Near Earth Asteroid Sample Return Mission

Marco Polo-R

S. Cnudde 16.01.13
MarcoPolo-R is a Near-Earth Asteroid (NEA) sample return mission under study at ESA (European Space Agency) in the framework of ESA’s Cosmic Vision programme as an M3 class mission candidate. It is in competition with four other missions and only in February 2014 will the final selection be made of the mission to be launched in 2022-24.

In a new era of Solar System exploration the MarcoPolo-R mission will allow Europe to contribute in a timely manner to the international sample return effort together with the OSIRIS-REx and Hayabusa2, already selected by NASA and JAXA (USA and Japan Space Agencies) respectively.

The cartoon tells a tale of the MarcoPolo-R character explaining his story from the industrial study, the instrument selection and why it is named MarcoPolo. The MarcoPolo-R robot explains the mission design and how the spacecraft will be built, its launch and interplanetary orbit, how the sample will be collected and returned to Earth. He discovers the difficulties that can be encountered during his adventure through the mission study, including the change of asteroid target. In the story, MarcoPolo-R is accompanied by a team of dedicated scientists and engineers who are working hard to define the complete mission.

The new target of MarcoPolo-R is the Potentially Hazardous Asteroid (PHA) 2008 EV5, discovered in 2008 when it was passing very close to the Earth. After multiple observations, including radar and spectra hinting at its primitive composition, 2008 EV5 has been identified by the science team as the best accessible scientific target with the additional benefit of a short mission duration of only 4.5 years.

MarcoPolo-R will provide a unique opportunity to enhance our knowledge of the nature of a unique population of primitive bodies. MarcoPolo-R will ensure that European laboratories involved in sample analysis are positioned at the forefront of this new era of sample return. MarcoPolo-R will allow scientists to study in the laboratory some of the most primitive materials available to investigate early solar system formation processes, to explore the initial stages of habitable planet formation, and understand the origin of life on Earth.

The mission study is supported by about 700 European scientists from 25 European countries as well as by NASA, JAXA and Brazilian colleagues.

M. Antonietta Barucci
LESIA-Paris Observatory
Leader of the ESA MarcoPolo-R mission study

Paris, 1 July, 2013
This cartoon story represents an example of the outreach activities connected with the MarcoPolo-R mission study.

More information on MarcoPolo-R at:
http://sci.esa.int/marcopolo-r
http://www.oca.eu/MarcoPolo-R/
Hi!

I am Marco Polo-R the robot.

My eyes are two cameras.

My ears are at the top of my head.

No, these are not wings but solar panels that feed me the power I need.

My unique leg is a collecting tool.

I want to go to a double asteroid and take a piece of it.

I am a space traveller.

Then I will put it in my belly and I will bring it back to Earth.
I BELONG TO AN INTERNATIONAL FAMILY OF ASTEROID EXPLORERS.

MY AMERICAN ANCESTOR, NEAR SHOEMAKER, WENT TO PEANUT-SHAPED ASTEROID EROS.

MY JAPANESE GRAND-AUNT HAYABUSA WENT TO THE SMALL ITOKAWA...

MY TWO COUSINS OSIRIS REX (US), AND HAYABUSA #2 (JAPAN) ...

She had some problems!

And myself, the European fellow...

We are training to run toward different asteroids...

Dig and bring back some pieces.

You know, I'm going to a double asteroid.

Pay for one and get two!

Scenario: M. Fulchi-Biondi - Dessin/Color: S. Cuvelier
Mom, how are small satellites born?

They are found in the dreams of scientists.

How do they become real thing?

They grow on paper and then pass to the engineers who build them.

So they are born already big!

Not always.

Between the papers and the workshop, they may shrink.

Why?

They are too expensive: smaller is cheaper.

What about me?

You are still wrapped in paper: you're still big and beautiful!

Marcello Fulchignoni & Sylvain Chudde
HOW WILL I REACH THE ASTEROID?

YOU WILL BE SENT INTO ORBIT AROUND THE EARTH BY A ROCKET NAMED SOYOUZ...

THEN, YOU WILL BE PUSHED INTO INTERPLANETARY SPACE BY A SMALLER ROCKET...

WHICH WILL PUT YOU IN THE RIGHT ORBIT TOWARD THE ASTEROID.

THE FREGAT...

WHEN WILL I HAVE TO SWITCH ON MY OWN ENGINE TO COVER THAT PATH?

ANY OBJECT IS ATTRACTING AND ATTRACTS ALL THE OTHER BODIES IN THE UNIVERSE.

A LONG THE WAY, BUT ONLY AS A SLOW AND CONTINUOUS PUSH.

IT'S THE GRAVITATIONAL FORCE: THE CLOSER AND MORE MASSIVE THE BODIES ARE, THE STRONGER IS THE FORCE.

... THE GRAVITATIONAL FORCE OF THE SUN AND THE PLANETS WILL ASSIST YOU TO REACH MORE EASILY THE ASTEROID.

WOW! YOU MEAN THAT ONCE ON MY WAY, I WILL TRAVEL FOR MILLIONS AND MILLIONS OF KILOMETRES ALMOST FOR FREE?

M. FUCHS, N. ONI, S. OUMOBE
I understood that the gravitational force is a natural, universal engine.

But to complete my sample return mission to my asteroid, it takes more than 10 years!

Is there a way to go faster?

To speed up your travel, we can use electric propulsion engines.

These engines eject heavy ionized atoms in a direction and you accelerate in the opposite one.

They were tested during the Deep Space 1 and SMART-1 missions and they were increasing the probes speed by 4.6 km/s!

So, I could go to and come back from my asteroid in a shorter time!

Who saves time saves money!

C. Fulchironi & S. Caruolo
OK GUYS, NOW IT'S TIME FOR YOU TO GIVE ME MY SHOPPING LIST.

ONLY NATURAL PRODUCTS, WE CHOOSE AN ORGANIC SHOP.

SO YOU WANT PREFERENTIALLY ORGANIC MATTER?

ANY MATERIAL HAVING ITS ORIGINAL COMPOSITION, JUST LIKE RAW FOOD.

LOOK ALSO FOR SOME WATER. IT'S A VITAL ELEMENT.

SPARKLING OR STILL?

SPARKLING? INTERESTING IDEA! "VOLATILES" Mmmm...
TAKE WHAT'S AVAILABLE.

OK. HOW MUCH OF THIS SHOULD I BRING BACK?

ISN'T THERE A PRICE/KG?

IT'S A FLAT RATE... TO MAKE IT CHEAPER, TAKE AS MUCH AS YOU CAN.

WHY IS THIS SO PRECIOUS?

IT MAY ALSO CONTAIN THE INGREDIENTS THAT SERVED TO START LIFE ON EARTH!

THAT'S TOO COOL! I CANNOT WAIT TO GO!

OUR PLANETARY SYSTEM IS LIKE AN OMELETTE! WE WANT TO LOOK AT THE "INGREDIENTS" OF THIS OMELETTE.

I SEE! I HAVE TO SHOP IN A PLANETARY BUILDING SHOP! THAT’S AWESOME!

WELL, FIRST YOU HAVE SOME HARD TRAINING TO DO.

STORY: P. FUCHS - DRAWING: S. CAUDE
I need to be ready for my long interplanetary trip in 2022-24.

I put 2 industries in competition: Astrium Ind and Thales Alenia Space Ind.

Industries are studying to provide me with all the necessary resources.

They have to take care of my weight to minimize the launch cost...

To make my electronic senses at a high level of performance...

To teach me how to communicate: to hear from and to speak to the Earth...

To provide me with a smart sample collector system and robust re-entry capsule...

To find the best way to come back safely to the Earth.

Scenario: A. Barucci - Dessin/Couleur: S. Caude
I have to find all the instruments listed here to assemble my payload.

Hi! I'm looking for a camera.

Second row, on the right.

I need navigation and close-up cameras, and a thin imaging system with narrow angle camera.

These are all too heavy!

I need two of these, a small imaging spectrometer in the optical and near infrared and a mid-infrared spectrometer.

Where the hell are the neutral particle analyzers?

They only sell big, heavy, old fashioned instruments here!

Is there anything here which I could be use?

No good. I have to wait for ESA's call for new instruments.
Mom, why did you name me Marco Polo?

It's a long story... Started in Japan some time ago.

Please, please, mom, tell me the story.

Our Japanese colleagues were interested in a joint asteroid mission with us, the Europeans...

And they suggested to name the mission Marco Polo, from the Venetian traveler of XII century...

...who gave in his book, "Il Niouco", the first news to Europeans on the existence of Japan.

So I waited you Marco Polo.

But why, R?}

Because your task is to return asteroid samples!

M. Fuchigami & S. Cnudde
We found a fantastic new target for your mission: the asteroid 2008 EV5.

Fantastic?! How? Where is it?

It's closer to the Earth. It's particularly primitive.

It will allow you to go there and return in only four and a half years.

That means I'll be back much sooner!

Yes... and your trip will cost much less.

How primitive is 2008 EV5? How do you know that?

Ground observations show water alteration of its surface...

Implying that 2008 EV5 grew by accretion of the first grains formed around the Sun.

Wow! I will be collecting the seeds of the planets!

Story: A. Barucci - Drawing/Color: S. Camidde.
My trip to the asteroid 2008 EV5 will start from Kourou in Guyana.

I will be on board a Soyuz-Fregat launcher that will take me on my way.

To speed up and reach the asteroid, I need the help (swing-by) of the Earth.

I will reach 2008 EV5 after two years.

I will make its full characterization over six months.

So I can choose where to collect the precious samples to bring back.

Then quickly I will collect a lot of samples, using the touch and go technique.

Finally, I will come back and will deliver my re-entry capsule with the samples in a friendly desert.

Scenario: A. Barnig - Design + Color: Sylvain Canu 10
Hey... guys, ESA finally selected the instruments for M.P.R.

Oh... good!

ESA received many new and high-quality instrument proposals and selected six.

With the selected payload, we can reach the mission's scientific objectives.

You got the camera for the global and local map of the asteroid.

“A close-up camera to show where the sample is collected.”

The radio science experiment for the mass determination of the asteroid.

The visible and near and far-infrared spectrometers for the surface compositional and thermal properties.
"You also have a small surface instrument for in-situ analysis named Vesta Vista 2.

Yoo hoo!

No, only Vista 2 will fly to detect possible activity around the asteroid.

Oh oh!

All these instruments are necessary for the selection of the sampling site.

Yes, but the main goal of your trip is sample return.

We have to build a "curation facility" where the sample can be handled and preserved.

Where?

Yaa... we have to retain samples for future generations.

Look at this sample, kid!

Be quiet, the mission has to be selected.

Damn!

Scenario: A. Barucci. Drawing/color: S. Chudde
My friend told me that you are working on a sampler device for me in the US.

Yes.

To bring back asteroid samples, we develop a rock chipper to crush also the hardest surfaces...

And using a neutral gas flow, we can collect up to a few hundreds grams of dust grains and small pebbles.

Impressive! Who is choosing the sampler for its payload?

ESA makes the final choice.

We hope that NASA and ESA will find an agreement and our device will be on board.

It's a matter of high diplomacy!

You don't imagine how much it's true.

I would like to host Americans and share with them my adventure.

M. Fillchignoni & S. Caudde.
What happens to the asteroid samples I will bring back to the Earth?

They will be put safely in the curation facility expressly built for this purpose...

That's all?

Absolutely not!

Those samples will be studied by the world's most qualified scientists with the best available instrumentation.

What are they looking for?

Chemical, mineralogical, elemental composition of samples' refractory and volatile components...

Age, analogies with known meteorites, search for unknown mixtures of minerals, search for interstellar grains...

And we are also looking for organic molecules that may have been relevant for the origin of life on Earth.

M. Fulchignoni & S. Cudde
How can I see the asteroid?

I give you different kinds of eyes, each with specific resolution and field of view.

“CUC,” the close-up camera, will allow you to see great details of a particular location on the surface.

What for?

We need a detailed knowledge of the geological context where the sample will be collected.

I see.

And what about the other eyes?

“MANAC,” the narrow angle camera, will help you to know with great accuracy the global shape and morphology of the asteroid.

Why is it so important?
Because with the knowledge of the mass and of the shape, we can infer the asteroid's bulk density.

But an asteroid is a rock, so we know more or less the density of a rock.

Yes but if the density is very low, it implies that there must be some voids inside the asteroid.

So, it is a way to know the internal structure without seeing it!

And "Nanac" will also give us details of all the craters and boulders on the surface!

Awesome! Small canyons and rocky mountains on an asteroid!

So, with these powerful eyes, I feel like I am the two billion dollar man!

Yes, but hopefully much cheaper...
Why must I send you the images of the asteroid surface?

Because we want to study its properties.

Because this gives us an estimate of the age of the surface.

Of course! The larger the number of craters, the older the surface. Very smart!

Yes, and this allows us to relate the properties of the returned sample to the collisional and dynamical history of the asteroid.

And should I also give you the size and number of boulders on the surface?

Yes, their characteristics can give us some hints on the mechanical properties of the asteroid.

Good question: we have been surprised to see many boulders on the small asteroid Itokawa, and their origin is still mysterious.

But why do we expect boulders on the surface?

They can be ejecta from craters that fall back on the surface, but high ejecta velocities and low asteroid gravity are inconsistent with this explanation.

What are the other explanations?

They may come from the interior as a result of asteroid vibrations.

Vibrations, impacts, boulder formations, my asteroid is like a living organism with many active processes going on!
Do you know what is a spectro-imager like MARIs, which is part of your instrumentation?

It's a kind of camera which takes plenty of images in a single shot, isn't it?

MARIs Polar Imaging Spectrometer

Quite right! In reality, the image is always the same but it's taken at different colors (technically at different wavelengths).

Wow! What do you do with that?

Each "color" (there can be more than 400) contains information on the asteroid composition.

And the thermal spectrometer "thermap" provides you with maps of the temperature of the asteroid.

Incredible! I will have eyes that are able to perform mineralogical analysis.

And they can also work as thermometers!
Why are you so sad?

You told me that I have to measure the mass of the asteroid... and I don't know how to do that.

Don't worry. There is a German team which will measure the 2008 EV5's mass with the on-board radio transmitter.

That's the radio science experiment.

How do they do that?

The asteroid's gravity is attracting you, and you accelerate toward the asteroid proportionally to its mass...

This acceleration produces a variation of the frequency of the radio signal you will send toward the Earth...

Wow!

This is known as the Doppler effect.

Measuring that variation of frequency, you measure the acceleration and consequently the asteroid mass.

Amazing!
Hi, Mr. R! This is a gift for you from Japan. A brand new LiDAR thanks a lot! But... what is a LiDAR good for?

LiDAR means "Light Detection and Ranging." It can measure the distance between you and the asteroid with a precision of a few meters.

Wow! Fantastic, thank you! So I can know exactly when I will touch the surface of 2008 EV5.

Yes. It's essential for guidance, navigation, and control (GNC) activities in the surface approach and sampling phases of your mission.

How does the LiDAR work?

A laser sends a light beam to the asteroid and you measure the time taken for the reflected signal to come back. The signal travels twice your distance from the asteroid at the speed of light.

OK, I understand. So, distance = (velocity × time) / 2, with light speed = 300,000 km/s.

M. Fulchignoni & S. Crudde
WHERE WILL I HAVE TO DELIVER THE RETURN CAPSULE WITH THE SAMPLES?

LET’S SEE... HAS TO BE A DESERT REGION... A FRIENDLY DESERT REGION.

THERE ARE NON-FRIENDLY DESERT REGIONS ON EARTH?

MOST OF THEM ARE DANGEROUS: TOO STILL, TOO CLOSE TO THE SEA, NOT PEACEFUL...

THE BEST SEEMS TO BE THE AUSTRALIAN DESERT.

HOW WILL YOU FIND MY RETURN CAPSULE?

THE CAPSULE RE-ENTRY TRACK WILL BE DETERMINED FROM SEISMOLOGISTS AND RADARS ON THE GROUND, CAMERAS IN PLANES AND HELICOPTERS UP TO ITS LANDING POINT.

SO WE WILL KNOW PRETTY WELL WHERE IT LANDED AND WE WILL RUN THERE.

PLEASE, PLEASE, DON’T FORGET TO COME!
Hi! I am Brasat. I am coming from Rio to meet you.

To meet me?! Really? Why?

I would be delighted to come with you to CobeVs. Bring me there please!

Why are you interested in asteroid sample return?

A star between the stars!

I need to learn how to go to the stars!

You are doing such interesting things. You are so mature... I'm sure you will be a wonderful teacher...

Ok let's go!

But in exchange you will teach me how to dance Samba in space.

M. Fulchignoni & S. Canuode
I am looking at my website...

There are all the comic strips telling my adventures...

There is a link to Facebook...

There is also plenty of news concerning my future: where I’m going, what I have to do...

You will find who my godfathers and godmothers are, who proposed me to ESA, where they come from all over Europe.

Let see how big my community is... just a minute... it’s fantastic!

I have more than 700 fans from European science institutions...

...who are supporting my ideas and my plans. I’m sure I will satisfy their expectations!

You can join the community...

Sign up now!

http://www.oca.eu/NanoPolo-R1

Scenario: P. Fucini’Gnoni. Dessin/Couleur: S. Claudde
“PHA” stands for Potentially Hazardous Asteroid. A PHA could hit the Earth in the future!

My target, asteroid 2008 EV5 is a “PHA”. What does it mean?

Wow! We have to do something to avoid that!

We are studying some techniques to mitigate the risks in the European project “NEOSHIELD”.

And you are supposed to provide close-up information on 2008 EV5...

Which could be useful to study the best way to avoid a collision, if its dangerousness is confirmed.

What can be the consequences of such an impact with the Earth?

A catastrophe which can affect large regions of the planet.

So, if I do a good job, I could be a hero who contributed to saving the Earth!!

M. Fulchignoni & S. Caucade.
LET’S SEE THE CHAPTER ON SAMPLE RETURN MISSIONS...

WOAH! NASA BROUGHT BACK TO EARTH MORE THAN 300 KG OF MOON SAMPLES...

AND THEY ALSO GOT SAMPLES FROM A COMET AND FROM THE SOLAR WIND!

AND JAXA MADE THE FIRST SAMPLE RETURN FROM AN ASTEROID!

BOTH JAXA AND NASA WILL SEND 2 NEW SAMPLE RETURN MISSIONS TO 2 NEAR EARTH ASTEROIDS: OTEROS-REX AND HAYABUSA 2 :)

THIS IS WONDERFUL!

Hey, what about sample return missions from ESA?

NOTHING YET?

DON'T WORRY.

IF I'M SELECTED, I WILL BE THE FIRST ONE! I'M SO PROUD OF THIS!
THE AUTHORS AT WORK:
A. BARUCCI, S. CNUDDE, S. FORNASIER, P. MICHEL, P. FULCHIGNONI.