Declaration of Interest to Propose a
Neutral Particle Analyser for the MarcoPolo-R Mission

RAMON

Part A: Technical Proposal

Introduction

RAMON (Released Atoms and Ions MONitor) to be flown on board the MarcoPolo-R Mission, consists of two neutral atom sensors able to detect and characterize the neutral atoms released from the surface of a near-Earth asteroid (NEA), and an ion monitor for the characterization of the space weathering of the surface. In particular:

- SHEAMON (Sputtered High-Energy Atoms MONitor) will investigate the ion-sputtering and backscattering process by detecting neutral atoms between ~10 eV and ~3 keV and determining their direction and velocity;
- GASP (GAs SPectrometer) will analyse the mass of the low-energy (below 10 eV) neutral atoms released by different surface processes;
- MIM (Miniaturized Ion Monitor) will measure the flux and energy spectra of precipitating and backscattered solar wind protons, which originate the Ion Sputtering and Backscattering processes investigated by SHEAMON.

The RAMON key questions are summarized as in the following:

- What processes happen on the surface of the NEA as a result of its exposure to space environment and collisions? What is the magnitude of the erosion due to space weathering at the NEA surface?
- What is the efficiency of each process as a function of environment conditions?
- Is the efficiency of particle release processes uniform on the NEA surface?
- What is the composition of the escaping material and consequently, how it relates to the surface composition and mineralogy?
- What is the role of the surface release processes in the body evolution?

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1. Definition of the science payload item proposed for study: RAMON

1.1. Scientific Objectives

A near-Earth asteroid (NEA) is eroded by different agents (solar wind precipitation, solar and cosmic ray bombardment and micrometeoroid impacts) and its surface composition is modified by this space weathering and gardening (Hapke, 2001). The release processes acting on the NEA surface, in ascending order of emission energy, are Thermal Desorption (TD, ~0÷1 eV), Photon Stimulated Desorption (PSD, up to 10 eV), Micrometeoroid Impact Vaporization (MIV, tens of eV) and Ion Sputtering (IS, ~1÷100 eV). In particular, IS is one of the most important processes that cause alteration and erosion of the surface; however, particles emitted from the body's surface due to all four surface release processes are lost in space because the gravitational escape velocity is very low (i.e., 1.63 m/s for a NEA mass of~10^{12} kg and a NEA Radius of ~ 0.5 km).
When SW protons precipitate onto the surface of a NEA, Ion Backscattering (IBS, 10eV - 1keV) can also take place. The impacting ions interact with the surface mostly as neutrals since capture of surface electrons leads to their neutralization (Massey and Burhop, 1952); a small fraction of ions are not neutralized. As a result, high energy (10eV – 1keV) neutralized atoms (and ions) can be measured in the environment around the NEA. IBS is not a real surface release process, being just the neutralization and reflection of the protons. However, its efficiency depends on the surface composition and so the detection of IBS fluxes is an important tool to characterize the surface properties. By measuring the ion component also, it is possible to estimate the neutralization efficiency at the surface, which is also related to surface properties. IBS has been already observed in space for the case of solar wind getting backscattered from the Moon's surface (McComas et al., 2009; Wieser et al., 2009; Saito et al. 2008), and from natural satellites like Phobos (Futaana et al., 2010a).
The investigation of the active processes as a function of external conditions and surface properties is crucial for a clear view of present loss rate and, eventually, of the evolution of the body. To distinguish between the active processes, the expanding gas flux, composition, energy and direction should be measured.
Most of the surface particles are released by thermal- or photon-stimulated desorption and are in the low energy range (about 1 eV). The detection of particles in the low energy range will provide information about the mass of emitted material, and on the net emission rate from the NEA surface.
Ion Sputtering is roughly stoichiometric, and detection of IS fluxes gives direct information on the surface composition. It is possible to investigate whether ion-sputtering process is active with a measurement of energy (or velocity) spectra; in fact, only IS releases particles at energies above 10 eV.
Finally, the estimation of the efficiency of ion backscattering active on the surface of the NEA, demands the concurrent measurements of both ion flux and high energy neutral flux.
A good angular resolution will permit to identify the regions more active in releasing neutrals, thus evidencing possible anisotropies of solar wind sputtering and/or of surface properties.

A comparison between precipitating ion fluxes (detected by MIM) and SHEA (detected by SHEAMON), will provide an indication of the surface efficiency in releasing particles, and it will reveal, therefore, necessary information for answering one of the main MarcoPolo-R Science questions '*What were the processes occurring in the early solar system and accompanying planet formation?*'

The identification of the mass of the released particles will give some hints on the NEA surface composition and the chemical processes that shaped it. So, GASP measurements can provide information on the possible existence of different volatiles or water molecules and Science Objective n. 2.F (*Characterize the chemical processes that shaped the NEA composition*) can be reached.

Ion sputtering and all other processes acting on the NEA surface will be investigated also thanks to joint analysis of data from other payload instrumentation on board the MarcoPolo-R mission that provides the remote-sensing of the surface properties (like V + NIR + MIR spectrometers and camera). In fact, additional information of the surface structure, mineralogy and composition will add constraints to model the release processes. Once the returned sample will be analyzed, even more detailed information will be achieved to be added to the RAMON data analysis. In fact MarcoPolo-R will provide, for the first time, the opportunity to have in situ observations of the released particles together with detailed laboratory information on the mineralogy and composition of the emitting surface.

In summary, the RAMON scientific objectives are:

1. To identify the particle release processes active on the NEA surface
2. To evaluate the efficiency of each process as a function of environment conditions
3. To evaluate the efficiency of each process as a function of surface properties
4. To determine the composition of the escaping material
5. To estimate the role of the surface release processes in the body evolution.

1.2. Signal estimation

1.2.1. Ion-sputtering at NEA

Ion-sputtering results from the impinging of an energetic ion of mass m_1 onto a surface; if the impact energy (E_i) is high enough, a particle (m_2) from the surface may be released (sputtered). In most cases, the ejected particle is neutral (Hofer, 1991). The energy transmitted in the collision is:

$$T = T_m \cos^2(\alpha_r)$$

$$T_m = E_i \frac{4\, m_1 m_2}{(m_1 + m_2\,)} \quad , (1)$$

where T is the transmitted energy, T_m is the maximum transmitted energy and α_r is the recoil angle of the ion. The distribution function (f_S) of the ejection energy has been empirically obtained (Sigmund, 1969; Sieveka and Johnson, 1984); the results are reproduced by the following function:

$$f_S\left(E_e, T_m\right) = c_n \frac{E_e}{\left(E_e + E_b\right)^3}\left[1 - \left(\frac{E_e + E_b}{T_m}\right)^{\frac{1}{2}}\right] \quad (2)$$

where E_b is the surface binding energy of the atomic species extracted, E_e is the energy of emitted particles, c_n is a normalization constant.

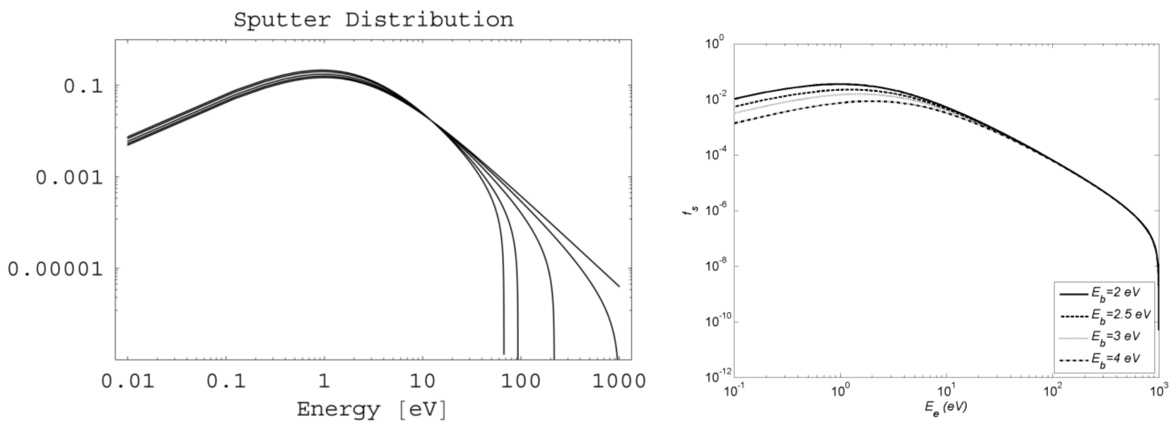

Figure 1. Solar wind sputtering normalized energy distribution function (left) for different species (Fe, Ca, Na, O, H) and (right) for different binding energies from a regolith.

The normalized energy distribution function assumes different profiles, depending on the considered species and binding energy,; anyway, generally it peaks at few eV but it extends up to hundreds of eV (Figure 1).
The other surface release processes acting on the NEA are not able to eject particles at energies above few eVs; hence, the detection of particles above 10 eVs is a method to identify the action of the ion-sputtering process.

Table 1: Bulk element abundances for CI, CM and Tagish Lake type chondrites (Plainaki et al., 2009).

Mass (amu)	**Element**	**CI (%)**	**CM (%)**	**Tagish Lake (%)**
1	H	55	45	47
12/13	C	8	6	9
24/25/26	Mg	11	15	14
27	Al	1	1	1
28/29/30	Si	10	15	13
32/31	S	4	3	3
40/44	Ca	1	1	1
54/**56**/57	Fe	9	13	11
58/60/59	Ni	1	1	1
Total		100	100	100

Plainaki et al. (2009) modeled the sputtered particles from a NEA. They considered a solar wind proton flux of $\varphi_{H+}=10^8$ $cm^{-2}s^{-1}$ as the total amount of the impinging particles. The NEA radius was assumed to be 0.5 km; its mass was taken as 10^{12} kg. Different kinds of NEA surfaces produce some differences in the yield of the process and, hence, in the total released flux (Hapke and Cassidy, 1978). A similar study has been performed by Schläppi et al. (2008) for the asteroids (2867) Steins and (21) Lutetia in preparation of the upcoming Rosetta flybys. Plainaki et al. (2009) considered three different cases of carbonaceous chondrites comprising the actual body of the near Earth object: CI, CM, Tagish-Lake types. The bulk abundances of the main elements constituting each one of the above mentioned categories are presented in Table 1. A summary of the input parameters used by Plainaki et al. (2009) is presented in Table 2.

Table 2: Input Parameters describing NEA environment

Parameter name	Symbol	Suggested Value
Solar wind flux	φ_{H+}	10^8 cm^{-2}s^{-1}
Energy of the incident particle	E_i	1000 eV
Mass of the incident particle	m_i	1 AMU (proton)
NEA Radius	R_{NEO}	500 m
NEA Mass	M_{NEO}	10^{12} kg
Mass of the ejected particle	m_e	depending on the species
Sputtering Yield	Y	0.05
Binding energy	E_b	2 eV

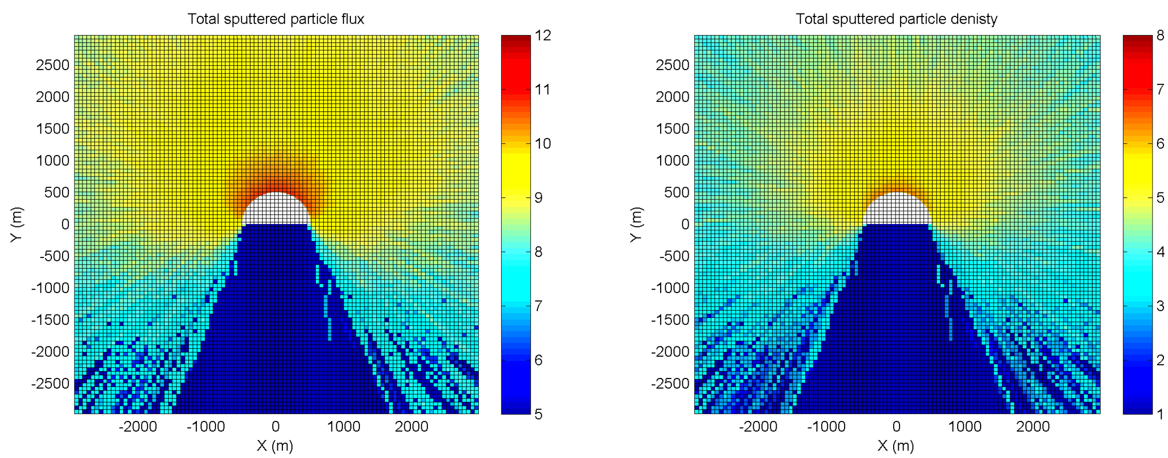

Figure 2: Sputtered particle flux (in logarithm of particles m^{-2} s^{-1}, left) and density (in particles logarithm of m^{-3}, right) distributions for impinging particle of energy ~1000 eV**.** The NEA surface is assumed to be consisting of CI chondrites. From Plainaki et al. (2009). Note that the units here are m^{-2} s^{-1} and m^{-3}.

According to the simulations (Plainaki et al. 2009), for the case of a NEA surface consisting of CI type chondrites, significantly higher fluxes of neutral sputtered particles (up to 10^7 particles cm^{-2} s^{-1}) appear in a region extending from the NEA surface up to an altitude of about 1 km (Figure 2, left). Because MarcoPolo-R will perform a NEA global characterization at a distance below 1 km, and a local characterization at a distance of about 100 m, RAMON will have a good possibility of recording significant fluxes of sputtered particles. According to the right panel of Figure 2, the derived total emitted particle density is sufficiently big, reaching the value of about 3 10^6 particles m^{-3} near the NEA surface. This result is in good agreement with the calculations made by Schläppi et al. (2008) for asteroids Lutetia at a distance of about 2.72 A.U, and Steins at 2.14 AU.

Note that Plainaki et al. (2009) considered only ion sputtering process as source for neutral particle production, since this process is the most important exospheric process on the sunlit side of an asteroid (Schläppi et al., 2008). This is an underestimation of the lower energies particles, since other processes (like PSD, TD and MIV) should be considered for gas density production. Schläppi et al. (2008) considered also these processes estimating that the major density of neutral particles emerging from asteroids about 10^6 particles m^{-3}. However since the considered asteroids are further away from the Sun, we can expect that the released particle density in the case of a NEA will be 1-2 orders of magnitude bigger.

However, the high-energy released particles (Sputtered High Energy Atoms – SHEA) originate only via ion-sputtering (Milillo et al., 2005, 2011). Anyway different environment conditions, (e.g. solar extreme event activity) can result in higher neutral fluxes. Plainaki et al. (2009) showed that the most important contribution to the total sputtered particle flux comes from the H particles emitted (about 3 10^8 particles cm^{-2} s^{-1}). This is due to the higher H abundance and to the higher H sputtering yield (Plainaki et al., 2009).

The H flux biggest difference between the cases of CM and CI chondrite-type NEA surfaces exists in the regions near the NEA surface.

The particles at energy E_e >10 eV are about 1% of the total, they are not gravitationally bound to the NEA, but they expand in space according to r^{-2} law. Finally, if the s/c will be at a distance of less than 1 km from the asteroid with radius ~0.5 km, the estimated flux of high energy (above 10 eV) particles is 3 10^4 $cm^{-2}s^{-1}$.

1.2.2. Ion Backscattering at NEA

The solar wind ions impinging upon the surface of a NEA can penetrate the asteroid's surface until they entirely lose their kinetic energy. During their penetration, these ions can be neutralized and make close collision with target molecules of the surface. As a result, a small fraction of the initial ion flux can be scattered back out of the surface, as neutral.

The efficiency of IBS depends on the surface type and on the ion's impact energy. Recently, energetic neutral atoms measurements from the Moon resulting from solar wind backscattering (McComas et al., 2009; Wieser et al., 2009) demonstrated that the neutrals coming out from IBS are about 10–20% of the impinging ion flux; moreover, the ionized part of the backscattered material is only few percent of the IBS neutral fraction (Saito et al., 2008). The backscattered particles are emitted with an angular spread of few steradians. On the basis of the above, the backscattered H flux at the NEA surface is estimated to be 10^7 $cm^{-2}s^{-1}$ sr^{-1}.

Since the backscattered solar wind ions are mostly 1 keV neutralized H^+, they are not gravitationally bound to the NEA, but they expand in space according to r^{-2} law. Therefore, if the s/c will be at a distance of less than 1 km from the asteroid with radius ~0.5 km, the estimated flux of backscattered H at 1 km from the NEA is 2 10^6 $cm^{-2}s^{-1}$ sr^{-1}.

1.3. Scientific performance requirements

The scientific performance requirements are obtained from the previous considerations and following the scientific performance requirements cited in the Science Requirements Document for the Neutral Particle Analyser (NPA):

GR-080: The flux, speed, direction and mass of atomic/molecular particles escaping from the surface should be measured to detect products of solar wind sputtering or *other active release processes. Then, the energy range from 0.01 to 1 keV shall be covered with an energy resolution of about 25 % and an angular resolution of 5°× 5°; the particles with energies <0.01 keV shall be measured with m/Δm of about 50.*

LR-040: The flux, speed, direction and mass of atomic/molecular particles escaping from the surface should be measured. Then, the energy range from 0.01 to 1 keV shall be covered with an energy resolution of about 25 % and spatial resolution at surface about 10 m; the particles at energy <0.01 keV shall be measured with m/Δm of about 50.

In Table 3 the summary of RAMON scientific performance requirements for each scientific objective is given:

Table 3: Summary of RAMON scientific performance requirements.

Scientific Topic	Signal Intensity	Energy Energy resolution	Major Components	Angular FOV Angular resolution	Time resolution (s)	Observable region
1. particle release processes identification	10^{2} cm^{-3}	< 1 eV Not req.	H, C, Mg, Si, S, Fe, others	- Not req.	60	Mainly dayside
	10^{4} cm^{-2} s^{-1} (for energy >10 eV)	>10 eV 25%	H, and refractories	5°×30° 5°×5°	60	Dayside
2. ion sputtering efficiency versus environment conditions	10^{4} cm^{-2} s^{-1}	>10 eV Not req.	H, and refractories	5°×30° 5°×5°	60	Dayside
3. ion sputtering efficiency versus surface properties	10^{4} cm^{-2} s^{-1}	>10 eV 25%	H, and refractories	5°×30° 5°×2°	60	Dayside
4.gas composition	10^{2} cm^{-3}	< 1 eV Not req.	H, C, Mg, Si, S, Fe, others	- Not req.	300	Mainly dayside
5. role of surface release processes in the evolution	10^{2} cm^{-3}	< 1 eV Not req.	H, C, Mg, Si, S, Fe, others	- Not req.	300	Mainly dayside
	10^{4} cm^{-2} s^{-1} (for energy >10 eV)	>10 eV Not req.	H, and refractories	5°×30° Not req.	300	Dayside
6: Solar wind monitoring	Ions: 10^{8} cm^{-2} s^{-1}	0.1-10 keV 10%	H^{+}, He^{++}	2π, 5°×5°	60	
7: ion backscattering versus surface properties	Ions: 10^{8} cm^{-2} s^{-1}	>10 eV, 25%	H+	2π, 5°×30°	60	Dayside
	Neutrals: 10^{6} cm^{-2} s^{-1}	>100 eV 10%	H	2π, 5°×5°	60	Dayside

1.4. Proposed scientific payload item: RAMON

In order to fulfil the scientific performance requirements in Table 3, we propose a payload item (RAMON) that consists of two neutral atom sensors able to detect and characterize the neutral atoms released from the surface of a NEA, and an ion monitor for the characterization of the space weathering of the surface:

- SHEAMON (Sputtered High-Energy Atoms MONitor) will investigate the ion-sputtering and backscattering process by detecting neutral atoms between ~10 eV and ~3 keV and determining their direction and velocity;
- GASP (GAs SPectrometer) will analyse the mass of the low-energy (below 10 eV) neutral atoms released by different surface processes;
- MIM (Miniaturized Ion Monitor) will measure the flux and energy spectra of precipitating and backscattered solar wind protons and alpha particles.

2. Rationale for proposing the study. Scope of the Study

From a scientific point of view, the objective of the study will be an improved estimation of the expected signal and possible background noises for a better evaluation of RAMON scientific performance requirements. This study will be done through theoretical and laboratory simulations.

From a technical point of view, the objective of the study will mainly address all the technological aspects that will allow at instrument system level to achieve all stated performances and scientific objectives. In particular the objectives are listed below.

a) To identify the best design concept for the mission.
b) To get a first design including thermal design, proximity and main electronics design.
c) To identify the instrument interfaces between the different sub-units and with the spacecraft.
d) To provide a detailed development plan and verification approach in particular for those subsystems critical for the achievements of the mission objectives.
e) To provide evidence that all the EEE, material and parts have a clear procurement scheme and schedule in line with ESA standards.
f) To provide evidence of the Product Assurance rules adopted for the achievements of all of the technical scopes of the study.
g) To detail a deep technology readiness analysis.
h) To prepare the instrument selection process.

3. Technical concepts, analyses and trade-offs.

3.1. Heritage

The PI group at IFSI has a great experience in energetic neutral particle detectors and in the related science. It has been involved in past projects (for instance SAC-B/ISENA), in nowadays operative instruments (MEX/ASPERA-3 and VEX/ASPERA-4) and in under-development instruments (for instance BepiColombo/MPO/SERENA; Orsini et al. 2008a). In particular, the SERENA package includes the ELENA sensor (emitted low energy neutral atoms) (Orsini et al. 2008b) imager under-development with IFSI responsibility (SERENA/ASI industrial contract between ASI and CGS-AMDL joint venture) and the mass spectrometer STROFIO, developed and optimized for detection of very tenuous gas environment, under SwRI responsibility. Presently a STROFIO prototype is been tested at Southwest Research Institute for applications

on the BepiColombo spacecraft to Mercury and the Ladee mission to the Moon. The University of Bern (UniBe) is highly involved in development and testing of Strofio.
RAMON will benefit of the inheritance from the BepiColombo/SERENA design also for what concerns the system control and power distribution unit, namely SCU. Such a board support S/C I/F and data handling computation services suitable at particle package level consists in one board containing the following functional blocks: a) Hi Rel FPGA based Control Unit (Spacewire hub, Leon2 FT); b) Hi Rel SRAM 512×2 kB EDAC Protected; c) HI Rel local power converter and power distribution switches; d) radiation tolerant EEPROM 128×2 kB EDAC Protected and optionally a radiation tolerant 200 MIPS DSP Based DPU Compressor.

3.2. Instrument concept

Detecting and characterizing neutral atoms in the energy range of interest, < 1 eV – 1.0 keV, in an environment of photon, electron and ion fluxes, require 1) highly effective suppression of photons, electrons, ions and 2) two sensors for particles above and below 10 eV.
In Figure 3, the RAMON basic concept is given. The incoming radiation made by neutrals, ions and photons impinges upon an aperture. The ions and electrons are deflected by electrostatic lens (B). The neutral particles pass through an entrance of about 1 cm^2 divided for detecting low energies and higher energies.
For low-energy particle detection (GASP sensor), the neutral particles pass through a carbon nanotube system (C1) that ionizes the particles with higher efficiency at lower energies. The ionized particles cross an electronic gate (C2) that provides the START of the detection. Then the particles are deviated and accelerated up to more than 1 keV by an electrostatic analyser (C3) and are detected by a MCP (C4). The time of flight provides information about mass (since the spread in energy is assumed negligible).
For detecting particles between 10 eV – 1 keV (SHEAMON sensor), the neutrals pass through a double grating system (with slits of nanometric dimension) (D1) that provides photon suppression. A shuttering system allows to move the two grids one with respect to the other to permit the neutrals to enter in the sensor only when the slits are aligned (open gate), which defines the START time. Then the neutrals fly into a ToF chamber and become ionized by using the technique of neutral-ion conversion surface (D2) (Wurz, 2000). The ionization efficiency is sufficient at the lowest particle energies and even increases for higher energies (Wurz et al., 2006). During particle impact at the conversion surface electrons are released, even at low impact energies (Wieser et al., 2005). An electrostatic system accelerates the released electrons keeping them well aligned to the original projection to the surface impacting point and pushing them toward the stop MCP detector, which also has position sensing capability (D3). The MCP will provide the STOP signal for the ToF measurement as well as the angular direction of the velocity of the registered neutral particle. The atom converted in ion by the conversion surface will be accelerated and detected by an additional MCP (D4) that will provide an additional STOP signal. To increase the Geometrical Factor, the detector can be used in open-gate mode and the ToF can be computed using the first MCP signal as START. In this way, the energy resolution will be lower, but thanks to the collimating properties of the entrance grids, which in this configuration are fixed, the angular resolution is higher. The common FOV of the two detection systems is 5°×30°. The higher energy distribution will be analyzed with an angular resolution of 5°×2° (high angular resolution mode) or 5°×5° (low angular resolution mode).
MIM is a very light charged ion sensor providing the information of the solar wind proton parameters. MIM is based on the MIPA sensor which will fly with BepiColombo as a part of

SERENA package. IRF inherits experiences of on-flight sensors such as SWIM onboard Chandrayaan-1 (Barabash et al. 2009) and PRIMA onboard PRISMA.

The SWIM sensor was successfully carried to the Moon in 2009, and reported new findings of the lunar plasma environment (e.g. Futaana et al., 2010b, Holmström et al., 2010, Lue et al., 2011). SWIM provided also the solar wind conditions to assist sciences conducted by the accompanied energetic neutral sensor. The PRIMA sensor was also successfully inserted into the Earth's orbit, and successfully conducted the operations (e.g. http://www.spaceportsweden.com/prima-1.aspx).

The primary scientific objective of MIM is to provide the solar wind conditions near the NEA, so that the good energy and the angular resolution will help because the solar wind a mono-energetic narrow beam. As the solar wind protons and alpha particles have different energy (per charge), thus, the energy spectra give separation between them, which means that the mass resolution is not necessary.

Figure 4 draws the principle of MIM functionality. The axi-symmetric deflection system extended from the sensor box provides the full 2π angular coverage with the target angular resolution of 5°×5°. The deflection system is composed of three electrostatic deflector plates (not shown). The high voltage is applied to different combination of the plates. Changing the combination allows measurements of ions from different azimuth directions. Changing the value of the applied voltage results in the polar angle change. The following electrostatic analyzer part will provide the energy resolution of the incident ions according to the high voltage setting. The selected ions produce secondary electrons at a monocrystal tungsten surface to be detected by a ceramic channel electron multipliers (CCEM).

All the RAMON operations will be controlled by an FPGA based microcontroller (Sensor Control Unit - SCU).

To accomplish the scientific objectives, the MIM sensor pointing is preferably to cover both the sun direction (to measure the solar wind) and the NEA (to measure the backscattered ions).

Taking into account the instrument elements, the response of GASP to a neutral density is evaluated in Table 4, the range of geometrical factor for different modes of SHEAMON is evaluated in Table 5 and the geometrical factor of MIM is evaluated in Table 6.

Table 4 GASP

Element	Value	Unit
Cross section	$1.4\ 10^{-16}$	cm^2
Ionization length	2	cm
Electron current	$6.2\ 10^{15}$	e^-/s=1 mA
Collection efficiency	0.1	
TOTAL	0.14	$(Cnt/s)/cm^{-3}$

Table 5 SHEAMON

Element	Value	Unit
FOV (5°×30°)	0.04	sr
Aperture	1	cm^2
Geometrical aperture ratio	0.2	
Shuttering grid	0.1	
Conversion surface efficiency (energy dependent)	0.001-0.1	
MCP electron efficiency	0.9	
MCP ion efficiency	0.5	
TOTAL	$4\ 10^{-4}$-$2\ 10^{-5}$	cm^2 sr

Table 6 MIM

Element	Value	Unit
FOV (5˚×5˚)	0.0076	sr
Aperture	0.04	cm^2
Energy resolution (ΔE/E)	10	%
Efficiency	10	%
TOTAL (Efficiency included)	3×10^{-5}	cm^2 sr eV/eV

According to the proposed design the estimated mass of the NPA sensor is about 2.5 kg and the total power requirement is about 11 W.

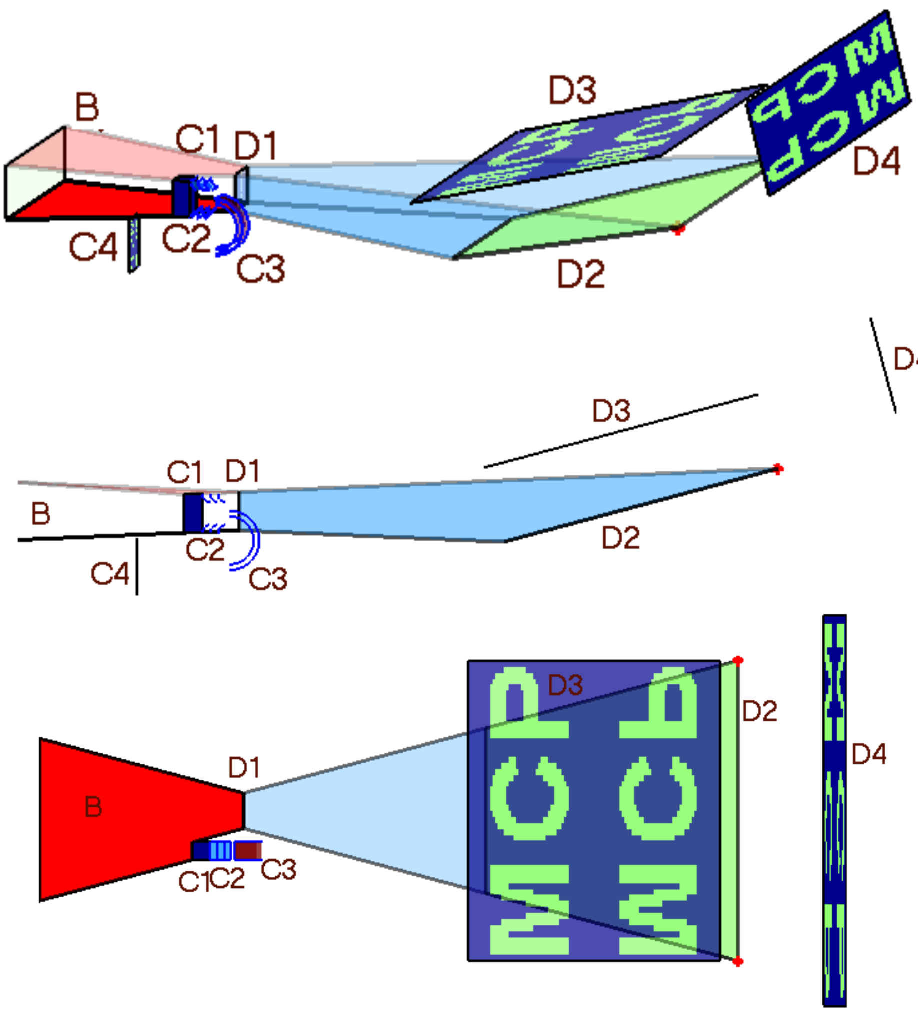

Figure 3. Different projections of the RAMON basic concept. SHEAMON/GASP inside sensor consists of the following subsystems:
A: Cover (not shown); B: Parallel plate collimator, balanced biased +5kV –5kV;
GASP: C1: nanotube for ionizing lower energies particles, C2: electronic gate, C3: ESA, C4: MCP, C5: 2D Anode system (not shown);
SHEAMON: D1 two nanogrids and the shuttering system, D2: Conversion Surface; D3 MCP electron detector; D4: MCP ion detector; D5: 2D Anode system (not shown).

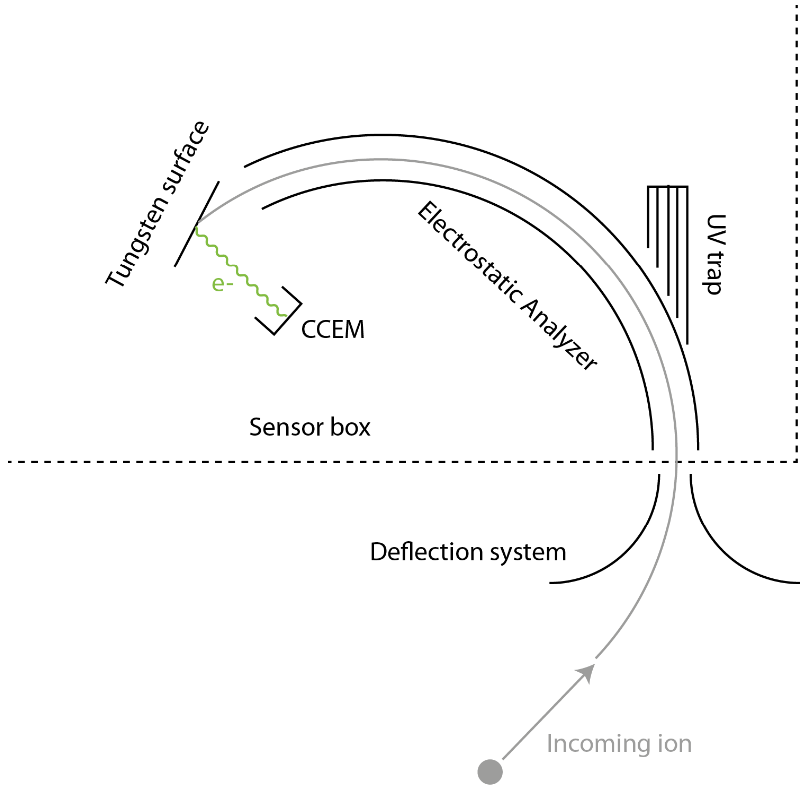

Figure 4: MIM basic concept.

The required telemetry resources are not expensive. For SHEAMON, if we consider 50 mass channels the low-energy detection requires about 15 bit/s for an integration time of 1 minute. If we consider 10 ToF channels and 30 angular directions the high-energy detection requires about 40 bit/s for an integration time of 1 minute. Data compression is provided by an included high reliability computation unit (factor 3 loss-less (Semi-log + Hartmann-Quadtree loss less) and 4.5 lossy (Semi-log + Hartmann-Quadtree lossy).

Table 7: Summary of RAMON resources

	Mass (kg)	**Power (W)**	**Volume (cm^3)**	**Data rate (bit/s)**
SHEAMON	1.1	7	20×10×10	40
GASP	1.1	1.5	15×10×10	15
MIM	0.3	2.5	9×10×13	40
SCU (Inside SHEAMON)	0.2	3	16×1×10	N/A
RAMON TOT	**2.5**	**14**	20×20×10	95

3.3. Thermal control requirement and Sun avoidance requirement.

No specific thermal control is required no Sun avoidance is required.

3.4. Pointing

SHEAMON and GASP sensors share the same entrance and must be allocated on the spacecraft so that they point toward the NEA. MIM has a 2 π FoV and should be placed so that the FoV looks partially to the NEA, and partially to the sun.

3.5. Calibrations

Tests and calibrations of the SHEAMON sensor will be performed at IFSI and at UniBe.
Tests and calibrations of the GASP sensor will be performed at SwRI.
Tests and calibrations of the MIM sensor will be performed at IRF.
Test of the RAMON integrated instrument will be performed under IFSI responsibility.
In flight calibration: far from sources during the cruise phase, it is requested to perform a functional test of the instrument to verify the readout noise threshold.

3.6. Cleanliness, planetary protection and pre-launch activities

The instrument (MCPs) requires purging and humidity monitoring up to launch.

3.7. Critical points

The sensors are adequate for environments requiring strong radiation shielding like the BepiColombo mission to Mercury. The environment and mission duration of MarcoPolo-R is less constraining in comparison.
The UV and IR noise should be better evaluated. Anyway, the RAMON design prevents UV noise; an IR filter could be added in the case IR radiation will not be negligible.

3.8. Present status of the analysis

The study performed for the previous MARCOPOLO proposal produced a first reliable estimation of the expected signal for RAMON for an appropriate definition of instrument requirements. The logic of the study focused in design definition of the instrument, in laboratory tests of instrument sub-systems to obtain confidence that all the stated performances and parameters will be achieved. The study was also devoted to the identification of critical technology and to the development planning.
The SHEAMON conversion surface and stop section are based on well known technologies. Anyway, the whole system will be tested in the future. Therefore, the main tests performed for SHEAMON are devoted to the start section characterization.

3.8.1. Nano-shuttering grid test for RAMON/SHEAMON sensor

The nano-shuttering grids are a new tool used for energetic neutral tagging at the entrance of the sensor very promising for the efficiency of removal of UV photons and for preserving direction/energy information of the particles. This technology is being tested for the ELENA sensor of the BepiColombo mission.

Mechanical and thermal test of piezo-device

The piezo-device has been fully qualified to show the ability to work for a very long time in the mission around Mercury.

An experimental set-up has been designed to let a tilting mirror (flexure design) make a mechanical work driven by the selected piezo, under vacuum and let sampled by an external laser system. Here are the main facts:

- Vacuum: 1.10^{-7} mbar (by Ion pumping).
- Possibility to heat the piezo under vacuum (e.g. up to 150 °C). The temperature has been let at RT for some part of the test, while was over 130°C for about 1/3 of the testing time.
- Piezo continuous solicitation: 20V pk-pk at 100 kHz .
- Test duration: the piezo-mechanical assembly is working after one year of uninterrupted operation.
- The operational frequency is just the same as the maximum designed for ELENA (100kHz).
- $3.0\ 10^{12}$ piezo cycles over 347 days.
- Week-by-week data have a reproducibility of ~50nm, at a given temperature: within this error vibration has been proven well constant.
- Temperature increase seems diminish a little the average oscillation value, while cooling down to RT the value seems to increase a little.

After 1 year the life time test is yet in progress. Data and further details are shown at the website http://stm8.artov.isc.cnr.it/BepiColombo/.

UV transmission test of the grid

It is necessary to know exactly the UV transmission properties of the grids. The comparison between results obtained by software tools and real data is necessary to confirm the validity of the computational effort**.**

Experimental tests for a single grid have been realized with synchrotron radiation at the Synchrotron facility "Elettra" – Trieste (N. Zema, ISM-CNR). The photon beam at λ =121.6 nm has been transmitted through a 200 nm slit (4μm pitch grating).

Experimental results were even better than theoretical predictions. The measured transmittance was 0.92% (see Figure 5) while the theoretical one was 0.95%.

The double grids shuttering system will have even better performances.

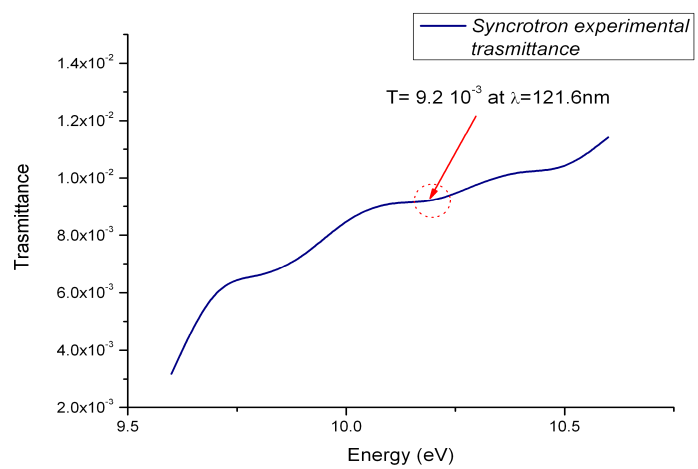

Figure 5. Experimental transmission data obtained at the Synchrotron facility "Elettra" – Trieste (N. Zema, ISM-CNR)

Preliminary particle transmission test of the shutter prototype

Shutter prototype II is shown in Figure 6 (left). It is mounted on a manipulator inside the vacuum chamber. The ion beam (He^+) impinges on the shutter and the beam modulation is detected with MCP detector (Figure 6, right).

The transmittance of the no-shuttering system was measured, as first test.

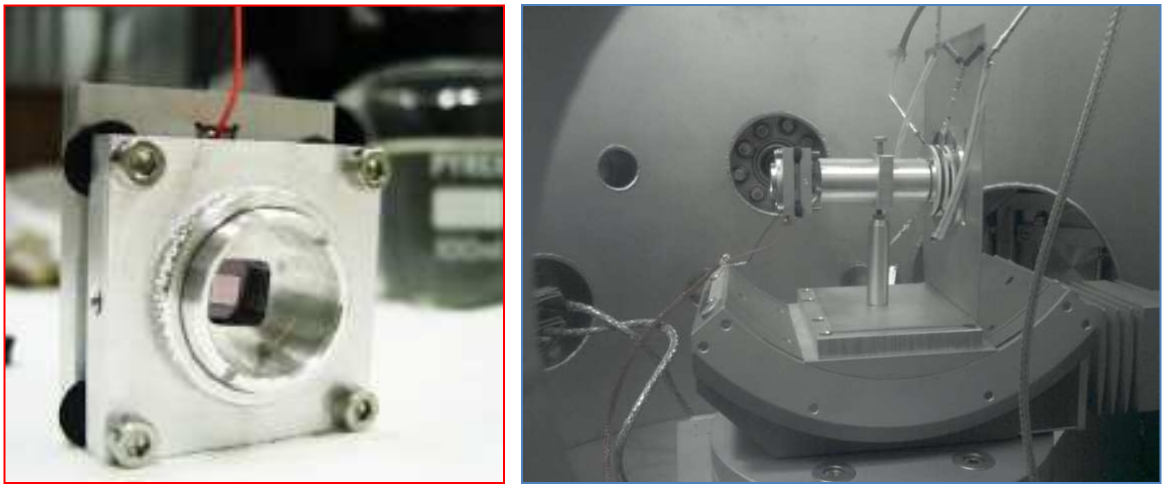

Figure 6. Left: Shutter prototype II. Right: Set up assembled into the chamber for shutter system test

We verified the correct transmittance of the system measuring the membranes particle flow.

3.8.2. Study of Sensor Control Unit design

A study on the instrument Sensor Control Unit (SCU) design was performed. The instrument can be simplified, including only minimal internal computation resources and, hence, requesting an external DPU. A second possibility is to over-sizing the DPU resources in order to have the possibility to hosting other sensors computations.

Finally, we foresee three SCU possibilities: external DPU, stand–alone DPU, DPU hosting other instruments.

4. Technology readiness analysis

Even though designs will be based on existing technologies, technological feasibility will be checked at each component level with manufacturers. This approach will refine the TRL (Technological Readiness Level) evaluation for each component and subsystems. In Table 8 an estimation of Technology Readiness Level (TRL) and Design Maturity Level (DML) is given. The proposed study is intended to give a better evaluation of the TRL and DML.

Table 8 TRL and DML

Sensor/subsystem	TRL	DML
SHEAMON Detector	4	2
GASP Detector	4	3
MIM Detector	7	2
Electronics	6	1
SHEAMON Entrance system	4	2
GASP Entrance system	5	2
TRL (Technology Readiness Level). 1: basic principles observed and reported; 2: technology concept and application formulated; 3: analytical and experimental critical function, characteristic proof-of-concept; 4: components validated in the laboratory; 5: component and/or breadboard validation in a relevant environment; 6: system demonstrated in relevant environment (ground or space); 7: system prototype validated in space environment; 8: system flight-qualified through tests; 9: system verified by successful mission. DML (Design Maturity Level). 1: existing HW; 2: existing + minor modifications; 3: existing + major modifications; 4: new, detail design available; 5: new, preliminary design available; 6: new, conceptual design available		

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5. Study logic

The proposed study will take advantage of already performed analyses in the frame of previous MarcoPolo mission proposal, as described in section 3.8 “Present status of the analysis”.

5.1. Expected signal and possible background noises estimations

Numerical models of particle release processes, of radiative emission from the body and of plasma environment will be developed and upgraded in order to achieve an appropriate evaluation of the signal and the possible background noise.
A laboratory facility will be set-up in order to obtain experimental simulations of particles release from a NEA analogue. Ion source and ultra-vacuum chamber provided with a remote control system are already available at IFSI. A NEA surface analogue (for ion-sputtering simulation) and a particle detector prototype will be implemented in the facility, thus allowing the required activities.

5.2. Design concept optimization

The scientific requirements will establish the instrument key parameters drivers for the design. The logic of the study will mainly focus in design definition of the instrument, in laboratory tests of instrument sub-systems to obtain confidence that all the stated performances and parameters will be achieved. The study of the instrument definition and design will be oriented to save mass and to increase the geometrical factor. This will be achieved by:
- optimizing the conversion surface efficiency and the related positioning system in SHEAMON;
- optimizing the ionization system in GASP;
- optimizing the design of the ToF system in GASP to reduce the mass;
- optimizing/consolidating the design of MIM.

This definition will include mechanical and thermal design, proximity and main electronics design.

The instrument interfaces between the different sub-units and with the spacecraft will be also defined.
The output of this technical study will allow the budgeting the spacecraft required resources.

5.3. Development plan definition

A detailed development plan and verification approach, in particular for those subsystems critical for the achievements of the mission objectives, will be defined, assessing a schedule risk analysis and identification of all critical items and, specifically, the radiation shielding analysis.
All the EEE, material and parts will have a clear procurement scheme and schedule in line with ESA standards, product assurance (PA) rules are adopted for the achievements of all of the technical scopes of the study.
A deep technology readiness analysis will be detailed. To prepare the instrument selection process, a management plan with roles and responsibilities for C/D phases will be also provided.

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Declaration of Interest to Propose a Neutral Particle Analyser for the MarcoPolo-R Mission

RAMON

Part B: Management Proposal

Table of Contents

1. Study team organization

1.1 Associated Institutions, key persons and team

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CNR/ISC, Roma, Italy, S. Selci (Stefano.Selci@isc.cnr.it), M. D'Alessandro (marco.dalessandro@isc.cnr.it)

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CNRS/IPSL/Service d'Aeronomie, F. Leblanc (francois.leblanc@aerov.jussieu.fr)

IRF (Swedish Institute of Space Physics), Kiruna, Sweden, S. Barabash (stas@irf.se), Y. Futaana (futaana@irf.se)

JHU-APL, Laurel, MD, USA G. Ho (george.ho@jhuapl.edu)

LESIA - Observatoire de Paris, France, M.A. Barucci (Antonella.Barucci@obspm.fr)

SwRI, San Antonio, TX, USA, S. Livi (Stefano.Livi@swri.edu), R. Goldstein (rgoldstein@swri.edu)

University of Bern, Switzerland, P. Wurz (peter.wurz@space.unibe.ch), J. Scheer (juergen.scheer@space.unibe.ch)

University of Virginia, USA, R.E. Johnson (rej@virginia.edu)

1.2 Major Responsibilities

The key members of the team are:

Principal Investigator:
Dr. Alessandro Mura (INAF/IFSI), supported by: the PI deputy (C. Plainaki); GASP co-PI (S. Livi); MIM co-PI (Stas Barabash), the Project Manager (Andrea Argan); the hardware providers and the other Co-Is. He has the responsibility of the whole project and of the SHEAMON sensor.

He is also responsible for science activities, funding, management and overall activities of the RAMON project.

PI Deputy
Dr. Christina Plainaki (INAF/IFSI). She will represent the PI and assist the PI for any necessity.

GASP Co-PI
Dr. S. Livi (SwRI). He is responsible of the GASP sensor delivery; he will coordinate the technical and scientific activities to be performed in the US.

MIM Co-PI
Dr. S. Barabash (IRF). He is responsible of the MIM sensor delivery;

Program and Design Manager
Dr. Andrea Argan (INAF). He has the responsibility to coordinate technical and programmatic activities of the whole project.

Leading Co-I's
Dr. Iannis Dandouras (IRAP) is responsible of SHEAMON HV power supply delivery.
Dr. Esa Kallio (FMI) is responsible of RAMON GSE delivery.
Dr. Peter Wurz (UNI of BERN) is responsible of conversion surfaces delivery and contributes to calibration activities.
Dr. Stefano Selci (CNR/ISC) and Andrea Maria Di Lellis (AMDL SRL) are responsible for the SHEAMON grid system
Dr. Roberto Leoni (CNR/IFN) is responsible for the manufacture of the SHEAMON grids

1.3 Instrument development management plan

The team will perform a study to define the hardware providers for the instrument. Presently, it is foreseen that:
The RAMON- SHEAMON sensor will be designed, tested and calibrated at INAF/IFSI, Rome, and manufactured under industrial contract from ASI.
The RAMON-GASP sensor will be designed, manufactured and delivered by SwRI.
The RAMON-MIM sensor will be designed, manufactured and delivered by IRF.
SCU will designed, manufactured and tested under industrial contract from ASI
RAMON AIV will be done under IFSI responsibility.

Table 1 Proposed responsibilities of the Institutions.

Group	Role	Responsibility
INAF/IFSI, Rome, Italy (with the contributions of CNR/IFN, CNR/ISC, INAF/OAR)	PI PM	RAMON AIV SHEAMON Sensor
ASI (with the contribution of industry)		SHEAMON AIV, SCU
SWRI, San Antonio, TX – USA (with the contribution of JHU/APL).	Co-PI	GASP Sensor
IRF, Kiruna, Sweden	Co-PI	MIM Sensor
Physikalisches Institut, University of Bern, Switzerland	Co-I	SHEAMON conversion surfaces, GASP Ion source, Calibration
IRAP, Toulouse, France	Co-I	SHEAMON High Voltages
FMI, Finland	Co-I	RAMON EGSE

Specific hardware participation from other providers within the team will be decided after a devoted team meeting.

1.4 Organization

The study team is appointed for a period of 12 months from January 2012. The technical study will be carried out under responsibility of INAF/IFSI. SHEAMON technical development will be studied by a consortium of INAF/IFSI, CNR/ISC, CNR/IFN, INAF/OAR, University of Bern, IRAP. SwRI will take the responsibility for the study of GASP technical development. IRF will take the responsibility for the study of MIM.

2. Study team background

2.1 Qualifications and Experience of PI Team and Key Staff

The RAMON team has gained relevant experience through a very long and successful heritage of space projects, actively participating to most of the major present and past ESA and NASA programs devoted to interplanetary space particle investigations as well as to planetary exploration. Among these programs, it is worth mentioning still operating or ongoing missions, like BepiColombo, CLUSTER, MARS EXPRESS, ROSETTA, DOUBLESTAR, VENUS EXPRESS, and NASA IMAGE, CASSINI and MESSENGER.

The RAMON Science Team incorporates most of the world experts in neutral atom imaging, including PIs and Co-Is of neutral atom and plasma instrumentation on board space missions devoted to both planetary exploration and space weathering. Moreover, qualified experts of the NEA environments are present in the team as well. The Project management together with the associated Technical Team ensures high quality technical production, given the past involvement in top-level technology applied to space instrumentation.

Istituto di Fisica dello Spazio Interplanetario[1] (IFSI, Rome, Italy), the PI Institute, is presently part of the "Istituto Nazionale di Astrofisica" (INAF). IFSI has been involved in space research since 1968, and throughout these 44 years of qualified work it has reached top international levels in both space science and space technology. Similar arguments are valid for the four major partner institutes (UniBe, IRAP, FMI, and SwRI), as well as for the rest of the RAMON team.

More details on team expertise may be found in the following, where CVs of all Team Leaders, Co-Is and team key persons are also given.

2.2 Curricula Vitae

Alessandro Mura (PI)
Education:
2003: PhD in Space Physics, University "Tor Vergata", Rome.
Thesis title: "ENA imaging of planetary environments"
1991-1998: "Laurea" Summa cum laude in Physics, University "La Sapienza", Rome
Professional experience:

[1] At the beginning of 2012, IFSI will merge with INAF/IASF in a new institute (IAPS)

2003 -2011: Permanent position as researcher in Space Physics at INAF/IFSI; Deputy-PI of JIRAM instrument on board NASA-JUNO mission (2011); Co-I of ASPERA-4 instrument on board ESA-VeX mission; Co-I of SERENA instrument on board ESA-BepiColombo mission; ELENA/SERENA core member, responsible of ELENA instrument operations, performance & signal simulation.
2000 -2003: Researcher (contractor) in Space Physics at INAF/IFSI; Team member of ASPERA-3 instrument on board ESA-MeX mission.
Scientific activity
PhD in planetary (Earth, Mars, Mercury) space physics, MEX/ASPERA-3 NPI and NPD instruments data analysis; Mercury magnetospheric/exospheric circulation numerical modeling; about 40 referred publications.

Christina Plainaki (deputy PI)
Education:
2001: B.Sc. degree in Physics, National and Kapodistrian University of Athens-Greece
2004: Master in Physics (Specialization: Astrophysics, Astronomy and Mechanics), National and Kapodistrian University of Athens-Greece
2007: Ph.D. in Physics (Ph.D. Thesis: *Solar cosmic ray physics using data from neutron monitors and satellites*), National and Kapodistrian University of Athens-Greece
Professional Experience:
14/2/2001-30/6/2003: Software engineering in "Development Innovations & Projects - SIEMENS" Centre, N. Kifisia-Greece
1/11/2003-31/10/2006: Post-graduate fellowship IRAKLITOS (Greek Ministry of Education and Religious Affairs), at the National and Kapodistrian University of Athens-Greece.
3/12/2007-31/8/2010: Research grant (Assegno di collaborazione ad attività di ricerca): 'ENA detection in the Solar System for understanding the dynamics of heliospheric and planetary environments', in IFSI-INAF.
1/9/2010-today: Postdoc Fellowship 'SERENA' for the project SERENA/BEPI COLOMBO (ESA space mission) in IFSI-INAF.
Expertise:
Monte Carlo modeling of Europa's exosphere
Monte Carlo modeling of Space Weathering taking place on Asteroids, on the Earth's Moon and on the icy surfaces of Jupiter's moons (Europa, Ganymede and Callisto)
Data analysis for the instrument 'Athens Neutron Monitor', in the section of 'Nuclear and Particle Physics' of the Department of Physics of the National and Kapodistrian University of Athens-Greece,
Developer (theory and code) of the models NMBANGLE and NMBANGLE PPOLA, for the analysis of solar extreme events registered at Earth
Co-author in 23 publications in refereed journals and 25 articles in Conference Proceedings

Stefano Livi (US Project Scientist, GASP PI), Southwest Research Institute
Education:
1974–1981, Universita' degli Studi di Firenze, physics department
1981–1982, Ph.D. student at Max-Planck-Institut für Aeronomie (MPAe)

1982, Dr. Rer. Nat. in Physics at the Universita' degli Studi di Firenze (Summa cum Laude)
1987, Dr. Res. in Astrophysics at the Universita' degli Studi di Roma (Summa cum Laude)
Employment:
1981-2000: Max Planck Institut für Aeronomie (now MPS)
2000-2006: Johns Hopkins University – Applied Physics Laboratory
2006- present: Southwest Research Institute
Professional experience:
Principal Investigator on Strofio – PIDDP, 2003–2007
Lead Investigator: CAMMICE/Polar, MIMI/CASSINI, ISENA/SAC-B, ROSINA/ Rosetta
Co-Investigator: MSIS/AMPTE, TAUS/Phobos, UVCS/SOHO, CELIAS/SOHO, Rapid/Cluster, MICS/CRRES, CEPPAD/POLAR, SWICS/Ulysses, HEP-LD/Geotail, EPD/Galileo, ASPERA-3/Mars Express, IMPACT/Stereo
Instrument Scientist: EPS/MESSENGER, PEPSSI/New Horizon

Stas Barabash (MIM PI)
Degrees:PhD in Space Physics, Umeå University/Swedish Institute of Space Physics, 1996
Docent, Umeå University/Swedish Institute of Space Physics, 1998
Professor in Space Physics, Umeå University/Swedish Institute of Space Physics, 2002
Position: Professor in Space Physics, Umeå University/Swedish Institute of Space Physics, 2002
Head of Solar System and Space Technology Program, Swedish Institute of Space Physics, since 2001. Deputy Director, Swedish Institute of Space Physics, since 2005
Professional experience:
Principle / Co – Principle Investigator on the following missions and experiments
Chinese microsat Yinghou-1, YPP; ISRO Chandrayaan–1, SARA; ESA / JAXA Bepi Colombo / MPO, MIPA; ESA / JAXA Bepi Colombo / MMO, ENA; ESA Venus Express, ASPERA–4; Chinese Double Star, NUADU; ESA Mars Express, ASPERA–3; Swedish nanosatellite Munin, DINA; Swedish microsatellite Astrid-1, PIPPI
Co – Investigator on the following missions and experiments
Swedish PRISMA, PRIMA; Russian Phobos-Grunt, DIM; Stratospheric balloon experiment P-BACE; ESA Venus Express, MAG; ESA SMART –1, D-CIXS; Russian Mars – 96, ASPERA – C; Russian Interbal Tail and Auroral, PROMICS-3; Russian Phobos –2, ASPERA.
Expertise: Wide experience in space plasma instrument design, development, calibration, operations, and data analysis
Expert in ENA diagnostic of space plasmas, conducted first – ever dedicated ENA imaging experiment in space at the Earth, Mars, Venus, and the Moon
Expert in solar wind interactions with non-magnetized bodies
Possess a firm experience of managing large international teams providing flight hardware
Publications: Author or co-author over 200 articles.

Andrea Argan, (Program and Design Manager), INAF
Education:
Degree in Electronic Engineering, University of Naples, Italy.
Fellowship on Particle Accelerator technologies,
Istituto Nazionale di Fisica Nucleare (INFN), Laboratori Nazionali di Frascati (LNF).

Employment:
March 2000 - Feb. 2002: Research grant, Consorzio Interuniversitario
per la Fisica Spaziale (CIFS), Italy.
March 2002 - Nov. 2004: Research staff member at the Istituto Fisica Cosmica, CNR, Milan
Dec. 2004 - Apr.2008: First Tecnologist, staff member at the Istituto di Astrofisica Spaziale e Fisica Cosmica (IASF), CNR (INAF since Jan 2005), Rome
Since May 2008: First Technologist, permanent staff member at the Project Departement, INAF-Headquarter, Rome.
Professional Experience: Responsible for the Payload Data Handling Unit on the AGILE satellite; AIV Manager of the AGILE satellite; Payload Manager of the AGILE satellite; Instrument Manager of the SIMBOL-X mission; System Manager of the NHXM mission; System Manager of the ASTRI Telescope; Member of the LOFT System Team: Contract Manager of the BEpiColombo-SERENA ASI-INAF scientific contract:; Contract Manager of the AGILE ASI-INAF scientific contract

Iannis Dandouras (Leading Co-I), Directreur de Recherche at CNRS, IRAP, Toulouse.
Education: 1980: B.Sc. degree in Physics, University of Athens, Greece. 1981: D.E.A. (MSc) in Space Physics, Paul Sabatier University. 1988: Doctorat d'Etat (Ph.D.), Paul Sabatier University, Toulouse.
Employment: 1984-1988: Graduate Research Associate, CNES, Toulouse. 1989: Post-Doctoral Research at the Space Sciences Laboratory, Univ. of California, Berkeley, and at the Univ. of Washington, Seattle, USA. Oct. 1989-Oct. 2009: Chargé de Recherche at CNRS, CESR, Toulouse. Since Oct 2009: Directreur de Recherche at CNRS, at the CESR laboratory, which since Jan 2011 is the IRAP.
Professional Experience:

- Principal Investigator, Cluster CIS Ion Mass Spectrometer.
- Deputy Principal Investigator, Double Star HIA Ion Spectrometer.
- Co-Investigator, Cassini MIMI Magnetospheric Imaging Instrument.
- Co-Investigator, BepiColombo SERENA Ion and Neutral Instrument.
- Co-Investigator, STEREO IMPACT Solar Wind Instrument.
- President (2008-2011), Solar-Terrestrial Sciences Division of the Europ. Geosciences Union.
- Member (2006-2011), CNES Sun-Heliosphere-Magnetosphere Advisory Group.
- Member, ESA Cluster Science Operations Working Group.
- Member, CNSA / ESA DSDS Implementation Working Group.
- Member, French Committee for SCOSTEP (Scientific Committee of Solar Terrestrial Physics).
- Past Member, French Space Weather Working Group (PNST/CNRS).

Over 220 publications in refereed journals.

Esa Kallio (Leading Co-I), Finnish Meteorological Institute, Helsinki, Finland
Education: 1996: PhD, Theoretical physics, University of Helsinki, Finland
Experience:
- 1/2008 -> present: Head of Space Weather Group at Earth Observation Unit, Finnish

Meteorological Institute.
- 1990-1996, 1997-2001, 9/2007 -> present: Senior scientist at Space Science Unit, Finnish Meteorological Institute
- 2001 - 8/2007: Academy Fellow, Finnish Academy of Science
- 1996-1997: PhD student, Space Science Laboratory, the University of California, Berkeley, USA

Expertise:
- Global numerical hybrid modeling of the solar wind interaction with the Solar System objects (Mercury, Venus, the Moon, Mars, Saturnian moon Titan, asteroids)
- Data analysis (ASPERA/Phobos-2, ASPERA-3/MEX, ASPERA-4/VEX, magnetometers)
- Participation in experimental space projects: [currently flying instruments] Co-investigator: ASPERA-3/MarsExpress, ASPERA-4/VenusExpress and ICA/ROSETTA particle instruments [instruments in preparation] Co-investigator: SERENA/BepiColombo, PHEBUS/BepiColombo and MEFISTO/BepiColombo instruments.
- Over 80 refereed publications (http://www.ava.fmi.fi/~kallio/publications_Esa.html)
- Activity in scientific societies: 2005-2007: ESA's Solar System Working Group (SSWG), member.

Peter Wurz (Leading Co-I)**,** Space Research and Planetary Sciences Division, Physics Institute, University of Bern, Switzerland

Education: Engineering school, Vienna, Austria, Department: Telecommunication and Electronics, 1980; M.S. Technical Physics, Technical University of Vienna, 1987; Ph.D. Technical Physics, Technical University of Vienna, 1990; Vienna Docendi, University of Bern, 1999; Titularprofessor, University of Bern, Bern, Switzerland, 2003; Associate Professor, University of Bern, Bern, Switzerland, 2008.

Professional Background: Electronics Engineer, 1981–1983, Datentechnik; Austria; Software Engineer, 1983–1985, Datentechnik; Austria; Research Assistant, 1985–1990, Institut für Allgemeine
Physik, Technical University of Vienna, Austria; Post-doctoral appointment, 1990–1992, Materials Science/Chemistry Divisions, Argonne National Laboratory, Chicago, USA; Research Associate, 1992–2000, Physics Institute, Department of Space Research and Planetary Sciences, University of Bern, Switzerland; Docent, 2000–present, Physics Institute, Space Research and Planetary Sciences
Division, University of Bern, Switzerland.

Relevant Experience: Dr. Wurz is Lead Co-Investigator for the RTOF instrument of ROSINA on the Rosetta mission (ESA), and is Co-Investigator on Charge, Element, and Isotope Analysis System (CELIAS) on SOHO (ESA/NASA), Low-Energy Neutral Atom (LENA) instrument on IMAGE (NASA), the ASPERA instruments on Mars Express and Venus Express (both ESA), on the PLASTIC instrument on the STEREO mission (NASA), the SERENA and ENA instruments on BepiColombo (ESA/JAXA), and the LASMA instrument on Phobos-Grunt (Roskosmos).
Dr. Wurz is author or co-author of 195 scientific papers in the refereed literature and of 56 other publications, on topics related to plasma physics, space science, space science instrumentation, ion optics, electron stimulated desorption, ion-sputtering, physical chemistry, and laser interaction with solids and particles**.**

JuergenScheer, Space Research and Planetary Sciences Division, Physics Institute, University of Bern, Switzerland
Education and relevant experience: M.S. in Physics, University of Osnabrueck, Germany, 1999. Research assistant at ETH Zurich, Switzerland, 1999 – 2001.Ph.D. in Physics, University of Bern, Switzerland, 2005.Topic: Neutral – Ion conversion surfaces in neutral particle sensing instruments for space science. Since 2005 – present: Research associate, instrument scientist and project manager at the Space Research and Planetary Sciences Division, Physics Institute, University of Bern, Switzerland. Experimental lead during the calibration campaign of the IBEX-Lo instrument at the University of Bern.Co-Investigator of the SERENA instrument suite for BepiColombo.

Maria Antonietta Barucci, senior astronomer (1st class) at LESIA-Observatoire de Paris.
Space mission instrument involvement: co-I of CIRS, HASI (Cassini-Huygens), OSIRIS, VIRTIS (Rosetta), AMIE (SMART-1), VIR (DAWN), SIMBIO-SYS (Bepi-Colombo).
Main relevant expertise: space weathering, small bodies, surface characterization, origin and evolution of the Solar System. Author of over 450 scientific articles including 190 on referred journal.

John Robert Brucato, Astronomer Researcher at the INAF-Astrophysical Observatory of Arcetri, Florence Italy
Research Experience: Spectroscopic (Vis-MIR) characterization of the physical-chemical properties of ices at cryogenics temperatures under bombardment with high energy ions simulating interplanetary and interstellar process; Spectroscopic (MIR-FIR) characterization of asteroids and satellites surfaces. Laboratory physical-chemical characterization of cosmic dust analogues such as carbonaceous materials and silicates. Photosynthesis of biomolecules in presence of inorganic catalysts under space simulated conditions. Laboratory analysis of IDPs, meteorites and Stardust samples.
Professional Activities and Service: President of Italian Astrobiology Society (since 2006); Secretary of International Society for the Study of the Origin of Life - ISSOL (since 2009). Associate scientist of CIRS instrument on NASA - Cassini mission (since 2005). Co-Investigator of LMC instrument on ESA - ExoMars mission (since 2010). He is author of about 65 scientific papers published in international refereed journals.

Elisabetta Dotto, astronomer researcher at INAF-Oss.A. di Roma. Space mission involvement: Team member of VIRTIS (Rosetta), Associate Scientist of CIRS (Cassini), Scientific support for the space mission studies Leonard, Apies, and Ishtar. Main relevant expertise: small bodies, spectroscopy. 70 refereed papers.

Yoshifumi Futaana
Education: 2003, PhD in Geophysics, Kyoto University, Japan.
Relevant Experience: Operation manager of ASPERA-4 on board Venus Express; Co-I of SARA instrument on board Indian Chandrayaan-1 mission

Relevant Expertise:
- Analysis of the ion spectra data from Martian moon Phobos in a perspective of the surface-plasma interaction.
- Analysis of Moon-solar wind interaction of energetic neutral atoms and ion spectra
- A feasible study of using energetic neutral atom data to understand the physics of the Moon-solar wind interaction by computer simulations.
- Analysis of the plasma and energetic neutral atom data from Mars and Venus.

Over 60 refereed publications (http://www.irf.se/~futaana/Pub.cv.html.en).

Raymond Goldstein, Southwest Research Institute

Education/Experience
- BS in Physics, City College of New York
- MS in Physics, Lehigh university
- Ph D in Physics, Lehigh University
- 1962-1967 Staff Scientist at Boeing Scientific Research Laboratory
- 1967-1999 Senior Scientist at Jet Propulsion Laboratory
- 1999-present Staff Scientist at Southwest Research Institute

George Ho, Senior scientist at JHU/APL
Education: B.S. (Summa Cum Laude), Augsburg College, 1991; M.S. (1996), Ph.D. (1998) both at University of Maryland
Employment: Postdoc at the JHU/APL (1998-2001); Senior scientist at JHU/APL (2001-today)
Professional Experience: *Lead Co-Investigator*: ESA's Bepi-Colombo SERENA/Strofio Investigation; *Instrument Scientist*: MESSENGER/EPPS, MMS/EPD; *Deputy Instrument Scientist*: XRS/ MESSENGER, New Horizons/PEPSSI; Science Team: ACE, Ulysses

Roberto Leoni, Senior Researcher at CNR-IFN, Roma, Italy.
Education: Laurea in Physics, 1979.
Field of activity: Superconducting devices, electron-beam lithography and thin film technology. Using the technological tools of the Microfabrication Facility of the IFN he studied devices for experiments concerning the electron cooling effect, on-chip electronic microrefrigerators and Single Electron Transistors (SETs). More recently, he develops detectors, like bolometers and superconducting single photon detectors (SSPDs). In particular, he develops SSPDs in the framework of the EU STREP project SINPHONIA and Nanoshuttering elements for BepiColombo/ELENA. He is responsible of the Electron Beam Lithography facility of the IFN and is author and coauthor of more than 100 scientific publications on International Journals.
Research Projects: Programma Nanotecnologie legge 95/95, Italy; strep EU projects: RSFQubit and SINPHONIA, ESA BepiColombo/ELENA.

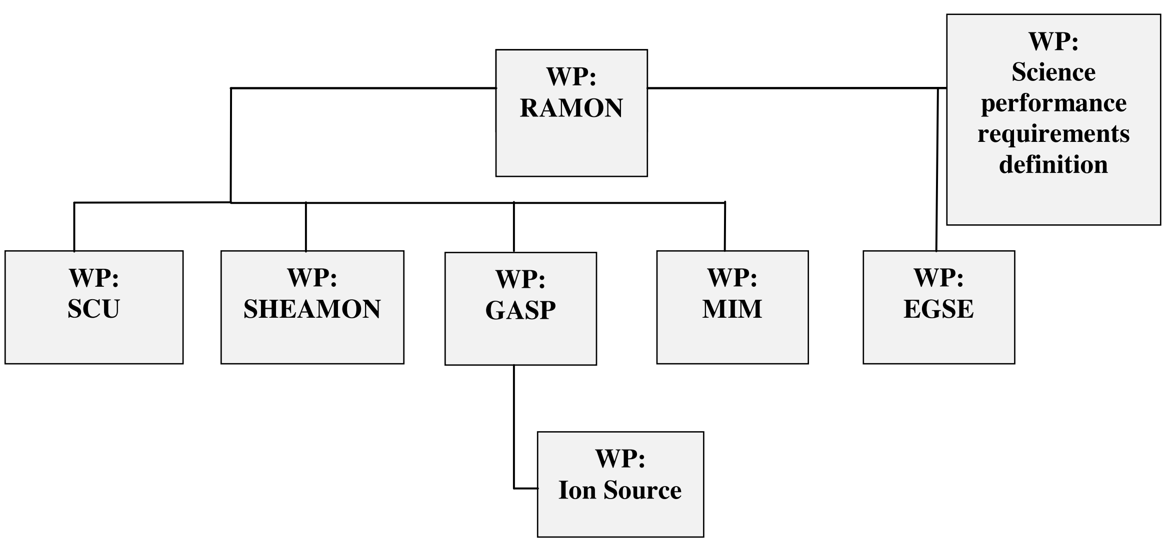
Maria Elisabetta Palumbo Researcher Astronomer at INAF – Osservatorio Astrofisico di Catania (Italy).

Education: She graduated with honors in Physics, at the University of Catania, in 1992. She got the Ph.D. in 1996 and a permanent position as Research Astronomer in 1995.
Expertise: she has been working in the Laboratory of Experimental Astrophysics, at the Catania Astrophysical Observatory, since April 1991. She has studied, by infrared absorption spectroscopy, the effects of ion irradiation on frozen gases (ices) at low temperature (10-100 K). She has also been involved in the Raman analysis of cometary dust samples collected by NASA/Stardust mission which have then been compared with spectra of laboratory analogues She is co-author of more than 60 articles published on refereed international journals.

Stefano Selci, Research Director at CNR, Rome, Italy.
Life & Career: He was born in Rome in 1954. He was graduated with honours in Physics in 1979, for researches on Surface Physics using optical spectroscopy. Winner of a National contest, he was researcher at University since 1984. In 1991 becomes Research Director as a winner of a CNR national contest. He was supervisor of several thesis degrees and Ph.D in Physics, organizer of NATO schools and Editor of Conference books, OSA Member, responsible of Strategic Projects, and responsible of Research Units for various projects, adviser for the Nobel Prize assignment in Physics (2002).
Stefano Selci is author of about 100 papers on national and international magazines. He has realized the first Italian STM microscope. He was working on quantum structures also by using temporal correlated ultrafast optical techniques. He is working now to develop superresolving new optical microscopy scanning techniques. A wide experience of special technologies like Ultra High Vacuum and nanotechnology allows participation to further projects, as, for instance, within the ELENA micro-shuttering neutral species device in BepiColombo space mission that will set off for Mercury in 2013.

3. Work breakdown structure and work package descriptions

3.1 Block diagram



3.2 Work packages description

WP TITLE:	**RAMON**				
CONTRACTOR:	INAF	MAJOR COSTITUENT:			
START EVENT:	1/2012	PLANNED DATE		ISSUE REF	
END EVENT:	12/2012	PLANNED DATE		ISSUE DATE	
WP MANAGER:	Alessandro Mura				
INPUT: ASI contract					
DESCRIPTION: **Scientific / Management Tasks** Development and coordination of the international team for the development of the instrument. **Technical Tasks** Thermal Analysis, Radiation analysis to the level of definition of the mission environment, Test reports on critical technologies, Defining the critical technological issues for subsystems, in order to achieve a TRL=5 by the end of 2012 Engineering Plan and detailed scheduling, Analysis of the achieved technological readiness level. Preparation for the subsequent selection phase.					
OUTPUT / DELIVERABLES: Bread boarding of the critical parts, to demonstrate the full feasibility of RAMON; Mechanical, Electrical and Thermal I/F control document; Development, Financial , Management and Product Assurance plans Publications Instrument design report Final report					

WP TITLE: **SCIENCE REQUIREMENTS**		
CONTRACTOR: INAF	MAJOR COSTITUENT:	
START EVENT: 01/2012	PLANNED DATE	ISSUE REF
END EVENT: 12/2012	PLANNED DATE	ISSUE DATE
WP MANAGER: Christina Plainaki		
INPUT: ASI contract		
DESCRIPTION: **Scientific Tasks** Theoretical studies of the release processes active on the surface of a NEA, of the efficiency of each process, dependence on the environment condition. Study on the role of release processes and space weathering in the evolution of the NEA. 3D modeling of the NEA exosphere. Public outreach.		
OUTPUT / DELIVERABLES: 3D model of exosphere and space weathering on the surface of a NEA Congress presentations and posters. Publications. Reports Final report		

WP TITLE: **SCU**		
CONTRACTOR: INAF	MAJOR COSTITUENT:	
START EVENT: 01/2012	PLANNED DATE	ISSUE REF
END EVENT: 12/2012	PLANNED DATE	ISSUE DATE
WP MANAGER: Andrea Argan		
DESCRIPTION: **Technical Tasks** FMECA of the RAMON System Control Unit, Preparation for the subsequent selection phase.		
OUTPUT / DELIVERABLES: Congress presentations and posters. Reports Final report		

WP TITLE: **SHEAMON**		
CONTRACTOR: INAF	MAJOR COSTITUENT:	
START EVENT: 01/2012	PLANNED DATE	ISSUE REF
END EVENT: 12/2012	PLANNED DATE	ISSUE DATE
WP MANAGER: Alessandro Mura		
INPUT: ASI contract		
DESCRIPTION: **Scientific Tasks** Simulation of the expected signal for the instrument (SHEAMON). Analysis of the scientific requirements for the instrument Modification of the concept of SERENA/ELENA instrument (on board BepiColombo ESA mission to Mercury) in order to optimize SHEAMON in the different environment. In particular, solution to increase the geometrical factor and decrease the mass will be studied. Analysis on how increase the sensitivity of the instrument by optimizing the conversion surfaces Public outreach. **Technical Tasks** Nano-shuttering grid test for RAMON/SHEAMON sensor Defining the critical technological issues for SHEAMON, in order to achieve a TRL=5 by the end of 2012 Preparation for the subsequent selection phase.		
OUTPUT / DELIVERABLES: Congress presentations and posters. Publications, Reports, Final report		

WP TITLE: **GASP**		
CONTRACTOR: SWRI	MAJOR COSTITUENT:	
START EVENT: 01/2012	PLANNED DATE	ISSUE REF
END EVENT: 12/2012	PLANNED DATE	ISSUE DATE
WP MANAGER: Stefano Livi		
DESCRIPTION: **Scientific Tasks** RAMON/GASP ion-optical gating system definition Simulation of the expected signal for the instrument (GASP). Analysis of the scientific requirements for the instrument Study for an optimization of the ionizing system of GASP, of its electronic gate and of its ToF system Public outreach. **Technical Tasks** Defining the critical technological issues for GASP, in order to achieve a TRL=5 by the end of 2012 Preparation for the subsequent selection phase.		
OUTPUT / DELIVERABLES: Congress presentations and posters. Publications. Reports, Final report		

WP TITLE: **GASP Ion Source**		
CONTRACTOR: UniBe	MAJOR COSTITUENT:	
START EVENT: 01/2012	PLANNED DATE	ISSUE REF
END EVENT: 12/2012	PLANNED DATE	ISSUE DATE
WP MANAGER: Peter Wurz		

DESCRIPTION:

Studies oriented to the definition of the ionization source. Possibilities include for the e- emitter system cold filaments as carbon nanotubes and Spindt cathodes, or advanced hot filaments (like LaB6 or BaO and similar). Hot filaments are presently the preferred solution already adopted for BepiColombo/SERENA-STROFIO based sensor.
As power resources on spacecrafts are usually very limited, different approaches to the conventional hot filament to generate the electrons needed for the electron impact ionization process, are being investigated. The electron yield, the lifetime and the linearity are important characteristics to be experimentally investigated.

OUTPUT / DELIVERABLES:
Reports
Final report

WP TITLE: **MIM**		
CONTRACTOR: IRF	MAJOR COSTITUENT:	
START EVENT: 01/2012	PLANNED DATE	ISSUE REF
END EVENT: 12/2012	PLANNED DATE	ISSUE DATE
WP MANAGER: Stas Barabash		

DESCRIPTION:

Scientific Tasks
Simulation of the expected signal for the instrument (MIM).
Analysis of the scientific requirements for the instrument

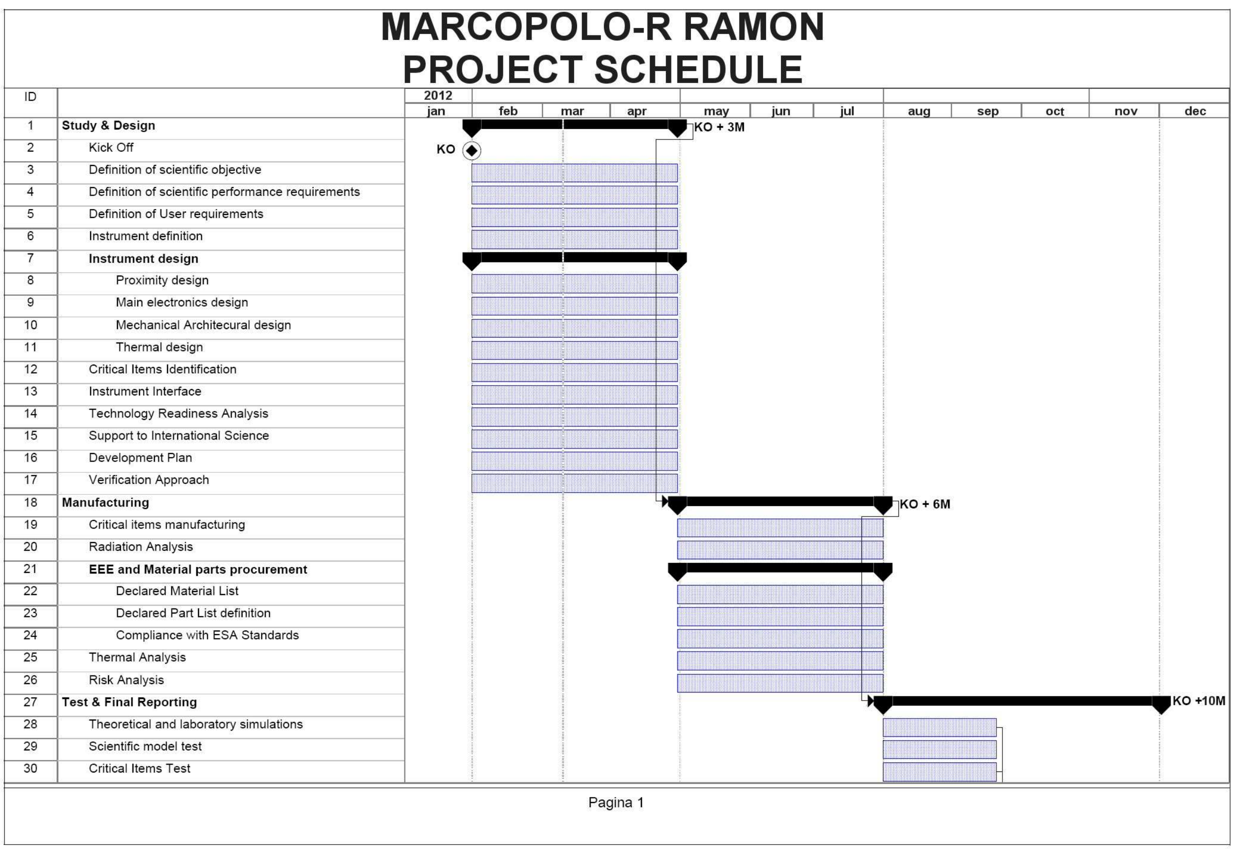
Public outreach.
Technical Tasks
Preparation for the subsequent selection phase.

OUTPUT / DELIVERABLES:

Congress presentations and posters.
Publications.
Reports
Final report

WP TITLE:	**EGSE**		
CONTRACTOR:	FMI	MAJOR COSTITUENT:	
START EVENT:	01/2012	PLANNED DATE	ISSUE REF
END EVENT:	12/2012	PLANNED DATE	ISSUE DATE
WP MANAGER:	Esa Kallio		
DESCRIPTION: **Technical Tasks** H/W spacecraft simulator design Software design Preparation for the subsequent selection phase.			
OUTPUT / DELIVERABLES: Congress presentations and posters Publications Reports Final report			

3.3 Schedule



4. Meeting Plan

The proposed meeting plan starts from T0 (T0=Jan, 15th) and it includes:

a kickoff meeting (T0+1 week),
a mid-term review (T0+ 5 months) ,
a progress meeting (T0+8 months),
and a final presentation (T0 + 11 months).

5. Study Outputs

Scientific outputs:

1) monthly reports,
2) science performance report,
3) international meeting presentations,
4) mission meeting presentations,
5) publications.

Technical outputs:

6) Bread boarding of the critical parts, to demonstrate the full feasibility of RAMON,
7) Instrument design report. The report will annex the following RAMON design items
    - At block level for standard non-critical parts.
    - Complete design for all critical items
    - Complete EEE parts, material and process lists
8) Mechanical I/F control document,
9) Electrical I/F control document,
10) Thermal I/F control document,
11) Thermal Analysis (up to 15 nodes),
12) Radiation analysis to the level of definition of the mission environment,
13) Test reports on critical technologies,
14) Engineering Plan and detailed scheduling,
15) Product Assurance Plan under which the study has been conducted,
16) FMECA of the RAMON System Control Unit,
17) Financial Plan,
18) Management Plan.

6. Proposed funding scheme of the study through Member States.

6.1 Funding scheme

PIs and Co-Is are responsible for funding, the management and the activities as listed below

All the funds needed for all the phases of the assessment study of the RAMON instrument will be provided by ASI and the National Funding Agencies of each Co-I country.

6.2 Leading funding agency

Italian Space Agency (**ASI, Agenzia Spaziale Italiana**), Unità Osservazione dell'Universo, Viale Liegi 26, 00198, Roma, Italy.
Contact person: Enrico Flamini, Tel. +39 06 85671, Fax. +39 06 85671, email: flamini@asi.it

6.3 Other funding agencies

SHEAMON: **Funding Agencies**: ASI; University of Bern, Physics Institute internal funding; PRODEX funding; CNES; FMI
GASP: **Funding Agencies**: NASA, SWRI
MIM: **Funding Agencies:** SNSB, IRF

Table 2 INAF (including AMDL, CNR): RAMON, SHEAMON and SCU

	Funding agency
Management	ASI
Engineering/Hardware	ASI
Travel	ASI

Table 3 SwRI (including JHU/APL, UniVirginia): GASP

	Funding agency
Management	NASA/SwRI
Engineering/Hardware	NASA/SwRI
Travel	NASA/SwRI

Table 4 IRF: MIM

	Funding agency
Management	IRF
Engineering/Hardware	IRF
Travel	IRF

Table 5 IRAP: SHEAMON HV

	Funding agency
Management	CNES
Engineering/Hardware	CNES
Travel	CNES

Table 6 FMI: RAMON GSE

	Funding agency
Management	FMI
Engineering/Hardware	FMI
Travel	FMI

Table 7 UniBe: SHEAMON conversion surface and calibration

	Funding agency
Management	UniBe
Engineering/Hardware	UniBe
Travel	UniBe

Table 8 LESIA - Observatoire de Paris: scientific participation

	Funding agency
Management	CNES
Engineering/Hardware	CNES
Travel	CNES

6.4 Appendix: Endorsement letters

Endorsement letters from the main funding agencies or letters from institutes are attached to this document.

Le lettere di Endorsement sono state eliminate