M.A. Barucci

l'Observatoire de Paris — LESIA

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.

Moscow, October 3rd, 2007

Team leaders:

M.A. Barucci (LESIA, Paris Observatory, F)

M. Yoshikawa (JSPEC/JAXA, J)

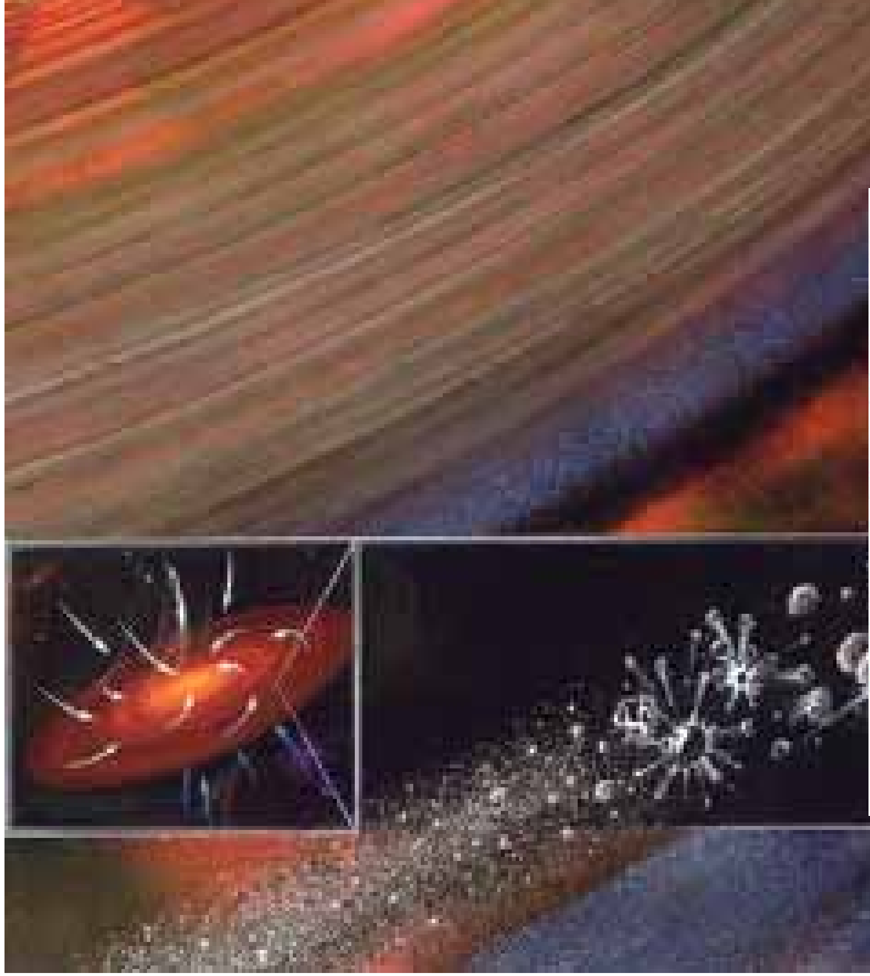
Core members :

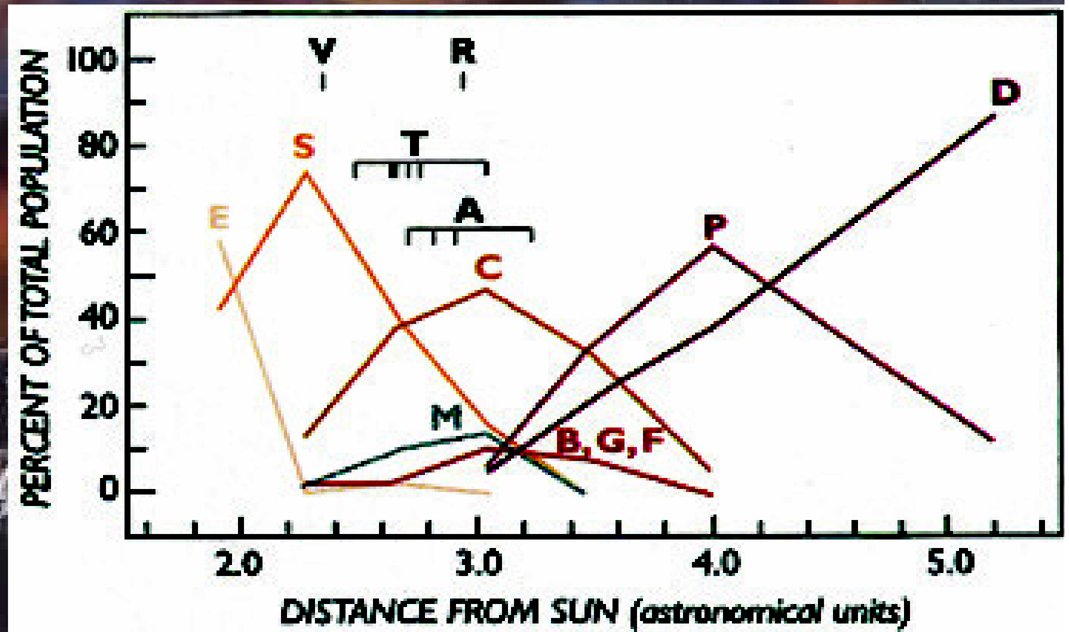
P. Michel (OCA, Nice F), J. Brucato (INAF, Naples I), I. Franchi (Open University, UK), E. Dotto (INAF, Rome I), M. Fulchignoni (Univ. Paris Diderot, F), S. Ulamec (DLR, Koln D, Europe) ;

J. Kawagushi (JSPEC/JAXA), H. Yano (JSPEC/JAXA, Japan) &

R.P. Binzel (MIT, Cambridge, USA)

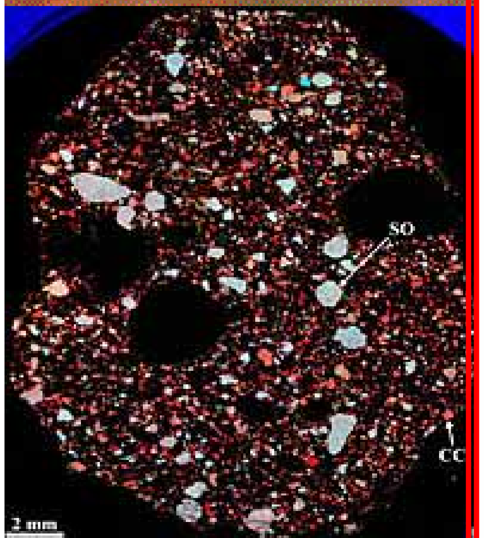
In the early solar nebula, the dust accreted to form planetesimals and the planetesimals accreted to form planetary embryos. In the asteroid belt this process was stopped when Jupiter formed.

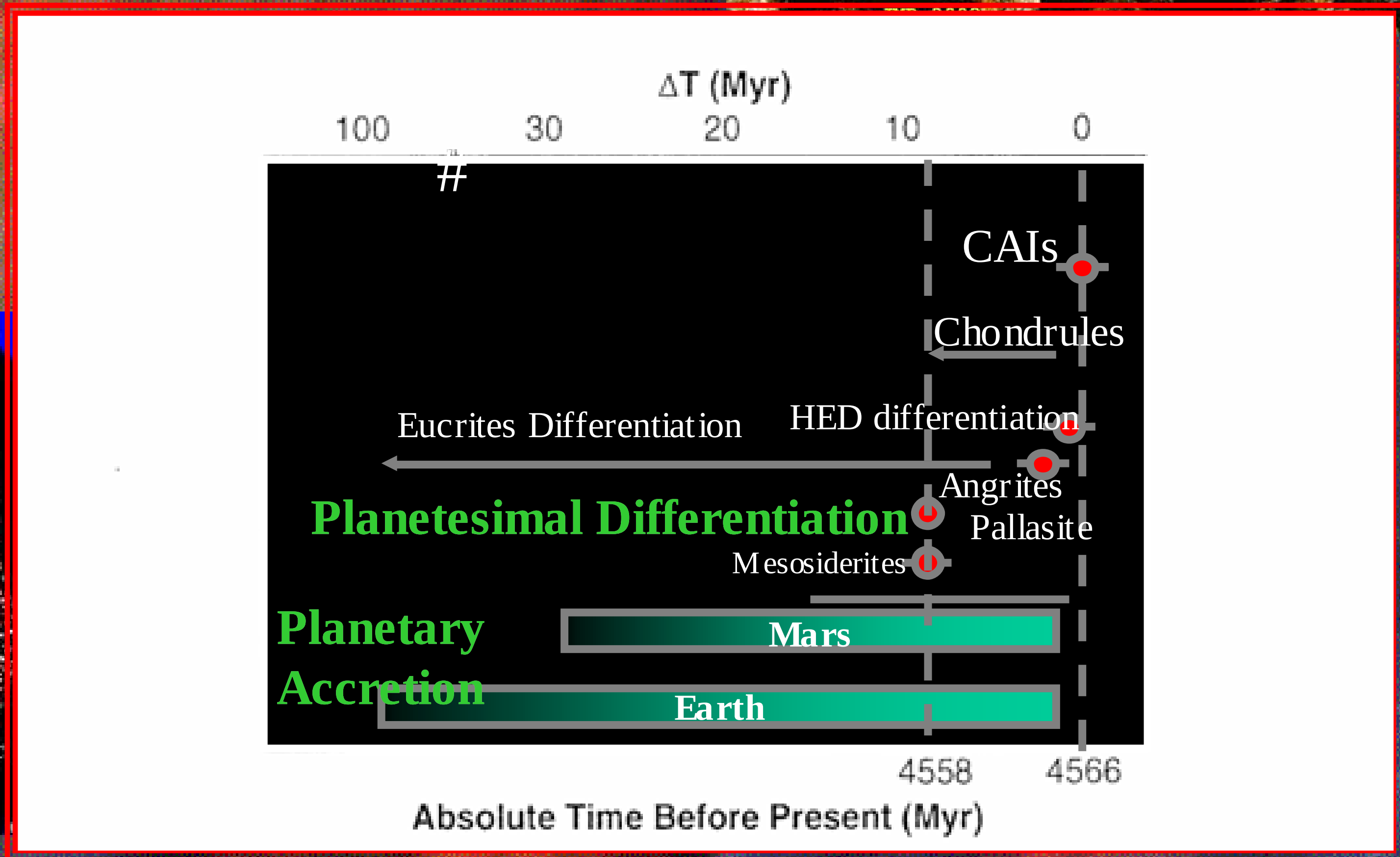


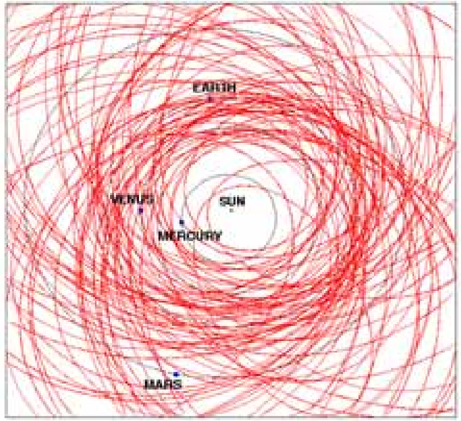


Good selected target:

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?

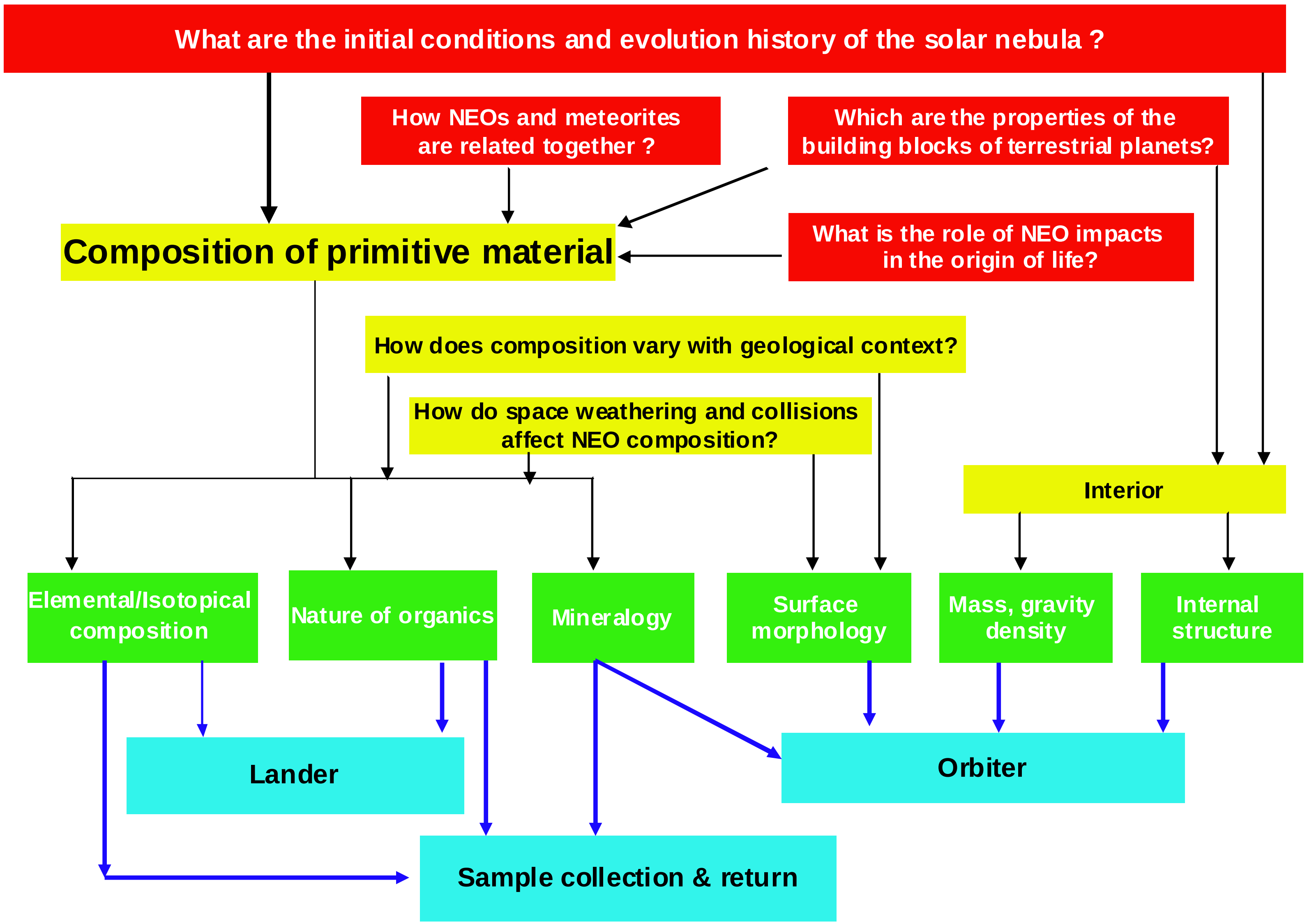
4) Do primitive class objects contain presolar material yet unknown in meteoritic samples?

5) What are the organics in primitive materials?

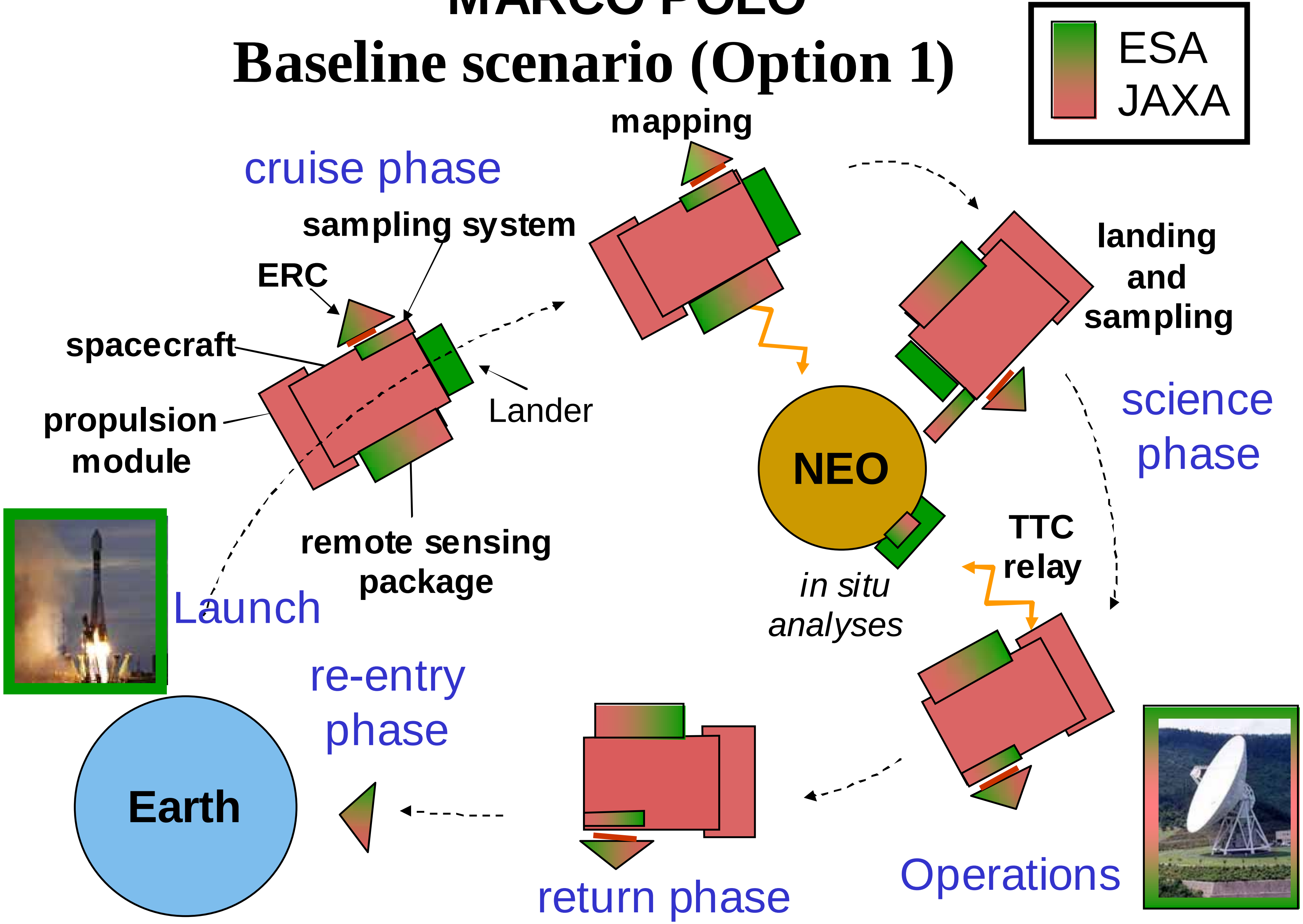
6) How NEO organics can shed light on the origin of molecules necessary for life?

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

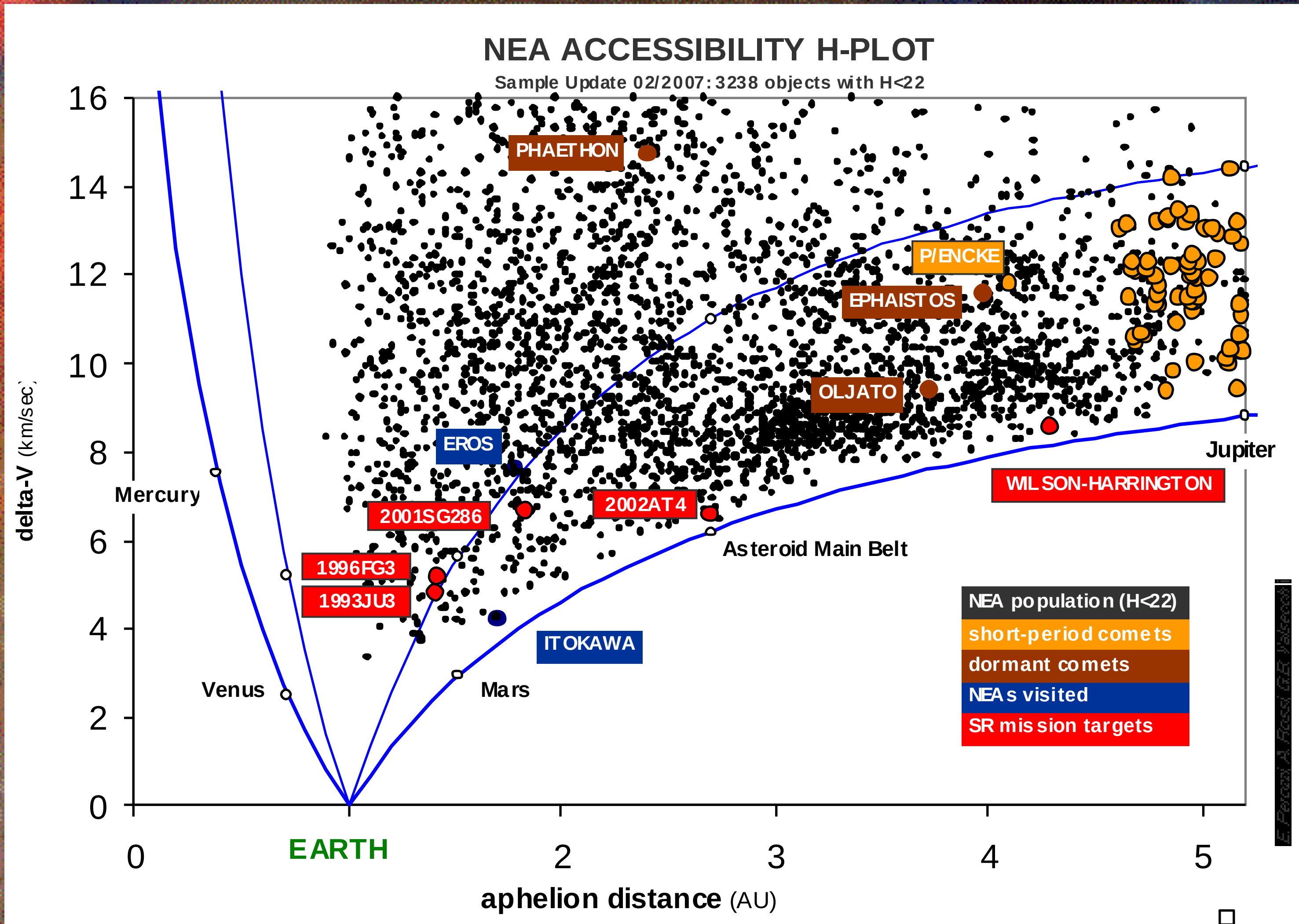
Scientific objectives of a NEO SR



MARCO POLO
Baseline scenario (Option 1)

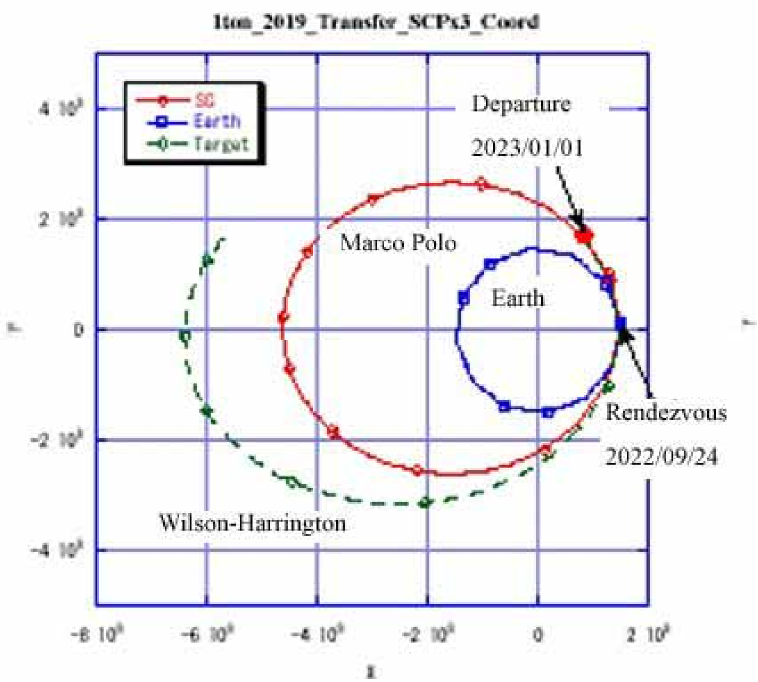


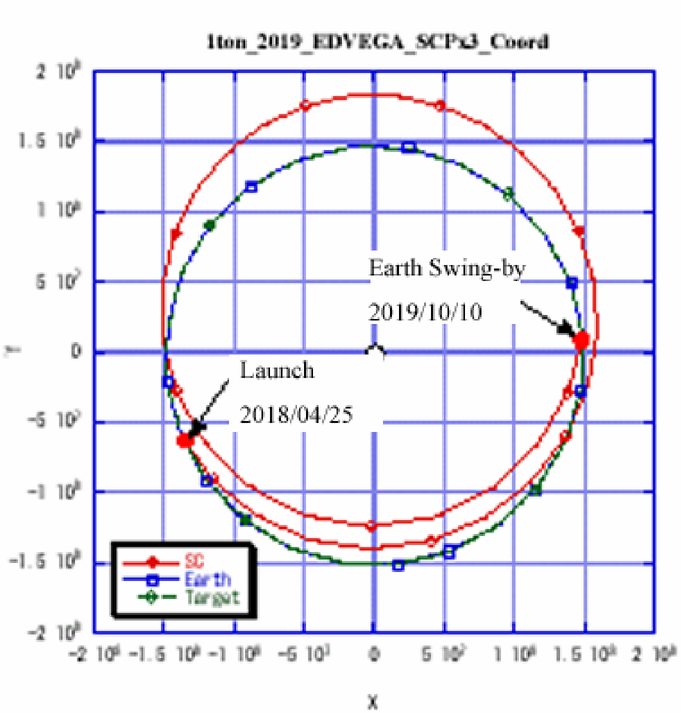
The accessibility of NEOs

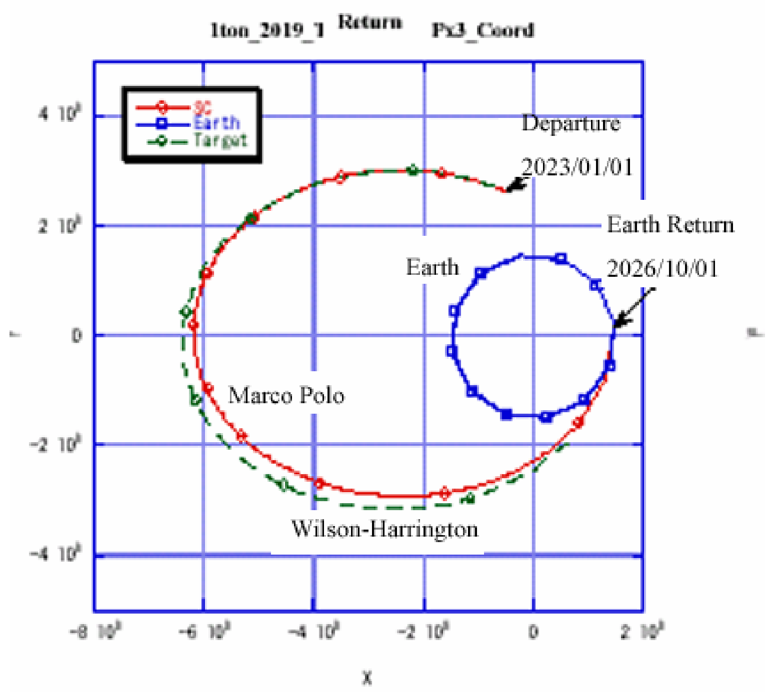


Baseline Marco Polo to 4015 Wilson-Harrington

Launcher : Soyuz Fregat
(indirect injection)

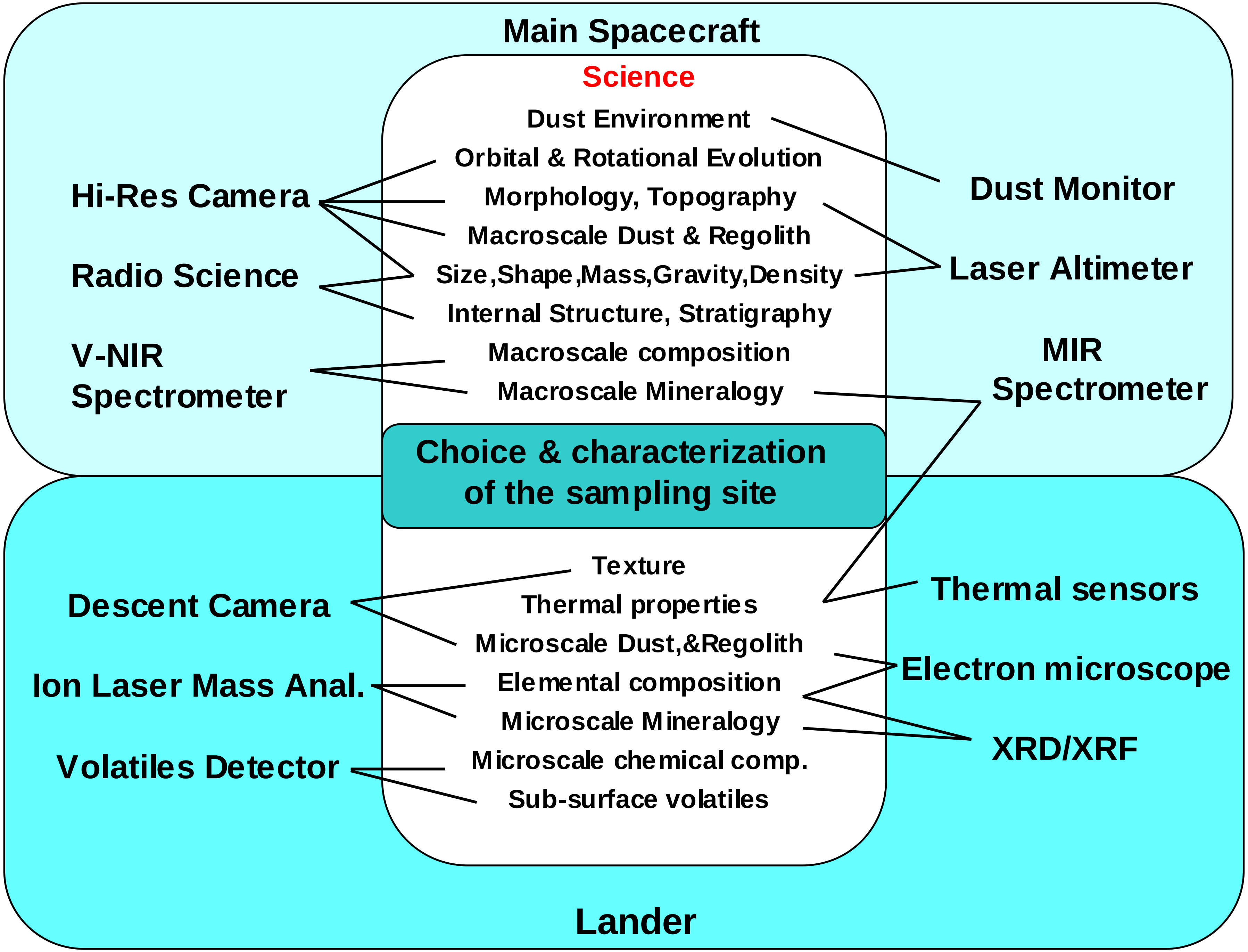






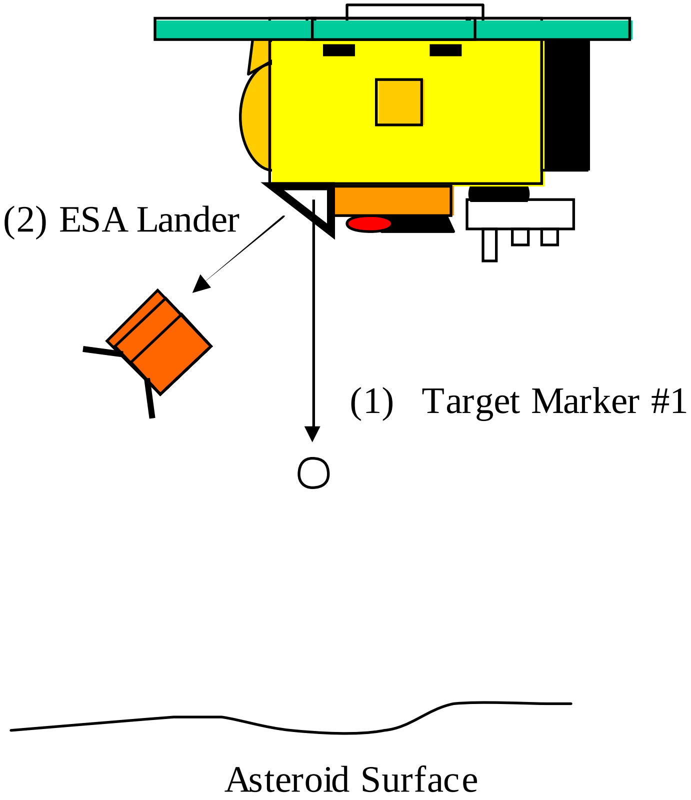
Selected targets/flexibility

Wilson-Harrington	q=1 UA Q=4.3	D 2-4 km	C - type	P = 6.1 hrs
2002 AT4	q=1.2 Q=2.7	0.3-0.4	D - type	?
2001 SG 286	q=0.9 Q=1.8	0.3-0.5	D - type	?
1996 FG3 (double)	q=0.7 Q=1.4	1.4 (1) 0.43 (2)	C - type	3.6

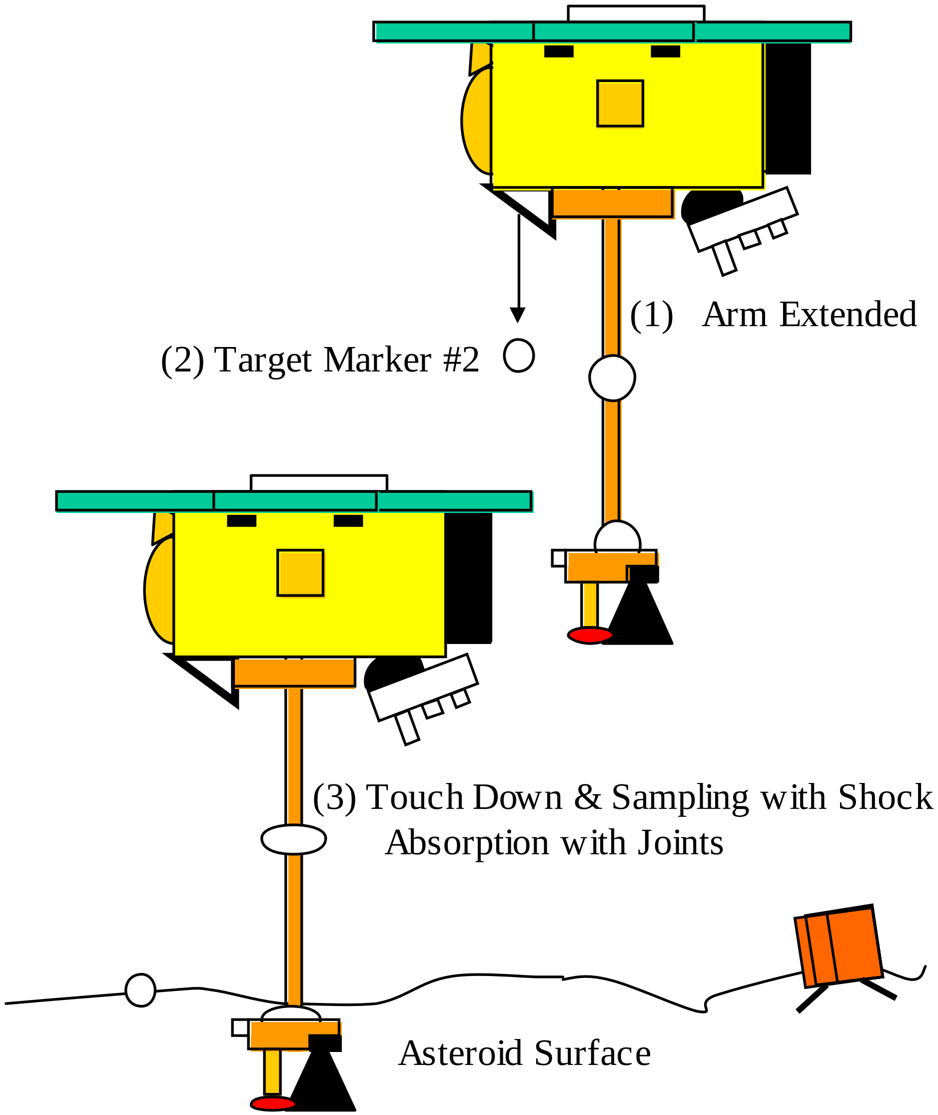


Main Spacecraft
Science
Dust Environment
Orbital & Rotational Evolution
Morphology, Topography
Macroscale Dust & Regolith
Size,Shape,Mass,Gravity,Density
Internal Structure, Stratigraphy
Macroscale composition
Macroscale Mineralogy
Hi-Res Camera
Radio Science
V-NIR Spectrometer
Dust Monitor
Laser Altimeter
MIR Spectrometer
Choice & characterization of the sampling site
Texture
Thermal properties
Microscale Dust,&Regolith
Elemental composition
Microscale Mineralogy
Microscale chemical comp.
Sub-surface volatiles
Descent Camera
Ion Laser Mass Anal.
Volatiles Detector
Thermal sensors
Electron microscope
XRD/XRF
Lander

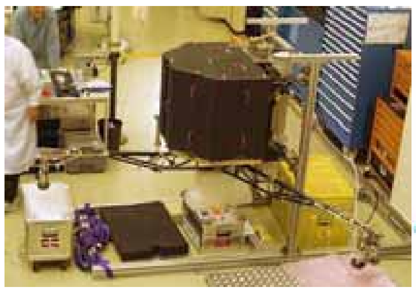
(The First Descent: Lander Release)

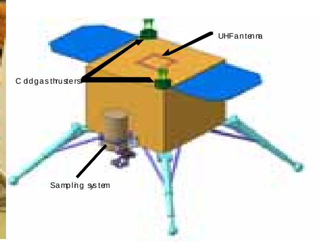


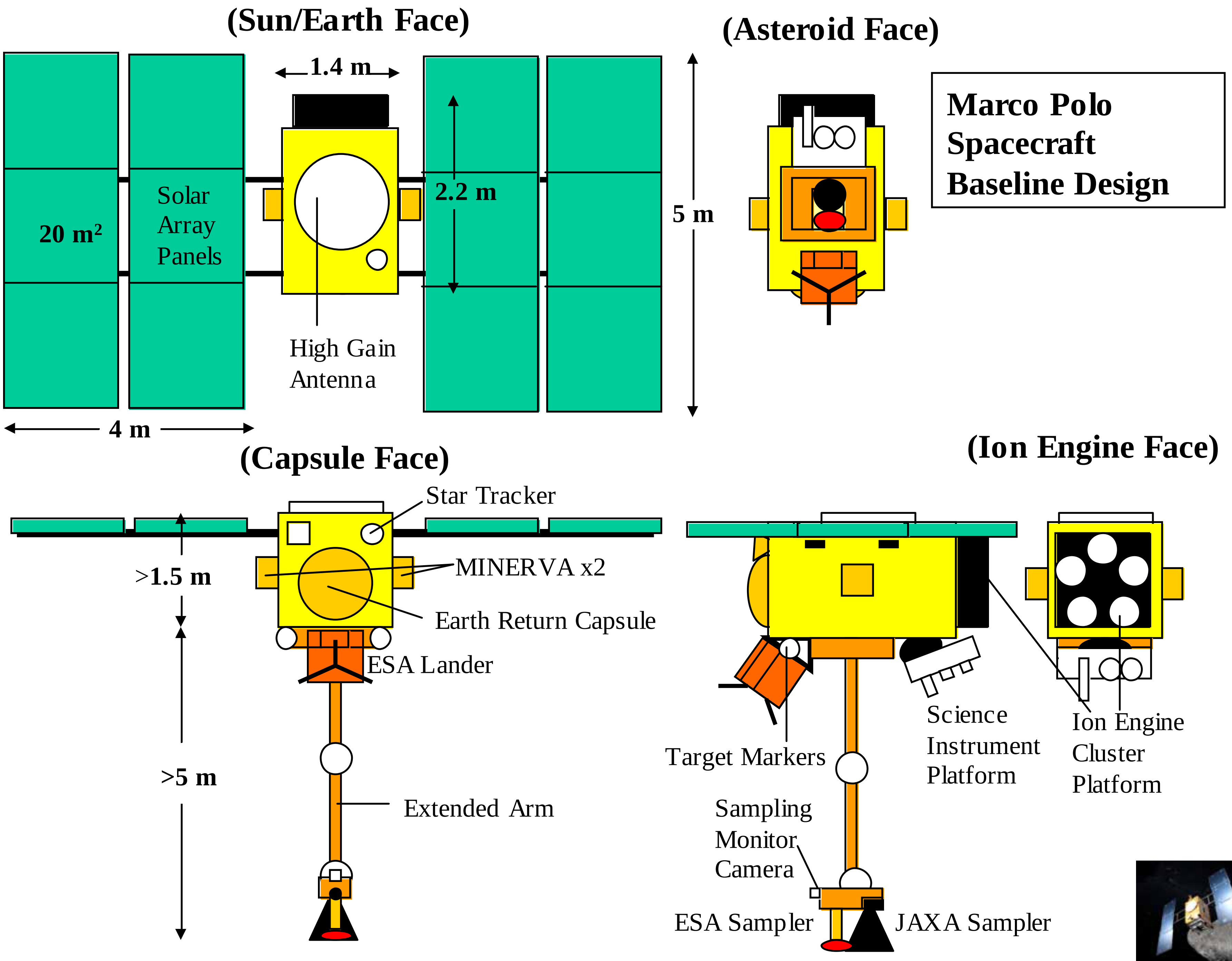
(The Second Descent: Touch & Go Sampling)



Lander : Philae heritage

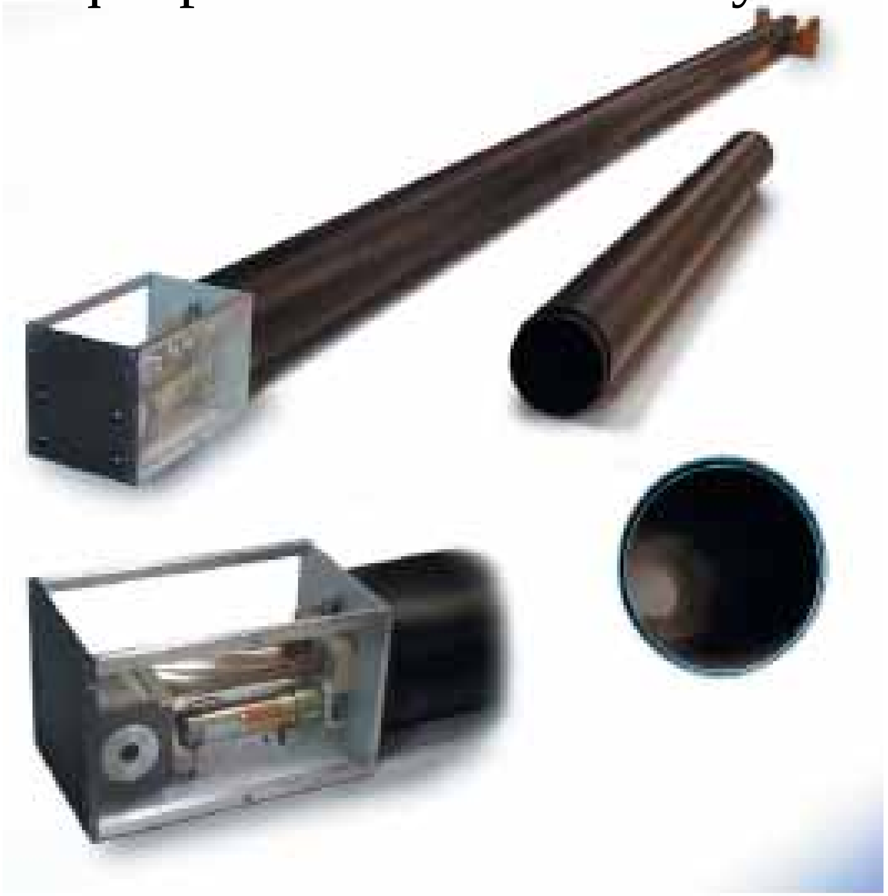





Marco Polo Spacecraft Baseline Design
(Sun/Earth Face)
1.4 m
20 m²
Solar Array Panels
2.2 m
5 m
High Gain Antenna
4 m
(Asteroid Face)
(Capsule Face)
Star Tracker
MINERVA x2
>1.5 m
Earth Return Capsule
ESA Lander
>5 m
Extended Arm
(Ion Engine Face)
Target Markers
Science Instrument Platform
Ion Engine Cluster Platform
Sampling Monitor Camera
ESA Sampler
JAXA Sampler

Telescopic mast for sampling devices

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



Example from Northrop Grumman (model 7301)

-Locks in place when Deployed

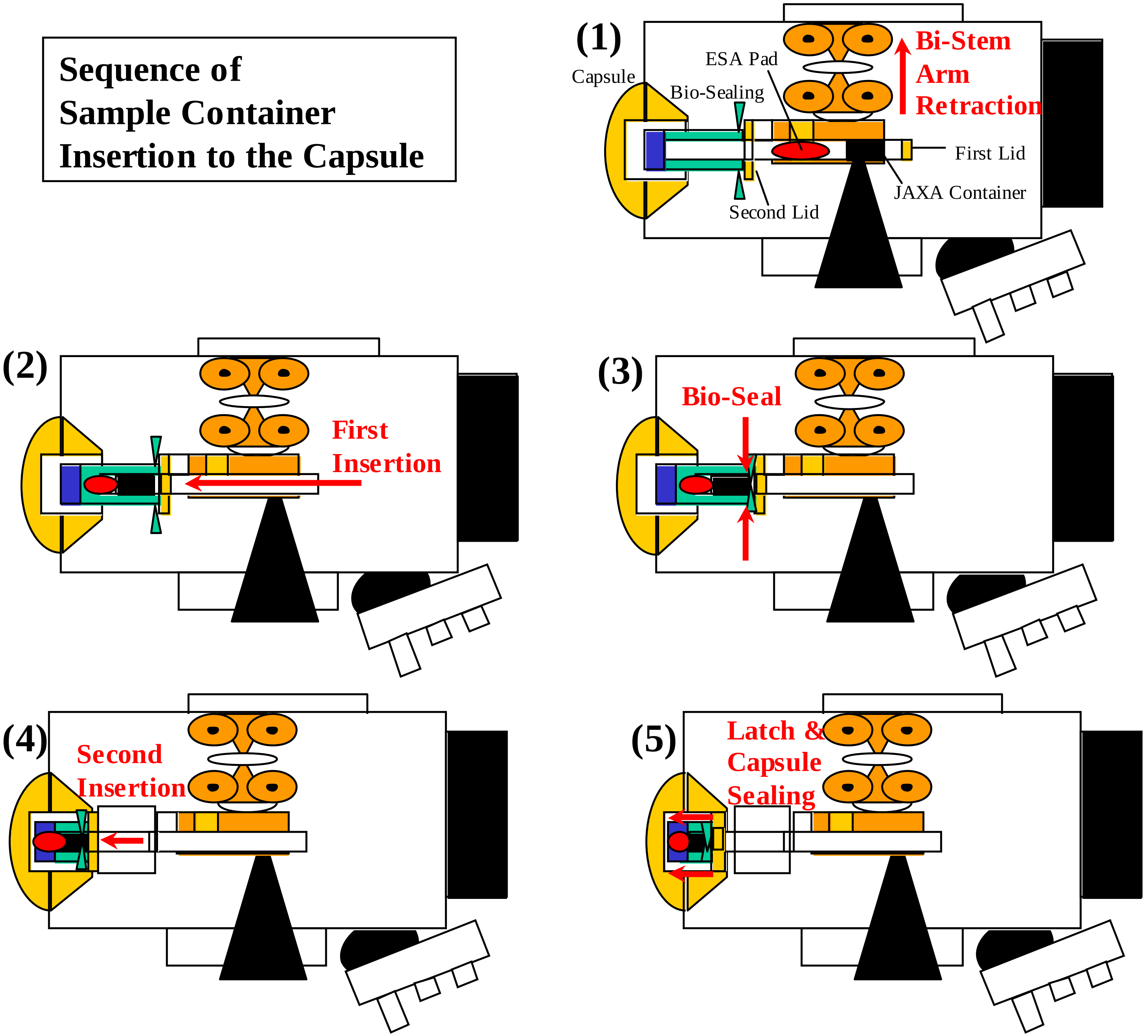
-Retractability feature

-Light and volume efficient

-Sized to fit various stengths and stiffness based on needs

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

Sequence of Sample Container Insertion to the Capsule



Laboratory investigation:

High spatial resolution and analytical precision are needed:

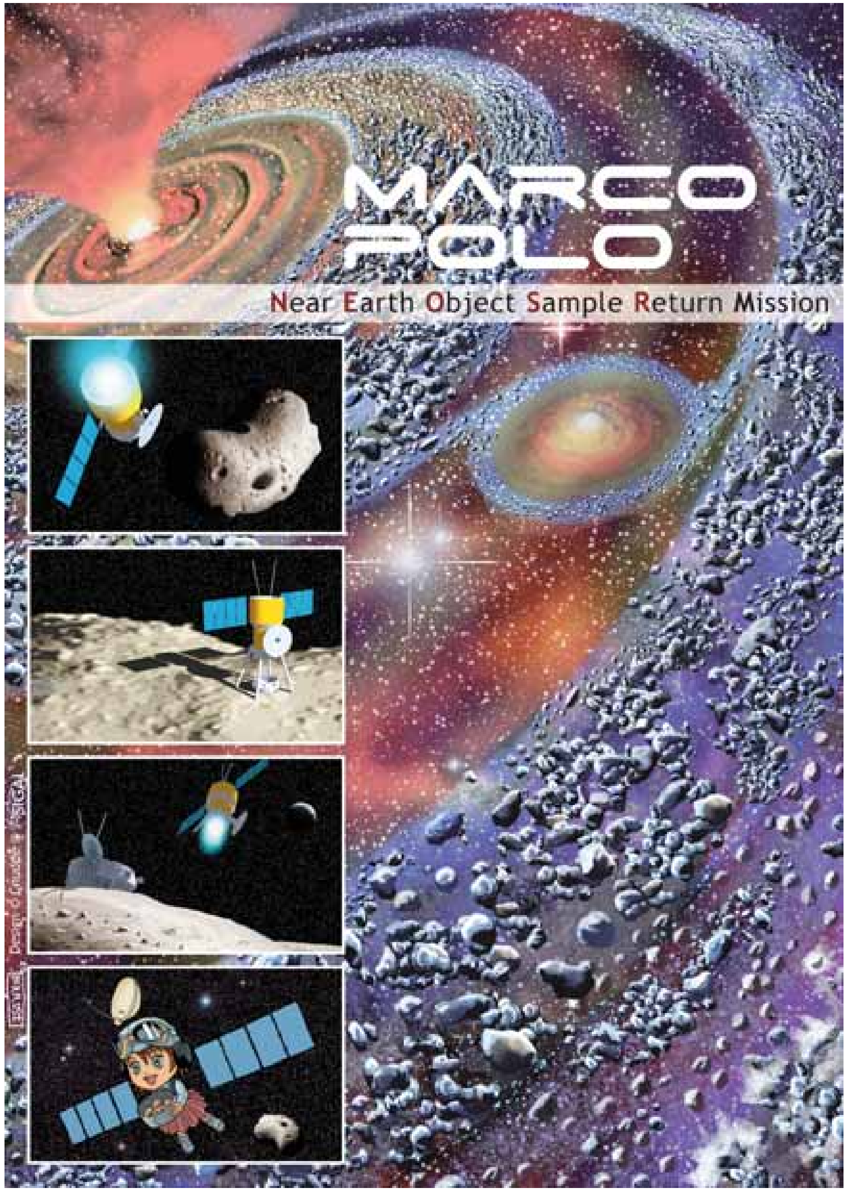
- Examples of the type of sample processing include preparation of polished flat surfaces (for optical, e-beam and ion beam studies), acid dissolution and solvent extraction.
- High precision analyses include determining trace element abundances to ppb levels and isotopic ratios approaching ppm levels 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.



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.

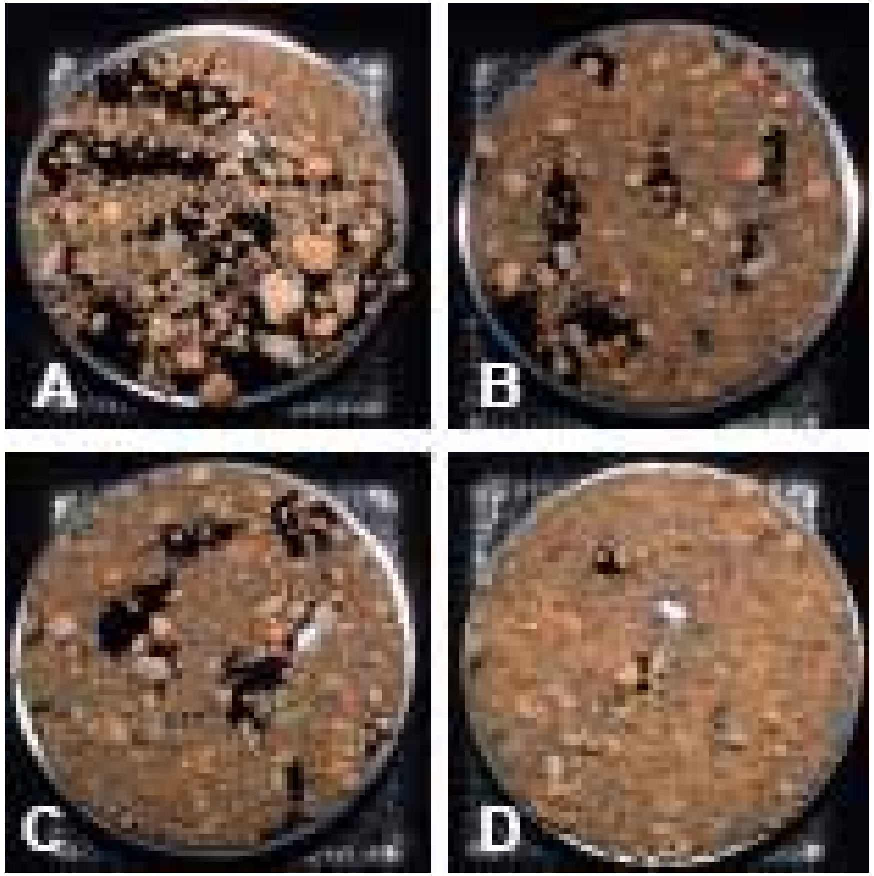
http://www.lesia.obspm.fr/cosmicvision/neosr

Other possible scenarios, all involving Soyuz Fregat

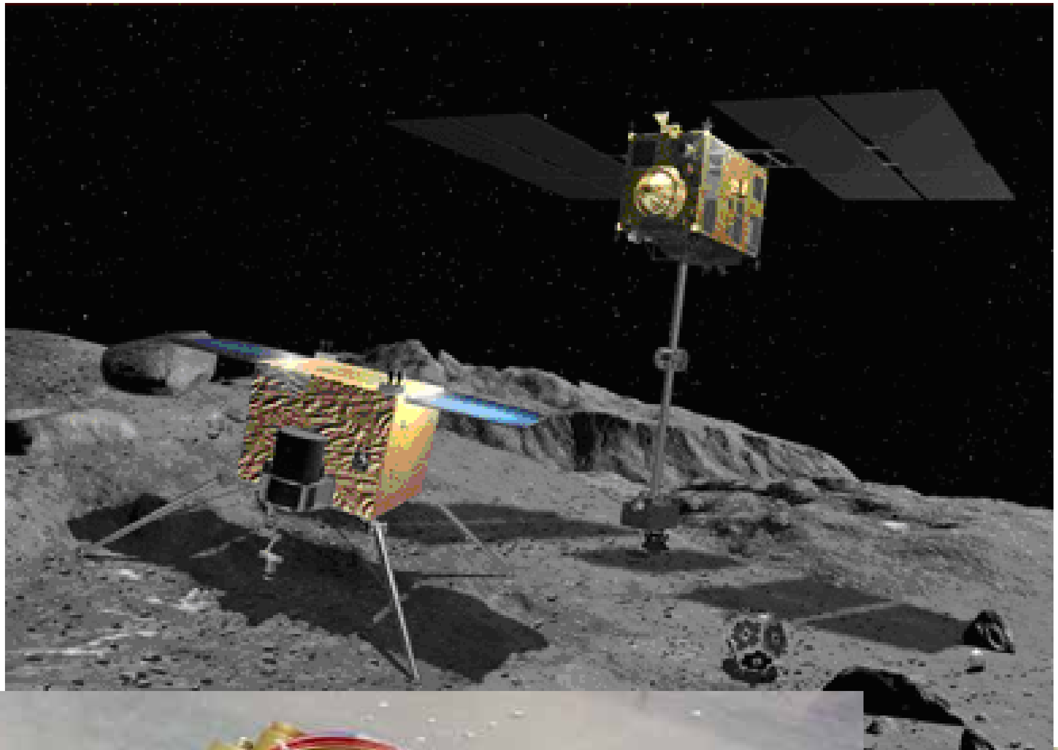
	$2002AT_4$ D type	$2001SG_{286}$ D type	1996 FG_3 C- binary	1999JU3 C type
Launch Date	03/23 2017	06/13 2017	07/20 2017	12/21 2016
V_{inf} km/s	3.5	4.1	3.46	4.42
Escape Mass	1320	1320	1320	736
RdV Date	06/06 2020	06/15 2019	04/19 2021	05/16 2018
Departure date	09/06 2020	09/15 2019	07/19 2021	11/07 2018
Departure mass	1057	1048	1090	601
Re-entry Date	03/29 2024	06/23 2022	05/16 2022	12/10 2020
Return V_{inf} km/s	6.0	6	8.35	4.58
Mission Duration	~7 years	~5 years	4.8 years	4 years

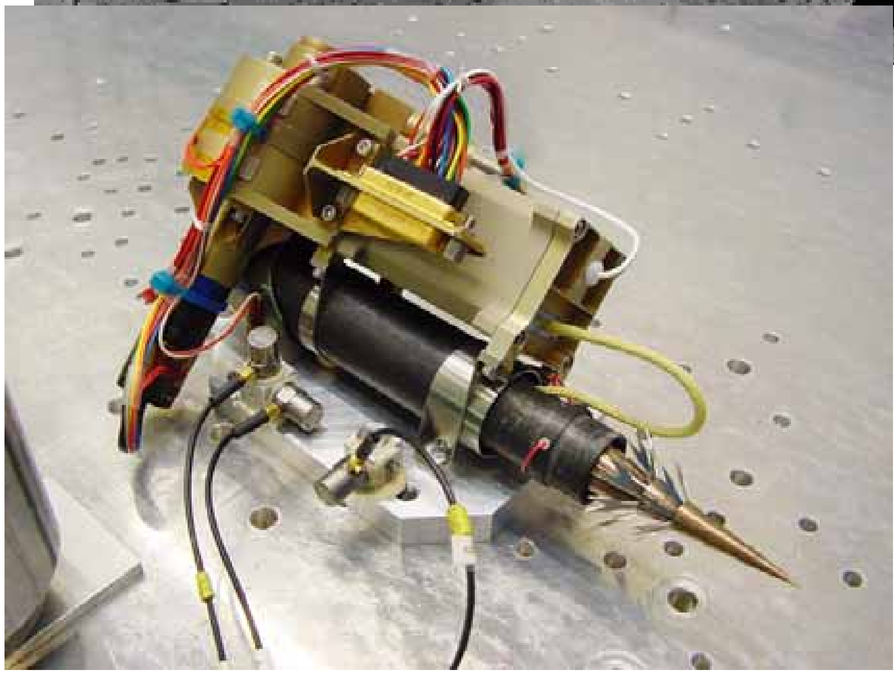
Sticky pad

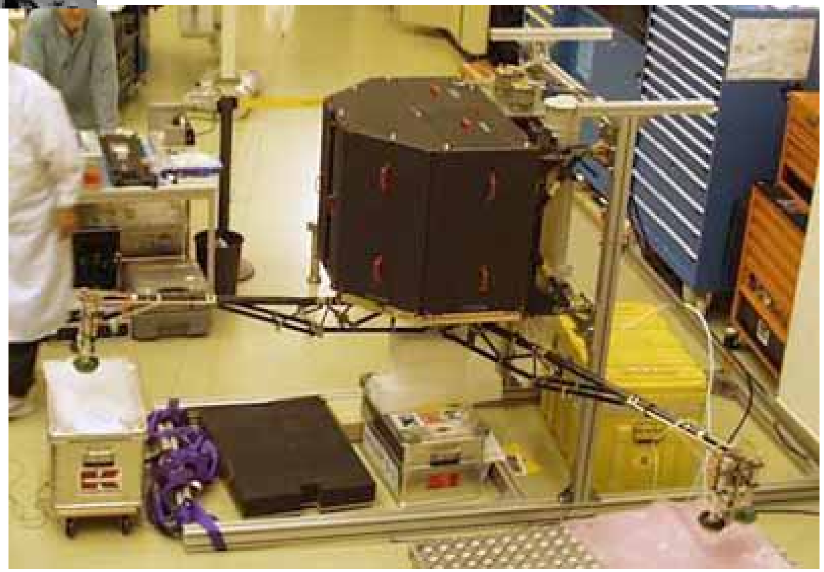
ARS (Asteroid Regolith Simulant)



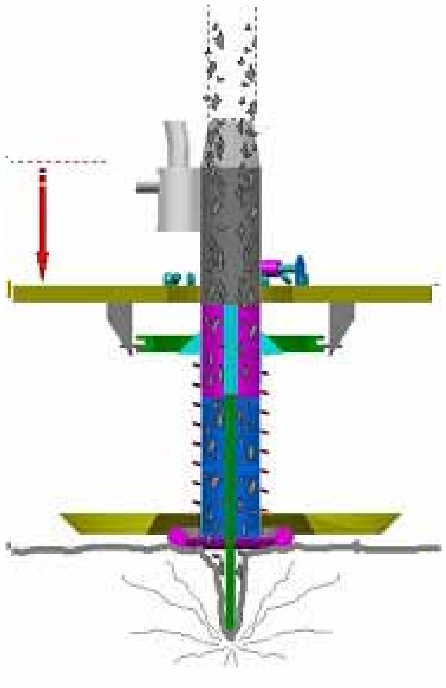
Increasing the applied force increases the contact with the simulant and thus increases the yield of each sample.
A: 67N; B:111N; C:160N; D:200N







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 inject 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).

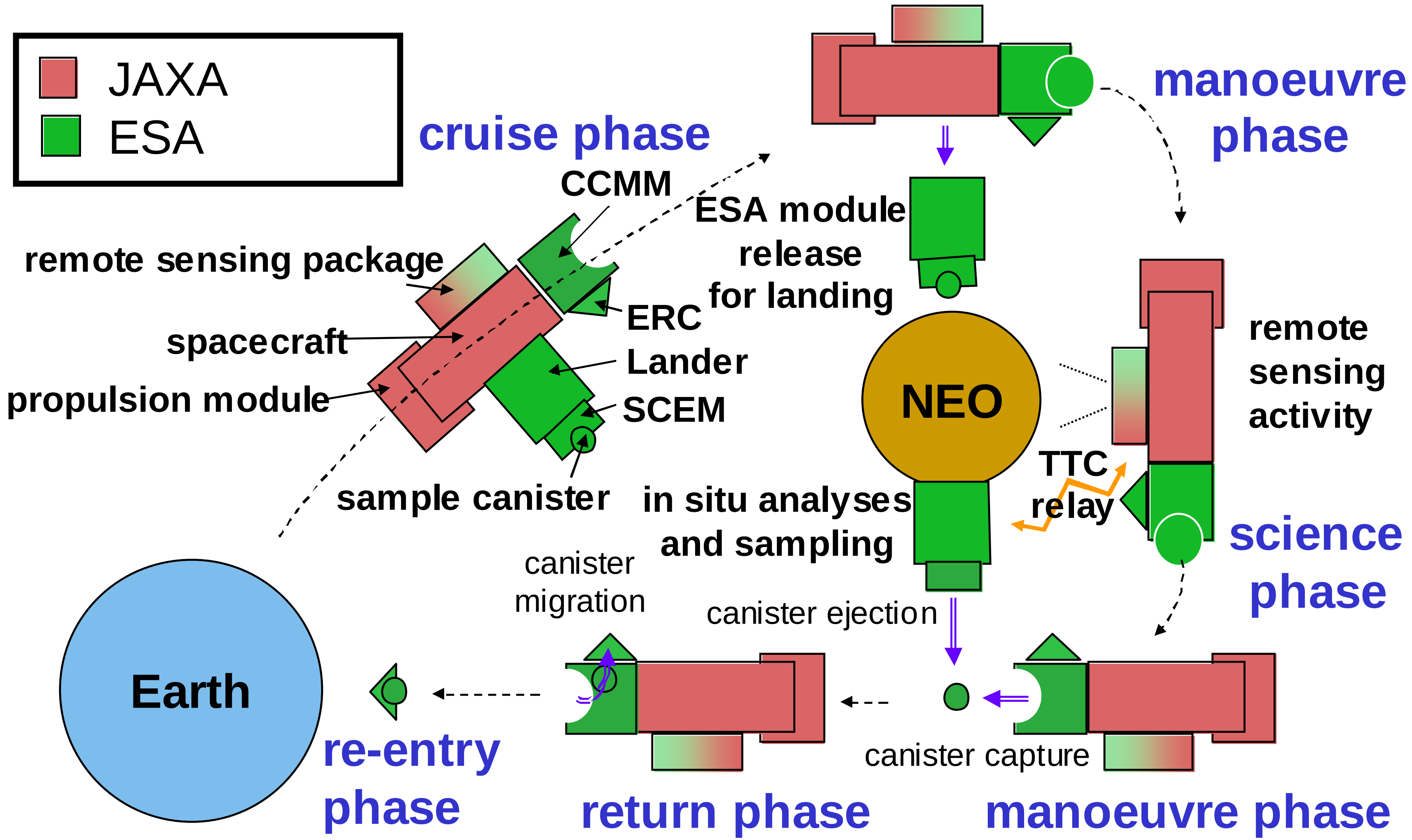
- Robotic devices (e.g., driller, robotic arms), containers and mechanisms involved in the sample collection, handling, sealing, transfer, storage.

- High-speed reentry capsule and related operations.

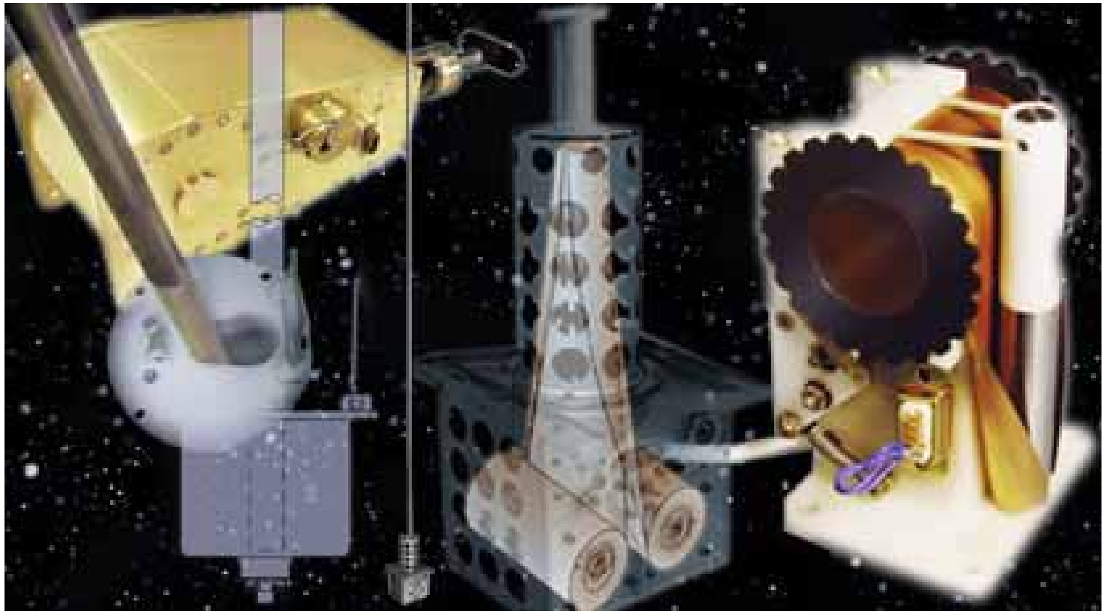
- To test new technology developments: on board artificial intelligence, telecommunication, in situ energy, re-entry velocity, planetary protection…..

- To prepare new adequate laboratory facilities for extraterrestrial sample analysis.

MISSION SCENARIO (option 2)

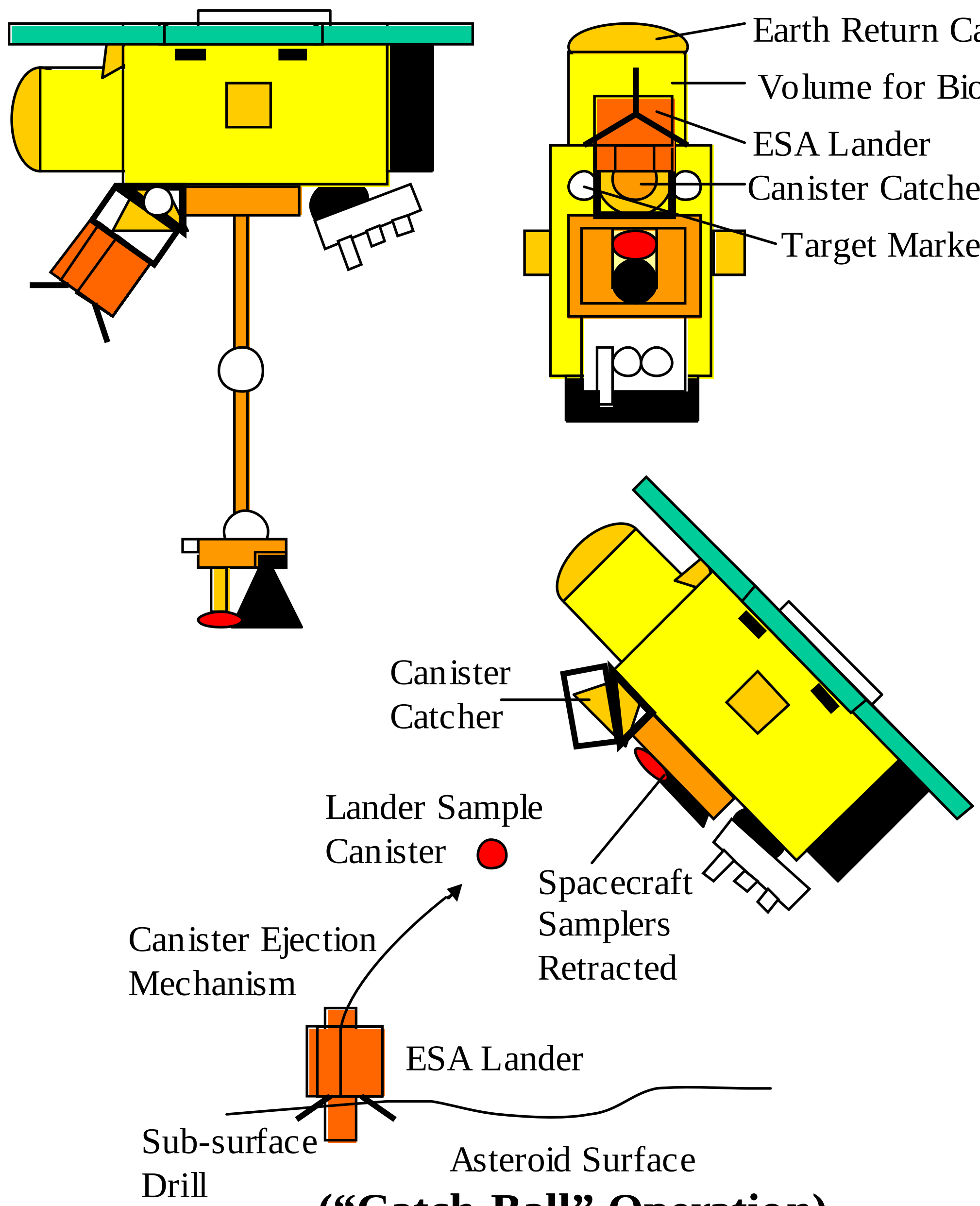


SCEM: Sample Conditioning and Ejection Mechanism
CCMM: Canister Capture and Migration Mechanism



- 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)



(“Catch-Ball” Operation)
(Option 2)