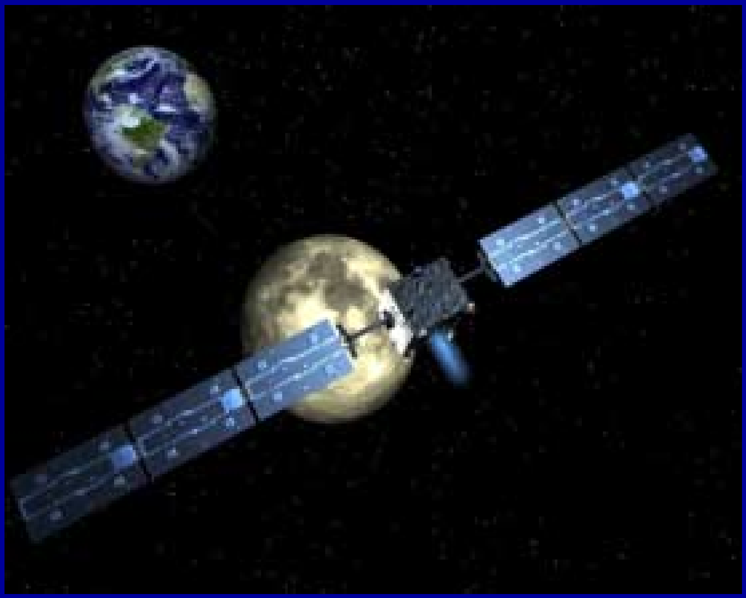
SMART-1 mission, technologies and science :

with Solar power to the Moon



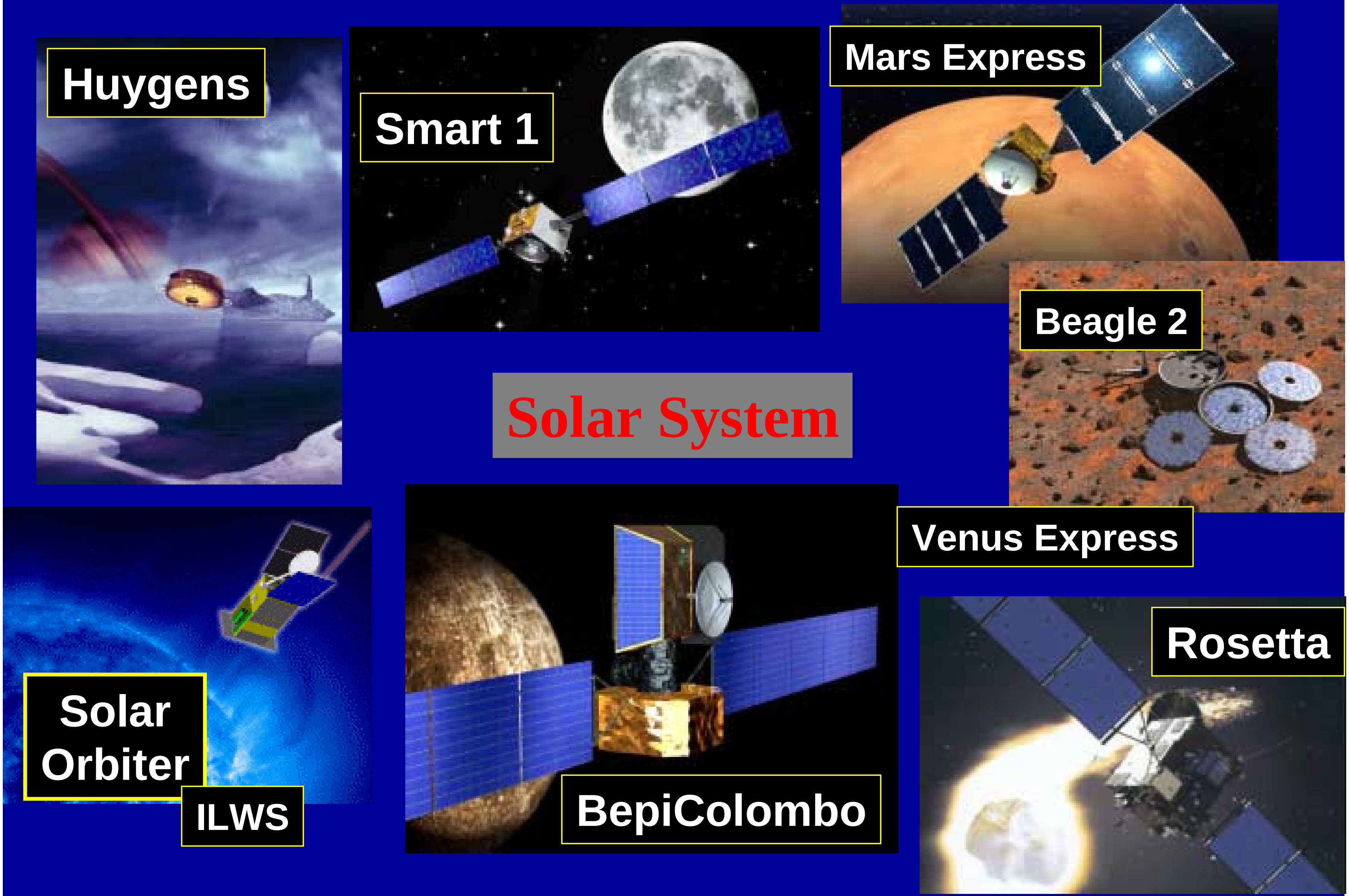
Bernard H. FOING*, Giuseppe Racca & SMART-1 Team**

SMART-1 Project Scientist & Chief Scientist, RSSD

***** SMART-1 Project Manager***

ESA Science Directorate

What European scientists want to do.



SMART-1 (http://sci.esa.int/smart-1/)

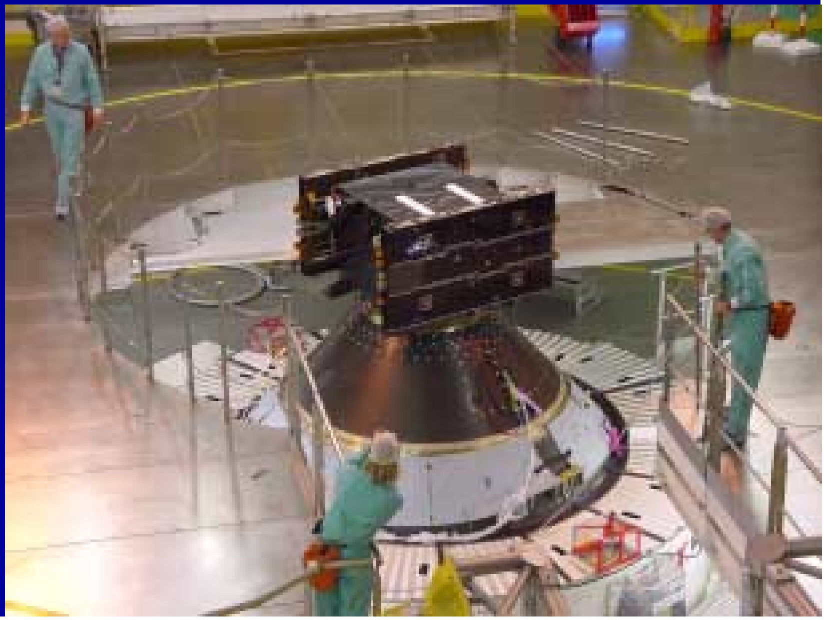
- **ESA SMART Programme: Small Missions for Advanced Research in Technology**
  - **Spacecraft & payload technology demonstration for future cornerstone missions**
  - **Management: faster, smarter, better, (harder)**
  - **Early opportunity for science**

SMART-1 (http://sci.esa.int/smart-1/)

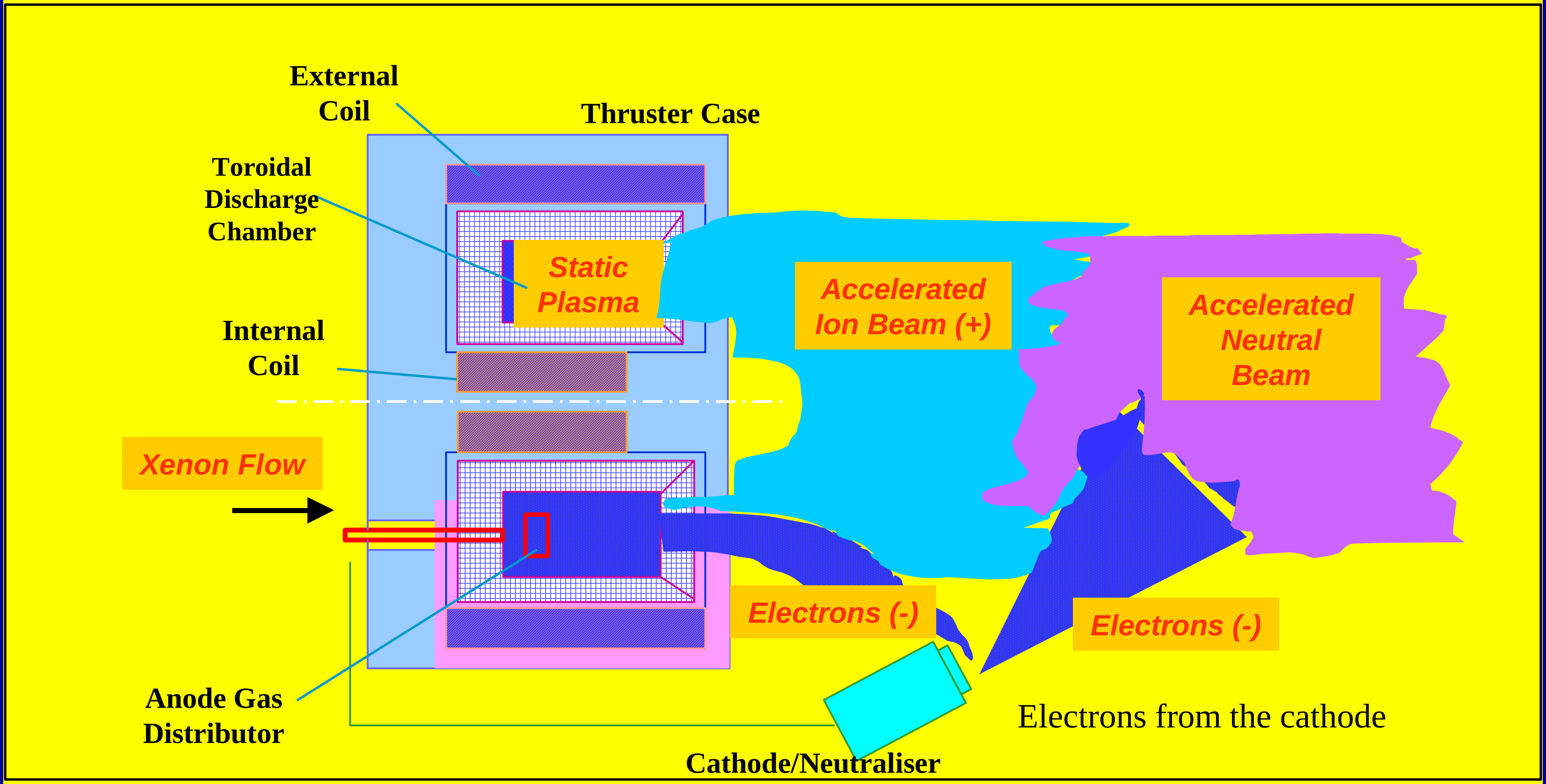
- ESA SMART Programme: Small Missions for Advanced Research in Technology

SMART-1 Solar Electric Propulsion to the Moon

- **Test for Deep Space Propulsion**
- **Mission approved and payload selected 99**
- **SMART-1 cost 80 + 30 MEuro**
- **19 kg payload (delivered August 02)**
- **370 kg spacecraft (tested, mounted)**
- **launch Ariane 5 due 27 Sept, 23UT, Kourou**



Stationary Plasma Thruster



The ion engine:

- SNECMA -SEP (F) (Stationary Plasma Thruster SPT-100, PPS-1350)
- High specific impulse (~1500 s)
- low thrust (~70 mN = 7 grams), low power consumption (~20 W/mN)

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Designing and developing the vehicle

- **Dedicated Spacecraft and Electric Propusion design**
- **Spacecraft 370 kg, Fuel 84 kg Xenon, Payload mass 19 kg,**
- **Modular S/C concept, advanced on-board technologies, CAN bus**
- **Li-C batteries, Multiple-junction Solar Arrays**
- **New Guidance Navigation / flight dynamics approach.**

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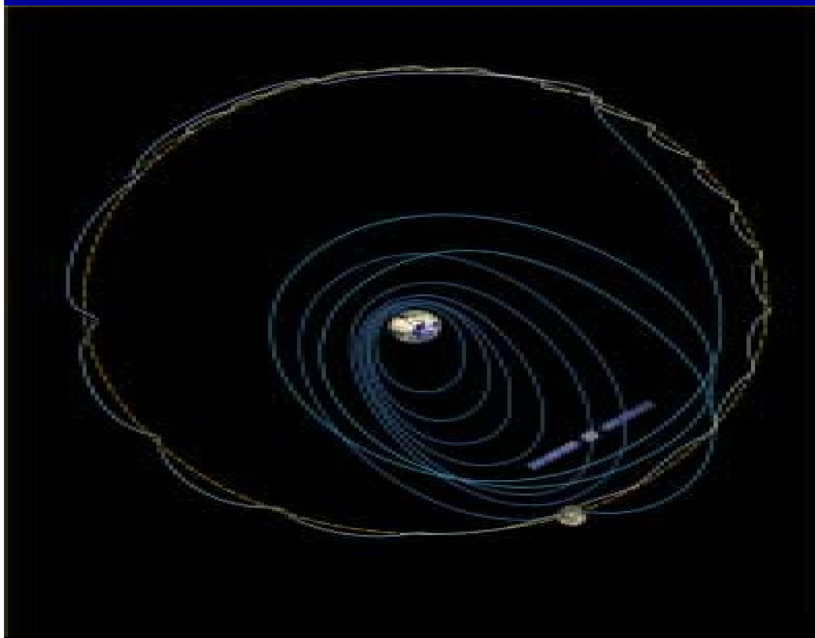
Learning to drive the Solar Powered vehicle

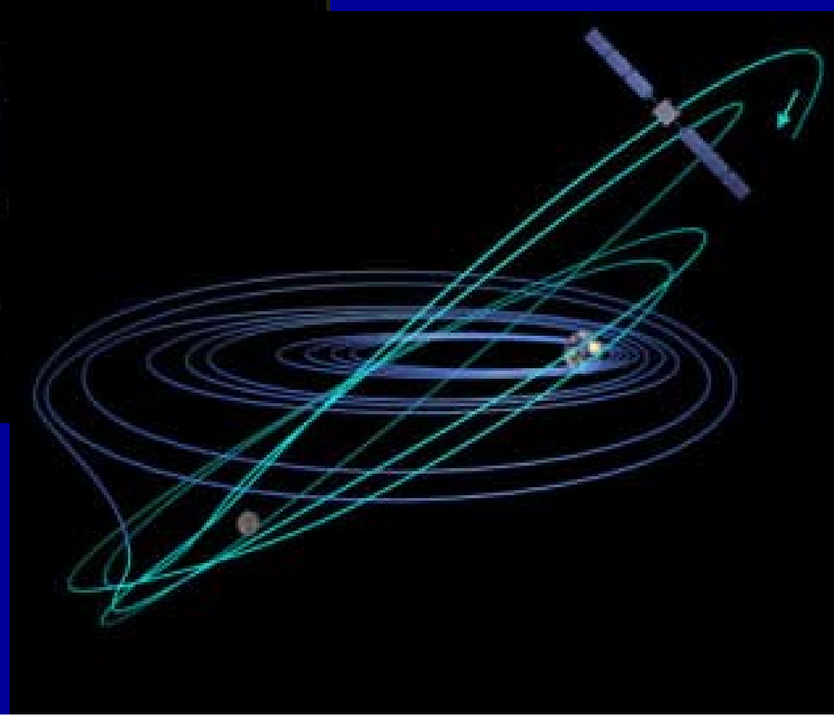
- **Earth-Moon transfer from GTO: 14-18 months (SPT only/coast arcs)**
- **Effects of Solar pannels degradation in radiation belts**
- **Use of lunar resonance gravity assist**
- **Flexibility and optimisation of navigation**
- **payload diagnostics of engine capabilities and environment**

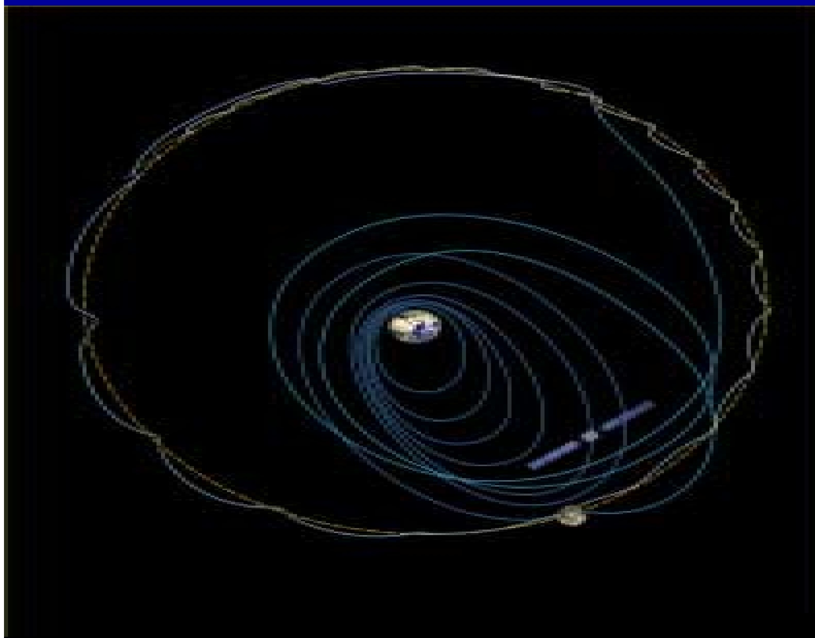


Propulsion to the Moon

- To be launched 27 September 2003 23h UT as Auxiliary passenger on Ariane 5 into Geostationary Transfer Orbit with INSAT3 E and e-Bird

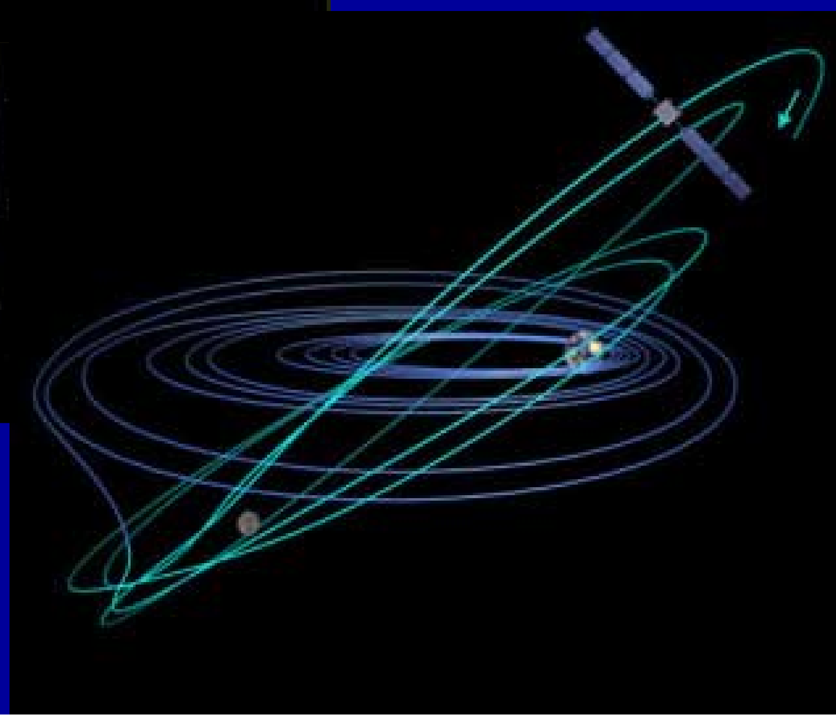
  (a bargain hitchhike to space)
- Spiral out cruise (15-18 month), SPT/coast arcs, lunar resonance swingbys & capture

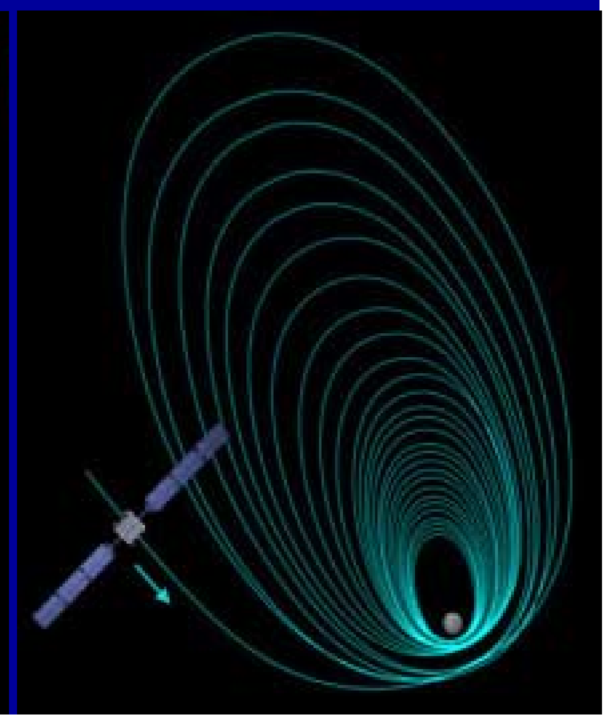




Propulsion to the Moon

- To be launched 27 sept 2003 as Auxiliary passenger on Ariane 5 into Geostationary Transfer Orbit (a bargain hitchhike to space)
- Spiral out cruise (15-18 month), SPT/coast arcs, lunar resonance swingbys & capture**, spiral in**
- **lunar science orbit (300-1000 km perilune - 10000 km apolune, 6 month + extension)**



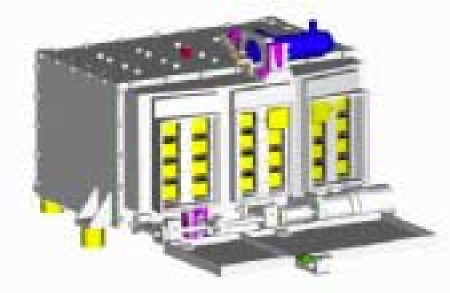


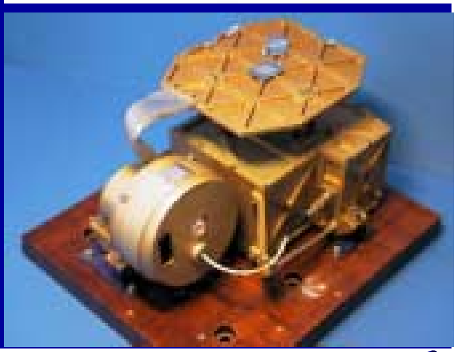
7 experiments and 10 investigations

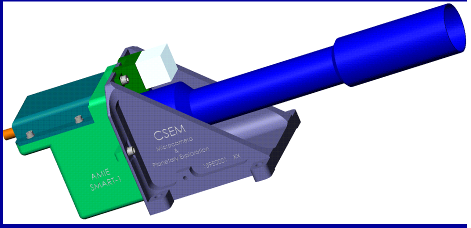
		Mass (kg)	Power (W)	PI Investigator
EPDP	Electric Propulsion Diagnostic Package	2.4	18	G. Noci (I)
•SPEDE	Spacecraft Potential Electron and Dust Exp.	0.8	1.8	A. Malkki (SF)
•KATE	Ka-Band TT&C Experiment	6.2	2	R. Birkl (D)
•*RSIS*	Radio-Science Investigations for SMART-1	*(KATE/AMIE)*		L. Iess (I)
•D-CIXS	Demo Compact Imaging X-ray Spectrometer	5.2	18	M. Grande (UK)
•XSM	X-ray Solar Monitoring	(with D-CIXS)		J. Huovelin (SF)
•SIR	SMART-1 Infrared Spectrometer	2.3	4	H.U. Keller (D)
•AMIE	Advanced Moon micro-Imager Experiment	2.1	9	J.L. Josset (CH)
Laser	Experimental Deep-space Laser link	*(using AMIE)*		Z. Sodnik (ESA)
OBAN	On-Board Autonomous Navigation Exp.	*(using AMIE)*		F. Ankersen (ESA)

Instrument Technology

- **D-CIXS (Compact Imaging X-ray Spectrometer)**
  - **Swept charge CCD, advanced micro structure collimator**
- **SIR (IR Spectrometer)**
  - **Monolithic quartz commercial grating spectrometer**
- **AMIE (High Resolution micro- Camera)**
  - **micro-camera, 3D electronics+ integrated Data Processor**
  - **Multicolour imaging, lightweight high resolution optics**
  - **Laser link with ESA Optical Ground Station in Tenerife**
  - **On Board Autonomous Navigation experiment**
- **SPEDE Spacecraft Potential Electron Dust Experiment**
- **EPDP Electric Propulsion Diagnostics Package**
- **KATE Deep Space X- Ka Communications &**
- **RSIS radio science**



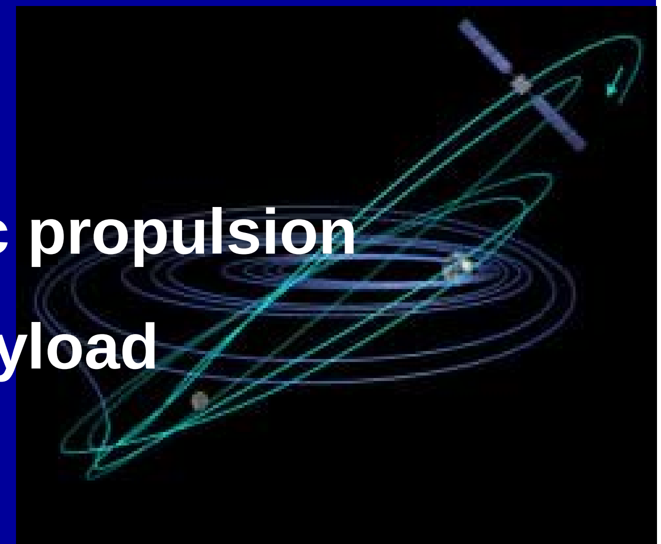




Smart-1 is not only

✓**Getting to the Moon by solar electric propulsion**

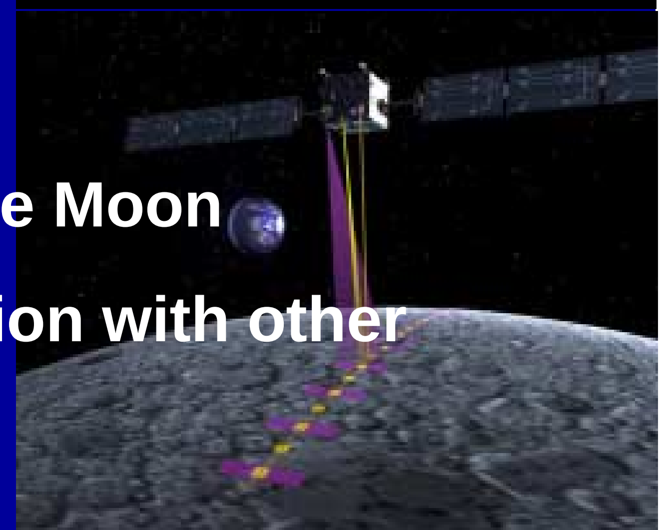
✓**Testing challenging miniaturised payload**



Smart-1 is also

✓**Making new exciting science on the Moon**

✓**Working in international collaboration with other Lunar missions**



Smart-1

7 experiments and 10 investigations

1. **Testing new techniques on the way to the Moon**

   EPDP and SPEDE

   KATE and RSIS

   Laser Link

   OBAN

2. **Performing cruise science** **D-CIXS, XSM & AMIE**

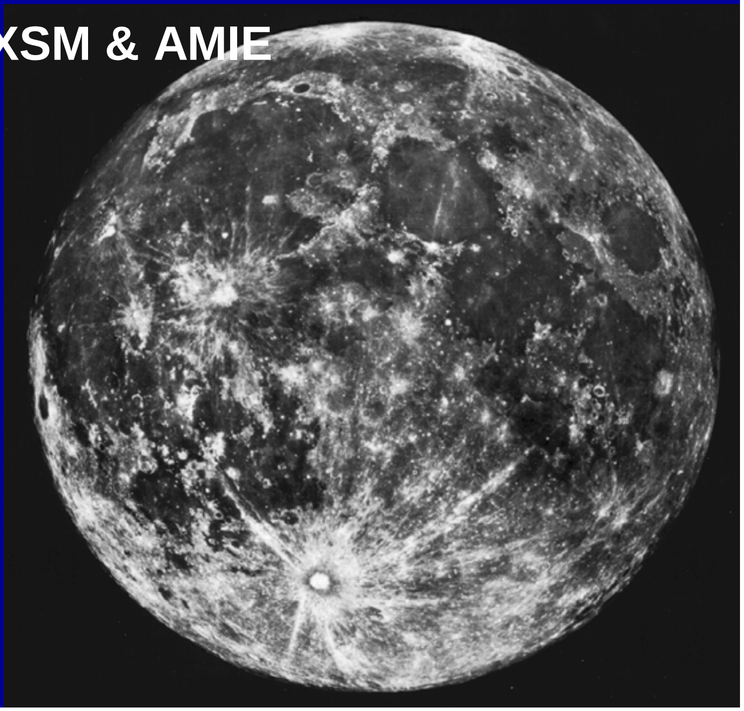
3. **Observing the Moon**

   AMIE

   SIR

   D-CIXS & XSM

   SPEDE & RSIS

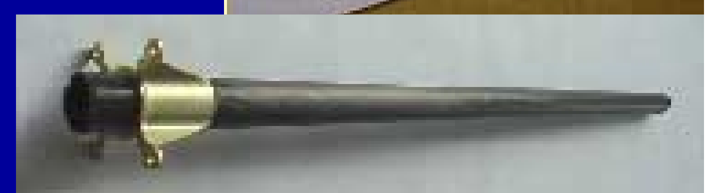


Smart-1

1. Testing new techniques on the way to the Moon

EPDP and SPEDE will monitor:

- **how the ion engine performs**
- **what are the possible side effects on spacecraft and instruments**
- **how the spacecraft interacts with natural electromagnetic phenomena in the space around it**



Smart-1

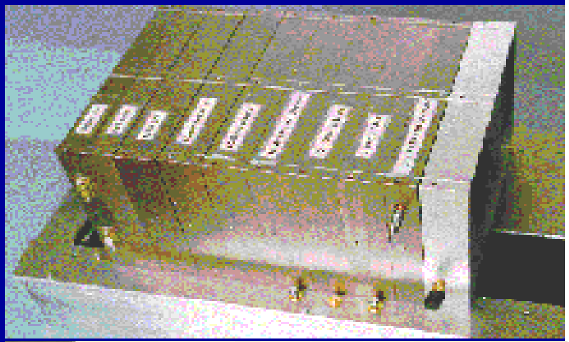
1. Testing new techniques on the way to the Moon

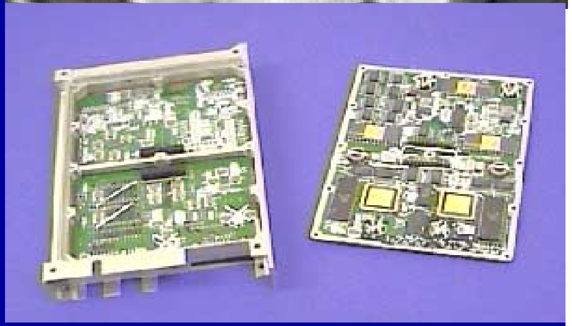
KATE will:

- **demonstrate the next generation of high bandwidth radio links between the Earth and far-flung spacecraft (deep space communication)**

RSIS will:

- **determine what is the precise thrust delivered by the ion engine**



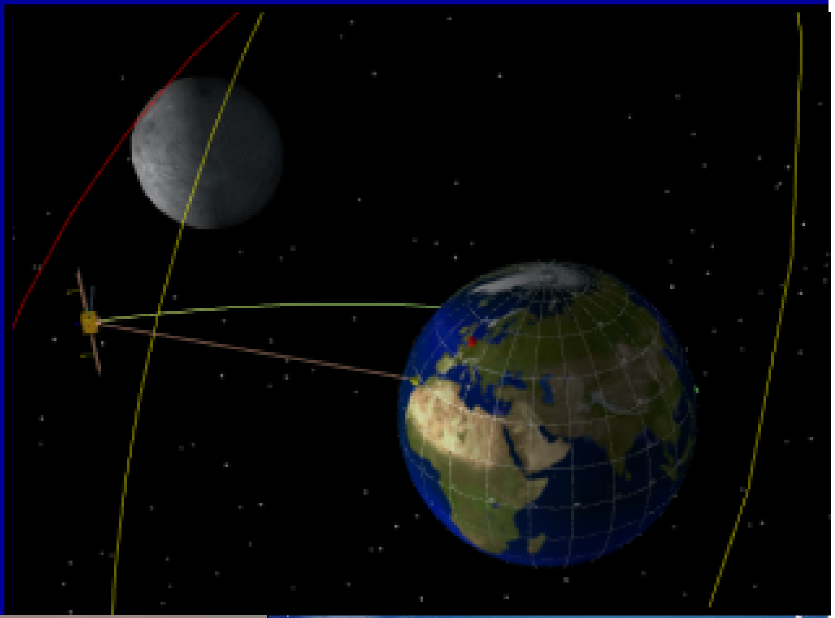


Smart-1

1. Testing new techniques on the way to the Moon

The Laser Link experiment will:

- **test laser beaming from Earth to a camera on a fast moving spacecraft for communication purposes**



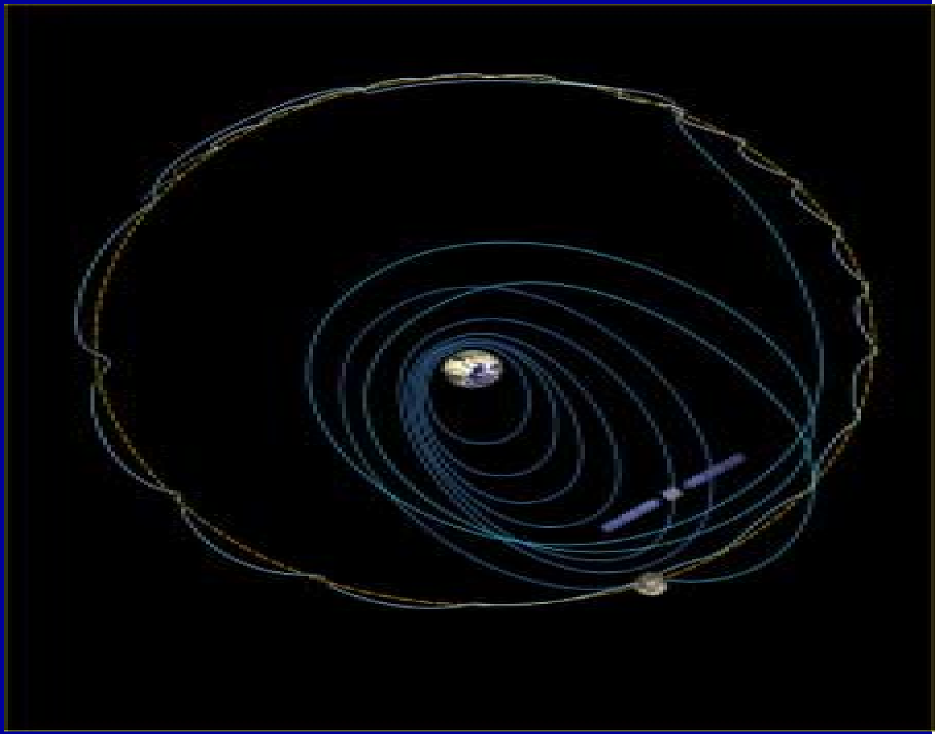
Smart-1

1. Testing new techniques on the way to the Moon

OBAN will:

- **evaluate a computer technique for on-board autonomous navigation**

  using images of the Moon, Earth, asteroids taken with AMIE referred to the stars seen by the star tracker



Smart-1

2. Performing cruise science

to test in space the instruments performance

D-CIXS will:

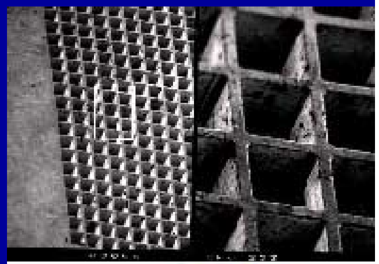
- **monitor the X-ray variability of the Earth magnetosphere and bright X-ray sources**

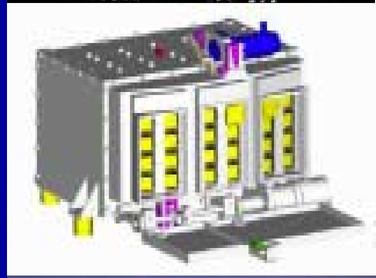
XSM will:

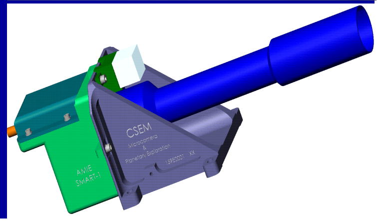
- **monitor continuously the solar variation in X-ray due to active regions of the Sun and solar flares**

AMIE will:

- **deliver images of the Earth and the Moon, for calibration but also for public and education projects**







Smart-1

3. Observing the Moon. Why?

After Apollo/Luna (35 years ago) and more recent lunar missions the knowledge of the Moon is still surprisingly incomplete…

We still want to know about:

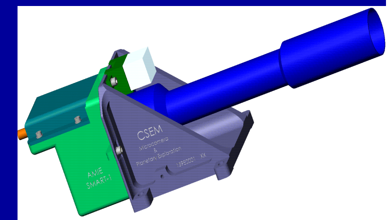
- **How the Earth-Moon system and rocky planets formed and evolved** (geochemistry and giant bombardment)

- **Geophysical processes** (volcanism, tectonics, cratering, erosion, deposition of ice and volatiles…)

- **How to prepare for future lunar and planetary exploration** (resources and landing sites)

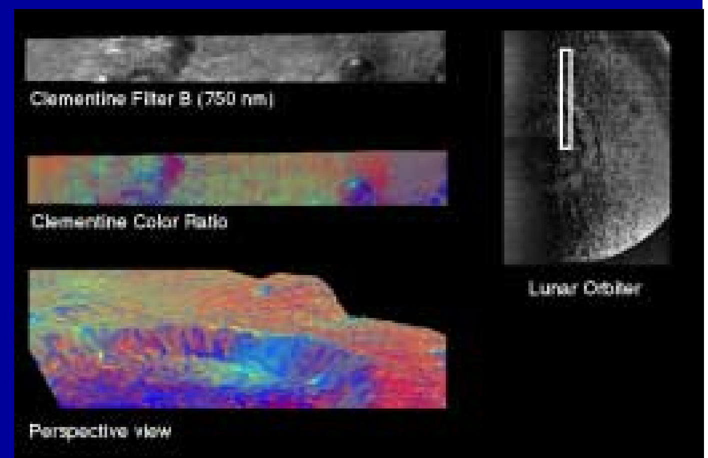
Smart-1

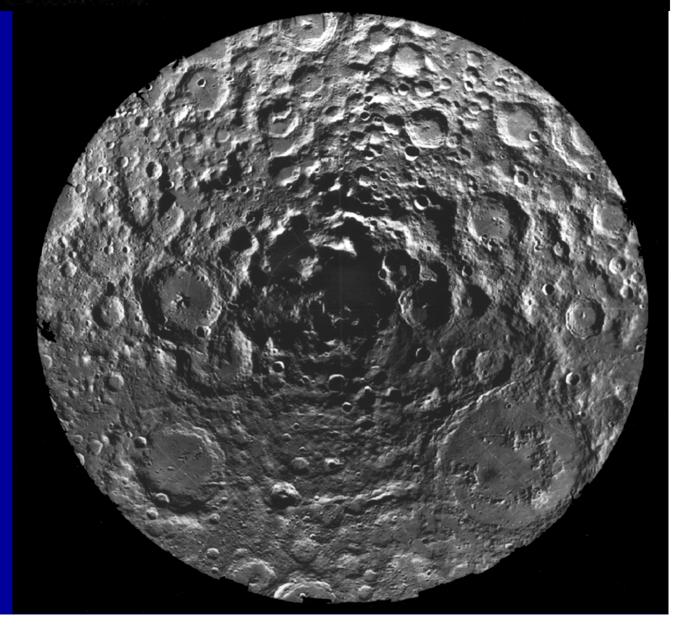
3. Observing the Moon



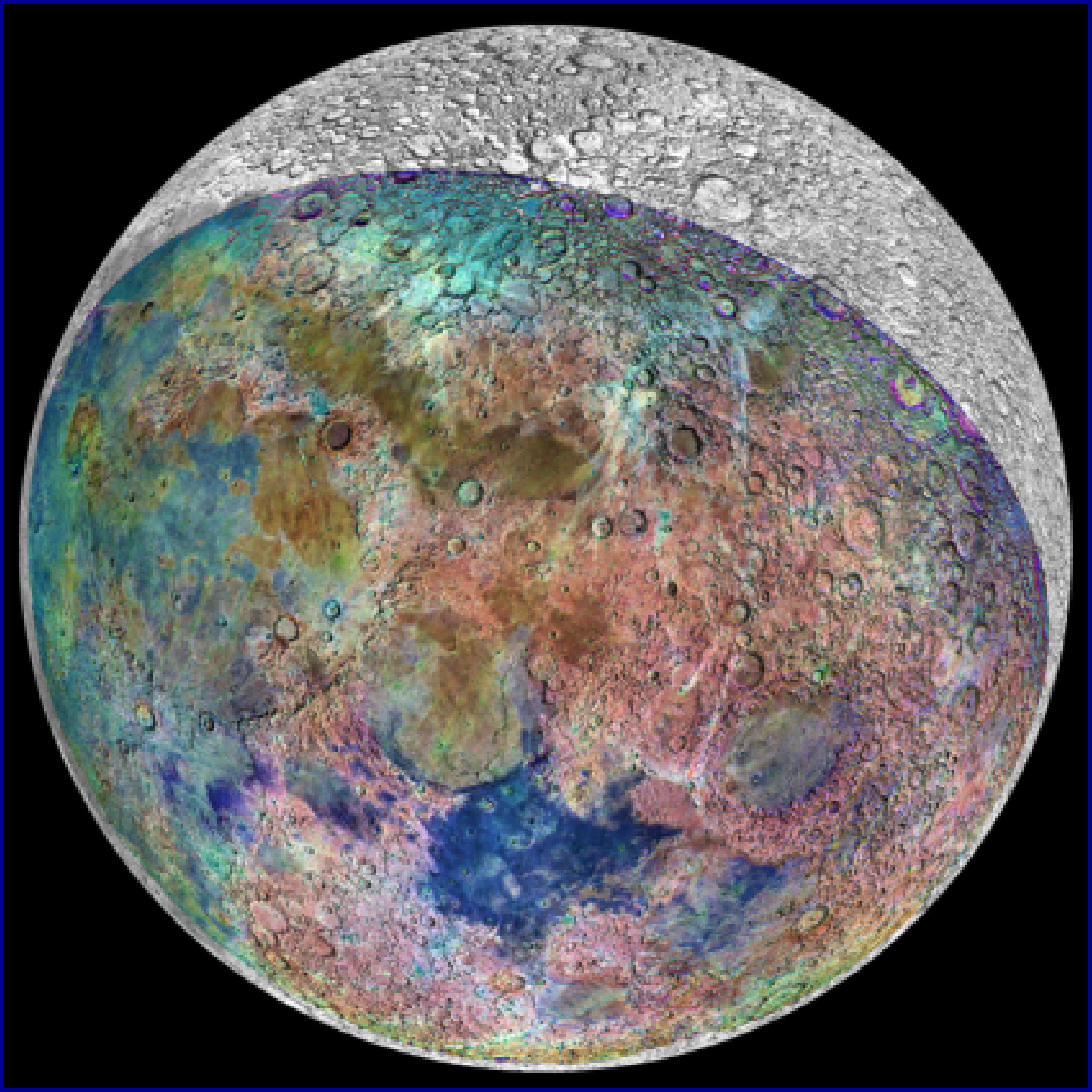
AMIE, the mini camera, will make multicolour imaging of the Moon for:

- **High resolution geology**
- **Stereo, multi-angle imaging**
- **Survey landing sites for sample return**
- **Repeated deep imaging of south pole**
- **Mapping ‘eternal’ light and shadow**
- **Search for potential water ice traps**
- **Potential for lunar bases, power, resources**
- **Preparation for future lunar exploration**





The colours of the Moon



Galileo lunar fly-by

Smart-1

3. Observing the Moon

The SIR spectrometer will look at the "invisible" Moon in the infrared:

- to chart the Moon's minerals
- to find the signature of volcanism and impacts
- to search for the fingerprints of water-ice by peeking into dark craters

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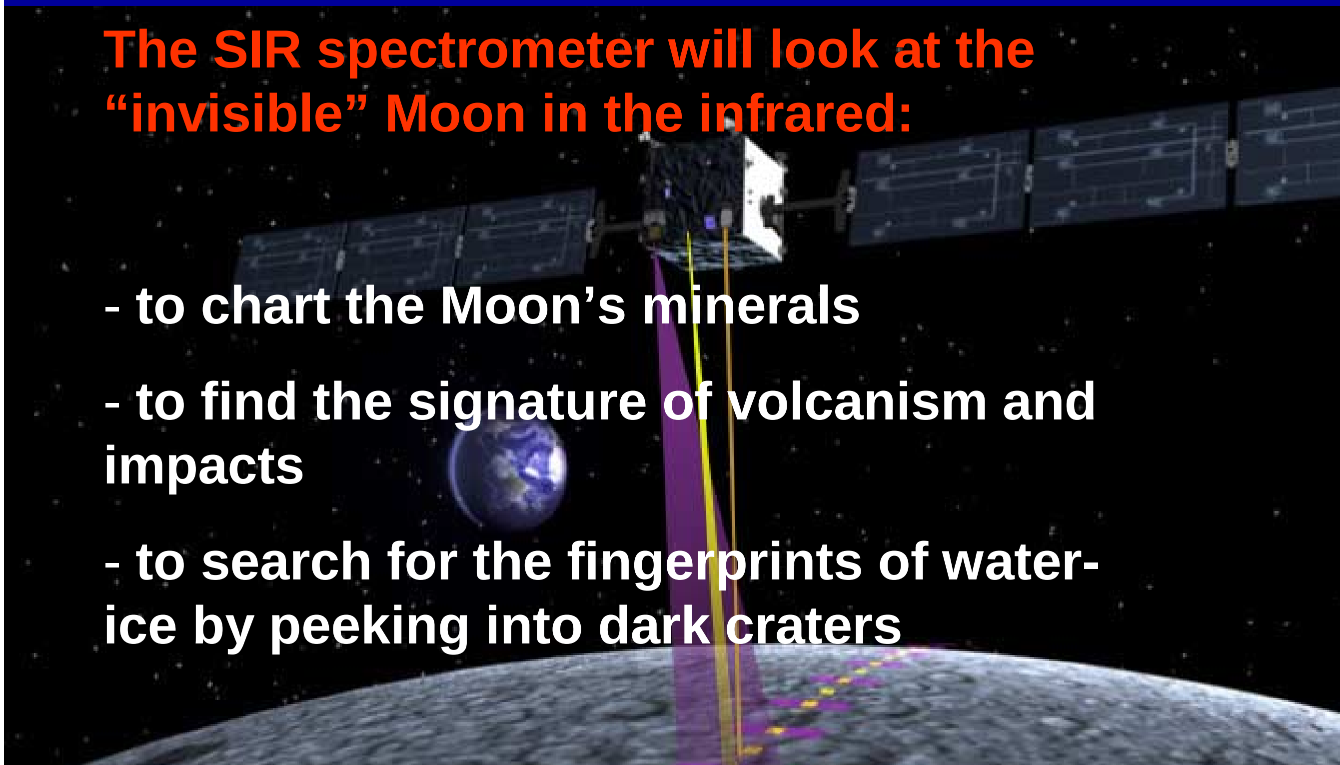
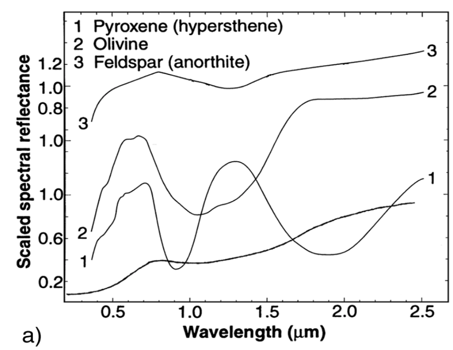
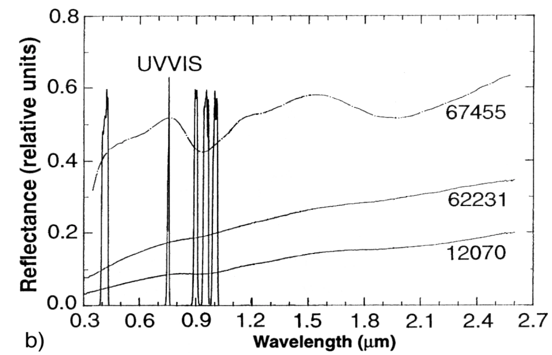




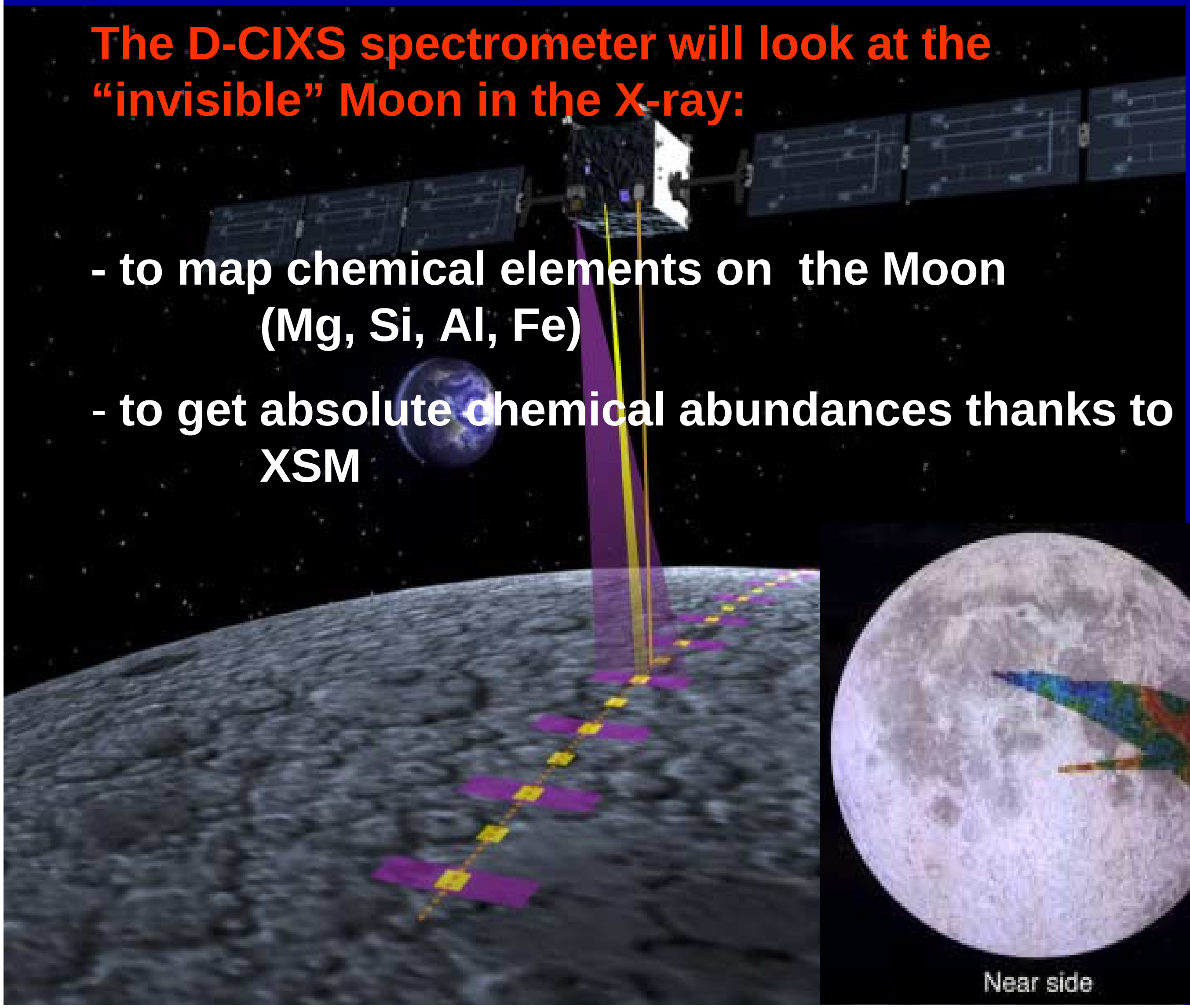


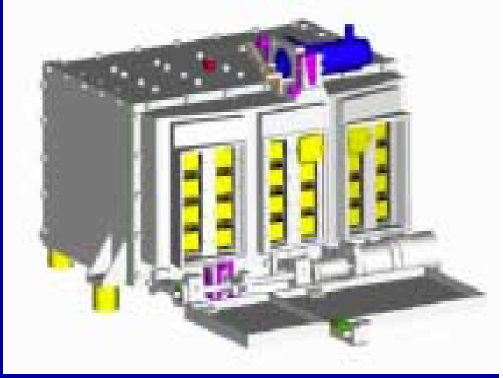
Smart-1

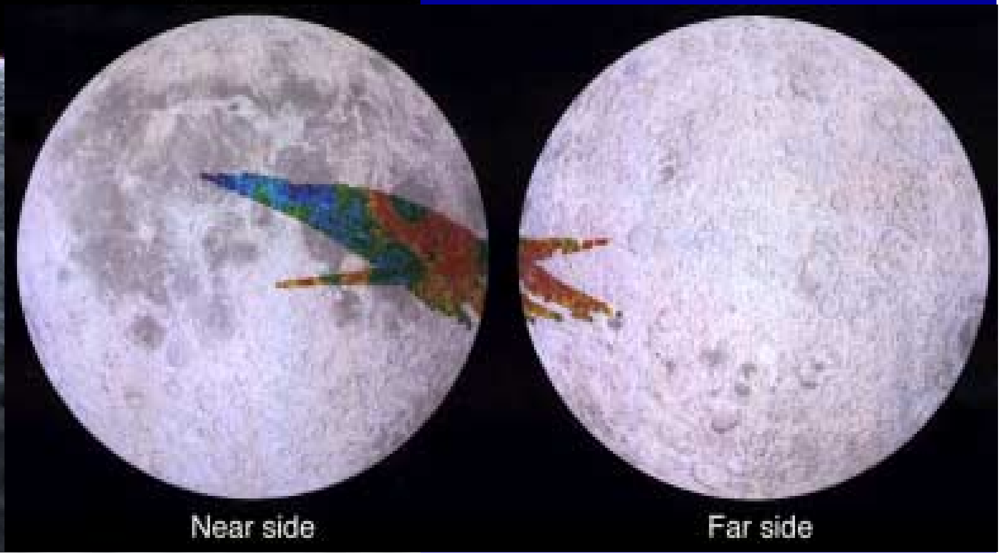
3. Observing the Moon

The D-CIXS spectrometer will look at the "invisible" Moon in the X-ray:

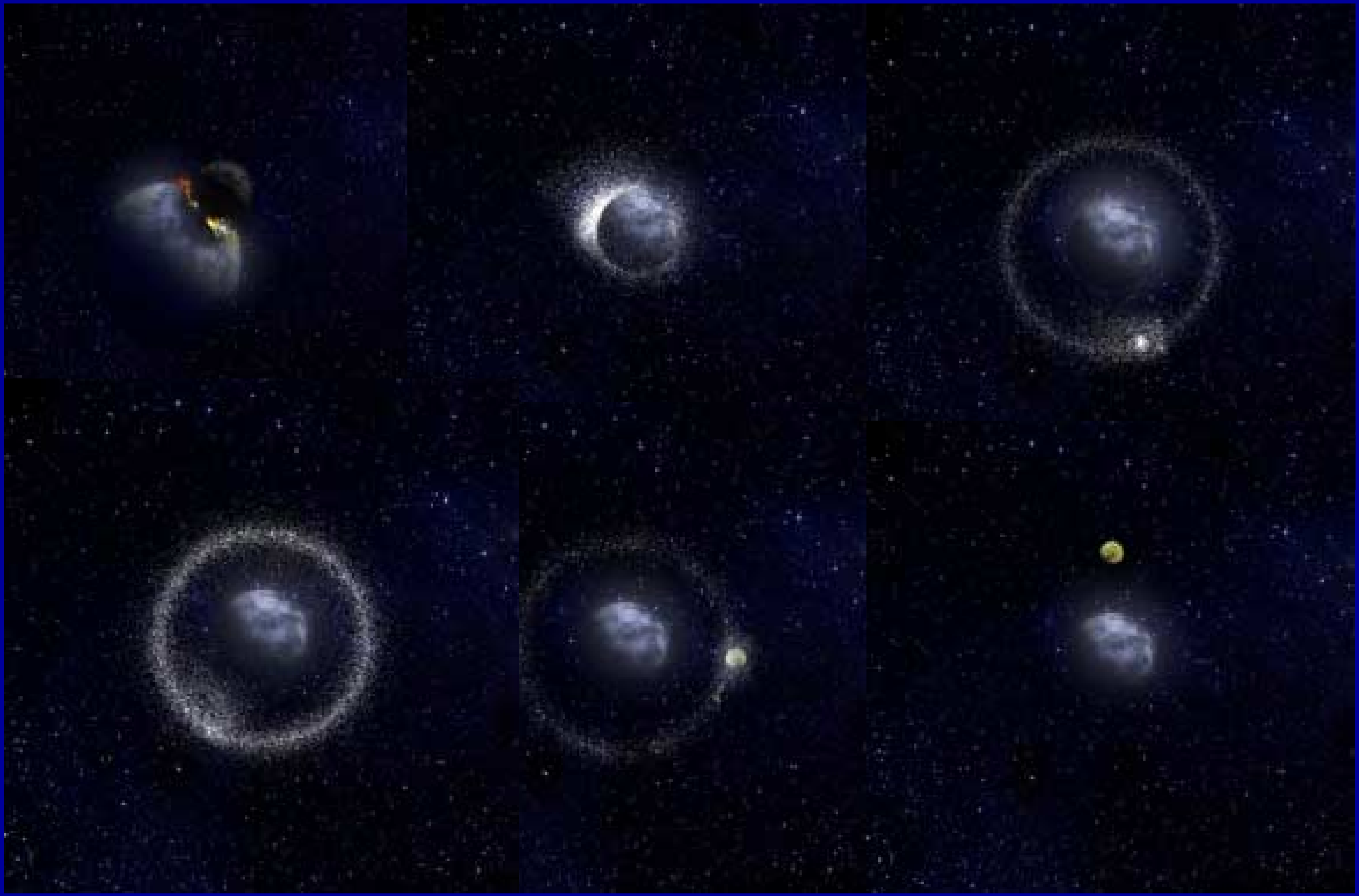
- **to map chemical elements on the Moon (Mg, Si, Al, Fe)**
- **to get absolute chemical abundances thanks to XSM**







…this will tell us more about
the origin of the Moon
(daughter of the Earth?),
and its evolution



Smart-1

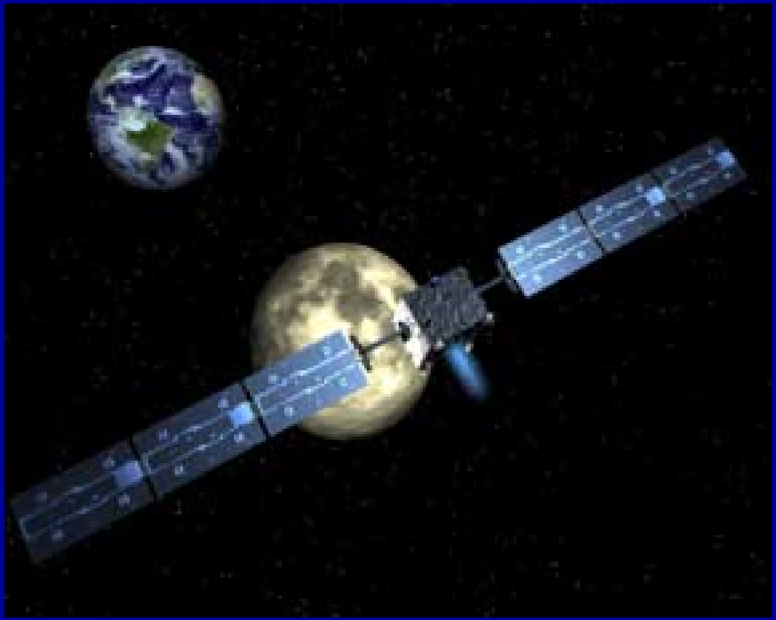
3. Observing the Moon

SPEDE will:

- **observe how the Moon leaves a wake in the solar wind**

RSIS will:

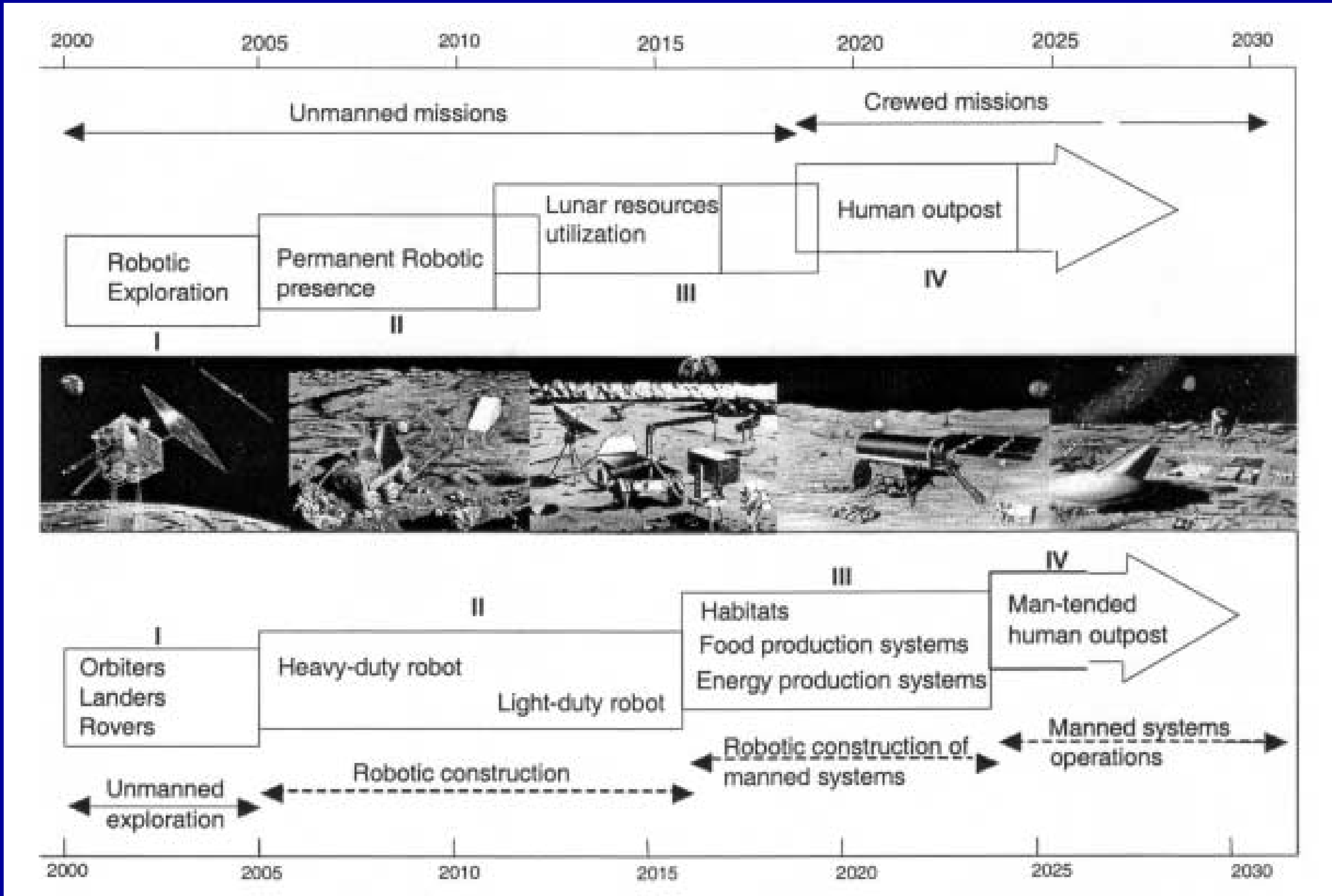
- **use radio waves positioning and AMIE images to demonstrate a new way of gauging the libration of planets and their moons**



International lunar exploration

- **Muses-A/Hiten (ISAS)** **1990**
  - **Circumlunar navigation**
- **Clementine (US, BMDO)** **1994**
  - **Multi-band Imaging, technology demonstration**
- **Lunar Prospector (US, NASA Discovery)** **1998**
  - **Neutron, gamma ray low resolution mapping**
- **SMART-1 (ESA Technology Mission)** **2003**
  - **Instrument technology, geochemistry, high resolution**
- **Lunar A (J, ISAS Science)** **2004**
  - **2 Penetrators with seismometers + equator cameras**
- **SELENE (J, ISAS/NASDA)** **2005**
  - **Ambitious orbiter instruments for science**
- **Chinese lunar orbiter,** **2007**
- **Chandrayan-1 (ISRO Lunar Orbiter, launch PSLV , India)** **2008**
- **South Pole Aitken Basin Sample Return** **2009**
  - **NASA New Frontiers Mission**

International (ILEWG) phased approach for lunar exploration



SMART-1 Summary

- ***SMART-1 Technology Mission:***
- ***Solar Electric Propulsion to tthe Moon***
- ***A challenging Miniaturised Payload:***
  - ***Plasmas (EPDP, SPEDE),***
  - ***Communications (KATE/RSIS)***
  - ***AMIE cam, infrared SIR, X-ray D-CIXS,***
- ***Technology and science objectives***
- ***Science performances, data***
- ***SMART-1 operations***
- ***Coordination with other missions***
- ***Preparing future exploration,***
- ***Engaging the public and youth***
- ***Europe to the Moon and beyond!***