CENTRE NATIONAL D'ÉTUDES SPATIALES

IPPW9 – session1

French Contributions to Entry and Surface Missions

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French Space Agency and Technical Center

CNES is a state-owned but independently-managed industrial and commercial organisation for scientific research and technical development.

Its task is to shape and implement France's Space policy for the benefit of Europe.

CNES is the French Space agency, in charge of programmes and also a technical center.

The Toulouse Space Center leads satellite and scientific instrument projects and operations

The centres

Headquarters

Launchers study, design, development of Ariane, Soyouz, Vega launch systems

Launch base Ariane 5 Soyouz Vega

Orbital vehicles study, design, development and control of satellites

Overview

French Contribution to Entry and Surface Missions :

- System and operations
- Instrument contributions
- Perspectives

cnes

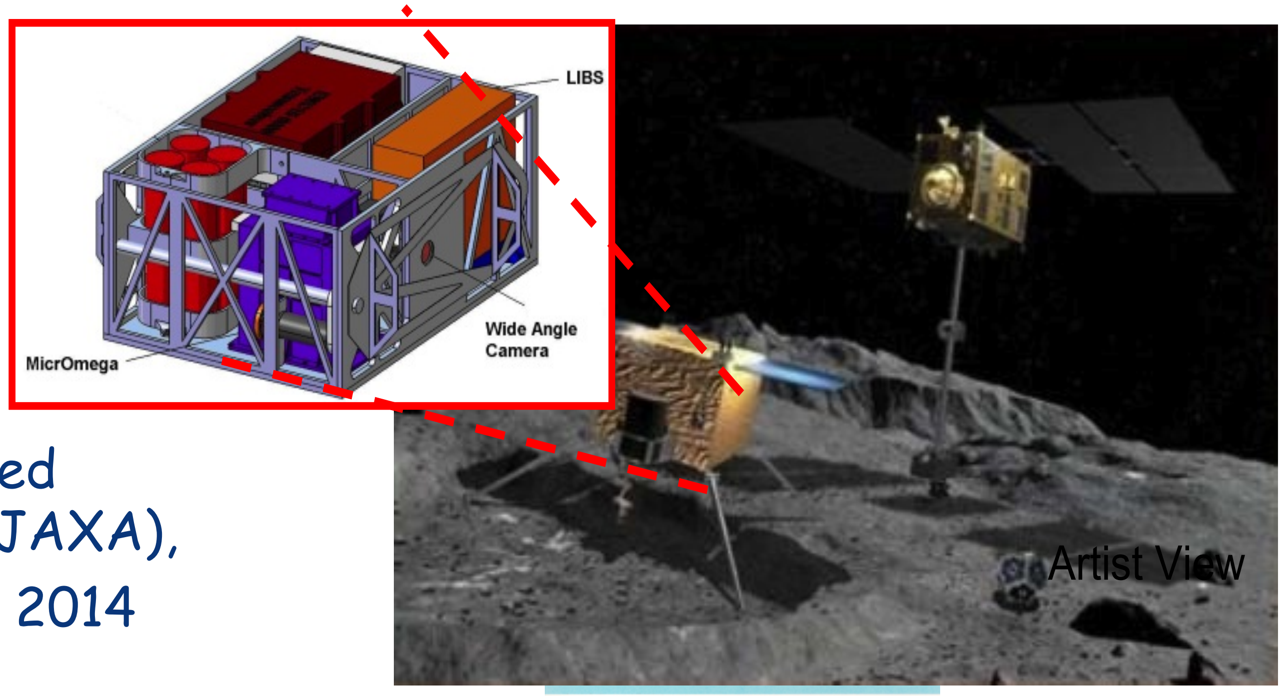
In-situ missions with French involvement

Mission	Target	Launch	Arrival	System involvement	Instruments
esa CASSINI-HUYGENS	Titan	15/10/1997	14/01/2005		4
ROSETTA LANDER	Churyumov-Gerasimenko Comet	02/03/2004	11/11/2014 (Philae landing)	Joint development & operations with DLR	3
MARS SCIENCE LABORATORY	Mars	26/11/2011	06/08/2012	Remote operations of 2 instruments	2
Phobos–Grunt ROSCOSMOS	Phobos	08/11/2011	Failed		3
esa NASA EXOMARS	Mars	May 2018	January 2019	Rover navigation algorithms	5
InSight JPL	Mars	March 2016	October 2016	Instrument operations TBC	1
Selene 2 JAXA	Moon	> 2015	> 2015		1
JAXA	1999 JU3 asteroid	July 2014	June 2018	Joint development with DLR	1
Marco Polo-R	1996 FG3 asteroid	~2021	2025	Joint development with DLR	TBD

Involvement at lander system level

- ➢ Development of Netlander, Mars geophysics network, up to phase B in 2002

- ➢ Rosetta's lander, Philae, in cooperation with DLR, launched in 2004 to comet Churyumov-Gerasimenko



- ➢ Mascot, with DLR proposed for flight on 'Hayabusa-2' (JAXA), Launch to NEO 1999JU3 in 2014

- ➢ Optionnal lander on Marco Polo-R proposal to ESA(s Cosmic Vision M3

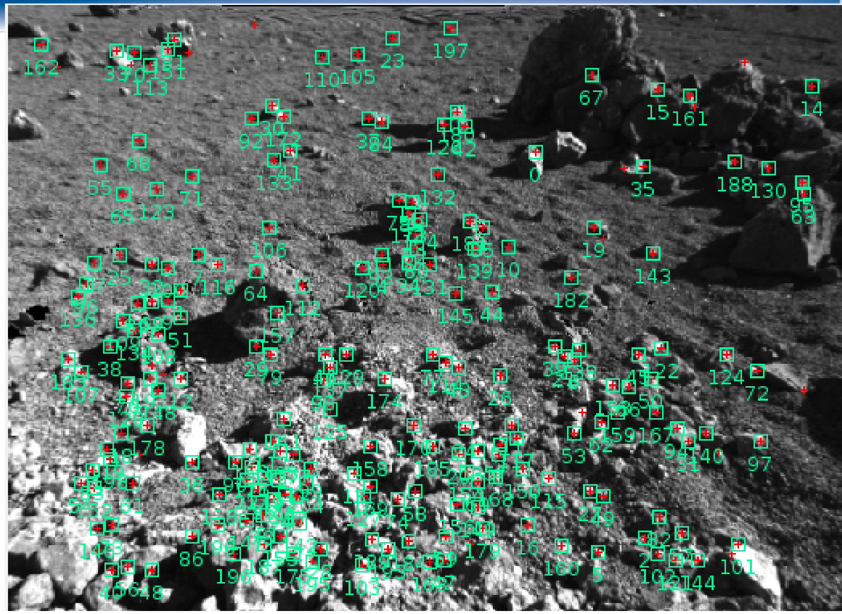
Autonomous navigation: 20 years of experience

EDRES consists in a collection of algorithms, applications and tools covering most of the functions for autonomous movement generation and execution for exploration rovers.

Since 2008, within the frame of ExoMars' rover phase B, CNES has transfered EDRES knowledge and supported ESA and its main industrial contractors on :

- Design of stereovision benches
- Perception & navigation algorithms
- Visual Motion Estimation
- Operations definition
- Tests facilities

Autonomous navigation: recent results



Successful remote experiment
(ESTEC/SEROM - June 2010)

Visual Motion Estimation performances, involving 2000 stereo images acquisitions along a 260m trajectory.

- 1% (1σ) accuracy position => **1m after a daily travel of 100 m.**
- 1.5° (1σ) heading accuracy at the end of the daily trip.
- Computing time estimated at **7.5 seconds** on the flight hardware.

November 2011: remote experiment with ExoMars instruments Pancam, Clupi and Wisdom

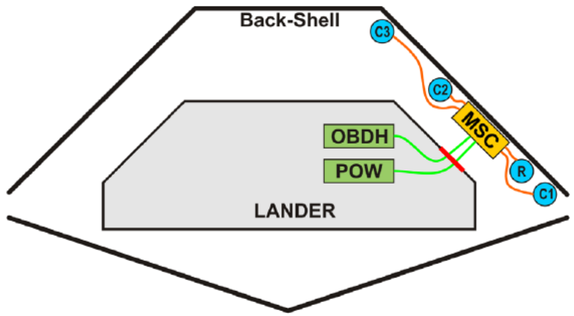
Entry Aerodynamics

Successful test of ARD (Atmospheric Reentry Demonstrator) in 1998

Intense simulation and test efforts to prepare the aerocapture of the orbiter of the attempted MSR mission with JPL in 1998 – 2001

Support to ESA on ExoMars :

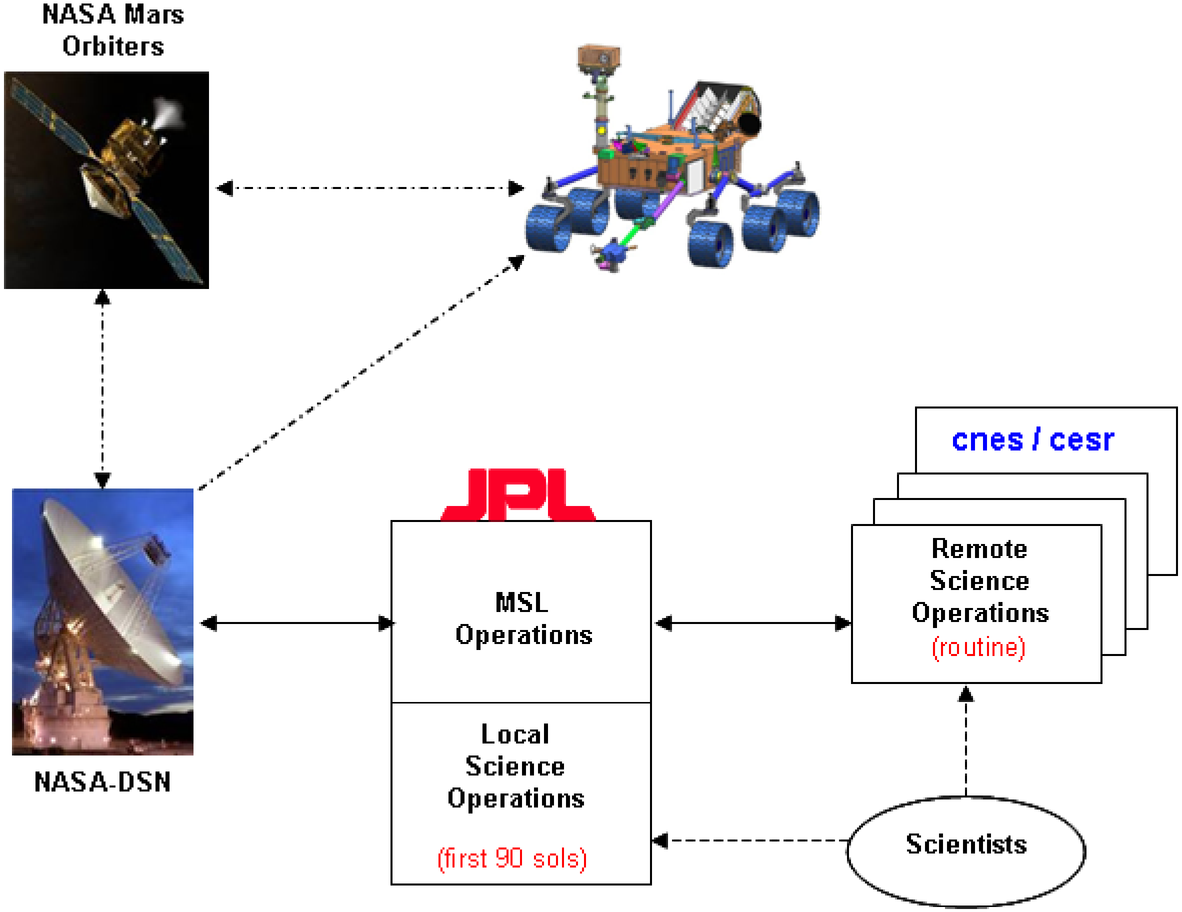
- Characterisation of dust influence on heatshield erosion
- Wind tunnel test preparation
- Modelling of radiative heatflux
- Development of **Icotom sensor**, narrow band radiative flux on back-shell, embedded in DLR's Comars+ heatflux package



MSC = Multiplexins Signal Conditioner, **C1 to C3** = COMARS, **R** = Radiometer, **OBDH** = On Board Data Handling, **POW** = Power Unit

Remote Operation Center for ChemCam

Tactical (daily) planning in Toulouse after the 1st 90 sols
~15 ChemCam analyses per sol
CNES : 18 days of early downlink activities
LANL : 18 days of late uplink activities



Balloon activities

Development of a large balloon intended for the VEGA mission to Venus in 1985

Advanced design of aerobots for Mars, in the 1990's

Participation to European Venus Explorer proposal to Cosmic Vision-M

Definition of a Technical Development Plan (TDP) for the balloon and the envelope of the Montgolfier of the TSSM mission proposed to Cosmic Vision L

Advantages of in-situ missions

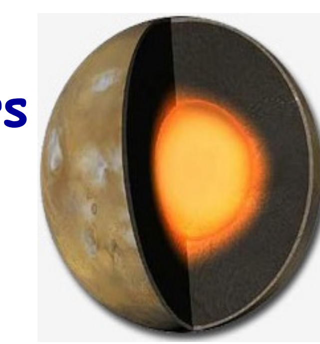
Ground truth for

- Orbital meteorology : Atmospheric packages
- Magnetic fields : Magnetometers

Comprehensive techniques of geophysics & geochemistry

- Elemental composition : **Chromatographs**, apX, Mass spectrometers, **Raman, LIBS, Spectro-imagers**

- Internal structure : **Radars, Seismometers**

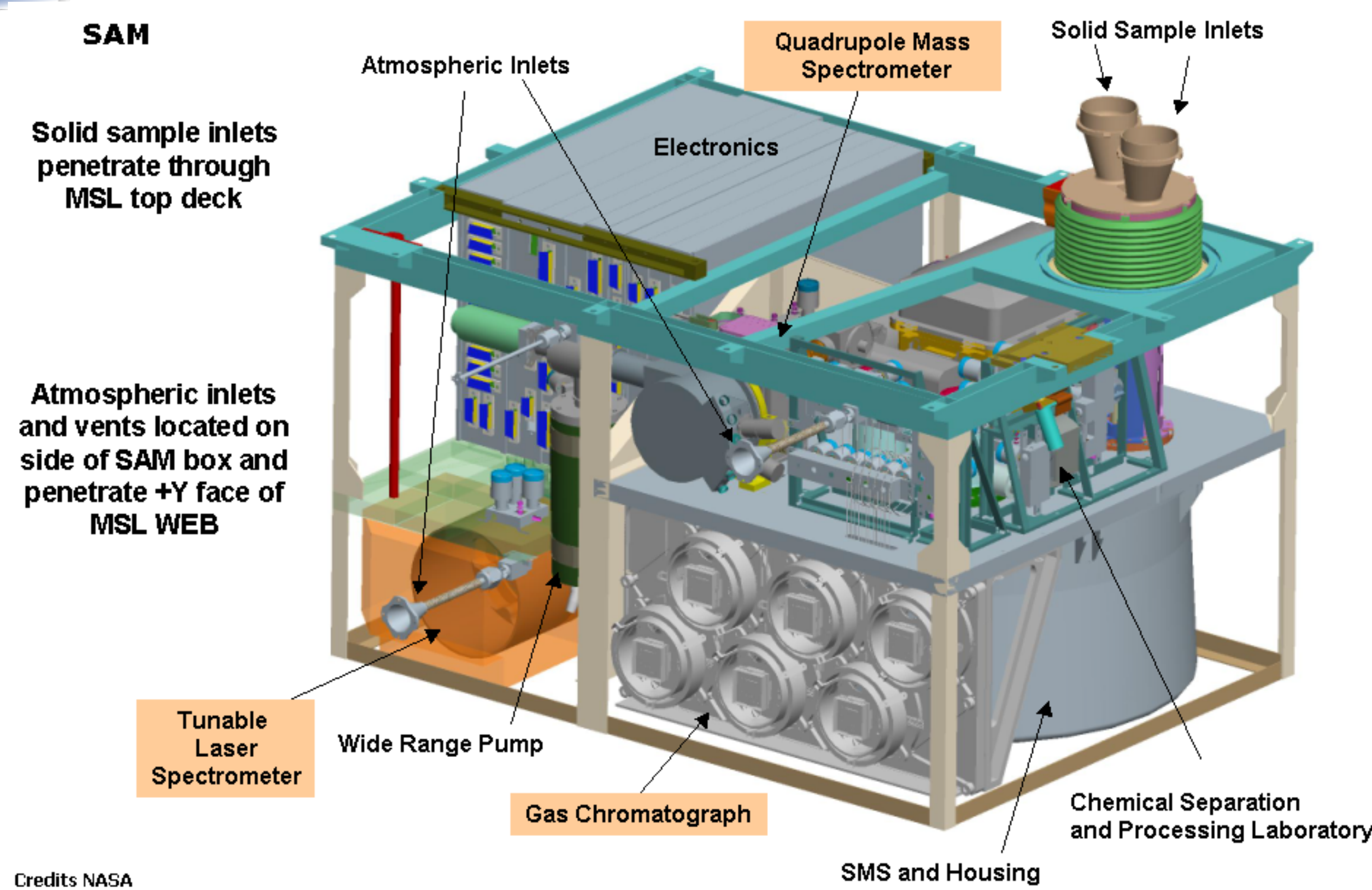


Main French in-situ instrument families

Mission	Chromatography	Laser Spectroscopy	Hyperspectral microscopic imager	Seismology	Ground Penetrating Radars
esa CASSINI-HUYGENS	Aerosol Collector Pyrolyser (ACP) Chromatograph columns of GCMS				
ROSETTA LANDER	Gas storage and chromatograph columns of COSAC		Visible microscope & IR spectrometer CIVA-M		Consert tomographer radar
MARS SCIENCE LABORATORY	Chromatograph columns of SAM suite	Mast Unit (laser) of ChemCam LIBS			
Phobos–Grunt ROSCOSMOS	Chromatograph columns and laser spectro. of GAP suite		MicrOmega		
esa EXOMARS	Chromatograph columns and He tank of MOMA	Control unit of Raman	MicrOmega		Wisdom subsurface radar
InSight JPL				SEIS Seismometer	
Selene 2 JAXA		LIBS laser & electronics		SEIS Seismometer	
JAXA			MicrOmega		
Marco Polo-R			MicrOmega	Seismic sensor	Tomographer radar

LATMOS, LISA & GSMA contribute to analytical suites

SAM's **Chromatograph columns** are supplied by the LATMOS. They separate and detect the organic compounds presents in the gaseous samples.



On Phobos-Grunt's Gas Analytical Package, LATMOS provides 2 **Chromatograph columns** & GSMA the **laser spectrometer** which measures in particular vapor isotopes.

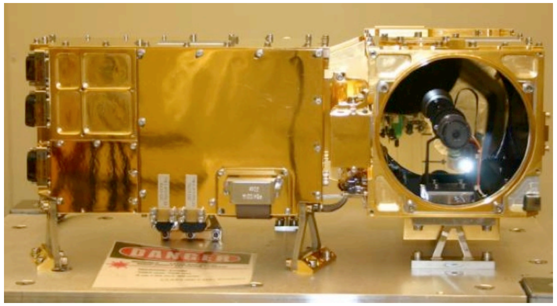
Raman & LIBS spectrometers

IRAP provides Chemam's Mast Unit on MSL's

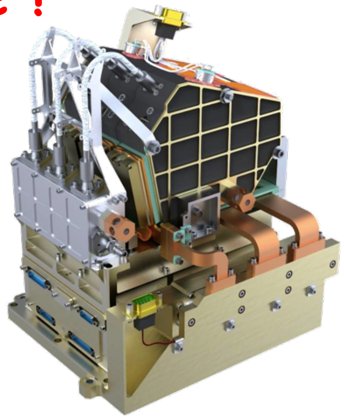
First LIBS in Space !

Elemental analyses through Laser-Induced Breakdown Spectroscopy

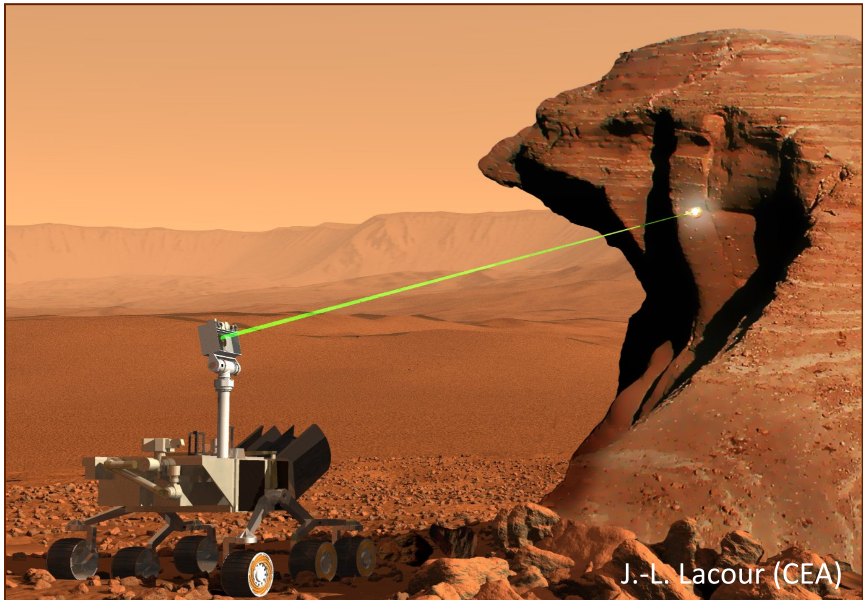
- Rapid characterisation from **1 to 9 m**
- Will identify and classify rocks, soils, pebbles, hydrated minerals, weathering layers, and ices
- Analysis spot size **< 0.5 mm**
- 240-850 nm spectral range
- High resolution : **1 mm @ 9 m**
- Not sensitive to dust



Mast Unit



Body Unit



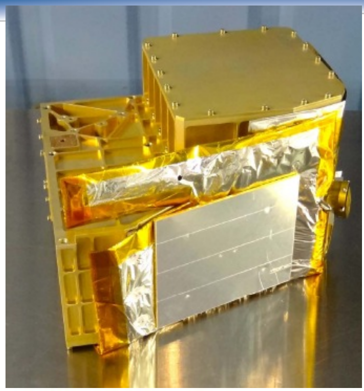
IRAP also develops laser control of ExoMars' Raman

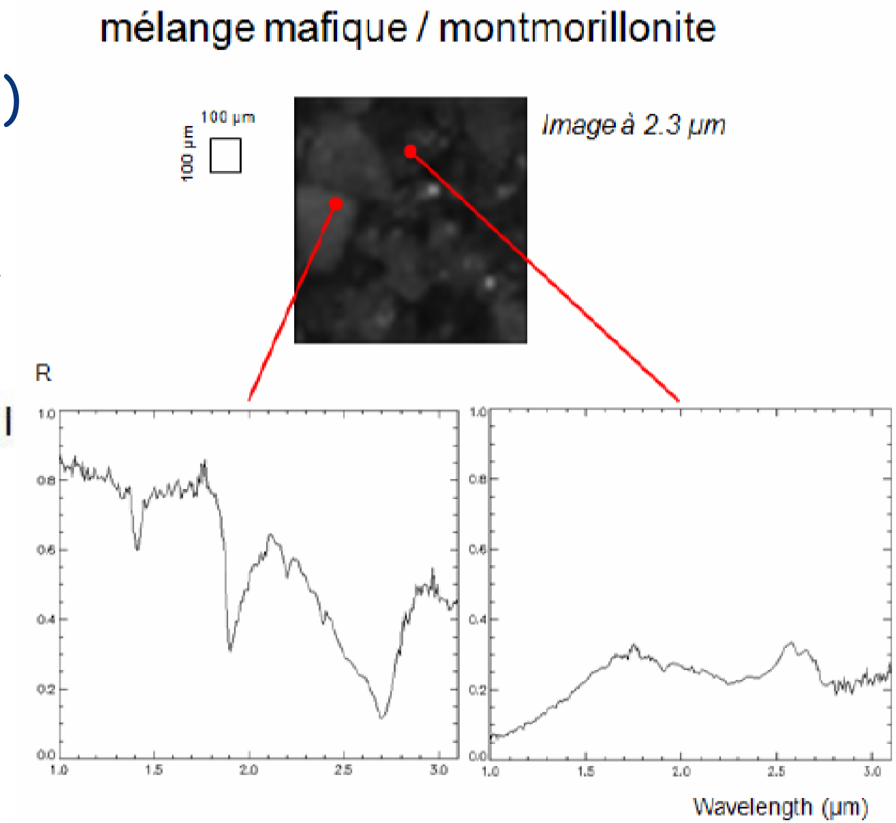
Discussions on going for Raman on Selene 2 mission

Hyperspectral microscopic imagers

MicrOmega, developed by IAS

Field depth ~ **10 mm**
Picture width ~ **5mm**, spatial sampling **20 µm**
IR Spectral range : λ from 0.9 µm to 3.2 µm
(=> 3,5µm)





- Phobos Grunt, delivered in July this year,
  Built in 16 months
  First of his kind !

- Mascot, launch to asteroid in 2014

- ExoMars, part of Pasteur on 2018 rover,

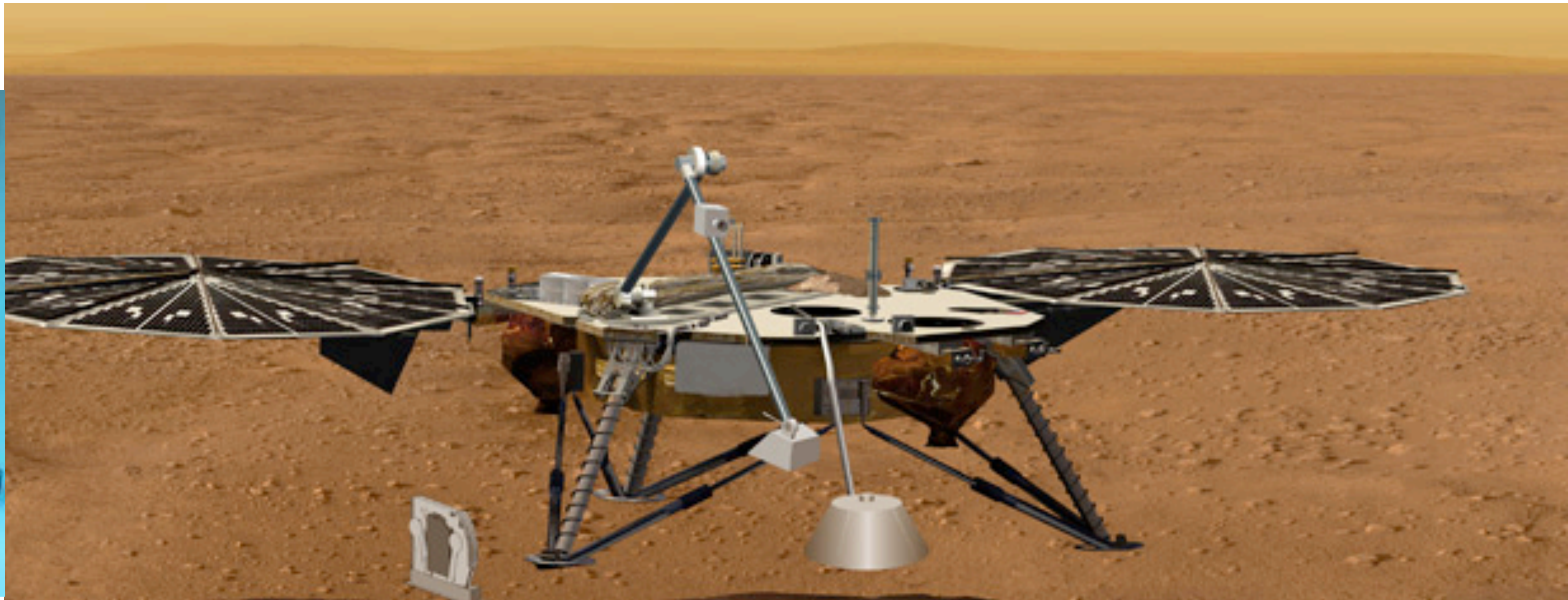
Highly sensitive Seismometers

< 10^{-9} $m.s^{-2}$ $Hz^{-\frac{1}{2}}$ from 10^{-3} up to 10 Hz

IPGP first delivered the Optimist seismometer for Mars 96

An improved version was later selected for Netlander, and carried out to end of phase B for ExoMars attempted Humboldt payload

Part of GEMS (GEophysical Monitoring Station) proposal for Discovery



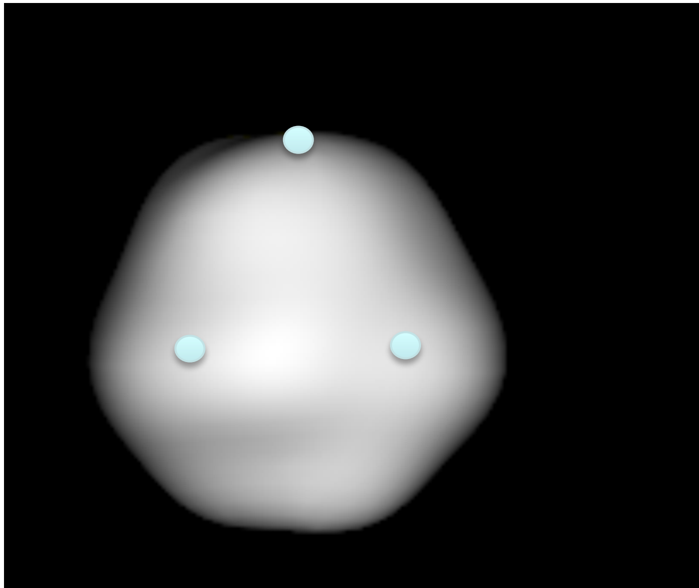
Active seismology on a small body

Measurement of meteorite impacts, and of seismic waves generated by an explosive load or an impactor on a Near Earth Asteroid.

IPGP would provide a set of > 1 Hz - medium sensitive geophone, carried on autonomous – less than 5 kg - GeoPODs.

BASIX Proposal to Discovery with Boulder University and JPL, Option on Marco Polo-R Cosmic Vision M3 proposal.

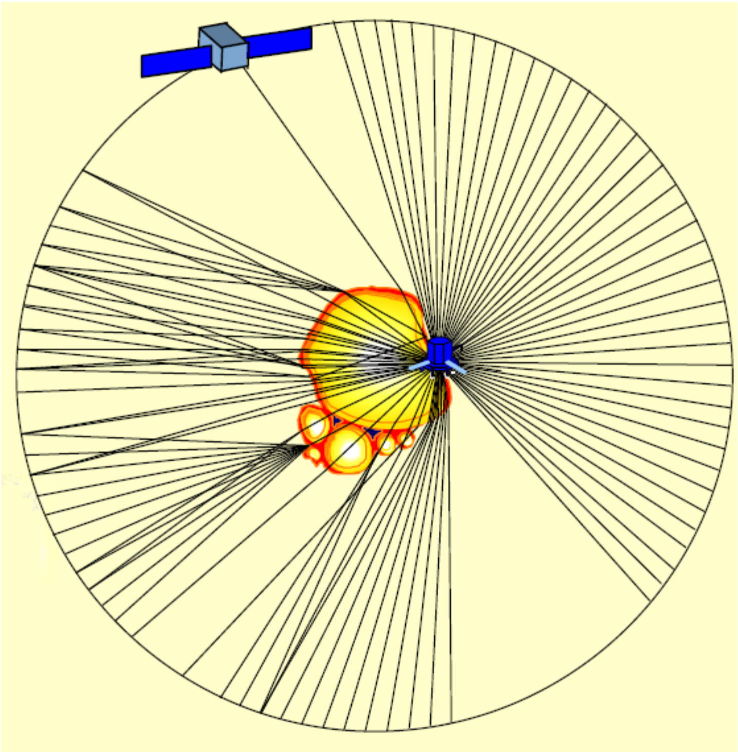
An even repartition of the GeoPODs over the asteroid is essential

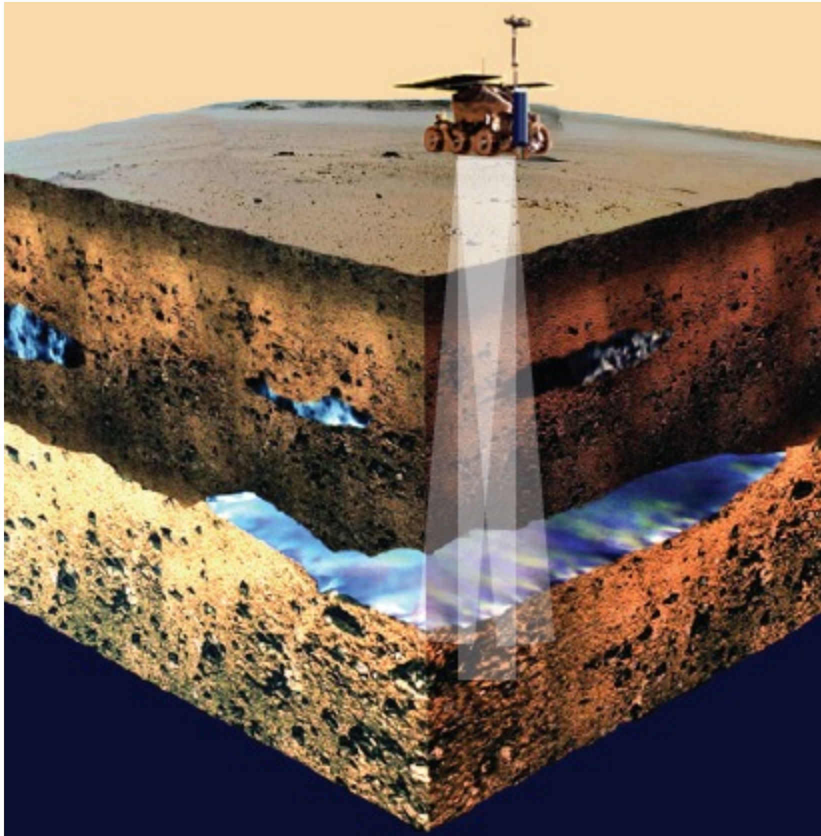


Tomography & Ground Penetrating Radars @ IPAG & LATMOS

WISDOM will explore with a centimetric vertical resolution the first 3 m of Mars' subsurface, in line with ExoMars' drill. This stepped-frequency UHF radar will characterise the 3-D geological structure, and possibly, the state of water and ice .

CONSERT, will perform tomography of a comet by transmitting a 90 MHz signal from Rosetta through the comet nucleus to Philae, and back.





Conclusion and perspectives

CNES has built-up significant expertise on aerodynamics at entry, lander development, rover navigation and in-situ instrument operations.

We intend to deploy instruments on the surface of Titan, comet nucleus, Mars, Phobos, the Moon and asteroids.

Five strong instrument families:
Chromatographs, Raman / LIBS, MicrOmega, Seismometers & Radars

Permanent improvement through R&D :

- Miniaturiation & power reduction
- Integration of spectrometry and imaging
- High resolution mass spectrometer based on the **Orbitrap** concept
- **Laser induced fluorescence** for organic characterisation
- **In-situ dating**

Thank you for your attention