French Contributions to Entry and Surface Missions

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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

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

Orbital vehicles study, design, development and control of satellites

Launch base Ariane 5, Soyouz, Vega

Headquarters

Paris 192

Toulouse 1760

Kourou 265
French Contribution to Entry and Surface Missions:

- System and operations
- Instrument contributions
- Perspectives
### In-situ missions with French involvement

<table>
<thead>
<tr>
<th>Mission</th>
<th>Target</th>
<th>Launch</th>
<th>Arrival</th>
<th>System involvement</th>
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<tr>
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<td>Joint development &amp; operations with DLR</td>
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<tr>
<td>Mars Science Laboratory</td>
<td>Mars</td>
<td>26/11/2011</td>
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<td>Remote operations of 2 instruments</td>
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<tr>
<td>Phobos-Grunt</td>
<td>Phobos</td>
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<td>ExoMars</td>
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<td>Selene 2</td>
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<td>&gt; 2015</td>
<td>&gt; 2015</td>
<td></td>
<td>1</td>
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<tr>
<td>1999 JU3 asteroid</td>
<td>July 2014</td>
<td>June 2018</td>
<td>Joint development with DLR</td>
<td>1</td>
<td></td>
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<tr>
<td>Marco Polo-R</td>
<td>1996 FG3 asteroid</td>
<td>~2021</td>
<td>2025</td>
<td>Joint development with DLR</td>
<td>TBD</td>
</tr>
</tbody>
</table>
- 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
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 transferred 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
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
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
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

<table>
<thead>
<tr>
<th>Mission</th>
<th>Chromatography</th>
<th>Laser Spectroscopy</th>
<th>Hyperspectral microscopic imager</th>
<th>Seismology</th>
<th>Ground Penetrating Radars</th>
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<tr>
<td>Aerosol Collector Pyrolyser (ACP)</td>
<td>Chromatograph columns of GCMS</td>
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<tr>
<td>Gas storage and chromatograph columns of COSAC</td>
<td></td>
<td>Visible microscope &amp; IR spectrometer CIVA-M</td>
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<td>Convert tomographer radar</td>
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<tr>
<td>Mars Science Laboratory</td>
<td>Chromatograph columns of SAM suite</td>
<td>Mast Unit (laser) of ChemCam LIBS</td>
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<tr>
<td>Phobos-Grunt</td>
<td>Chromatograph columns and laser spectro. of GAP suite</td>
<td>MicrOmega</td>
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<td>Wisdom subsurface radar</td>
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<tr>
<td>潮流</td>
<td>Chromatograph columns and He tank of MOMA</td>
<td>Control unit of Raman</td>
<td>MicrOmega</td>
<td></td>
<td>SEIS Seismometer</td>
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<td>InSight</td>
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</tr>
<tr>
<td>Seine 2</td>
<td>LIBS laser &amp; electronics</td>
<td></td>
<td></td>
<td>SEIS Seismometer</td>
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<tr>
<td>Marco Polo-R</td>
<td></td>
<td></td>
<td></td>
<td>MicrOmega</td>
<td>Seismic sensor</td>
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<td>Tomato grapher radar</td>
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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

IRAP also develops laser control of ExoMars’ Raman Discussions on going for Raman on Selene 2 mission

IPPW9 – 18/06/2012
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**
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
**CONSERT**, will perform tomography of a comet by transmitting a 90 MHz signal from Rosetta through the comet nucleus to Philae, and back.

**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.
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