NEO Sample Return Mission
« Marco Polo »
Proposal to ESA COSMIC VISION

This proposal, prepared by a joint European Japanese team, is supported by 440 confirmed scientists.

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R.P. Binzel (MIT, Cambridge, USA)
In the early solar nebula, the dust accreted to form planetesimals and the planetesimals accreted to form planetary embryos. In the asteroid belt this process was stopped when Jupiter formed.
Good selected target: the most primitive C or D asteroids
Origin of the Life:

• The planets of the inner Solar System experienced an intense influx of cometary and asteroidal material for several hundred million years after they formed.

• The earliest evidence for life on Earth coincides with the decline of this enhanced bombardment. The fact that the influx contained vast amounts of complex organic material offers a tantalising possibility that it may be related to the origin of life.
Main questions:

1) What were the initial conditions and evolution history of the solar nebula?

2) Which were the properties of the building blocks of the terrestrial planets?

3) How did major events (e.g. agglomeration, heating, ...) influenced the history of planetesimals?

4) Do primitive class objects contain presolar material yet unknown in meteoritic samples?

5) What are the organics in primitive materials?

6) How NEO organics can shed light on the origin of molecules necessary for life?

7) What is the role of NEO impacts in the origin and evolution of life on Earth?
Scientific objectives of a NEO SR

What are the initial conditions and evolution history of the solar nebula?

Composition of primitive material

- How NEOs and meteorites are related together?
- Which are the properties of the building blocks of terrestrial planets?
- What is the role of NEO impacts in the origin of life?

How does composition vary with geological context?

How do space weathering and collisions affect NEO composition?

Elemental/Isotopical composition
Nature of organics
Mineralogy
Surface morphology
Mass, gravity density
Internal structure

Interior

Lander

Orbiter

Sample collection & return
MARCO POLO
Baseline scenario (Option 1)

Launching Operations

Earth

Cruise phase:
- Spacecraft
- Propulsion module
- Sampling system
- ERC

Science phase:
- Landing and sampling

Mapping:
- Remote sensing package

In situ analyses:
- Operations

Return phase:
- Lander

Re-entry phase:
The accessibility of NEOs

NEA ACCESSIBILITY H-Plot
Sample Update 02/2007: 3238 objects with H<22

NEA population (H<22)
short-period comets
dormant comets
NEAs visited
SR mission targets

NEA population (H<22)
short-period comets
dormant comets
NEAs visited
SR mission targets
Baseline Marco Polo to 4015 Wilson-Harrington

Launcher: Soyuz Fregat
(indirect injection)
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<th></th>
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<th></th>
<th>D</th>
<th>C - type</th>
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<td>2001 SG 286</td>
<td>0.3-0.5</td>
<td>D - type</td>
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Choice & characterization of the sampling site

Dust Monitor
- Laser Altimeter
- MIR Spectrometer

Dust Environment
- Orbital & Rotational Evolution
- Morphology, Topography
- Macroscale Dust & Regolith
- Size, Shape, Mass, Gravity, Density
- Internal Structure, Stratigraphy

Macroscale composition
- Macroscale Mineralogy

Descent Camera

Hi-Res Camera

Radio Science

V-NIR Spectrometer

Lander


Volatile Detector

Thermal sensors
- Electron microscope
- XRD/XRF

Texture
- Thermal properties
- Microscale Dust, & Regolith
- Elemental composition
- Microscale Mineralogy
- Microscale chemical comp.
- Sub-surface volatiles

Main Spacecraft

Science
- Dust Environment
- Orbital & Rotational Evolution
- Morphology, Topography
- Macroscale Dust & Regolith
- Size, Shape, Mass, Gravity, Density
- Internal Structure, Stratigraphy
- Macroscale composition
- Macroscale Mineralogy
- Texture
- Thermal properties
- Microscale Dust, & Regolith
- Elemental composition
- Microscale Mineralogy
- Microscale chemical comp.
- Sub-surface volatiles
**The First Descent: Lander Release**

1. Target Marker #1
2. ESA Lander

**Asteroid Surface**

**Lander: Philae heritage**

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**The Second Descent: Touch & Go Sampling**

1. Arm Extended
2. Target Marker #2
3. Touch Down & Sampling with Shock Absorption with Joints

**Asteroid Surface**
Telescopic mast for sampling devices

The Storable Tubular Extendable Member (STEM™) is a unique product with over 30 years of space flight heritage.

- Locks in place when deployed
- Retractability feature
- Light and volume efficient
- Sized to fit various strengths and stiffness based on needs

Length: up to 14 m
Diameter: 16 cm
Mass: 12.8 kg

Example from Northrop Grumman (model 7301)
Sequence of Sample Container Insertion to the Capsule

(1) Capsule
- ESA Pad
- Bio-Sealing
- First Lid
- JAXA Container
- Bi-Stem Arm Retraction

(2) First Insertion
- First Lid

(3) Bio-Seal

(4) Second Insertion

(5) Latch & Capsule Sealing
Laboratory investigation:

High spatial resolution and analytical precision are needed:

• Examples of the type of sample processing include preparation of polished flat surfaces (for optical, e-beam and ion beam studies), acid dissolution and solvent extraction.

• High precision analyses include determining trace element abundances to ppb levels and isotopic ratios approaching ppm levels of precision, normally with a spatial resolution of a micron or less.

• Such information can only be achieved by large, complex instruments – e.g. high mass resolution instruments (large magnets, high voltage), bright sources (e.g. Synchrotron) and usually requires multi-approach studies in order to understand the nature and history of specific components.
Conclusion:

A sample return mission to a NEO, has the potential to revolutionize our understanding of primitive materials essential to understand the conditions for planet formation and emergency of life.

It can provide us important information needed to develop strategies to protect the Earth from potential hazards.

Moreover robotic sample return mission to NEOs will be pathfinders for sample returns from high gravity bodies and, later on, for human missions that might use asteroid resources to facilitate human exploration and the development of space.
The Lander is named SIFNOS from the Aegean island of Sifnos. During the early Bronze Age (3000 BC), settlers from Asia Minor came to the island of Sifnos and meddled with the inhabitants, developing the Early Western culture.

MARCO POLO, the Venetian marchand and explorer, was mentioning for the first time in Europe the existence of Japan and its culture in the accounts of its travels in China given in its book “Il Milione”.

He was referring to the Japan as “Cipangu”

The Lander is named SIFNOS from the Aegean island of Sifnos. During the early Bronze Age (3000 BC), settlers from Asia Minor came to the island of Sifnos and meddled with the inhabitants, developing the Early Western culture.
Other possible scenarios, all involving Soyuz Fregat

<table>
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<th>2002AT₄ D type</th>
<th>2001SG₂₈₆ D type</th>
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<th>1999JU₃ C type</th>
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<td><strong>Launch Date</strong></td>
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<td>06/13 2017</td>
<td>07/20 2017</td>
<td>12/21 2016</td>
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<td><strong>Vₘ∞ km/s</strong></td>
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<td>4.1</td>
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<td><strong>Escape Mass</strong></td>
<td>1320</td>
<td>1320</td>
<td>1320</td>
<td>736</td>
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<td><strong>RdV Date</strong></td>
<td>06/06 2020</td>
<td>06/15 2019</td>
<td>04/19 2021</td>
<td>05/16 2018</td>
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<td><strong>Departure Date</strong></td>
<td>09/06 2020</td>
<td>09/15 2019</td>
<td>07/19 2021</td>
<td>11/07 2018</td>
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<td><strong>Departure mass</strong></td>
<td>1057</td>
<td>1048</td>
<td>1090</td>
<td>601</td>
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<td><strong>Re-entry Date</strong></td>
<td>03/29 2024</td>
<td>06/23 2022</td>
<td>05/16 2022</td>
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<tr>
<td><strong>Return vₘ∞ km/s</strong></td>
<td>6.0</td>
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<td>8.35</td>
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<tr>
<td><strong>Mission Duration</strong></td>
<td>~7 years</td>
<td>~5 years</td>
<td>4.8 years</td>
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Increasing the applied force increases the contact with the simulant and thus increases the yield of each sample.

A: 67N;  B: 111N;  C: 160N;  D: 200N
DEIMOS SAMPLE RETURN
Sampling Mechanisms Concept

- Concept: Touch & Go with a collection based on gas injection
  - Touch & Go direct collection: To avoid the anchorage reliability and feasibility concerns
    - Quite unknown soil nature & Weak gravity
    - Reduction of unbalance risk thanks to wide spread pad and penetrator retractability.
  - Sample collected thanks to gas injection
    - A penetrator enters the ground and injects a gas flow
    - The ejected material is guided towards receptacles
    - Sample down to few cm below the surface
  - Compatible with redundancy
  - Access to internal (few cm) materials
Such a Sample Return mission would allow us to perform first-class science investigations and to test/validate the following key innovative functions/technologies relevant:

- Guidance, navigation, control and autonomy approach of the mother spacecraft during the cruise and target approach phases.

- Navigation sensors and control strategies for the soft and precision landing and for the obstacle avoidance (to a limited extend, due to the different gravity and relative dynamics conditions and for the lack of atmosphere).
• Robotic devices (e.g., driller, robotic arms), containers and mechanisms involved in the sample collection, handling, sealing, transfer, storage.

• High-speed reentry capsule and related operations.

• To test new technology developments: on board artificial intelligence, telecommunication, in situ energy, re-entry velocity, planetary protection.....

• To prepare new adequate laboratory facilities for extraterrestrial sample analysis.
MISSION SCENARIO (option 2)

Earth

JAXA
ESA

remote sensing package
spacecraft
propulsion module

NEO

ESA module
release for landing

manoeuvre phase

remote sensing activity
cruise phase

ERC
Lander
SCEM

in situ analyses and sampling
canister ejection
canister migration

science phase

TTC
relay

return phase

manoeuvre phase

canister capture

SCEM: Sample Conditioning and Ejection Mechanism
CCMM: Canister Capture and Migration Mechanism
• The Storable Tubular Extendable Member (STEM™) is a unique product with over 30 years of space flight heritage including programs such as Voyager, GPS IIR, Hubble Space Telescope and Mars Pathfinder. These products are available as the most simple STEM mechanism or the smaller package of the BI-STEM™ or the Interlocked BI-STEM which provides improved torsional rigidity and allows longer deployed lengths.

• STEM has been produced from 12 millimeter to 50 millimeter diameters and is manufactured in beryllium copper for antenna elements and stainless steel for structural applications.
(Modified Spacecraft Configuration for Sub-surface Sampling by Lander)

Earth Return Capsule
Volume for Bio-Sealing
ESA Lander
Canister Catcher
Target Markers

Canister Catcher
Lander Sample Canister
Spacecraft Samplers Retracted
Canister Ejection Mechanism
ESA Lander
Sub-surface Drill
Asteroid Surface

("Catch-Ball" Operation)
(Option 2)