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MarcoPolo-R mission

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Abstract

MarcoPolo-R is a sample return mission to a primitive Near-Earth Asteroid (NEA) selected for an assessment study at ESA in the framework of ESA Cosmic Vision 2 program.

MarcoPolo-R will rendezvous with a primitive NEA, scientifically characterize it at multiple scales, and return a unique sample to Earth unaltered by the atmospheric entry process or terrestrial weathering.

1. Introduction

Small bodies, as primitive leftover building blocks of the solar system formation process, offer clues to the chemical mixture from which the planets formed some 4.6 billion years ago. In addition, they retain material that predates the solar system and contains evidence for interstellar processes and its original formation in late-type stars.

Current exobiological scenarios for the origin of life on Earth invoke an exogenous delivery of organic matter: primitive bodies could have brought these complex organic molecules capable of triggering the pre-biotic synthesis of biochemical compounds on the early Earth. Moreover, collisions of NEAs with the Earth pose a finite hazard to life. For all these reasons, the exploration of such objects is particularly interesting and urgent.

The main goal of the MarcoPolo-R mission is to return unaltered NEA material for detailed analysis in ground-based laboratories. The limited sampling provided by meteorites does not offer the most primitive material available in near-Earth space. More primitive material, having experienced less alteration on the asteroid, will be more friable and would not survive atmospheric entry in any discernible amount. Moreover, the limited amount of samples successfully returned by the JAXA mission Hayabusa are identified as coming from a highly processed S-type asteroid.

MarcoPolo-R will allow us to study the most primitive materials available to investigate early solar system formation processes. Moreover, MarcoPolo-R will provide a sample from a known target with known geological context. Direct investigation of both the regolith and fresh interior fragments is also impossible by any means other than sample return. MarcoPolo-R will answer the fundamental scientific questions as outlined in Figure 1.

2. The project

This project is based on the previous Marco Polo mission study, which was selected for the Assessment Phase of the first round of Cosmic Vision. Its scientific rationale was highly ranked by ESA committees, and it was not selected to proceed to the next step because the estimated cost was higher than the allotted amount for an M-class mission. For MarcoPolo-R, a potential NASA contribution is proposed, with a US consortium including the APL - John Hopkins University, JPL, NASA ARC, NASA LaRC, and MIT.

The baseline target is a binary asteroid (175706) 1996 FG3, which offers a very efficient operational and technical mission profile. A binary target also provides enhanced science return. The choice of this target will allow new investigations to be performed more easily than at a single object, and also enables investigations of the fascinating geology and geophysics of asteroids that are impossible at a single object. Several launch windows have been identified in the time-span 2020-2024. A number of other possible primitive single targets of high scientific interest have been identified covering a wide range of possible launch dates. The baseline mission scenario of MarcoPolo-R to 1996 FG3 is as follows:

A single primary spacecraft, carrying the Earth re-entry capsule and sample acquisition and transfer system, will be launched by a Soyuz-Fregat rocket from Kourou into GTO.

Two similar missions for the baseline target with two launch windows, in 2021 and 2022 and for both sample return in 2029, have been defined. Earlier or

later launches, in 2020 or 2024, also offer good opportunities.

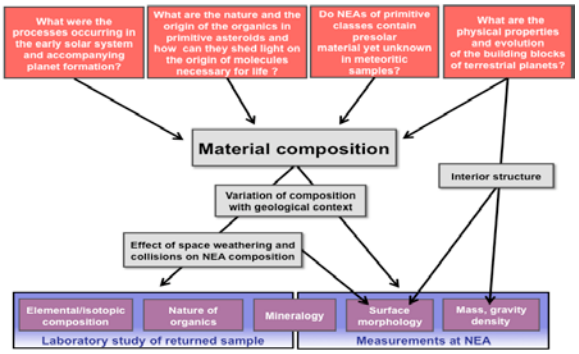

Fig. 1. Logical flow to answer to the fundamental question

Once at the NEA, a number of potential sampling sites are characterized by remote sensing measurements. The spacecraft will then attempt to sample surface material on the most suitable site (*i.e.* the location yielding the best compromise between science return and risk-mitigation). The spacecraft will then continue performing orbital science, or will wait in a safe position until it departs from the asteroid and returns to Earth. The scientific payload includes state-of-the-art instruments, e.g. a camera system for high resolution imaging from orbit and on the surface, spectrometers covering visible, near-infrared and mid-infrared wavelengths, a neutral-particle analyzer, a radio science experiment and optional laser altimeter. If resources are available, an optional Lander will be added to perform in-situ characterization close to the sampling site, and possibly internal structure investigations.

MarcoPolo-R takes advantage of three industrial studies completed as part of the previous Marco Polo mission (see ESA/SRE (2009)3, Marco Polo Yellow Book) and of the expertise of a consortium already worked on the NASA NEAR Shoemaker mission.

4. Conclusions

MarcoPolo-R will return bulk samples from an organic-rich binary asteroid to Earth for laboratory analyses, allowing us to:

• explore the origin of planetary materials and initial stages of habitable planet formation;

• identify and characterize the organics and volatiles in a primitive asteroid;

• understand the unique geomorphology, dynamics and evolution of a binary NEA.

In addition to addressing the exciting science goals, the MarcoPolo-R mission also involves technologies for which technical development programmes are well under way. It is the ideal platform to (i) demonstrate innovative capabilities such as: accurate planetary navigation and landing, sample return operational chain; (ii) prepare the next generation of curation facilities for extra-terrestrial sample storage and analysis; (iii) develop high speed re-entry capsule; (iv) pave the way as a pathfinder mission for future sample returns from bodies with high surface gravity.

MarcoPolo-R will ensure that European laboratories involved in sample analysis remain world class facilities spanning the entire breadth of expertises required for the science success of the mission.

The public outreach possibilities of MarcoPolo-R are considerable because of the enormous fascination of the general public for asteroids. On the strategic and political front there is also a considerable interest in prediction and mitigation of an NEA impact.

The assessment study is started at ESA on May 2011 and will continue until middle 2013. In this timeframe independently two European industries will study in detail the project. A particular care will be also devoted to consolidate the European and US collaboration to bring this mission feasible.

The possibility for participation as an ESA Mission of Opportunity to the NASA sample return mission OSIRIS-REx will be also analysed as a possible precursor.

Acknowledgements

We are grateful to all European supporters of MarcoPolo-R (560 on April 18th, 2011). The list is continuously updated on the following web site: http://www.oca.eu/MarcoPolo-R/

References

[1] ESA/SRE(2009)3, Marco Polo Yellow Book.