evaluation of materials and advanced architectures to enhance resilience and optimize structural performance.

Task 2.5 – Predictive AI Housing Integration (M4–M18)
• Design and optimization of the protective housing unit for AI modules and laser systems.
• Integration of new materials for improved vibration damping and thermal management.
Task 2.6 – SaaS Cloud-Based Decision Support System (M1–M18)
• Development of a hybrid cloud-edge AI system enabling real-time data processing, model updating, and operational decision support.

Work Package Number	3		Lead	STRATH	
Work Package Title	**Implementation and Integration**				
	Start Date	6	End Date	32	

Objectives
To integrate, assemble, and validate all SOLARIA subsystems — including AI control units, laser optics, and CubeSat platforms — ensuring full system functionality and readiness for in-orbit deployment.

Description of work:
Task 3.1 – Predictive AI Box Preparation (M6–M24)
- Production and setup of hybrid nano-structured predictive AI housing units.
- Integration of hardware CPU components, sensors, and communication interfaces.
- Mechanical and electronic interfacing to enable seamless system control and CubeSat integration.

Task 3.2 – Laser and Electronics Integration (M20–M32)
- Assembly of laser ablation modules and optical components into CubeSat structures.
- Validation of full communication between AI systems and laser targeting mechanisms.
- Laboratory calibration and commissioning, including safety certification measures.

Task 3.3 – SaaS Cloud Decision Support System Development (M6–M24)
- Finalization of cloud-based architecture integrating the Hybrid Fuzzy Artificial Neural Network prototype.
- Real-time data acquisition system deployment and optimization of system interfaces for operational control.

Task 3.4 - System Testing and Validation:
- Full system integration tests under simulated space conditions (thermal vacuum environment).
- Deployment readiness assessment to ensure operational resilience and compliance with orbital mission requirements.

Work Package Number	4		Lead	IRIS	
Work Package Title	**Experimental Testing and Data Collection**				
	Start Date	28	End Date	36	

Objectives
To rigorously test and validate the fully integrated SOLARIA system under simulated space and extreme environmental conditions, ensuring operational performance, resilience, and readiness for deployment.

Description of work
Task 4.1 – Calibration and Validation in Laboratory Environments (M30–M34)
- Calibration of integrated predictive AI box and laser modules under controlled lab conditions.
- Performance validation of detection, tracking, and debris engagement functions using thermal-vacuum chambers.
- AI model verification through stress testing and operational disturbance resistance analysis.

Task 4.2 – Extreme Environment Testing and Final Validation (M33–M36)
- Testing of system performance under simulated low/high thermal stress conditions (-200°C to +100°C).
- Mechanical stress validation to assess robustness of laser ablation, AI autonomy, and dynamic control.
- Experimental simulation of zero-gravity conditions using parabolic flight campaigns.

All tests will focus on validating operational efficiency, autonomous decision-making, and resilience to extreme environmental variables critical for in-orbit functionality.

Work Package Number	5		Lead	D4S	
Work Package Title	**Communication, Dissemination, and Exploitation**				
	Start Date	1	End Date	36	

Objectives
To ensure that the scientific and technological results of SOLARIA are widely disseminated, exploited by key stakeholders, and aligned with EU strategic priorities in space sustainability and innovation

Description of work
Task 5.1 – Dissemination and Communication Strategy (M1–M36)
- Development of a comprehensive Communication and Dissemination Plan targeting scientific communities, industrial stakeholders, and policymakers.
- Regular dissemination through open-access publications, newsletters, social media updates, conferences, and workshops.
- Creation of project branding and outreach materials, promoting SOLARIA's objectives and results.

Task 5.2 – IPR Management and Technology Transfer (M1–M36)
- Monitoring and protection of project foreground IP through patents, design rights, and confidential know-how strategies.
- Support to partners in assessing exploitation routes and ensuring alignment with European industrial interests.
- Facilitation of knowledge transfer towards SMEs, research institutions, and industrial players within the EU.

Task 5.3 – Exploitation and Market Analysis (M1–M36)
- Continuous monitoring of market trends, user needs, and regulatory developments in the space debris mitigation sector.
- Development of preliminary exploitation plans for SOLARIA's core technologies, including potential commercial pathways post-project.
- Evaluation of sustainability, environmental impacts, and alignment with EU space safety frameworks.

Task 5.4 – Innovation Impact Monitoring and Risk Analysis (M1–M36)
- Assessment of innovation potential and replication strategies.
- Monitoring of competitive landscapes and emerging technologies.
- Identification and mitigation of business-related risks impacting exploitation strategies.

Task 5.5 – Clustering and Cross-Project Cooperation (M1–M36)
- Establishment of collaborations with other Horizon Europe projects and European platforms working in the fields of Space Situational Awareness (SSA), Space Traffic Management (STM), and sustainable space operations.
- Organization of joint workshops, policy dialogues, and strategic foresight activities to amplify SOLARIA's impact within the European innovation landscape.

[R]= Report; [DEM]= Demonstrator

3.2 Capacity of Participants and Consortium as a Whole

The SOLARIA consortium brings together five highly complementary institutions from Italy, Spain, Germany, and the United Kingdom, each contributing specific and strategic expertise across aerospace engineering, laser physics, optical systems, AI and machine learning, orbital dynamics, and regulatory governance.

This configuration provides the interdisciplinary depth and operational capacity required to deliver a high-risk, high-gain innovation effort, fully aligned with the objectives of the EIC Pathfinder Open.

Expertise and Roles:

• **Durante Space Tech (D4S, Spain):**

Expert in system integration, CubeSat platforms, and real-world prototyping.

D4S coordinates the project and leads WP1. It also contributes to system integration, AI edge-cloud orchestration, and field testing and supports hardware development, contributing agile iteration capacity and experience in lightweight aerospace systems. The company has led multiple Horizon and ESA pilots with a strong focus on transitioning from early-stage concepts to robust hardware demonstrators and market-ready components. D4S personnel has experience in EU projects since 1995 and coordinated 6 FP6 projects and managed m,ore than 40 projects.

• **Politecnico di Milano (POLIMI, Italy – Coordinator):**

A world leader in orbital mechanics and space systems engineering. POLIMI contributes to orbital dynamics modelling, mission design, and subsystem validation. It leads WP4 and supports dissemination and data governance, leads risk monitoring, and contributes to dynamic modeling, mission design, and mechanical simulations. It has coordinated over 20 EU-funded projects (FP7, H2020, Horizon Europe), ensuring excellence in technical execution, administration, and dissemination. POLIMI also contributes to international research infrastructures on orbital optimization and spaceflight dynamics.

• **International Institute of Applied Research and Technology (I2ART, Germany):**

Leads development of the predictive AI control systems, multi-pass trajectory optimization algorithms, and SaaS cloud architecture. I2ART has developed proprietary reinforcement learning frameworks and cloud–edge AI retraining tools for cyber-physical systems, and has successfully participated in model licensing and technology transfer initiatives with research institutions and SMEs.

• **University of Strathclyde (STRATH, UK):**

Recognized for leadership in space policy, SSA/STM compliance, and regulatory frameworks. STRATH oversees environmental and legal alignment, policy integration, and innovation foresight strategies. The team contributes to European space governance dialogues and has supported strategic exploitation planning in space-tech, law-tech, and sustainability programs. The personnel of the University of Strathclyde has long term experience in coordination of big consortium projects.

• **IRIS s.r.l. (Italy):**

Specialist in high-efficiency, space-grade laser technology. IRIS leads the system design of the laser ablation architecture and provides expertise in thermal, vibrational, and material resilience studies. The company has a proven track record in prototyping, laser certification, and optical integration for harsh environments, and has supported IP valorisation and product spin-offs in previous EU-funded innovation actions. IRIS personnel has a long experience in EU projects since 1998.

Each partner plays a distinct and non-overlapping role, with clear task assignments and leadership responsibility across work packages.

The consortium structure ensures cross-domain feedback, iterative co-development, and rapid problem-solving capacity throughout the project.

Access to Critical Infrastructure:

Each participant has access to advanced facilities and tools essential for successful implementation:

- D4S: CubeSat assembly, precision prototyping, and integration facilities.
- POLIMI: Orbital simulation labs, thermo-vacuum chambers, structural testing.
- IRIS: Laser development and environmental testing laboratories.
- I2ART: Cloud-edge AI training clusters, high-capacity model validation pipelines.
- STRATH: Policy research centers, regulatory archives, and STM simulation environments.

Open Science and Gender Equality Commitment:

SOLARIA adheres to Open Science principles by publishing in open-access journals, sharing FAIR-compliant data, and engaging early-career researchers in knowledge transfer.

Gender equality is embedded in project governance and recruitment, with attention to inclusive team composition and balanced representation in research and leadership roles.

Conclusion:

The SOLARIA consortium is strategically structured and technically equipped to deliver disruptive innovation in space debris mitigation.

It unites academic excellence, industrial feasibility, regulatory readiness, and open, inclusive practices — ensuring that the project's ambitions can be achieved both technically and societally.

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Table 3.1c: List of Deliverables

Only include deliverables that you consider essential for effective project monitoring.

[R]= Report [DEM]= Demonstrator

Deliverable number	Deliverable name	Work package number	Lead participant	Type	Dissemination level	Delivery date
D1.1	Project quality handbook	WP1	D4S	R	PU	M3
D1.2	Data management plan	WP1	POLIMI	R	PU	M6, M36
D1.3	Periodic report	WP1	D4S	R	PU	M12, M30
D1.4	Midterm periodic report	WP1	D4S	R	PU	M18
D1.5	Final report	WP1	D4S	R	PU	M36
D2.1	Integrated self-learning predictive AI box	WP2	ART	R	SEN	M18
D2.2	Preventive system design and implementation	WP2	ART	R	SEN	M18
D2.3	Control Channels system design	WP2	D4S	R	SEN	M18
D2.4	System performance and simulation	WP2	STRATH	R	SEN	M18
D2.5	Integrated predictive AI box house	WP2	POLIMI	R	SEN	M18
D3.1	Integrated predictive AI box setup	WP3	ART	DEM	SEN	M30
D3.2	Delivery of fully working integrated predictive AI box prototypes	WP3	STRATH	DEM	SEN	M30
D4.1	Report on the laboratory test	WP4	IRIS	R	PU	M36
D4.2	Report on the field tests	WP4	IRIS	R	PU	M36
D5.1	Communication & dissemination plan	WP5	D4S	R	PU	M6
D5.2	First draft of the exploitation plan	WP5	STRATH	R	PU	M18
D5.3	Final exploitation plan	WP5	STRATH	R	PU	M36
D5.4	EU gender clustering activities	WP5	POLIMI	R	PU	M18, M36

Table 3.1d: List of Milestones

Milestone number	Milestone name	Related WPs	Due date	Means of verification
M1	Project Kick-Off	WP1	M1	Consortium agreement signed, project governance structure established, work plan reviewed and validated by all partners.
M2	System Design Validation	WP2	M18	Completion of full SOLARIA system design, including laser modules, AI predictive algorithms, CubeSat platforms, and SaaS architecture. Validation of system architecture against project objectives.
M3	Full System Integration Completed	WP3	M30	Physical integration of AI modules, laser systems, sensors, and CubeSat platforms into operational prototypes. Successful completion of laboratory integration tests.
M4	Preliminary Experimental Validation Completed	WP4	M24	Initial validation of laser system, CubeSat platforms, and AI control modules under laboratory thermal-vacuum conditions. Confirms subsystem functionality and readiness for integrated system testing.
M5	Regulatory Compliance Checkpoint	WP5	M26	Technical and legal verification ensuring SOLARIA system compliance with European Space Situational Awareness (SSA) and Space Traffic Management (STM) standards. Internal audit and alignment with EU space governance frameworks.
M6	Final Field Validation and Deployment Readiness	WP4	M34	Completion of full system validation under simulated extreme conditions (temperature, mechanical stress, zero gravity tests) and certification of readiness for orbital deployment operations.

Table 3.1e: Critical risks for implementation

#@RSK-MGT-RM@#

In a high-risk, high-gain project like SOLARIA, several critical risks have been identified. The consortium has defined specific mitigation strategies to ensure agile response and risk containment.

Risk category	Specific risk	Mitigation Strategy
Technological risks	Laser ablation may not achieve the necessary debris trajectory change at low power	Adaptive tuning of laser parameters; redundancy in target engagement through multi-pass strategy
Technological risks	AI tracking algorithms may fall in highly dynamic debris fields	Adaptive tuning of laser parameters; redundancy in target engagement through multi-pass strategy
Project Execution Risks	Delay in CubeSet integration	Early engagement with multiple launch providers; parallel validation of ground-based simulations
Partner Expertise Risks	Loss of key personnel (laser systems, AI)	Cross-training of teams; redundancy of critical skill sets across partners
Market and User Risks	Regulatory constraints on laser usage in space environment (simulated)	Early and proactive engagement with ESA and EU regulatory bodies; design compliance with SSA/STM norms
Competition Rieks	Emergence of alternative debris removal technologies	Agile system modularity enabling SOLARIA to evolve with market trends; integration flexibility into broader STM systems

#§RSK-MGT-RM§#

Table 3.1f: Summary of staff effort

Person Month Participation	WP1	WP2	WP3	WP4	WP5	Total
DURANTE SPACE TECH	**19**	12	17	17	14	79
POLITECNICO MILANO	3	7	17	**29**	8	64
I2ART	3	15	**24**	15	12	69
University of Strathclyde	3	13	15	12	**20**	63
IRIS SRL	3	**24**	14	15	12	68
Total Person Months	31	71	87	88	66	**343**

Table 3.1g: 'Subcontracting costs' items No subcontracting only audit certificates, if required.

Table 3.1h: 'Purchase costs' items (travel and subsistence, equipment and other goods, works and services)

D4S	Cost (€)	Justification
Travel	15000	Travel expenses for 7 general+7WP meetings, hosting meetings and dissemination workshops, traveling to tests locations (Traveling costs from Canary is higher than intracontinental flights)
Materials/ Consumables	17000	Materials for AI testing interfaces, laser targeting prototypes, signal visualization rigs, dissemination demo kits, and system prototyping materials (cabling, hardware shells).
POLIMI	**Cost (€)**	**Justification**
Travel	12000	Travel expenses for 7 general+7WP meetings, hosting meetings and dissemination workshops
Materials/ Consumables	16000	Materials for orbital testbed setup, simulation environment support, and visualisation/demo hardware used for validation of orbital control logic
I2ART	**Cost (€)**	**Justification**
Travel	12000	Travel expenses, hosting meetings and dissemination workshops.
Materials/ Consumables	18000	Cloud training environments, testbed setups for agent training, data logging hardware, local server nodes, and simulation signal management devices
STRATH	**Cost (€)**	**Justification**
Travel	12500	Travel to project and technical meetings
Materials/ Consumables	17500	Technical materials for regulatory sandboxing, scenario-based safety testing, open data infrastructure, and documentation for SSA/STM alignment and policy integration

IRIS	Cost (€)	Justification
Travel	11000	Travel to project and technical partner meetings, eventual fee for participation in different workshops, etc.
Materials/ Consumables	24000	Materials for development of multi-pass laser emitter modules, low-power beam modulation devices, optics testing, alignment systems, and prototyping of precision impulse control platforms

Table 3.1i: ‘Other costs categories’ items (e.g. internally invoiced goods and services) - not applicable

Table 3.1j: ‘In-kind contributions’ provided by third parties - not applicable

#§QUA-LIT-QL§# #§WRK-PLA-WP§#

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