Development and testing of a magnet moving system for APHRODITE, a lab-on-chip analytical device for the International Space Station

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Statement of the Problem: Astronauts' self-use diagnostic tools in space missions are now a priority in aerospace research. In the past, space activities were in Low Earth Orbit (LEO), allowing swift Earth returns. On the International Space Station (ISS), biological samples were stored and sent back to Earth for analysis. This will not work for missions beyond low Earth orbit, like future lunar missions. Automated onboard tools are needed to analyze biomarkers in real-time, eliminating the need to return samples. Developing integrated chemical-clinical systems is vital for in-flight medical diagnostics and telemedicine support for astronauts as we venture further into space.

In this paper, we present APHRODITE, a compact and versatile biosensor to be launched on the ISS for conducting analyses of astronaut saliva for a quantitative determination of the levels of cortisol and dehydroepiandrosterone (DHEA), chosen as biomarkers for alterations of the immune system. The key technical solution of APHRODITE is based on the combination of a lab-on-chip with the use of functionalized microbeads (MBs). The paper provides a focus on the magnet moving mechanism design and testing since it is a core subsystem embodying the innovativeness of the project.

Methodology and Theoretical Orientation: An overview of the APHRODITE device is initially presented with a focus on the key aspects of its principle of operation. In addition, the design process of the core magnet subsystem is presented, including different configurations, evaluations through simulations, manufacturing, integration with the other subsystems and testing of the resulting device.

Findings: The presented and tested magnetic subsystem design reached the expected performance of operation, proving the validity of APHRODITE principle of operation that will enable new research on the astronaut of the ISS.

Conclusion & Significance: Aphrodite is enabling human exploration in space. Once validated in flight, APHRODITE could immediately be used in many studies conducted on the ISS to investigate the effect of the space environment on the human organism. It could also be adapted to the determination of other biomarkers of interest, since it is a reconfigurable device. In addition, APHRODITE has strong commercial and technological transfer potential. The system is designed for use in the space environment, but its characteristics are suitable for many applications on Earth.

The development and testing of the Ground Model (GM) will continue according to the launch schedule that will bring the device in space in 2025.

Biography

Nithin Maipan Davis is an accomplished aerospace engineer specializing in cube satellite subsystem design and testing. Currently holding a research grant at Scuola di Ingegneria Aerospaziale – Università degli Studi "La Sapienza" in Rome, Italy, he focuses on microfluidic chip design and system engineering for the Aphrodite Project, utilizing tools like SolidWorks and Valispace. Previously, as a Junior Research Scholar at the same institution, Nithin contributed to the Astro Bio Cube Satellite project, excelling in antenna system testing, PCB design, wiring harness development, and software GUI creation. He holds a master's in aerospace engineering from Sapienza University, where his thesis showcased his expertise in antenna design and telemetry data analysis. Proficient in various software tools, project management, and multilingual communication.

About research topic

The authors acknowledge the Italian Space Agency (ASI) that funded the system development and future flight to the ISS in the frame of the programme «Ricerche e dimostrazioni tecnologiche sulla Stazione Spaziale Internazionale – VUS3: ISS4EXPLORATION».

This research introduces APHRODITE, a novel biosensor designed for the ISS, addressing the need for in-flight medical diagnostics in deep space missions. APHRODITE analyzes cortisol and DHEA levels in astronaut saliva, vital for monitoring immune system changes. Its innovative design combines a lab-on-chip with functionalized microbeads and a meticulously tested magnetic subsystem. APHRODITE's successful testing validates its potential for enhancing space exploration. Beyond space, this technology holds commercial and terrestrial applications. Scheduled for a 2025 launch, the Ground Model (GM) development ensures its readiness for space deployment.

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About institution

The School of Aerospace Engineering of the "La Sapienza" University of Rome is responsible for the coordination and supervision of the project. By virtue of its natural vocation, the research experiences of the School of Aerospace Engineering fit exclusively in the field of space experimentation from the study of space missions to the development of new hardware and software components up to the creation of complete satellite systems. The research activity of the School of Aerospace Engineering includes numerous scientific collaborations with national and international research groups and companies engaged in scientific research and technological activities in the Space field, in particular: Telespazio, Thales Alenia Space, Kayser Italia Srl, Gauss Srl, National Institute of Astrophysics, National Research Council, University of Bologna, Polytechnic of Milan. These collaborations are demonstrated by joint participation in research projects and scientific publications. The school has several experiences in development of lab-on-chip devices for space applications through the participation in several projects supported by ASI like PLEIADES, Astro Bio CubeSat, and APHRODITE.

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