**ESA’s Cosmic Vision Plan and Outer Planets**

Michel Blanc  
CESR, Toulouse, France  

OPAG meeting, Boston, may 1st-2nd, 2007

**Cosmic Vision process**

- Cosmic Vision 2015–2025 process launched on 2 April 04 with call for Science themes
- In excess of 150 responses received! (Horizon 2000 + consultation received less than 100 responses) including many proposals for Outer Planets
- July 04: Analysis of responses by the ESA Science advisory bodies (AWG, SSWG, FPAG, SSAC)
- 15-16 September 04: Workshop in Paris (~400 participants)
- Spring 05: presentation of Cosmic Vision 2015-2025 to community: ESLAB symposium with a summary article on Outer Planets exploration (Blanc et al.) including many U.S. authors
- Oct. 05: Final Cosmic Vision document

**Grand themes**

1. What are the conditions for life and planetary formation?  
2. How does the Solar System work?  
3. What are the fundamental laws of the Universe?  
4. How did the Universe originate and what is it made of?

**1. What are the conditions for life and planetary formation?**

Place the Solar System into the overall context of planetary formation, aiming at comparative planetology

1.1 From gas and dust to stars and planets.  
1.2 From exo-planets to bio-markers.  
1.3 Life and habitability in the Solar System.
1.3 Life and habitability in the Solar System

Explore ‘in situ’ the surface and subsurface of the solid bodies in the Solar System more likely to host—or have hosted—life.

Appearance and evolution of life depends on environmental conditions (geological processes, water presence, climatic and atmospheric conditions, Solar magnetic and radiation environment).

Mars is ideally suited to address key scientific questions of habitability. Europa is the other priority for study of internal structure, composition of ocean and icy crust and radiation environment around Jupiter.

2. How does the Solar System work?

2.1 From the Sun to the edge of the Solar System

Study the plasma and magnetic field environment around the Earth, the Jovian system—as a mini Solar System—, the Solar poles and the heliopause where the Solar influence area meets the interstellar medium.

The structure of the magnetic field at the solar surface requires observations from above the poles to understand the field’s origin.

The Solar System pervaded by the solar plasma and magnetic field provides a range of laboratories to study the interactions of planets (Jupiter) with the solar wind. In-situ observation of the heliopause would provide ground truth measurements of the interstellar medium.


2.2 Gaseous Giants and their Moons

Study Jupiter In-situ, its atmosphere and internal structure.

Giant planets with their rings, diverse satellites and complex environments, constitute systems which play a key role in the evolution of planetary systems.

Tools: Jupiter Exploration Programme JEP
From themes to proto-missions

- How does the Solar System work?
  - Solar Polar Orbiter (Solar Sailor)
  - Helio-spause Probe (Solar Sailor)
  - Earth Magnetospheric Swarm
  - Jovian In-situ Planetary Observer (JIP)
  - Kuiper belt Explorer
  - Near-Earth Asteroid Sample & Return

- What are the conditions for life & planetary formation?
  - Far Infrared Interferometer
  - Jupiter Magnetospheric Explorer (JEMP)
  - Near Infrared Terrestrial Planet Interferometer
  - Europa Orbiter
  - Mars In-situ Programme (Rovers & sub-surface)
  - Mars Sample and return
  - Terrestrial Planet Autonomous Surveyor
  - Terrestrial Planet Spectroscopic Observer
  - Terrestrial Planet Imaging Observer

- From dust and gas to stars and planets
- From exo-planets to biomarkers
- Life & habitability in the solar system
- Looking for life beyond the solar system

Implementation and Selection Process

Call for two mission classes, M (<300 M€) and L (<650 M€)

- Over 60 LOI’s submitted, April 2007, ~ 25 in Solar System
- Full proposals due, June 29, 2007 - mission concepts only, 36 pages total – means ‘zero dollar’ studies!
- International collaboration encouraged, requires letters from partner agencies.
- At least 3 proposals expected for Outer planets: Jupiter-Europa, TANDEM, Kronos
- Shows STRONG and BROAD interest from European space sciences community for outer planets: from space plasmas to astrobiology through geosciences and planetary formation (= astronomy...)

Next steps: class M (<300 M€)

<table>
<thead>
<tr>
<th>Activity</th>
<th>Date</th>
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<tbody>
<tr>
<td>ESA Internal Assessment Phase</td>
<td>November 2007 - end May 2008</td>
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<tr>
<td>Industrial Assessment Phase (emphasis on payload, cost and risk)</td>
<td>June 2008 - August 2009</td>
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<tr>
<td>Open presentation of study results &amp; Working Group recommendation for Definition Study Phase</td>
<td>September - October 2009</td>
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<tr>
<td>SSAC down selection to 2 missions for Definition Phase</td>
<td>October 2009</td>
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<tr>
<td>SPC confirmation of 2 missions for Definition Phase</td>
<td>November 2009</td>
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<td>2 missions in competitive Definition Phase</td>
<td>April 2010 - September 2011</td>
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<tr>
<td>Working group SSAC evaluation and recommendation for adoption of one mission</td>
<td>September 2011-October 2011</td>
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<tr>
<td>SPC Confirmation of one mission for ITT release</td>
<td>November 2011</td>
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<tr>
<td>SPC mission adoption (CA and Payload Format Agreement)</td>
<td>June 2012</td>
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<tr>
<td>Mission definition: Implementation Phase</td>
<td>September 2012</td>
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<td>Mission Launch</td>
<td>mid 2017</td>
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Next steps: class M (<300 M€)

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<th>Activity</th>
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<tr>
<td>Internal Assessment Phase, focused on identification of key technology areas (up to 3 proposals)</td>
<td>November 2007 to May 2008</td>
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<tr>
<td>Industrial Assessment Phase and definition of TDP (3 proposals)</td>
<td>June 2008 - June 2009</td>
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<tr>
<td>Working group evaluation and recommendation for down-selection from 3 to 2 Class L concepts to compete with LISA for Definition Phase</td>
<td>July 2009 – September 2009</td>
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<tr>
<td>From 2L concepts = LISA, SSAC recommendations for two missions to enter Definition Phase, TDPs activated (or continued if LISA) for the two missions entering Definition Phase as well as for the remaining (third) mission concept</td>
<td>October 2009</td>
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<tr>
<td>Two missions confirmed by SPC for entering Definition Phase</td>
<td>November 2009</td>
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<tr>
<td>Two missions in competitive Definition Phase</td>
<td>January 2010 – June 2011</td>
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<tr>
<td>Working group/SSAC evaluation and prioritisation</td>
<td>July 2011 – October 2011</td>
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<tr>
<td>Confirmation by SPC of first mission for ITT release *</td>
<td>November 2011</td>
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<tr>
<td>NPC mission adoption (Team and Payload Formal Agreement)</td>
<td>July 2012</td>
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<tr>
<td>Start of industrial Implementation Phase</td>
<td>September 2012</td>
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<td>Mission Launch</td>
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A new journey to Saturn’s system to study in depth the new worlds revealed by Cassini-Huygens: Titan & Enceladus in particular

Athena Coustenis et al.  
http://www.lesia.obspm.fr/cosmicvision/tandem/

A combined Post-Cassini exploration of Titan & Enceladus.

In situ study of the Titan atmosphere, the surfaces, the interiors, the magnetospheric interactions and the Astrobiological potentials of both satellites

Preferred mission scenario

A combination of
- Orbiters (Titan + Enceladus)
- Probes and Balloon(s) on Titan and/or Landers with surface package
- Penetrators/Landers for Enceladus

Balloon on Titan floating within a few km above the surface

Surface package
**Mission to Europa and the Jupiter System**

Michel Blanc et al.

http://jupiter.europa.cesr.fr/

**KRONOS:**

ESA contribution to a NASA-led New Frontiers mission.

*In situ* studies of the Saturnian atmosphere

Lead: B. Marty
Co-leads: T. Guillot, A. Coustenis

http://www.lesia.obspm.fr/cosmicvision/kronos/

**Preferred mission scenario**

A combination of

- Orbiter (?) or solar-powered carrier
- 2 probes into Saturn’s atmosphere
- Microsats for ring science

Microwave probe entering Saturn’s atmosphere

**Four Mission Targets:**

1. **EUROPA**

2. **Jovian Satellites**

3. **Jupiter’s Atmosphere**

4. **Jupiter’s Magnetosphere**
**International collaboration**

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<th>NASA</th>
<th>ESA</th>
<th>JAXA</th>
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<td>Flagship missions:</td>
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<tr>
<td>Europa</td>
<td>Jupiter-Europa Proposal</td>
<td>Jupiter-Europa with Magnetospheric Orbiter</td>
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<td>JSO</td>
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<tr>
<td>Titan</td>
<td>Tandem Proposal</td>
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<td>Enceladus</td>
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<td>New Frontiers</td>
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<tr>
<td>Saturn Probe</td>
<td>KRONOS proposal</td>
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**Future Space Plasma Missions at JAXA - 2020’s**

- **Planetary Magnetospheres**
- **The Plasma Universe**
- **Geospace Exploration**

- **SCOPE/CrossScale ESA/JAXA Multiscale at the same time in Earth magnetosphere ~2016 (to be proposed to ESA CosmicVision)**

**JAXA/ESA view:**

- **Europa Orbiter**
- **The mothership Data relay Imaging platform**
- **Plasma Imaging**
- **Magnetospheric dynamics**
- **Tidally driven activity of Galilean satellites**
- **In situ measurements**

**ERG**
A small explorer into the inner-magnetosphere and relativistic particle acceleration processes ~2011
**The strength of International Collaboration**

- We need an international Science and Technology Road Map to outer planets to be able to fly at least one mission every decade
- Broad scientific scope, mission complexity, technological challenges and cost REQUIRE international collaboration
- In return, outer planets exploration is a fantastic platform for international collaboration

Let us use it to follow and broaden the examples of Cassini-Huygens and Bepi-Colombo

The next flagship-class missions to the outer planets require innovative approaches to mission design and development:
- Optimize science return,
- Use each partner’s specific interests and know-how,
- Minimize total and per partner costs vs. Science return

We need to define the best methodology to work together, starting from an open « tree » of mission scenario options

(See example of « Billion $ study » methodology shown yesterday)

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**Scientific objectives for Titan’s atmosphere**

- Dynamics, meteorology and radiative transfer
- Titan’s chemistry and the chemistry of the evolution
- Titan’s climate and methane cycle

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**TANDEM Scientific Objectives: Interiors**

Why is Titan different from Callisto and Ganymede?
What lies in the interior of Enceladus and causes the jets?

Structure and composition of the interior?
Magnetic field, internal ocean?
Reservoir of volatiles?
Evolution and outgassing mechanisms?

Science questions that will remain after an extended and successful Cassini-Huygens mission.
1) What is the small-scale geological structure of the surface and how does it correlate with surface forming processes.
2) What is the composition, distribution and physical state of materials on and beneath Titan’s surface and how is it related to geology?
**Scientific Objectives**

*Upper atmosphere/Magnetospheric interaction*

* Highlights: not covered by the very successful Cassini mission or only in a limited way!
  - "Agnostosphere" (~400 km – 950 km)
  - Recent observations (negative ions, evidence for aerosols...) point to Titan’s atmosphere as a chemical reactor of 1000 km depth
  - Magnetotail/Wake at high altitudes
  - This complex region of Titan’s induced magnetosphere warrants careful 3D-studies
  - Magnetospheric Variability
  - Influence of Saturn’s magnetospheric dynamics on Titan’s induced magnetosphere out to ~ 10 RT
  - Internal magnetic field (permanent or induced)
  - EM sounding of electrolytic ocean, core characteristics

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**ESLAB symposium inputs April 2005**

**Definition of a Road Map to the origins of the solar system**

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**Example of science vs payload for interiors**

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<tr>
<th>Scientific objectives</th>
<th>Measurements</th>
<th>Instruments</th>
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<tr>
<td>1) Present-day interior structure: rocky core and liquid water/ice shells</td>
<td>Spatial and temporal variations of topography, gravity field and magnetic field on global and local scales.</td>
<td>On a polar (?) orbiter: Radio science experiment, Radar or Laser altimeter, Magnetometer, HR Near-Mid-IR Multispectral Radar Imaging</td>
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<td>2) Seismic and cryovolcanic activities</td>
<td>Seismic survey</td>
<td>On an aerial platform: Gradiometer, Accelerometer, Radar altimeter, Magnetometer, Ground Penetrating Radar, GCMS, IR Spectroscopy</td>
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<td>3) Internal reservoirs of volatiles and outgassing processes</td>
<td>Subsurface sounding</td>
<td>On a lander: Geophysical surface package (including seismometer &amp; magnetometer), Ground penetrating radar, Surface sampling analysis package, GCMS</td>
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<td>4) Early Titan: internal evolution, crust and atmosphere formation</td>
<td>Near-surface thermal gradient and thermophysical properties</td>
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<td></td>
<td>Composition of surface materials, and of cryovolcanic magma and gases</td>
<td>Noble gases abundances and isotopic ratios in major species.</td>
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