Dear Friends and Partners,
To whom it may concern,

As part of our new initiative, code-named HELIOS, we are establishing an integrated R&D environment aimed at developing an embodied AI assistant capable of joining long-duration orbital and interplanetary missions as an autonomous, adaptive, and socially intelligent crew member.

In this context, we are actively seeking partners from industry, academia, and research organizations working in the areas of embodied and cognitive systems, next-generation human–machine interfaces, and on-board or edge AI computing platforms.

While we welcome all forms of collaboration — including joint research proposals, bilateral funding frameworks, supervision or co-supervision of MSc and PhD theses, and academic exchange through student mobility, postdoctoral placements, or visiting researcher programs — our current priority is to pursue domain-driven innovation through close cooperation with technology developers and research institutions.

Please refer to the attached research proposal for additional information.

We would be happy to start a conversation and explore potential forms, scopes, and areas of collaboration if you or your organization see potential alignment with this initiative — including, but not limited to, the areas listed in the *Selected Research Areas* section.

If you have any questions or would like to explore possible collaboration, please don't hesitate to reach out at siwik@agh.edu.pl.

Yours sincerely,
Leszek Siwik

Faculty of Space Technologies
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1. Executive Summary

The acronym HELIOS stands for Humanoid and *Embodied AI for Long-term Interplanetary, Orbital and Space Systems* and refers to an research and development initiative aimed at developing an embodied AI assistant capable of supporting long-duration orbital and space missions as an autonomous, adaptive, and socially intelligent crew member.

These embodied systems are envisioned to assist astronauts across a wide range of operational scenarios — from routine daily tasks and cognitively demanding workflows to high-risk operations in hazardous environments like radiation exposure, vacuum conditions, or mechanically unstable zones.

One of the core objectives of HELIOS is to advance research on AI models and system architectures tailored to embodied agents. This includes both the adaptation and fine-tuning of existing frameworks, such as Large, Small and Vision Language Models, as well as the design of new, modular architectures optimized for real-world, multimodal, mission-critical environments.

The project investigates how such models can be dynamically integrated with perceptual, motor, and interaction subsystems onboard humanoid or non-humanoid robotic platforms — enabling context-aware autonomy, natural communication, and socially and emotionally responsive behavior in collaboration with human crew members.

Beyond single-agent capabilities, HELIOS also explores multi-robot coordination, decentralized decision-making, and scalable team dynamics — including hybrid human–robot collaboration within shared mission workflows.

The platform is envisioned as a universal testbed for next-generation space robotics — open to experimentation, validation, and cross-sector innovation.

2. Selected Research Areas

Research Areas include but are not limited to:

a. Embodied AI for Collaborative Operations
   - Development and integration of cognitive AI agents enabling robots to understand context and intent.
   - Adaptive mission execution using evolving models synchronized with crew and telemetry data.
   - Design of teamwork protocols for human–robot cooperation in dynamic scenarios.
   - Modeling of avatar-based interaction behaviors to support intuitive collaboration and familiarity.

b. Multi-Agent Robotic Collaboration
   - Autonomous coordination among multiple embodied/humanoid agents to accomplish team tasks.
   - Development of decentralized communication frameworks and consensus-building mechanisms.
   - Learning-based optimization of group behavior in tasks such as inspection, logistics, or habitat maintenance.

- Scalable collaboration strategies for robot-only operations and joint human-robot teams.

c. Health and Mental State Monitoring
    - Real-time integration of physiological, behavioral, and environmental data to track astronaut well-being.
    - AI-driven analysis of fatigue, cognitive load, emotional state, and psychological stress.
    - Predictive health modeling and early warning systems for intervention and adaptation.
    - Conversational agents delivering contextualized emotional support and behavioral coaching.

d. Immersive Social and Emotional Interaction
    - Simulation of familiar individuals (e.g., family members, mission control staff) through expressive avatars.
    - Personalization of voice, expression, and behavior for emotional immersion and psychological relief.
    - Social memory mechanisms for maintaining long-term relational continuity with crew members.
    - Evaluation of emotional resilience and mission cohesion enhanced by socially intelligent robots.

e. Next-Generation Human–Robot and Robot–Robot Interaction and Communication
    - Development of intuitive, context-aware communication channels between humans and embodied robotic agents, including multimodal signaling (gesture, gaze, spatial cues, tactile input).
    - Design and evaluation of non-verbal communication frameworks enabling (humanoid) robots to convey intent, state, and uncertainty in dynamic environments.
    - Exploration of robot–robot communication protocols for real-time coordination, distributed decision-making, and fault tolerance in multi-agent systems.
    - Integration of shared situational awareness frameworks, enabling both human and robot agents to align on goals, task status, and environmental context through naturalistic or semi-structured interaction models.

f. Adaptive and Resource-Aware AI Deployment in Constrained Environments
    - Development of adaptive AI execution frameworks capable of dynamically selecting optimal deployment strategies (edge, fog, mist, cloud) based on current resource availability, mission criticality, and context.
    - Exploration of energy-aware AI planning, including inference scheduling based on solar exposure, thermal constraints, and power budgeting scenarios typical for orbital and planetary missions.
    - Design of on-chip AI and neuromorphic solutions for ultra-low-latency, low-power local inference in embedded robotic subsystems (e.g. sensors, actuators, locomotion control).
    - Implementation of distributed inference models, enabling robots to offload or share processing tasks in multi-agent systems, including peer-to-peer AI collaboration and decentralized decision fusion.
    - Investigation of real-time load balancing and cooperative task-driven compute distribution among embodied/humanoid agents under changing environmental and energy conditions.

g. Autonomous Task Execution in Extreme Environments
    - Execution of technical, logistical, and mechanical operations aboard spacecraft and orbital stations.
    - AI-based adaptation to hazardous conditions such as depressurization, radiation, or contamination.
    - Onboard contingency management and anomaly handling with minimal ground support.

3. Expected Outcomes

The expected outcomes include but are not limited to:

a. A flexible and reconfigurable embodied/humanoid research platform for AI integration and testing;
b. AI models enabling embodied agents / humanoid systems to participate in autonomous, cooperative, and emotionally aware operations; Demonstration of multi-agent robotic coordination in realistic mission scenarios;
c. Validated protocols for mental state assessment and adaptive emotional support;
d. Frameworks for trust calibration and task delegation between humans and robotic teammates; Foundational technologies and insights for future space mission architectures involving human-embodiedAI coexistence;
e. Novel communication frameworks for human–robot and robot–robot interaction, including multimodal signaling, intent expression, shared situational awareness, and real-time coordination in distributed autonomous systems;
f. Adaptive AI deployment strategies for resource-constrained environments, including energy-aware inference scheduling, AI-on-chip architectures, and distributed computing models for real-time task execution and collaborative reasoning across multiple humanoid agents.

4. About the Initiator

The HELIOS initiative is led by the Faculty of Space Technologies at AGH University of Science and Technology in Krakow, Poland (EU), home to a growing ecosystem of interdisciplinary research teams collaborating across a wide spectrum of scientific and engineering domains including:

a. Orbital and Planetary Space Missions,
b. Life Sciences for Space,
c. Materials and Technologies for Space,
d. Lightweight Structures and Planetary Infrastructure,
e. Space Sensors,
f. Advanced Space Propulsion,
g. Satellite Telecommunications,
h. Bioastronautics and Habitats,
i. Satellite Data Processing, Earth and Celestial Body Observation,
j. AI, Cybersecurity and Software Systems for Space,
k. Humanoid Intelligence for Space Exploration.

Within the Faculty, — initiated and led by Prof. Tadeusz Uhl — we operate a range of dedicated research laboratories and in-house experimental facilities like: Analog Habitat & AstroLab, SpaceEduLab, Sensors for Space Lab, SatLab, Mission Control Center or Environmental Simulation, that are available as assets in collaborative projects.

Beyond the Faculty itself, the initiative is supported by AGH UST’s institutional infrastructure, including:

a. The Center of Excellence in Artificial Intelligence (CEAI) – a university-wide platform for cutting-edge AI research and cross-sector collaboration;
b. The Academic Computer Centre Cyfronet AGH – part of the National HPC Competence Centre and host of the AI Factory initiative, providing access to large-scale, high-performance computing resources for training and deploying AI models.

For more information, please refer to the Faculty and University webpages.

5. Collaboration Framework & Contact

We welcome both formal and informal forms of collaboration — including joint research proposals, bilateral funding schemes, supervision or co-supervision of MSc and PhD theses, as well as academic exchange through student mobility, postdoctoral placements, or visiting researcher programs.

Our primary focus, however, is on substantive collaboration with partners engaged in the development of humanoid robotics, embodied and cognitive systems, next-generation HMIs, and on-board or edge AI computing platforms.

If you or your organization **see potential alignment** with the **HELIOS** initiative — in any relevant area, including but not limited to those listed in the *Selected Research Areas* section — please don't hesitate to reach out at siwik@agh.edu.pl.

We would be happy to start a conversation and explore possible forms, scopes, and areas of collaboration.

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