ASTROBIO-CUBESAT: A HIGHLY INTEGRATED LABORATORY TO TEST IN SPACE IMMUNOASSAY TECHNIQUES TO DETECT BIOMOLECULES. J.R. Brucato, A. Nascetti, L. Iannaccoli, A. Meneghin, D. Pagliula, G. Poggioli, S. Pirrotta, C. Pacelli, G. Impresario, S. Carletta, L. Schirone, M. Anfossi, M. Mirasoli, D. Calabria, L. Popova, A. Donati, A. Bardi, M. Balsamo; 1INAF-Astrophysical Observatory of Arcetri, largo E. Fermi n.5, 50125 Firenze, Italy (john.brucato@inaf.it), 2School of Aerospace Engineering, Sapienza University, Roma, Italy, 3ASI - Italian Space Agency, Roma, Italy, 4Department of Chemistry, University of Torino, Torino, Italy 5Department of Chemistry "G. Ciamician", University of Bologna, Bologna, Italy 6Kayser Italia S.r.l., Livorno, Italy

Introduction: AstroBio CubeSat (ABCS) is a 3U CubeSat (100×100×340 mm) selected by European Space Agency (ESA) to be launched on fall 2020 with the Vega C qualification maiden flight, as a piggy back of the ASI LARES2 satellite. The main objective of ABCS is to test in harsh Earth orbit environment an innovative Lab-on-Chip (LoC) technology which addresses the search for molecular evidences of life in space. The LoC is based on enzymatic biomimicking assays coupled with chemiluminescence detection (Figure 1) [1, 2]. The chosen approach should constitute the first step to implement a mature technology with the aim to check the stability of chemicals and biomolecules involved in the experiment in space.

Figure 1: schematic representation of biosensor Lab-on-Chip with integrated a-Si:H photosensors.

ABCS structure and goals: ABCS has a 3U Cubesat structure made in Al5046. The payload consists of a LoC inserted in a readout board, together with an interface board containing peristaltic pumps and drivers for pumps, Radiation Field Effect Transistors (RADFETs) and pressure/temperature sensors. Peristaltic pumps are controlled by drivers while injecting fluid in the LoC (Figure 2). The payload is placed inside a pressurized box, shown in Figure 3. Pressurization ensures fluids to be kept in the liquid phase.

The mission objective is to test in space environment a highly integrated laboratory using immunoassay techniques exploiting chemiluminescence detection.

The experiment will consist in a set of microfluidic paper-based analytical device (µ-PAD) on cellulose support with immobilized biomolecules targets. Liquid reagents will solubilize and be transported on targets, triggering specific reactions and allowing chemiluminescence reactions to be detected by photodiodes placed on reaction sites. The readout board will perform photocurrent measurements. The mission aims at evaluating the overall system functionality in an extremely harsh environment such as: handling of liquids in microgravity, chemicals and biomolecules stability in space, LoC and photocurrent characterization, readout noise evaluation.

In addition to RADFETs, ABCS mounts four Ancillary Radiation Dose Sensors (ARDS) developed by Thales. ABCS harsh mission environment is perfect to assess the radiation dose these components can take before failure. Each component flows current depending on the radiation dose until component failure. ARDS provides additional data to better assess radiation dose effects.

ABSC Project is funded and managed by the Italian Space Agency (ASI) in cooperation with INAF-Astrophysical Observatory of Arcetri. Partners of the projects are the School of Aerospace Engineering of Sapienza University of Roma, which was involved mainly in the technological aspects, the University of Bologna and the University of Torino, which addressed science issues and solution approaches of the experiment, and SME Kayser Italia which contributed to ABCS project with their know-how in space system integration and engineering aspects.

ABCS mission design and operations: ABCS will be deployed in an approximately circular orbit at about 5900 km altitude and 70° of inclination, spending a significant amount of the orbital period within the internal Van Allen belt, very close to its radiation peak point.

Simulations on radiation dose are made considering 2 hours from the launch until the deployment (according to LARES2 releasing approx. 5000 seconds after the launch). The simplified model takes into consideration the dose collected at the center of an aluminum sphere.
representing the payload box. We considered a worst case of two hours stay at an altitude of 3500 km on an equatorial orbit, where radiation is larger. The simulation shows that, for the interval between the launch and the deployment, there is a dose of 1613 rad for 24 hours: this means about 134 rad for 2 hours. Considering then the nominal orbit of 70° at 5840 km of altitude the corresponding radiation dose is 1661 rad.

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The Figure 4 shows an example of access to ABCS from Rome with coverage over a 7 days period. The time period represented is in April 2021. Further analyses showed that similar patterns occur regardless the time period during the whole year.

The main challenge in ABCS mission is to mitigate the effects of the expected very high flux of charged particles. In addition, given all the requirements of a biological payload, keeping temperature and pressure within requirement range to prevent reagents degradation represents one more challenge.

These criticalities required a series of innovative technological solutions. The pressurized environment is ensured within an inner aluminum box, hosting both the experiment and the main subsystems (batteries, on-board data handling, telemetry, tracking and control), hermetically sealed and providing shielding from radiation and charged particles (Figure 3). A thermal control system (insulation and an active heather) is also present inside the pressurized box, maintaining the temperature in the desired range.

The in-orbit validation of the proposed technology would represent a significant breakthrough for autonomous execution of bio-analytical experiments in space, with potential application in search for signs of life in planetary exploration missions, space bio-laboratories without human support and health monitoring in manned missions.

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