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Biological assessment of Ariane 5 fairing

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Abstract

United Nations Space Treaties [United Nations, Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, 610 UNTS 205, resolution 2222(XXI) of December 1966., United Nations, Agreement Governing the Activities of States on the Moon and Other Celestial Bodies, UN doc A/RES/34/68, resolution 38/68 of December 1979.] require the preservation of planets and of Earth from contamination. All nations part to these Treaties shall take measures to prevent forward and backward contamination during missions exploring our solar system. As observer for the United Nations Committee on Peaceful Uses of Outer Space, the COSPAR (Committee of Space Research) defines and handles the applicable policy and proposes recommendations to Space Agencies [COSPAR Planetary Protection Panel, Planetary Protection Policy accepted by the COSPAR Council and Bureau, 20 October 2002, amended 24 March 2005. http://www.cosparhq.org/scistr/PPPolicy.htm.]. The goal is to protect celestial bodies from terrestrial biological contamination as well as to protect the Earth environment from an eventual biohazard which may be carried by extraterrestrial samples or by space systems returning to Earth. According to the applicable specifications, including in our case the French requirements [CNES, System Safety. Planetary Protection Requirements. Normative referential CNES RNC-CNES-R-14, CNES Toulouse, ed. 4, 04 October 2002.], the prevention of forward contamination is accomplished by reducing the bioburden on space hardware to acceptable, prescribed levels, including in some instances system sterilization, assembling and integrating the appropriate spacecraft systems in cleanrooms of appropriate biological cleanliness, avoiding or controlling any recontamination risk, and limiting the probability impact of space systems. In order to prepare for future exploration missions [Debus, A., Planetary protection: organization requirements and needs for future planetary exploration missions, ESA conference publication SP-543, pp 103–114, 2003.], and in particular for missions to Mars requiring to control the spacecraft bioburden, a test program has been developed to evaluate the biological contamination under the fairing of the Ariane 5 launcher.

Keywords: Planetary protection; Ariane 5; Biological assessment; Bacterial spores

1. Goal of the tests

Bacterial spore assessments have been performed under the fairing of the Ariane 5 launcher during the last days of the Rosetta mission launch campaign. The measurements were taken after the spacecraft encapsulation until the roll-out of the launcher to the launch pad. After the spacecraft encapsulation, it is no longer possible to assess its recontamination. The only way to avoid its recontamination is to protect it by implementing a bioshield jettissoned in flight. But a bioshield is additional mass and needs additional operations, impacting the mass budget, the reliability of the mission, and finally the cost. Taking into account that some landing missions on Mars require a reduction of the surface bioburden, but not sterilization (e.g. missions to non special regions and missions not investigating for present Mars life; category 4a per COSPAR policy); and that adding a bioshield could be very difficult to implement

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for some spacecraft configurations, it would be desirable to find better alternatives for limiting spacecraft recontamination. This would require the ability to predict the recontamination level under the fairing, and to develop an appropriate recontamination budget in the bioburden control plan to ensure that biological contamination specification at launch are met (Debus, 2006). The goal of our test program is to demonstrate the feasibility of such measurements and to provide a preliminary evaluation of bacterial spore levels at different times under the fairing.

2. Context

Rosetta is a cometary mission. It is a category 2 mission according to the COSPAR classification (COSPAR Planetary Protection Policy, 2002). For this reason, the spacecraft did not require any active bioburden reduction, meaning that the test was conducted under worst case conditions, without biological cleanliness measures. The test was accommodated in parallel with the activities of the launch campaign, and all priorities were given to these latter activities. The schedule, the different exposure times of witness plates, the number and location of access doors to the fairing were imposed by the launch campaign authorities. The configuration of the spacecraft under the fairing did not enable swabbing of spacecraft surfaces. Only three fairing doors were usable. With these conditions, the measurements were made indirectly by e means of biological witness plates collecting bacterial spores inside the fairing at each door level. This test was consequently a feasability study giving only an evaluation of the bioburden level inside the fairing, and any extrapolation of these results to the entire fairing was very approximate. Prior to encapsulation, the internal side of the fairing was wiped with IPA (isopropylic alcohol) according to the standard procedures. Consequently, the bacterial spores collected on the witness plates came mainly through the fairing ventilation system and from the spacecraft itself.

3. Test procedure

3.1. Biological contamination witness plates

The bacterial spores have been collected using the frames as shown in Fig. 1. Each frame was built in aluminium alloy and designed with windows in order to receive two biological contamination witness plates, having each a surface of 300 cm^2, made with sheets of Tyvek®. The frames were screwed on metallic arms interfacing with the internal side of each of the fairing doors, and were exposed to the fairing environment after the doors were closed. They were designed so that, after exposure, it was easy to open the frames to remove and store the witness plates quickly under sterile conditions. It was also possible to assess outside environments by laying the sampling frame directly on tables. Before their use, all frames, entirely equipped with the witness plates, were sterilized by autoclaving (steam sterilization 121 °C, 30 min, 2 bars) at the Institut Pasteur of Cayenne inside special bags opened just before their use.

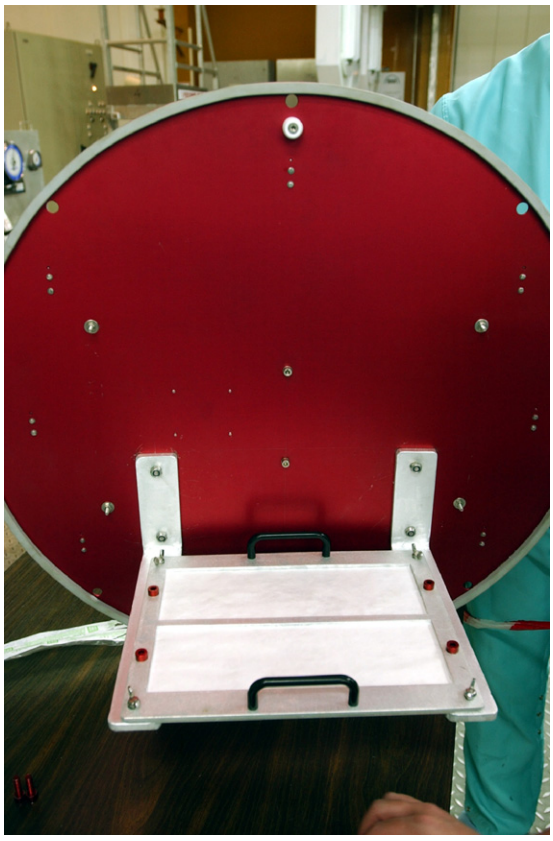

Fig. 1. Biological witnesses system on a fairing door (photo CNES/Arianespace).

3.2. Bacterial spore collection and enumeration

After their exposure to each defined environment, each sampling frame was immediately opened. The two biological contamination witness plates were removed with sterile pincers and placed individually into sterile bags, and shipped to the Institut Pasteur in Cayenne in order to prepare the spore culture with a maximum delay of 6 h. There, the culture and spore enumeration (aerobes and anaerobes) were performed according to the standard procedures equivalent to the ones of NASA, 1999 (NPG 5340.1B), including the heat shock (15 min/80 °C in order to kill all vegetative microorganisms), the use of sonication in order to release the bacterial spores in flasks of sterile water, the use of TSA (Trypto Caseine Soja) as culture media, the incubation at 37 °C of one half of the Petri dishes in aerobic conditions, one half in anaerobic conditions, and lastly, the enumeration after 24, 48 and 72 h.

3.3. Calculation of contamination levels

The results have been corrected with three factors. First, the analysis and culture procedures were assessed by ana-