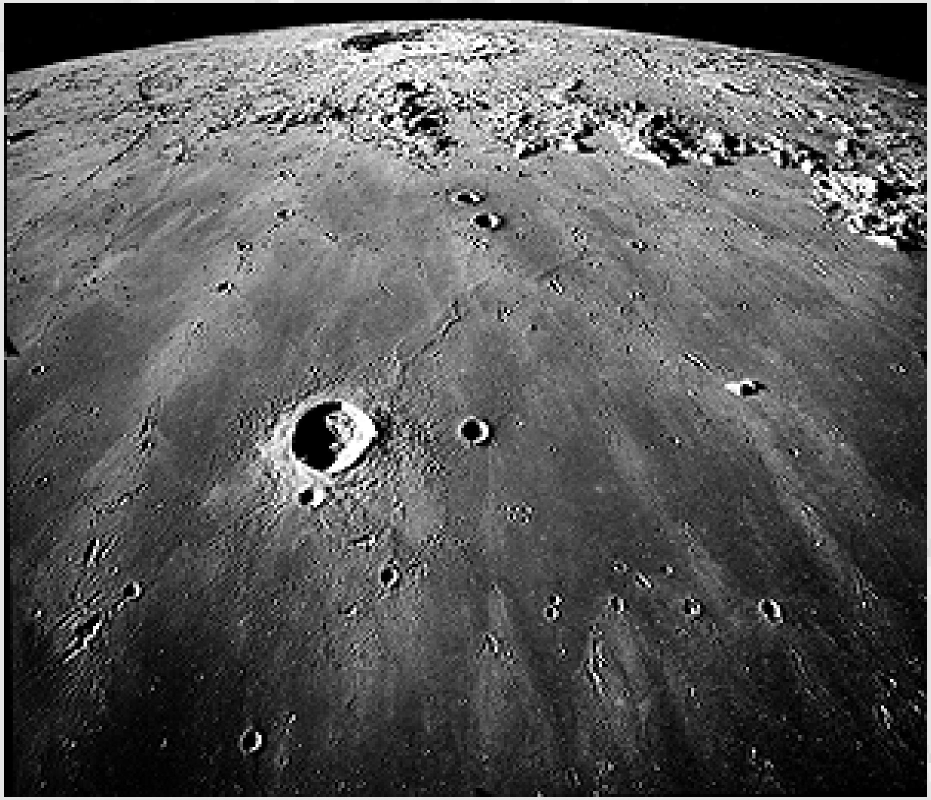
ASI Future Plans

for the Moon



Sylvie Espinasse

Observation of the Universe

ASI

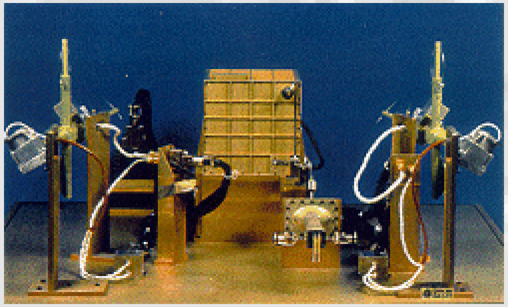
Present missions

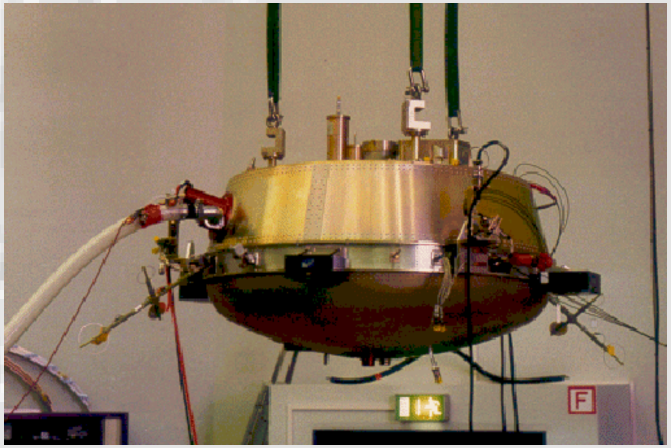
- Italy is currently present with several payloads and subsystems on robotic missions exploring the Solar System…

First steps….
Participation to the CASSINI-HUYGENS mission

- NASA-ESA-ASI mission, launched on October 15th, 1997 from KSC with a TITAN IVB/Centaur to reach Saturn after a 7 years cruise and 4 planetary swing-bys (Venus-Venus-Earth-Jupiter)
- 1 orbiter (NASA) + 1 probe Huygens (ESA)

Italian participation to CASSINI-HUYGENS





- Italy is participating to 3 out of 12 experiments on-board Cassini:
    - **VIMS-V**
    - **Radio Scienza**
    - **Radar**
- Italy realized the High Gain Antenna (HGA) for the TLC system and the Ka Transponder and provided the experiment HASI to Huygens

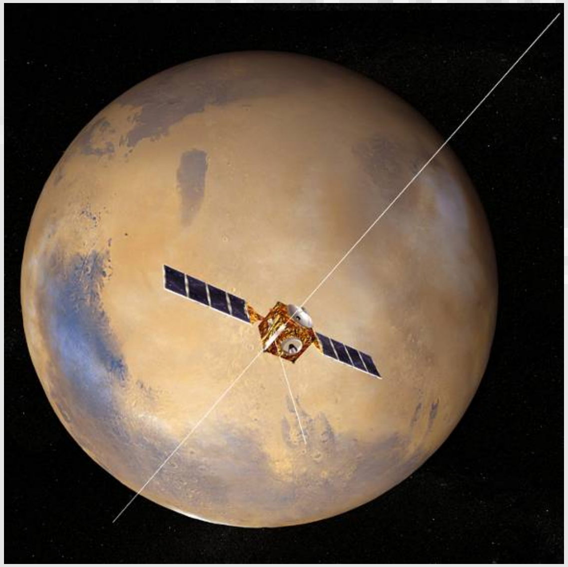
Saturn and around…

- This image of Saturn's moon **Titan** from the Synthetic Aperture **Radar** instrument on the **Cassini** spacecraft shows the south-western area of a feature called Xanadu (bottom right of the image). The area is bright because it reflects the radio wavelengths used to make this radar images. The image was taken on April 30, 2006.

Credit NASA/JPL

Mars Express

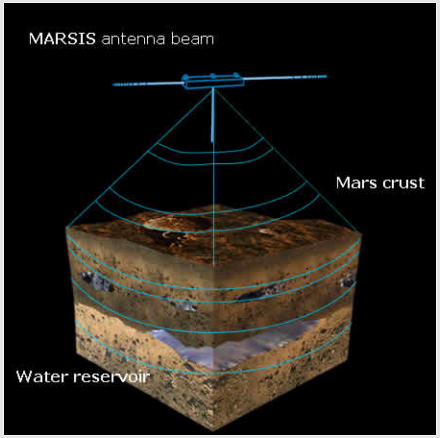
Launched to Mars June 2nd, 2003 from Baikonour, in orbit since January 2004

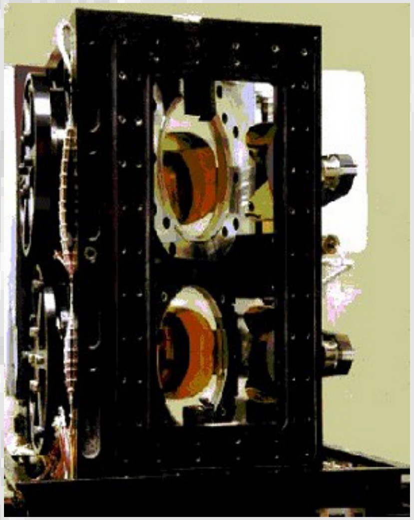


MEX is the first **ESA** flexible mission

Italian contribution:

- PFS Planetary Fourier Spectrometer PI
- MARSIS Radar sounder PI
- ASPERA Neutral atoms co-I
- OMEGA Imaging spectrometer co-I
- Interdisciplinary scientist

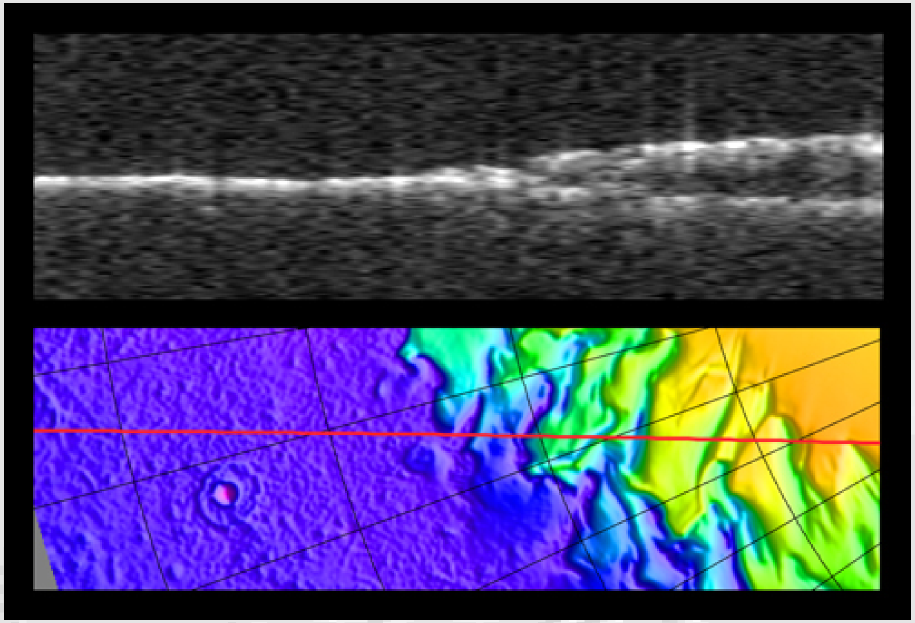




Status: extended mission

Mars Express

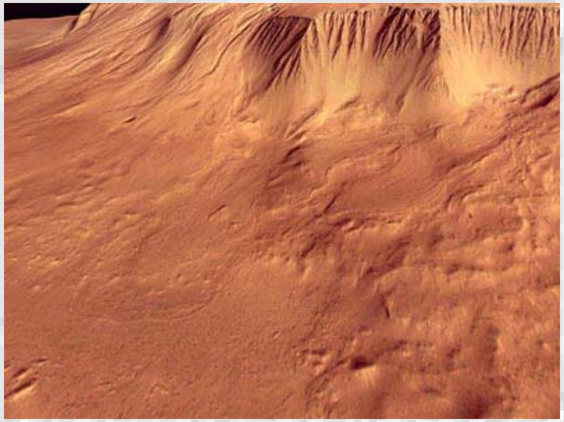
- **MARSIS uncovers underground ice (30/11/2005)**
- The upper image is a radargram from the Mars Advanced Radar for Subsurface and Ionospheric Sounding (MARSIS), showing data from the subsurface of Mars in the layered deposits that surround the north pole. The lower image shows the position of the ground track on a topographic map of the area based on Mars Orbiter Laser Altimeter data. The images are 458 kilometers (285 miles) wide.



Credit: ASI/NASA/ESA/Univ. Rome/JPL/MOLA Science Team

SHARAD – Mars Reconnaissance Orbiter

- SHARAD is a facility instrument provided by ASI to the NASA MRO mission, launched to Mars from KSC on August 12th, 2005.
- SHARAD is a radar sounder designed to seek liquid or frozen water down to 1 km depth under the Martian surface.
- Italy is the only European country participating to missions to Mars launched in 2003 and 2005.



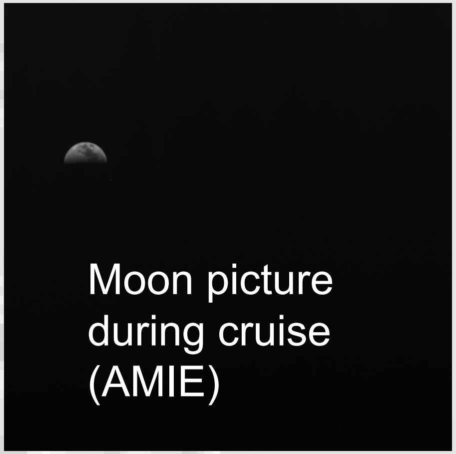
SMART-1

Launched to the Moon on September 27, 2003 from Kourou, arrived to the Moon in November 2004

SMART-1 is the 1st **ESA** mission of the **S**mall **M**issions for **A**dvanced **R**esearch in **T**echnology programme.

Italian contribution:

- RSIS (**R**adio **S**cience **I**nvestigation with **S**MART-1), Principal Investigator
- EPDP (**E**lectric **P**ropulsion **D**iagnostic **P**ackage) Principal Investigator
- AMIE (**A**dvanced **M**oon micro-**I**mager **E**xperiment) Co-Investigator (PDU provided)



Moon picture during cruise (AMIE)

Status: mission ended early September with a crash of the S/C at the Moon surface observed through ground based observations.

Rosetta

Launched to Comet P/Churyumov-Gerasimenko

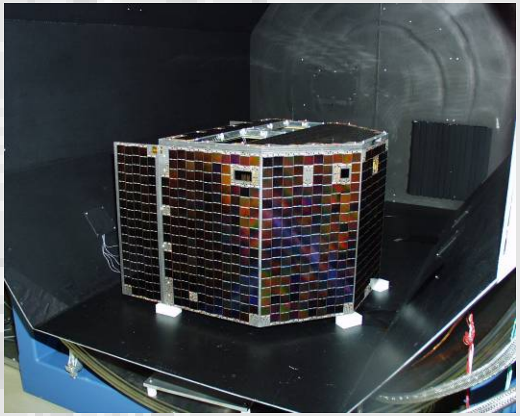
on March 2, 2004 from Kourou

Rosetta is a Cornerstone Mission of the

ESA Scientific Programme Horizon 2000.

Italian contribution:

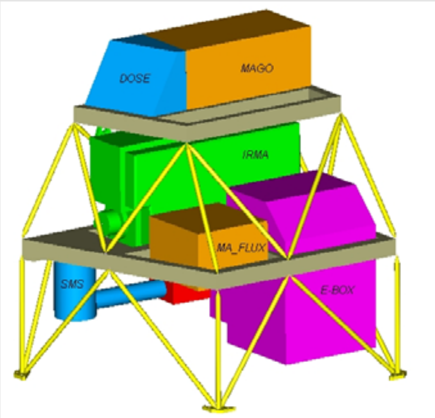
- VIRTIS (**V**isual **IR** **T**hermal **I**maging Spectrometer), Principal Investigator
- GIADA (**G**rain **I**mpact **A**nd **D**ust **A**nalyser), Principal Investigator
- OSIRIS (**W**ide **A**ngle **C**amera) Co-Investigator
- SD2 (Sample acquisition and distribution) Principal Investigator; SA (**S**olar **A**rray) on Philae (lander)
- Rosetta Lander Consortium Membership

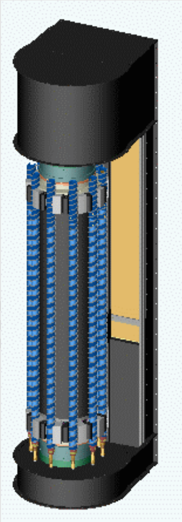


Status: cruise phase

NASA Mars Sample Return 2003-2005

- On the basis of an agreement between NASA and ASI, Italy was committed to provide a drill for subsurface samples acquisition and an in-situ package to perform in-situ analysis



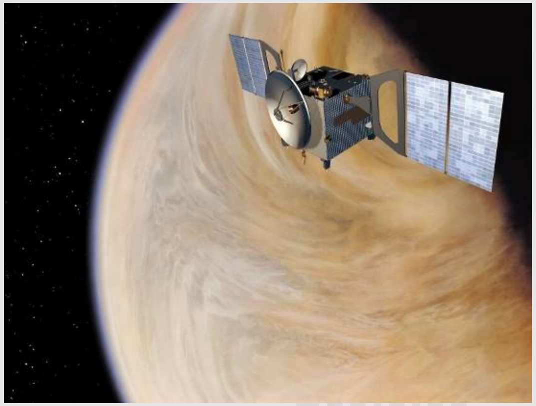


Venus Express

VEX is an ESA mission to VENUS

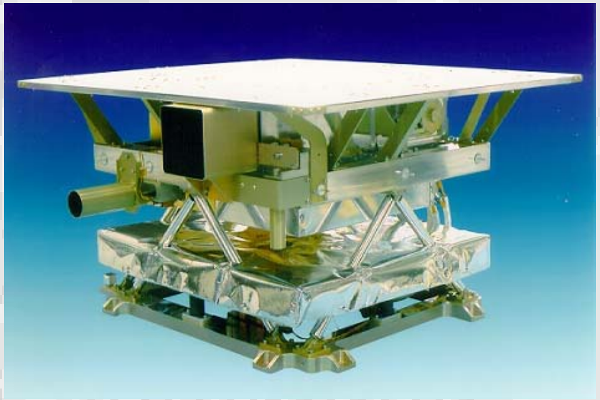
Launch: 9 November 2005 from Baikonur

VEX P/L is constituted mainly by Spare Models from Rosetta and Mars Express



Italian contribution:

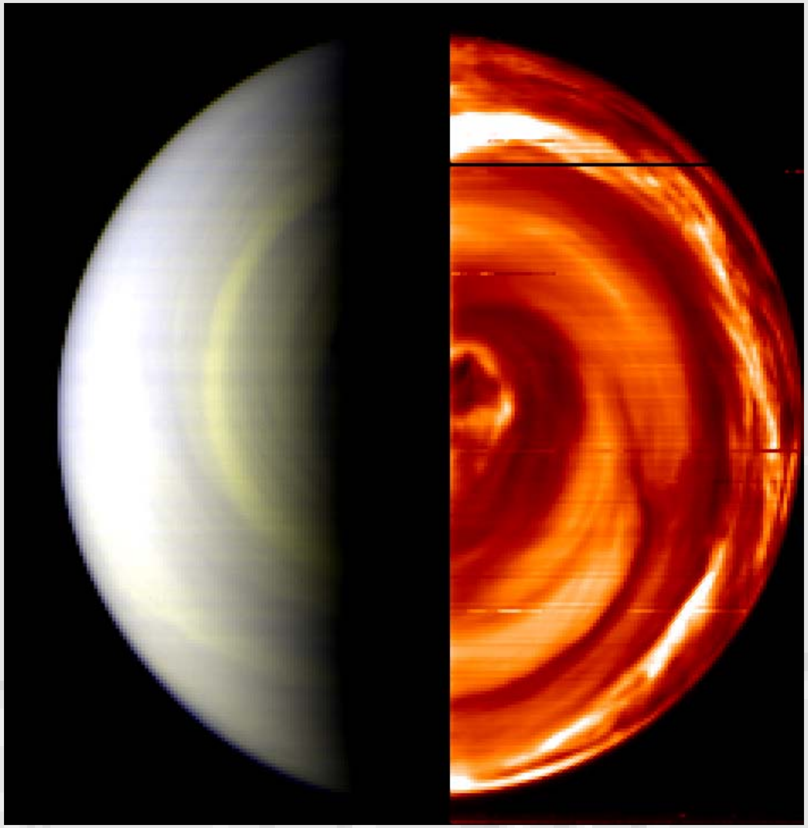
- VIRTIS (**V**isual **IR** **T**hermal **I**maging Spectrometer), Principal Investigator
- PFS (**P**lanetary **F**ourier **S**pectrometer) Principal Investigator
- ASPERA-4 (ENA) Co-Investigator



Venus Express

- This false-colour composite, built with images taken by the VIRTIS Spectrometer is one of the first-ever views of the southern hemisphere of Venus. The images were taken on 12 April 2006 from a distance of 206 452 kilometres, as the spacecraft passed below the planet in an elliptical arc. The dark vortex shown almost directly over the South pole is a previously suspected but until now unconfirmed structure that corresponds to a similar cloud structure over the North pole.

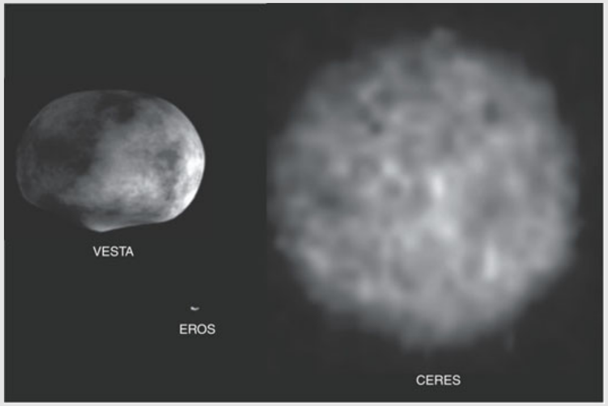
- The VIRTIS composite image shows Venus's day side at left and night side at right, and corresponds to a scale of 50 kilometres per pixel. The more spectacular night half, shown in reddish false colour, was taken via an IR filter at a wavelength of 1.7 microns, and chiefly shows dynamic spiral cloud structures in the lower atmosphere, around 55 kilometres altitude. The darker regions correspond to thicker cloud cover, while the brighter regions correspond to thinner cloud cover, allowing hot thermal radiation from lower down to be imaged.

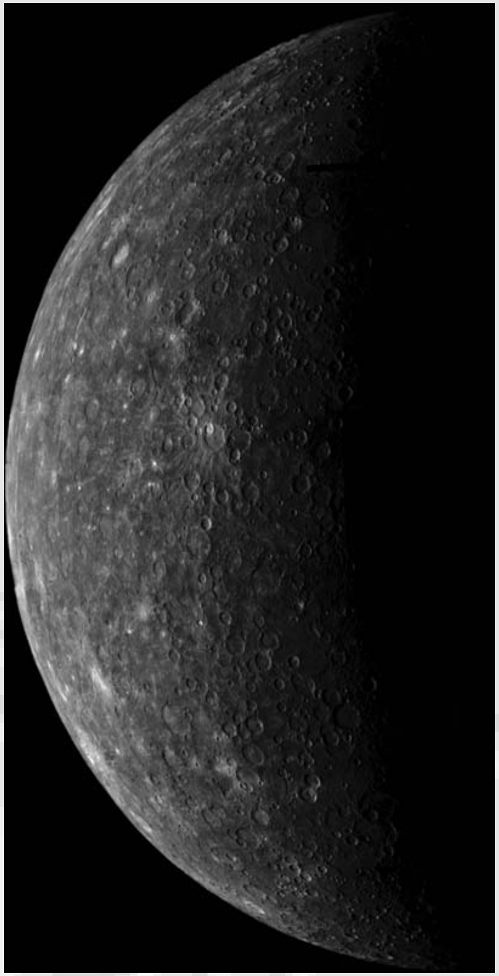


Credit ESA/VIRTIS

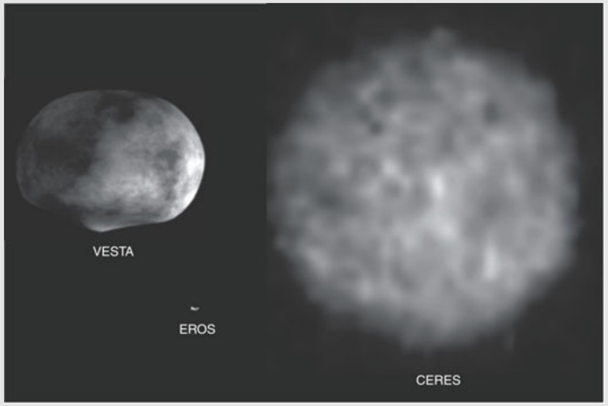
Future missions

- … and we are planning to continue our participation to the international planetary tour…



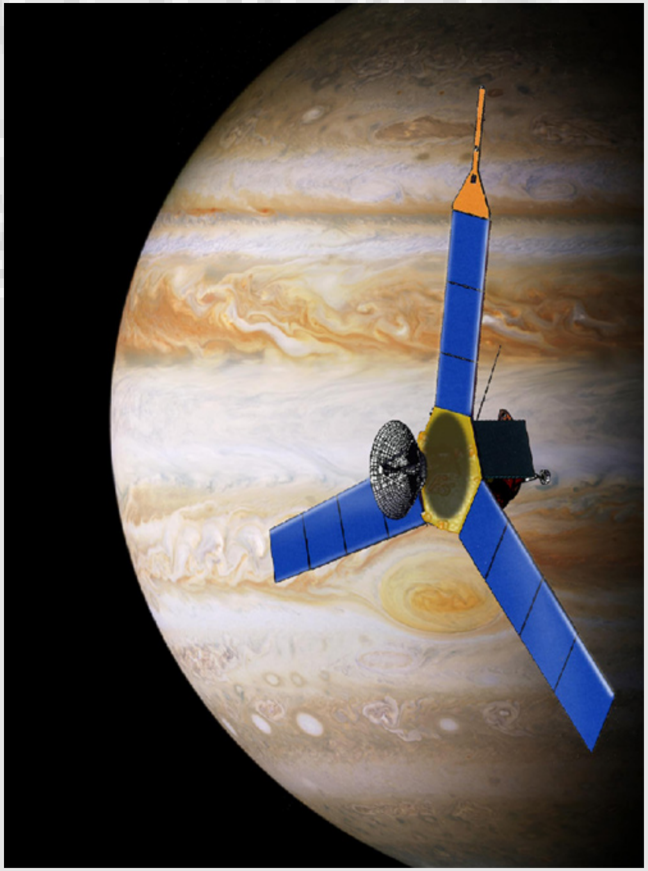


Dawn



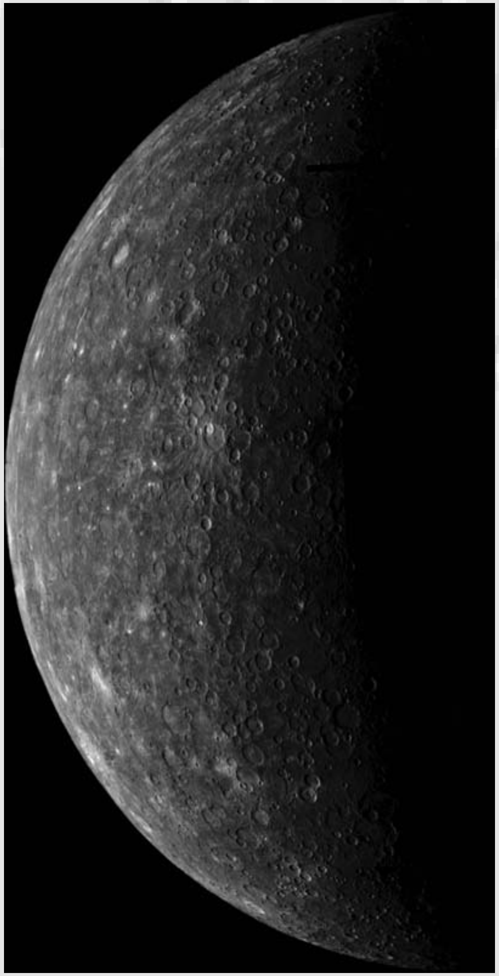
- Italian contribution to the **NASA Discovery Dawn** mission to be launched from KSC in June 2007 towards the asteroids Vesta and Ceres: VIR-MS **V**isual **I**nfra**R**ed **M**apping **S**pectrometer

Juno



- Italy will participate to the **NASA New Frontiers mission** JUNO to Jupiter to be launched in 2011 providing a spectrometer, a camera, the Ka Transponder and the antenna for TLC.

Bepi Colombo



Bepi Colombo (launch 2013)

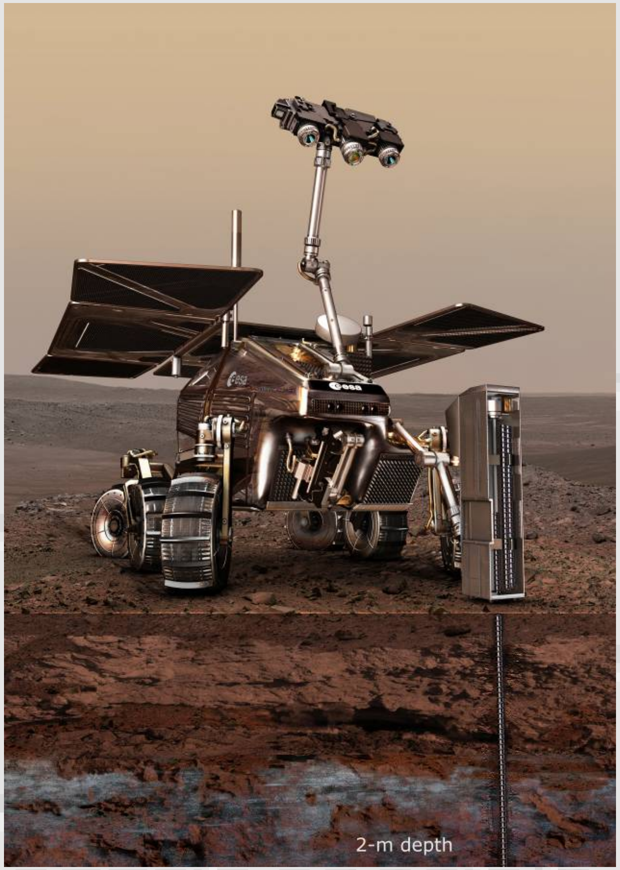
BepiColombo is an **ESA** mission to Mercury realized in partnership with **JAXA (Japan),** composed by two S/C

On board the European S/C there are 4 Italian PI instruments:

- SIMBIO-SYS:Optical suite with Cameras and Spectrometer
- MORE: Radio Science
- ISA: Accelerometer
- SERENA: Neutral and Ionized atoms Imager

AURORA

- During the last ESA Council meeting (Berlin, December 5-6, 2005), ASI became the main contributor **(40%)** and supporter of the European Exploration programme AURORA: Italy will go to Mars together with ESA and focusing on the short-medium term on robotic exploration with ExoMars and the following Sample Return mission.
- The ExoMars mission has the objective to establish whether life ever existed or is still active on the red planet today (launch scheduled in 2013).
- Prime contractor, S/Ss and P/Ls.



… and what about the Moon ?

- We are strongly committed with Moon exploration:
  - ASI Top Management has proposed to the government a national programme for Moon exploration and it has been approved by the Italian government early this year as an important element of our National AeroSpace Plan 2006-2008.

Moon Exploration National Programme

- The elaboration of this programme is on-going and it is involving the whole scientific community, the industries and the Agency:
  - ASI has issued an AO to the national community to carry out 13 studies, 3 for science and 10 for technologies to elaborate a national "Vision for Moon Exploration", 16 studies have been awarded.
  - KO held in ASI on September 26th, 2006, duration 8 months.
  - Scientists are asked to identify their scientific objectives and to derive measurements and requirements to meet these objectives.
  - These requirements constitute the input to the technological studies related to P/L, robotics, platform and transport.
  - The output of these activities will be integrated in the Italian vision for Moon exploration to be released by spring 2007.

Moon Studies

SCIENCE

1. Moon Science and Resources
2. Earth Observation
3. Universe Observation

TRANSPORT

1. Launcher
2. Transfer Module
3. Descent and Landing System

PLATFORMS

4. Orbiter
5. High Mobility Vehicle

PAYLOAD and ROBOTICS

6. In-Situ Analysis
7. Robotics
8. Remote Sensing
9. Microwave
10. High Energy

ROADMAP

Study of the Moon and its resources

- **Many probes have orbited around the Moon, it has been explored by humans and sampled, but the origin and the evolution of the Moon are still debated!**

- **Many open questions:**
- What is the horizontal and vertical structure of the lunar crust?
- What is the composition and the structure of the lunar mantle?
- What has been the extension and importance of the magmatic ocean?
- What is the relation between surface material and internal structure and lunar evolution, origin of surface material?
- Lunar asymmetry: what is its origin and what are the possible implications on the internal evolution and the material distribution?
- What is the origin, the evolution and the distribution of the lunar volcanism (maria)?
- What is the chronology of the large impact basins and their influence on the lunar crust evolution?
- What is the origin of the lunar paleomagnetism?
- …
- Which risks are associated to human exploration (radiation, dust and regolith,…)
- Resources distribution (minerals, water ice, solar radiation,…)
- …

Study of the Moon and its resources

- Critical review of the state of the art of the current knowlegde of the Moon :
  - Origin and evolution (theories of giant impact)
  - Differentiation processes, interior models, crust evolution
  - Craterization processes
  - Chronology (absolute and relative)
  - …
- and of the open related questions:
  - Moonquakes
  - Exosphere
  - Libration
  - Volatile depletion
  - …
- >>>Measurements and requirements

Study of the Moon and its resources

SCIENCE THEMES	SUB THEMES	SCIENCE AND TECHNOLOGY OBJECTIVES	DETAILED SCIENCE OBJECTIVES	MEASUREMENTS	Requirements Range		Sensitivity		Coverage/resplution	
					Value	Unit	Value	Unit	Value	Unit
origin and evolution	global composition	Moon global composition	Map of Si, Al, Mg, Ca Fe, Na, O, C	X-Ray Spectra of highlands and Maria	0.5-20	keV	<200	eV	Global Coverage	1-10 Km at 100 Km altitude
			Map of olivines/ pyroxenes	VIS-IR Spectra of highlands and Maria	0.3-5	µm	10	nm	Global Coverage	1-10 Km at 100 Km altitude
		Magma Ocean Model	Mapping distribution and relative abundance of mafic mineral and plagioclase	VIS-IR Spectra Maria	0.3-5	µm	10	nm	Regional Coverage	1-10 Km at 100 Km altitude
		Constrain Theories of the origin of the lunar upper mantle	sampling composition of different location of lunar maria	VIS-IR Spectra Maria samples	0.3-5	µm	10	nm	Local coverage	in situ
				X-Ray diffratometric analysis					Local coverage	in situ
				Raman spectra					Local coverage	in situ
		origin and evolution of Lunar Crust	composition of different crater central peaks	VIS-IR Spectra of central peaks	0.3-5	µm	5	nm	Local coverage	< 100 m

Study of the Moon and its resources

Exosphere

Science Objectives	Detailed Science Objectives	Measurements / *Detection Thecnology*	[Spectral Range] *Resolution*		Sensitivity SNR[b] Or *NEDT*[c]		Spatial Coverage And *Resolution*	Temporal resolution
			Value	Unit	Value	Unit		
Atmospheric chemistry	Aerosols Optical Properties	Scattered and reflected spectral sunlight Radiance from the Earth and solar Irradiance *Multispectral algorithms in atmospheric spectral window*	[0.4 – 3.0] < 10 @ VIS < 20 @ NIR	µm µm nm	> 200 @VIS >100@NIR	-	250 x 250 m^2 @ VIS 500 x 500 m2 @ VIS	1 hour
	Trace gases content (O_3,NO_x,SO_2,CO,…)	Scattered and reflected spectral sunlight Radiance from the Earth and solar Irradiance *DOAS[a] thecnique*	[0.2 – 3.0] < 0.2	µm nm	>1000@ [UV-VIS] >50@NIR	- -	*10x20 km^2* *5x10 km^2* (only for limitated areas for air quality applications)	30 min 1 hour
Clouds properties	Radiative & Microphysical properties -Cloud amount in terms of Cloud Optical Thickness -Particle size in terms of efficient radius -Cloud liquid and ice water content -Precipitation rate -Cloud liquid and ice water content Temperature Humidity profile	Scattered and reflected spectral sunlight Radiance from the Earth and solar Irradiance Inversion at nonabsorbing λ in VIS and at absorbing λ in NIR Measurements in Absorption Bands of oxygen and water vapour Microwave sounding	[0.6 – 0.8] < 0.15 [1.5 – 4.5] < 0.5 54, 118, 425, 183, 380	µm µm µm µm GHz	> 0.5 0.25 (for 1.6 µm) 0.35 @ 300 (for 3.9 µm) TBD	W/m^2sr µm K TBD	*3x3 km^2* *3x3 km^2* *< 30x30 km^2*	15 min 15 min 15 min

Study of the Moon and its resources

SUB THEMES	SCIENCE AND TECHNOLOGY OBJECTIVES	DETAILED SCIENCE OBJECTIVES	MEASUREMENTS	Requirements Range		Sensitivity		Coverage/resplution	
				Value	Unit	Value	Unit	Value	Unit
VOLCANISM/ LOCAL DIFFERENTIATION	Characterization of Maria, and volcanic regions	Si, Al, Mg, Ca Fe, Na, O, C detection	X-Ray Spectra of mare and craters	0.5-20	KeV	< 200	eV	Regional Coverage 1-10 Km at 100 Km altitude	
		Basalt Distribution	VIS- IR Spectra of mare and craters	0.3-5.2	µm	01-ott	nm	Regional 10-100 m at 100 Km IFOV 100 microrad	
		Geomorphology	Color Stereo-imaging	0.3-0.9 5 filters	µm	20 (bandpass)	nm	Regional and Local IFOV 10 -50 microrad/px	
		Gravimetry	Gradiometers Electromagnetic(radio or laser) orbital tracking	Anomalies of 20 mgal Gravity field resolution up to harmonic degree 40 to 80		1	mgal	Regional Scale To be improved on the far side	
		Figure	Altimetry Laser or Radar Altimeters Seismic measurements Lunar Librations	Improve Clementine LIDAR data Re definition of theory Use of all existing data		Better then 40 m vertical on 100 m spot		Orbital Global In situ	
		Relative dating	Crater Counting	Better then 100 m		10	m	Mare regions	
		Absolute dating	Laboratory measurement	Rb-Sr, Sm-Nd, 40Ar/39Ar		N.A.		In situ Sample return Re-examination of lun .sample	
		Thermal Flux	Improve Apollo measurements	Drill at higher depth		> 2	m	In Situ	

Study of the Moon and its resources

- A broad set of measurements and related requirements identified with strong scientific rationale
- Next step:
  - Revisit these tables w.r.t. data available from future missions
  - Identify those measurements that allow to meet several scientific objectives and priorities among these measurements
  - Identify with the P/Ls studies, the instruments that need strong technological development
  - Interaction with Robotic/Platform/Transport studies>>>mission scenarios

Observation of the Universe from the Moon

- **Study based on the following advantages:**
  - Absence of atmosphere >>> electromagnetic spectrum fully accessible
  - Environment thermally stable for the instruments (no atmosphere, slow rotation)
  - Passive cooling of IR instruments in permanently shadowed sites
  - Low gravity (50-100m diameter telescopes)
  - Absence of magnetic field >>> no concentration of charged particles >>> no disturbances on the instruments
  - No human electromagnetic interferences (far side)
  - Stable environment, low seismicity >>> pointing accuracy for interferometers
  - Long observation time, no mass and energy limitation with regard to free-flyers, possibility of refurbishment

X/Gamma, UV-Visible-IR, Radio/mm, Particles

- For all these 4 areas, an analysis is performed to identify some “discovery windows” that could be opened through observations from the Moon.
- Trade-offs between Earth-based observations and LEO/HEO observations.
- >>>Identification of new observations techniques for an observatory on the lunar surface.

High-energy Astronomy

- The Moon is the ideal site to perform surveys of the sky at different frequencies to monitor variable sources for long period of time.
- High-energy astronomy from the Moon should be based on: simple instruments with no/not demanding pointing requirements, possibility to use large areas and large FoV.

High-energy Astronomy

- X-ray timing: Timing pulsar, QPO, High resolution timing study of erratic oscillation of BH candidates, High resolution timing study of bursts from Type I bursters, rapid busters, bursting pulsars and magnetars.
- All sky ray-imager: Deep observation of the X-ray sky aimed at obtaining a survey and at monitoring variable sources.
- Gamma ray imager: Deep observation of the soft gamma-ray sky aimed at a sensitive survey (and monitoring of the variable sources) as well as at a study of the polarization.
- Plastic imager: To supply a detector for high energy gamma rays to probe the most energetic phenomena occurring in our Universe, Galactic sources as well as diffuse emission extragalactic sources (AGNs GRBS) as well as fundamental physics.

High-energy Astronomy

SUB THEMES	SCIENCE AND TECHNOLOGY OBJECTIVES	DETAILED SCIENCE OBJECTIVES	SITE	MEASUREMENTS		Operative Range		Sensitivity		Operative Temperature		Angular resolution	Focal length	Spectral/energy resolution	Time resolution	FoV
						Value	Unit	Value	Unit	Value	Unit					
GRIM Gamma Ray Imager on the Moon	Deep observation of the soft gamma-ray sky aimed at a sensitive survey (and monitoring of the variable sources) as well as at a study of the polarization	sensitivity and angular reoslution will be 20 to 50 times better than the typical values for orbiting instruments	On the lunar equator to "see" the whole sky the axis of the istrument is parallel to the lunar surface	modular structure: we forsee an array of 3x3 1sq m detectors based on CdZnTe cristals 5 mm thick. Additiona modules can be placed behind to take advantage of multiple interactions to detect higher energy photons	about 10 m above the detector array we forsee a modular mask composed by an array of 6 x 6 1 sq m basic masks	0.01-10	MeV	1 mcrab @100 keV for a 10 ksec observing time	erg/cm2/sec	TBD	°C	0.3-1.7 arcmin	10 m (TDC)	abou 1% at 100 keV	1 microsec	4-20° (FWHM)

UV , Visible , IR

- Telescopes to perform surveys and interferometry taking advantage of the absence of atmosphere and the possibility to use big telescopes (large FOV, large areas)
  - Sun: Magnetic features of the Sun and their temporal evolution.
  - Solar System: Monitoring and search for comets and minor bodies in the Solar System.
  - Wide Field Survey: Diffraction limited Survey.
  - Interferometry: To demonstrate optical and UV and NIR interferometry from distinguished stations on the Lunar Surface, to achieve kilometric baseline resolution.

- A 1 to 2 m Gregorian telescope for Solar Observations.
- Aiming to explore magnetic tubes fluxes, their evolution and interaction with other Solar features.
- Spectropolarimetry essential
- Moderate Field of View required (100x100 arcsec square)
- Diffraction limited

- A thermal InfraRed telescope
- 4m and 8m classes solutions to be investigated (JWST as benchmark!)
- Stellar formation in low-z Universe, ultra-luminous IR galaxies and far-z isotopical abundances
- High Resolution Spectroscopy necessary
- Location on the far side of the Moon a strong plus
- Synergy with Solar observations…?

- Interferometry uses the unique ability of the Moon surface to provide extremely long, stable and remotely re-deployable baselines
- A few to several 1 to 2m classes telescopes and more than one recombining station
- Compact objects studies (Galactic center BHs, BHs in nearby Galaxies) by differential astrometry

UV, Visible, IR

SUB THEMES	SCIENCE AND TECHNOLOGY OBJECTIVES	DETAILED SCIENCE OBJECTIVES	SITE	MEASUREMENTS		Operative Range		Sensitivity		Operative Temperature		Angular resolution	Focal length	Spectral/energy resolution	Time resolution	FoV
						Value	Unit	Value	Unit	Value	Unit					
Interferometry	To demonstrate optical and UV and NIR interferometry from distinguished stations on the Lunar Surface. To achieve kilometric baseline resolution, although with poorly covered uv plane.	Center of our Galaxy, survey of Stars diameters, Cepheids and Mira direct angular size measurements in temporal resolved mode, splitting of a large number of eclipsing stars to achieve direct mass determinations.	Flat surface where re-deployement of the interferometric units is possible.	Fringe visibility.	Each unit is a small 30 to 100cm diameter telescope.	300-2100	nm	15	AB mags.	TBD	°C	Up to micro-arcsec regime	N/A	Poor	Seconds	Extremely small (less than one arcsec)

Particles

SUB THEMES	SCIENCE AND TECHNOLOGY OBJECTIVES
High energy gamma rays	Ultra-High Energy Acceleration Processes Discovery of new particles
Very high energy neutrinos (a)	Ultra-High Energy Acceleration Processes Discovery of new particles
Very high energy neutrinos(b)	Ultra-High Energy Acceleration Processes Discovery of new particles
High energy cosmic rays	Ultra-High Energy Acceleration Processes
Solar plasma (a)	Solar wind study on board a Lunar orbiter. Plasma interaction with non magnetized bodies
Plasma and planetary surface intractions (b)	Study of the planetary exosphere generation on board a lunar orbiter. Ion-sputtering process study, relatively to the production of the planetary exosphere and "space weathering"
Gravitational waves	Moon resonant modes measurement
Gravitational waves	Interferometric detector
Fundamental physics	Moon internal dynamics. Transponders to measure with high accuracy the relative distance on the moon surface

Particles

SCIENCE THEMES	SCIENCE AND TECHNOLOGY OBJECTIVES	DETAILED SCIENCE OBJECTIVES	Sito	MEASUREMENTS	Requirements Range /sensitivity		Coverage/resolution	Notes	Notes
Misure di raggi gamma di alta energia	Fisica fondamentale Processi di accelerazione ad altissima energia Ricerca di nuove particelle	Rivelazione di raggi gamma utilizzando la regolite lunare come materiale passivo per formare un calorimetro elettromagnetico in grado di misurare sia l'energia che la direzione di provenienza delle particelle	Rivelatore inserito nel suolo lunare	Barre di scintillatore inserite nel suolo lunare in fori di 20 mm di diametro, distanziati uno dall'altro di circa 5 cm (o 10 cm). La profondita' dei fori e' 10 cm per la prima circonferenza (di raggio anch'essa di 10 cm), 20 cm per la seconda, 30 per la terza etc. fino a raggiungere almeno 6 circonferenze). Le barre di scintillatore sono sezionate e lette in profondita' a passi di 10 o 5 cm.	1 - 300 GeV	.--> risoluzione energetica 20%/Sqrt(E) --> risoluzione angolare < 1 grado	il piu' grande possibile 10000 cm2 sr e' l'obbiettivo per un modulo puo' essere realizzzato in piu' di un sito		
Misure di neutrini di altissima energia (a)	Fundamental Physics Ultra-High Energy Acceleration Processes Discovery of new particles	Detection of fast coherent Cherenkov radio-pulses emitted by particles showers produced by the interaction of Ultra-High Energy Cosmic Particles with the lunar regolith.	Lunar satellite Orbital height: (100-500) km	Large acceptance (towards the Moon limb) and almost isotropic apparatus. 1) Three dipole aerials in orthogonal configuration. 2) Other configurations.	Frequency range: 0.01÷1.0 GHz Bandwidth: (100-400) MHz	Pmin < -140 dBm/Hz	Large acceptance	Measurement of the polarization.	

Radio and Cosmology

- Advantage of the absence of interferences for radioastronomy on the far side
- Surveys and interferometry using several antennas

Radio and Cosmology

SUB THEMES	SCIENCE AND TECHNOLOGY OBJECTIVES	DETAILED SCIENCE OBJECTIVES	SITE
Radio astronomy at Ultra low frequency, low and high resolution	Interferometric arrays, surveys	First detection of cosmological large scale filaments, Amplification of magnetic fields in large scale structures, Low energy end of the spectrum of relativistic particles in radio sources, Detection of radio emission from DM annihilation	Far side
Radio astronomy at low frequency, low and high resolution	Interferometric arrays, surveys	Pointed observations,Life-cycle of radio sources and radio loud-radio quiet dichotomy, Particle acceleration sites in the Universe, Low energy end of the spectrum of relativistic particles in radio sources, Low energy end of the spectrum of relativistic particles in radio sources, Detection of radio emission from DM annihilation	Far side
Radio astronomy at medium frequency, low and high resolution	similar to LOFAR and LWA …	Pointed observations,Life-cycle of radio sources and radio loud-radio quiet dichotomy, Particle acceleration sites in the Universe, Low energy end of the spectrum of relativistic particles in radio sources, Low energy end of the spectrum of relativistic particles in radio sources, Detection of radio emission from DM annihilation	Far side
CMB polarisation (E and B mode) and gravitational waves	Stokes' parameter maps, cosmological models verification, high frequency polarisation surveys.mm and sub-mm optics and large focal plane detector arrays. Interferometric systems	Correlation modes, Inflation and primordial quantum fluctuations, structure formation, reionisation, cosmological parameters, particle physics.	Far side
CMB spectral distortions	Bose-Einstein, free-free and Comptonisation-like distortions, Cosmological parameters. Radiometric systems for high accuracy absolute temperature measurements	Thermal history of the Universe, energy dissipation processes, reionisation, particle decays, radiative processes.	Far side

Radio and Cosmology

CBM Spectral Distortion

DETAILED SCIENCE OBJECTIVES	SITE	MEASUREMENTS		Operative Range		Sensitivity		Operative Temperature		Angular resolution	Spectral resolution	FoV
				Value	Unit	Value	Unit	Value	Unit			
Thermal history of the Universe, energy dissipation processes, reionisation, particle decays, radiative processes.	To minimise the instrumental noise and RF interferences, the experiment should be located in a shaded crater on the dark side of the Moon	Radiometers	Pointing	0.4-50	GHz	<1 mK sec$^{1/2}$		20-30	K	7/8 deg	10%	$>10e4$ deg^2

Observation of the Universe from the Moon

- Status:
- the Moon offers great opportunities of science!
- several experiments identified (>30)
- >>> interaction with technological studies to look at feasibility

Earth Observation from the Moon

- Study based on the analysis of the advantages and drawbacks depending on the observation platform: Earth, satellite, Moon.
- Analysis of the science that can be done only from the Moon or in a better way than that allowed from a satellite by remote sensing, in particular those phenomena characterized by:
  - global (or very large area) observation because of their impact on large areas (ozone distribution)
  - simultaneous observation of different point of the Earth to explore spatial correlation over wide areas (vegetation, oceans)
  - phenomena requiring continuous observation of the same area for a certain interval of time (weather systems)
  - phenomena happening with low frequency and whose location is not clearly stated (meteoroids impacts)
  - phenomena relevant to the Earth-Moon system (tides)

Earth Observation from the Moon

OUTPUT

- Scientific purposes achievable with the state of the art current technology
- Identification of technology R&D needed
- Demonstration, if any, of improvement of EO from the Moon versus satellite remote sensing
- Requirements for remote sensing instruments design, trade off and selection
- Instrument installation site selection

Earth Atmosphere observation

1. Assessment of observations requirements for monitoring and tracking weather systems based on:
   - the study of the dynamic and life cycle of tropical cyclones, tornadoes, weather fronts and depression
   - the study of cloud properties (radiative and microphysical)
   - analysis at global and local scale of atmospheric chemistry, atmospheric aerosols and gases characteristics
2. Analyzing Earth's viewing conditions from the Moon

   Then:
   - trade-off analysis between the observational requirements and the viewing conditions allowing to focus the potential of Moon based atmospheric observations
   - critical comparison will be conducted with respect to existing and planned EO-mission for atmospheric observation.

Earth Atmosphere observation

Science Objectives	Detailed Science Objectives	Measurements / *Detection Thecnology*	[Spectral Range] *Resolution*		Sensitivity SNR(b) Or *NEDT(c)*		Spatial Coverage And *Resolution*	Temporal resolution
			Value	Unit	Value	Unit		
Atmospheric chemistry	Aerosols Optical Properties	Scattered and reflected spectral sunlight Radiance from the Earth and solar Irradiance *Multispectral algorithms in atmospheric spectral window*	[0.4 – 3.0] < 10 @ VIS < 20 @ NIR	µm µm nm □	> 200 @VIS >100@NIR	-	250 x 250 m^2 @ VIS 500 x 500 m2 @ VIS	1 hour
	Trace gases content (O_3,NO_x,SO_2,CO,…)	Scattered and reflected spectral sunlight Radiance from the Earth and solar Irradiance *DOAS(a) thecnique*	[0.2 – 3.0] < 0.2	µm nm	>1000@ [UV-VIS] >50@NIR	- -	*10x20 km^2* *5x10 km^2* (only for limitated areas for air quality applications)	30 min 1 hour
Clouds properties	Radiative & Microphysical properties -Cloud amount in terms of Cloud Optical Thickness -Particle size in terms of efficient radius -Cloud liquid and ice water content -Precipitation rate -Cloud liquid and ice water content Temperature Humidity profile	Scattered and reflected spectral sunlight Radiance from the Earth and solar Irradiance Inversion at nonabsorbing λ in VIS and at absorbing λ in NIR Measurements in Absorption Bands of oxygen and water vapour Microwave sounding	[0.6 – 0.8] < 0.15 [1.5 – 4.5] < 0.5 54, 118, 425, 183, 380	µm µm µm µm GHz	> 0.5 0.25 (for 1.6 µm) 0.35 @ 300 (for 3.9 µm) TBD	W/m^2sr µm K TBD	*3x3 km^2* *3x3 km^2* *< 30x30 km^2*	15 min 15 min 15 min

Earth Ocean observation

- Observation from the Moon can adequately cover the vast, rapidly varying ocean phenomena at the appropriate time and space scales:
  - Global climate change
  - Sea-ice melting and formation
  - Ocean optical properties
  - Mapping of marine currents
  - Study of the marine environment (phytoplankton, pollutants, suspended matter, Dissolved Organic Matter (DOM), Harmful Algal Blooming (HAB), Surface Sea Temperature (SST))

Earth Ocean observation

SCIENCE AND TECHNOLOGY OBJECTIVES	DETAILED SCIENCE OBJECTIVES	MEASUREMENTS	Spectral range	Spectral resolution	Sensitivity	Excitation source	Coverage	Observation requirements
Atmospheric processes	Sea Surface Temperature (SST) mapping	IR radiometric imaging	10-12 μm 3.5-4 μm					
Optical oceanography; Water masses characterisation	Ocean optical properties; ocean colour; water quality	VIS reflectance imaging	390-1040 nm					
Sea-ice melting and formation	Coverage, temperature of ice sheets and caps; floating oceanic ice	IR radiometric imaging VIS reflectance imaging	10-12 μm 3.5-4 μm 390-1040 nm					
Marine biology; fisheries science	Phytoplankton, phytobenthos, pollutants, Dissolved Organic Matter (DOM), Harmful Algal Blooming (HAB); primary production by marine phytoplankton	VIS reflectance imaging Laser Induced Fluorescence (LIF)	390-1040 nm under evaluation					
Coastal waters and other optically-complex waters	water quality; suspended matter; DOM; pollutants; eutrophication processes;	VIS reflectance imaging Laser Induced Fluorescence (LIF)	390-1040 nm under evaluation					
Pollution monitoring	Oil slicks type and thickness; pollutants; wastewaters; silt runoff	VIS-IR reflectance imaging Laser Induced Fluorescence (LIF)	390-1040 nm under evaluation					<

Vegetation Monitoring

- Vegetation monitoring is actually an essential component for the investigation and control of global ecological processes and vegetation damage. Main topics under study are:
  - Global climate change
  - Carbon cycle
  - Monitoring of the agro-forestry resources: vegetation coverage and biomass; precision farming
  - Land usage, desertification
  - Primary production and vegetation stress monitoring, photosynthesis efficiency

Vegetation Monitoring

SUB THEMES	SCIENCE AND TECHNOLOGY OBJECTIVES	DETAILED SCIENCE OBJECTIVES	MEASUREMENTS	Spectral range	Spectral resolution	Sensitivity
Global change	Carbon cycle; net primary production	Photosynthesis efficiency	Sun-induced fluorescence in Fraunhofer and atmospheric lines; thermal IR, reflectance	at least four spectral lines at 760nm, 687 nm, 656 nm, 486 nm (possibly also Fe I 685.52 nm);10-12 µm; 390-1040 nm and SWIR		
			Laser Induced Fluorescence (LIF) spectroscopy; thermal IR, reflectance	under evaluation		
		Light use efficiency	VIS reflectance imaging	390-1040 nm		
		Wet biomass-WBM, dry biomass-DBM, leaf area index-LAI, and plant height-PLNTHT	VIS-IR reflectance imaging	390-1040 nm		
	Global land cover	Cover type and extent; desertification	VIS-IR reflectance imaging	390-1040 nm		
Resource management; sustainability	Land use	Anthropogenic impact; human-induced changes; global crop area	VIS-IR reflectance imaging	390-1040 nm		
	Natural vegetation classification; forestry management	Major ecosystem estimate	VIS-IR reflectance imaging	390-1040 nm		
	Crop type; species identification	Crop inventories; extensive subsistence agriculture	VIS-IR reflectance imaging	390-1040 nm		
	Crop and vegetation stress - early warning	Photosynthesis efficiency	Sun-induced fluorescence in Fraunhofer and atmospheric lines; thermal IR, reflectance	at least four spectral lines at 760nm, 687 nm, 656 nm, 486 nm (possibly also Fe I 685.52 nm);10-12 µm; 390-1040 nm and SWIR		
			Laser Induced Fluorescence (LIF) spectroscopy; thermal IR, reflectance	under evaluation		

Earth radiative budget

- Magnetic features of the Sun (Solar dynamo models): continuous high-precision measurements of the classical observables on the photosphere/chromosphere and the solar irradiance will help model validation for the basic phenomena occurring in the solar convection zone and their macroscopic time scales.
- Total Solar Irradiance (TSI) and Spectral Solar Irradiance (SSI) are of great importance for solar physics and the evolution of the Earth's climate.
- Global Circulation Models evolving towards Earth System Models need SSI as one of the main input.

Earth radiative budget

- As a consequence, the following main measurement campaigns should be accomplished from lunar sites:
  - TSI: high-sensitivity and high-accuracy redundant instruments with very low degradation, or the new-generation (NGI) for short, instruments. NGI radiometers will be necessary
  - High-resolution SSI in the full UV-band by NGI spectrographs
  - Global UV Backscattering from chemical elements of stratosphere (NGI)
  - Global high-precision measurements of the terrestrial, or long-wave, spectral radiation from 4 to 100 μm, at least (NGI again)

Earth radiative budget

Science Objectives	Detailed Science Objectives	Measurements / *Detection Technology*	[Spectral Range] *Resolution*		Sensitivity SNR[b] Or *NEDT*[c]		Spatial Coverage And *Resolution*	Temporal resolution	Bit rates
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Weather Systems	Tropical cyclones, tornadoes, weather fronts and depression	Scattered and reflected spectral sunlight Radiance from the Earth and solar Irradiance	[5 – 14] > 0.5	µm µm	0.75 @ 250 (for 5-8 µm) 0.25 @ 300 (for >8 µm)	K K	*3x3 km^2*	15 min	< 15 GB / day

Earth radiative budget

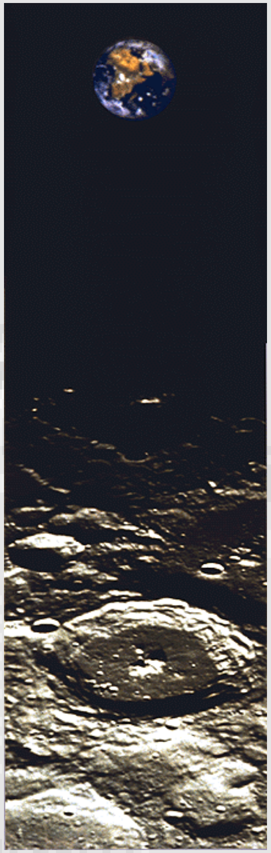
SUB THEMES	detector localization	SCIENCE AND TECHNOLOGY OBJECTIVES	Spectral bands	spectral resolution	Observation geometry	field of view	bit rate	Ground validation measurement
Solar Measurement Campaign	in-situ, both near and far sides	Total Solar Irradiance	from XUV to FIR	N/A	stable Sun pointing (max 0.5 deg)		> 5 Mb/day (raw data)	
		Solar Luminosity Oscillation Imaging			1 arc-min alignment		> 7.2 Mb/s (raw data)	
		Spectral Solar Irradiance						
		Near UV radiance variability						
		radiance variability						
Earth Measurement Campaign	in-situ, near side	Global UV Backscattering						
		Visible band reflection						

Earth Observation from the Moon

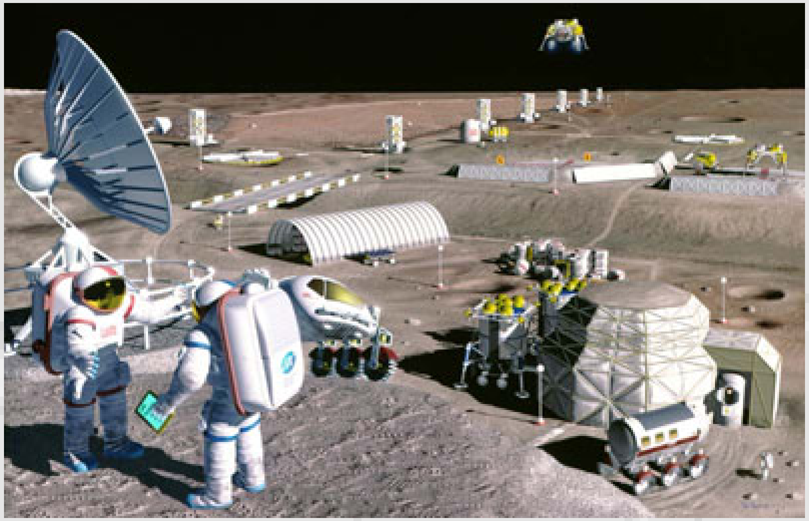
- Status:
- fields of interest identified
- requirements on measurements on-going
- >>> interaction with technological studies to look for feasibility and trade-off w.r.t other platforms

ASI Approach

- On the **short term**, ASI National Programme for Moon exploration will be mainly science oriented and based on the requirements of the Italian scientific community:
  - Study of the Moon and its resources
  - Science from the Moon, using the Moon as a platform for:
    - Universe observation
    - Earth observation



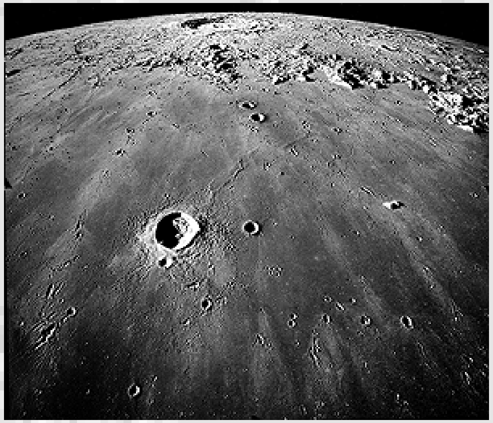
ASI Approach



- On the **medium term** the Moon will be considered for resources exploitation and a test-bed for Mars exploration.
- On the **long term**, it will be considered also as a permanent base for Earth natural satellite exploitation and for the preparation of the Mars exploration and beyond.

ASI Approach

- On this basis, phase AB of the first mission, very likely an orbiter mission, shall start in 2007 and in parallel some of the most critical technologies to implement future missions (in-situ) will be studied and developed (breadboarding and tests on Earth at representative sites).
- Such national programme is fully open to international collaborations, in particular on possible synergies with other national/international programmes.



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