MARCO POLO: A NEAR EARTH OBJECT SAMPLE RETURN MISSION. M. A. Barucci[1], M. Yoshikawa[2], P. Michel[3], J. Kawaguchi[2], H. Yano[2], J. R. Brucato[4], I. A. Franchi[5], E. Dotto[6], M. Fulchignoni[7], S. Ulamec[8], H. Boehnhardt[9], M. Coradini[10], S. F. Green[5], J.-L. Josset[11], D. Koschny[12], K. Muinonen[13], J. Oberst[14] and the MARCO POLO science team. [1]LESIA, Paris Observatory, Meudon, France (antonella.barucci@obspm.fr), [2]JSPEC, JAXA, Kanagawa, Japan (makoto@isas.jaxa.jp), [3]Observatoire Côte d'Azur, Nice, France, [4]INAF-OAC, Naples, Italy, [5]PSSRI, Open University, UK (i.a.franchi@open.ac.uk), [6]INAF-OAR, Rome, Italy, [7]Univ. Paris, Diderot, France, [8]DLR, Köln/Berlin, Germany, [9]MPI, Lindau, Germany, [10]ESA, Paris, France, [11]Space-X Explor. Inst., Neuchatel, Switzerland, [12]ESTEC, Noordwijk, Netherlands, [13]Univ. Helsinki Observatory, Finland, [14]DLR, Berlin, Germany.

Introduction: MARCO POLO is a joint European-Japanese sample return mission to a Near-Earth Object. In late 2007 this mission was selected by ESA, in the framework of COSMIC VISION 2015-2025, for an assessment scheduled to last until mid 2009.

This Euro-Asian mission will go to a primitive Near-Earth Object (NEO), such as a C or D type asteroid. The spacecraft will rendezvous with the object, and over an extended period scientifically characterize it at multiple scales and bring samples back to Earth for detailed scientific investigation.

Scientific Objectives: Small bodies, as leftover building blocks of the Solar System formation process, offer important clues to the chemical mixture from which the planets formed some 4.6 billion years ago. Some of these bodies appear to be particularly primitive, rich in organic carbon and composed primarily of aqueously altered, or (pristine?) anhydrous, silicates. It is likely that some of these bodies are the source of the carbonaceous chondrites, from which much of our current knowledge of Solar System formation has been derived. However, our meteorite collections are heavily biased towards tough and coherent specimens that have survived the violent process of atmospheric entry. As a consequence, our collections contain materials that are the result of some combination of thermal and shock metamorphism and aqueous alteration on the parent asteroid. Primitive material less processed on the parent body is likely to be largely destroyed during atmospheric entry – and therefore we anticipate material returned from a primitive asteroid will contain materials without any known meteorite analogue. Such materials offer an un-rivalled opportunity to investigate the pre-cursor materials to the solar system, the processes and chronology in the solar nebula and as accretion progressed.

Pristine samples of the organic-rich material from a primitive asteroid are particularly intriguing. Current exobiological scenarios for the origin of Life invoke an exogenous delivery of organic matter to the early Earth: it has been proposed that primitive bodies could have brought these complex organic molecules capable of triggering the pre-biotic synthesis of biochemical compounds. Returned samples offer an opportunity to explore the spectrum of materials in the Solar System, such as those that cannot be delivered to the surface of the Earth in useful amounts, but may nevertheless be delivered in volume as fine dust.

The surface of an NEO will be a reasonably well mixed regolith, the result of impact processing and disruption – samples of which offer the opportunity to investigate the diversity of materials that are present within such a body. When combined with detailed knowledge of the geological context ascertained from characterisation of the asteroid at all scales by the orbiting spacecraft this offers a unique insight into the structure and formation processes of a primitive body. Characterisation of the returned samples and the remote data can also be used to establish the links between meteorites and asteroid spectral classes, particularly understanding the effects of space weathering on the materials present on the surface of a primitive asteroid.

The scientific objectives of MARCO POLO will therefore contribute to a better understanding of the origin and evolution of the Solar System, the Earth, and possibly Life itself. Indeed, MARCO POLO will also provide critical information on the volatile-rich (e.g. water) nature of primitive NEOs, which may be particularly important for future space resource utilization. Moreover, collisions of NEOs with the Earth pose a finite hazard to Life. For all these reasons, the exploration of such objects is particularly critical and urgent.

Mission Scenario: MARCO POLO is a proposal offering several options, leading to great flexibility in the actual implementation. The baseline mission scenario is based on a launch with a Soyuz-type launcher and consists of a Mother Spacecraft (MSC) carrying a possible Lander named SIFNOS, small hoppers, sampling devices, a re-entry capsule and scientific payloads. There are a considerable number of primitive NEOs that are good candidate targets, fulfilling the principle criteria of spectral type, orbit, size, ground-based viewing opportunities in the near future, etc. Detailed mission scenarios are being explored for maximum scientific return.

For all of the targets, the MSC leaves Earth orbit, cruises toward the target with ion engines, rendezvous with the target, conducts a global characterization of the asteroid, including features such as size, shape, mass, mineralogical and geochemical variation and regolith properties, in order to select a sampling site(s). The MSC can deliver small hoppers (MINERVA type, JAXA) and SIFNOS. The latter, if added, will perform a soft landing, anchor to the target surface, and make various *in situ* measurements of surface/ subsurface materials near the sampling site.

Two surface samples will be collected by the MSC using "touch and go" manoeuvres. Two complementary sample collection devices will be used in this phase: one developed by ESA and another provided by JAXA, mounted on a retractable extension arm. The dual sampling techniques provide the ability to collect the optimum blend of sample characteristics – in terms of number of regolith particles and particle size, stratigraphic integrity, sub-surface material and total sample mass – of the order of 100g.

After completion of the sampling and ascent of the MSC, the arm will be retracted to transfer the sample containers into the MSC. The MSC will then make its journey back to Earth and release the re-entry capsule into the Earth's atmosphere.