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Sample Canister Capture Mechanism for Mars Sample Return: Functional and environmental test of the elegant breadboard model ☆

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ABSTRACT

The paper provides recent updates about the ESA study: Sample Canister Capture Mechanism Design and Breadboard developed under the Mars Robotic Exploration Preparation (MREP) program. The study is part of a set of feasibility studies aimed at identifying, analysing and developing technology concepts enabling the future international Mars Sample Return (MSR) mission. The MSR is a challenging mission with the purpose of sending a Lander to Mars, acquire samples from its surface/subsurface and bring them back to Earth for further, more in depth, analyses. In particular, the technology object of the Study is relevant to the Capture Mechanism that, mounted on the Orbiter, is in charge of capturing and securing the Sample Canister, or Orbiting Sample, accommodating the Martian soil samples, previously delivered in Martian orbit by the Mars Ascent Vehicle. An elegant breadboard of such a device was implemented and qualified under an ESA contract primed by OHB-CGS S.p.A. and supported by Politecnico di Milano, Department of Aerospace Science and Technology: in particular, functional tests were conducted at PoliMi-DAST and thermal and mechanical test campaigns occurred at Serms s.r.l. facility. The effectiveness of the breadboard design was demonstrated and the obtained results, together with the design challenges, issues and adopted solutions are critically presented in the paper. The breadboard was also tested on a parabolic flight to raise its Technology Readiness Level to 6; the microgravity experiment design, adopted solutions and results are presented as well in the paper.

1. Introduction

The Mars Sample Return (MSR) is an international endeavour mission to return samples from Mars surface to Earth. Several MSR mission architectures have been studied in the past years [1]; current approach (iMARS Phase 2) proposes to implement dedicated mission spacecraft elements spread in time over a sequence of launches: e.g. a Caching rover, a Mars orbiter including the Earth Return Vehicle and a Surface element, called Lander, including the Ascent Vehicle. In this architecture, the caching rover will be placed on Mars surface and a robotic system will collect samples of Martian rocks, soils and atmosphere. Once these samples have been collected, they will be loaded within an Orbiting Sample (OS) canister and the Ascent Vehicle will launch it from Martian surface into orbit.

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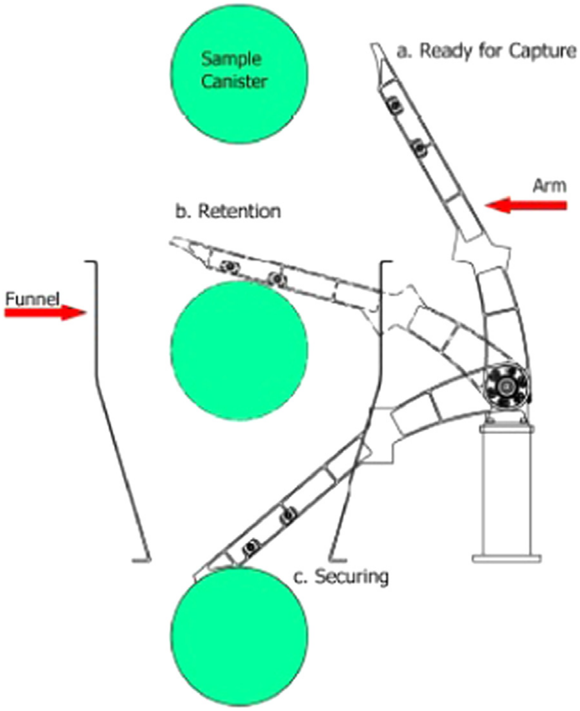

Fig. 1. SCCM operative modes.

After that, the orbiter waiting in Mars orbit will perform a rendezvous manoeuvre to capture the OS and secure it within the Earth re-entry capsule. Subsequently, the latter will return to Earth following a ballistic trajectory. In this context, the Sample Canister Capture Mechanism (SCCM) will be the robotic device aimed at ensnaring and securing the OS during the rendezvous manoeuvre; Fig. 1 shows the phases of the OS capture: starting from the Ready for capture configuration, once the OS enters the funnel, the arm starts closing to the retention configuration preventing the OS from escaping. The operation are concluded with the arm moving to the securing position thus driving the OS inside the Earth re-entry capsule.

Previous studies [2,3] investigated such a technology considering different concepts; this design activity, performed under the ESA Study "Sample Canister Capture Mechanism Design and Breadboard" [4], aimed at validating an alternative concept able to avoid the drawbacks of the previous solutions. The critical requirements driving the SCCM design are:

- OS mass of 6 kg;
- incoming velocity range of 5–15 cm/s;
- angular misalignment from nominal trajectory up to 5°;
- radial offset from nominal trajectory up to 10 cm;
- capture procedure completed in less than 90 s;
- SCCM resettable within 60 s from activation;
- maximum stowed envelop of 800 × 800 × 500 cm;
- lowest stowed natural frequency greater than 100 Hz;
- autonomous capture operation.

The present work takes place in the framework of an ESA contract primed by OHB-CGS and supported by Politecnico di Milano – Department of Aerospace Science and Technology aimed at:

- SCCM Elegant Breadboard Model MAIT;
- Ground functional tests;
- Environmental tests (thermal-vacuum and mechanical vibration tests);
- Flight test campaign on Parabolic Flight.

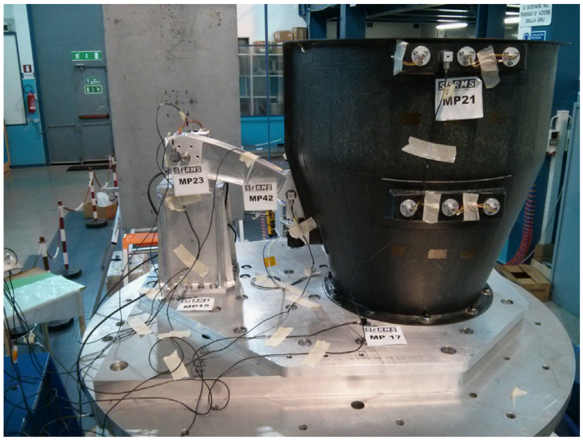

Fig. 2. Elegant Breadboard Model, as built.

2. Breadboard manufacturing, assembly and integration

The Elegant Breadboard Model (EBM) was designed to be as representative as possible of the Flight Capture Mechanism (FCM) in order to guarantee the applicability of the tests results to the designed concept; in particular the EBM provides the key functionalities (e.g., arm operations) and performances (e.g., arm speed, operations duration) of the flight model. Components as the motor, the OS detection sensors (optical instruments) on the funnel and the Hold Down Release Mechanism (HDRM) selected for the EBM have the same functionalities of the FCM ones but were not space proven for procurement issues. The EBM was assembled and integrated at PoliMi-DAST, in particular the Funnel is made of CFRP, the Support Tower, the Arm and the Baseplate are Aluminium parts and the Actuation Chain is composed of Aluminium and Steel parts. The optical instruments were provided by CISAS together with their own electronics while the DC motor was purchased from Phytron GmbH. With respect to the previous EBM design [4] the motor changed, therefore some modifications were implemented to cope with the new mechanical test requirements; in particular the Support Tower and the Motor Interface Flange were extensively reshaped in order to improve the frequency response while reducing the acceleration levels of the Breadboard under qualification vibrational tests. These modifications, verified during the tests presented in this paper, shall be implemented on the Flight Capture Mechanism (Fig. 2).