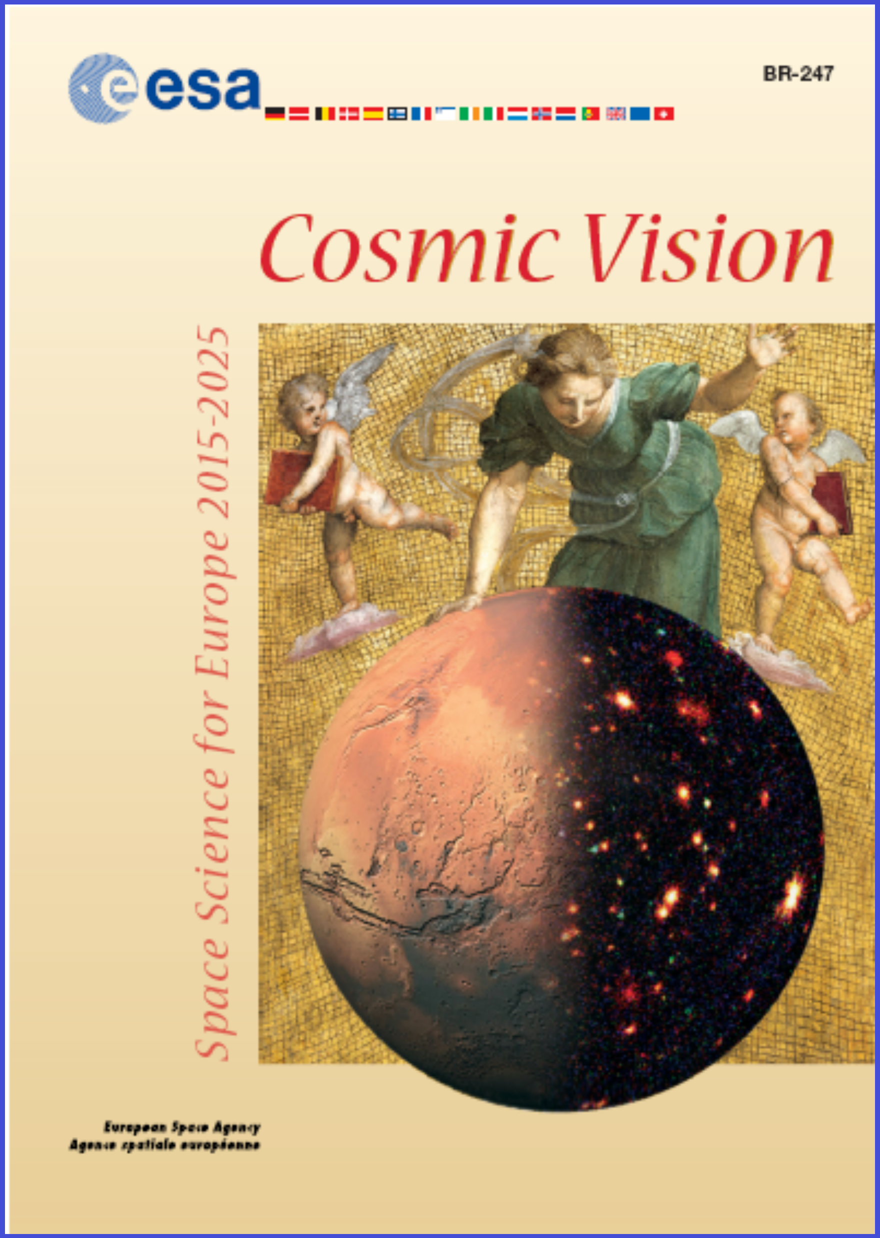
ESA's Cosmic Vision

A major opportunity for international collaboration

Michel Blanc

CESR, Toulouse, France

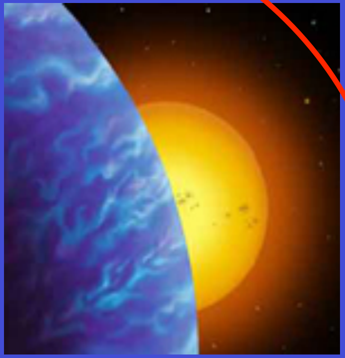


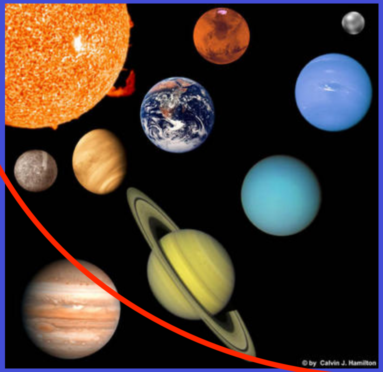
IPPW-5, Bordeaux, France, June 25, 2007

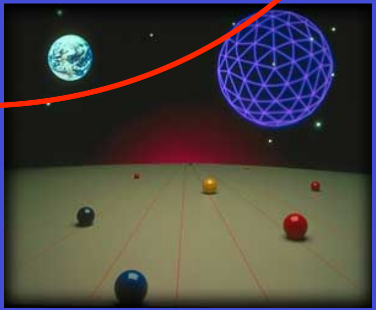
Grand themes

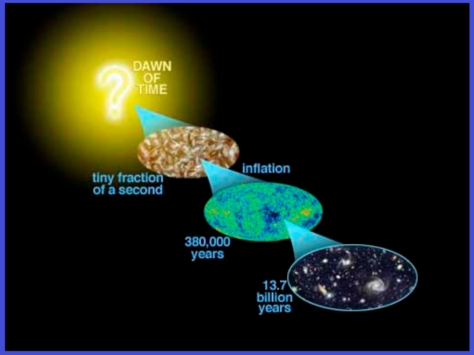
1. What are the conditions for life and planetary formation?
2. How does the Solar System work.
3. What are the fundamental laws of the Universe?
4. How did the Universe originate and what is it made of?

We are here !

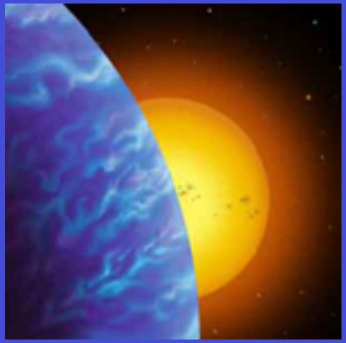








1. What are the conditions for life and planetary formation?

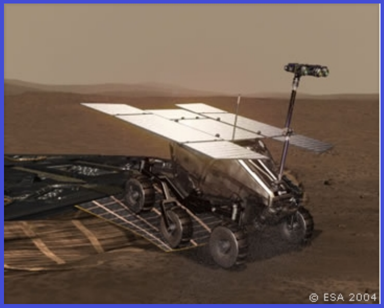


Place the Solar System into the overall context of planetary formation, aiming at comparative planetology

1.1 From gas and dust to stars and planets.

1.2 From exo-planets to bio-markers.

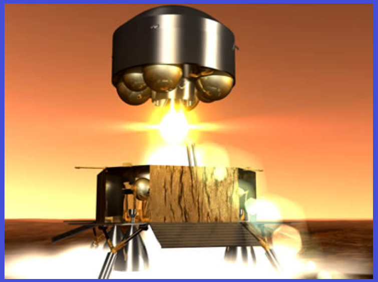
1.3 Life and habitability in the Solar System.



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

2.2 Gaseous Giants and their Moons

2.3 The Building Blocks of the Solar System: Asteroids and Small Bodies

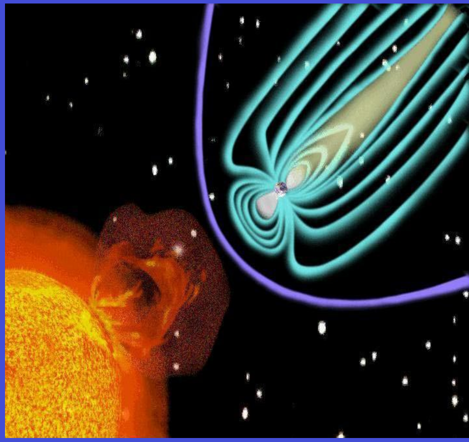
2.1 From the Sun to the edge of the Solar System

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 .



Tools: Solar Polar Orbiter, Earth magnetospheric swarm, Jupiter Probe, Interstellar Helio-Pause Probe.

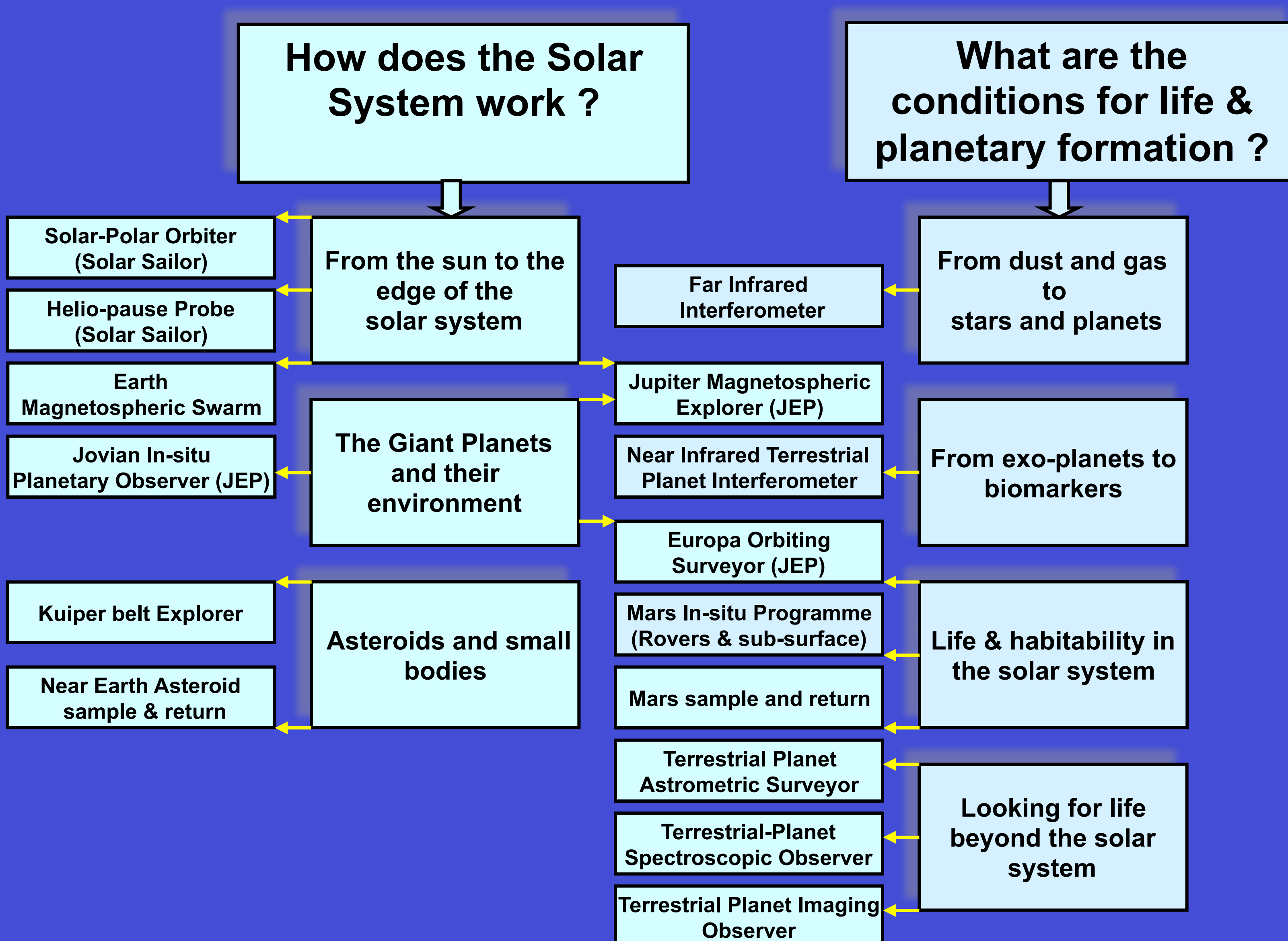
2.2 Gaseous Giants and their Moons

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

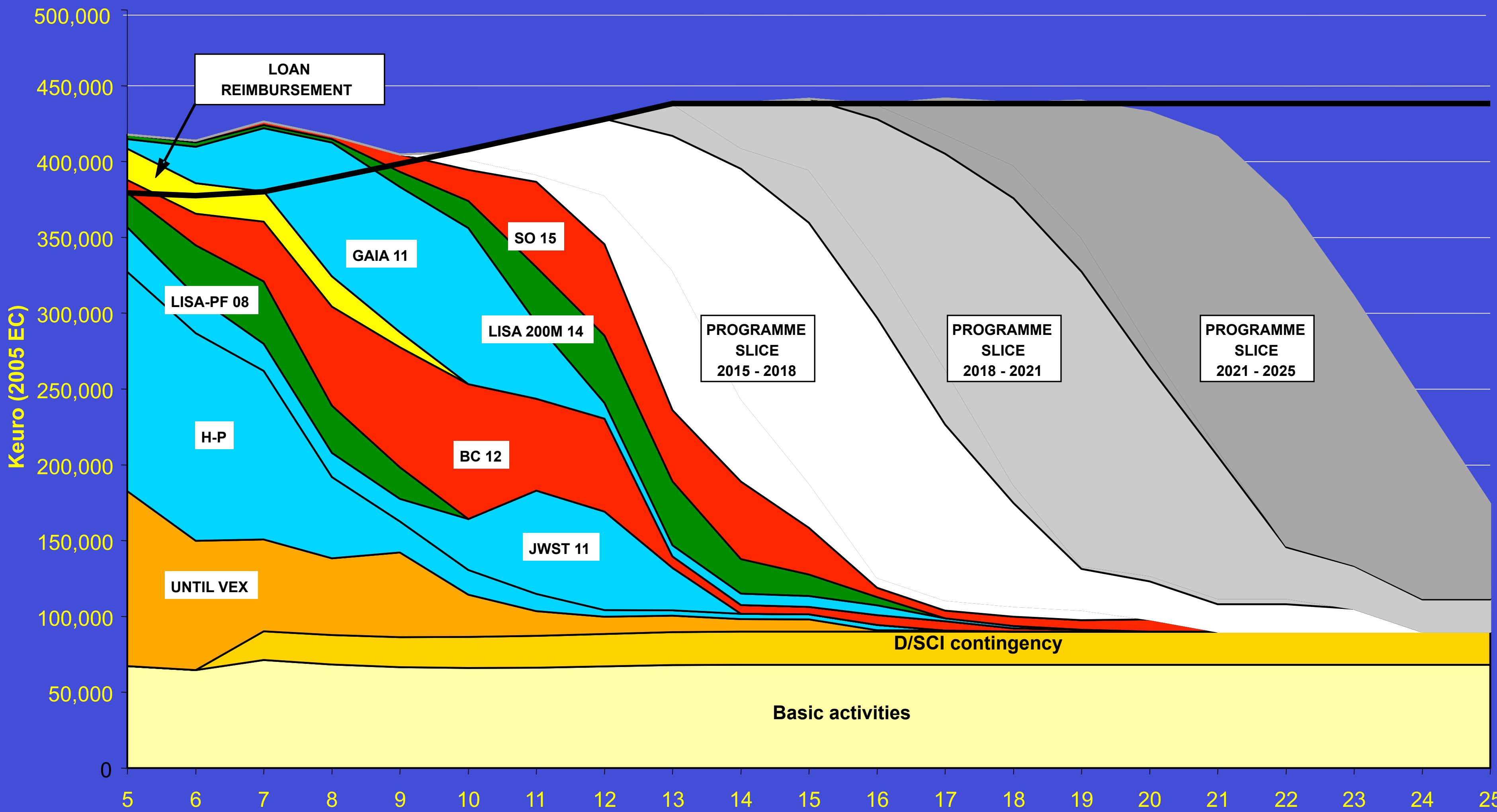
Giant planets with their rings,diverse satellites and complex environments, constitute systems which play a key role in the evolution of planetary systems.

Tools: Jupiter Exploration Programme/ JEP

From themes to proto-missions



COSMIC VISION 2015 - 2025
ESA Corridor Planning
Three programme slices



IMPLEMENTATION AND SELECTION PROCESS

Call for two mission classes:

- M (<300 M€), earliest launch date mid 2017

- L (<650 M€), earliest launch date 2018

Over 60 LOI's submitted, april 2007, ~ 25 in Solar System

Full proposals due, june 29, 2007- mission concepts only, 36 pages total

- International collaboration encouraged, requires letters from partner agencies.

- Many proposals expected for planets and solar system
  see next slide

- Shows STRONG and BROAD interest from european space sciences community for planetary sciences: from space plasmas to astrobiology through geosciences and planetary formation (= astronomy….)

Missions proposed

- LunarEx - A Lunar Penetrator Mission
- European Moon and Mars Planetary Observatories
- Mars Origins Mission" to Noachian-Mars
- MEMO: Mars Environment and Magnetic Orbiter
- Venus Troposphere
- EVE: European Venus Explorer - an in-situ mission to Venus
- Comet Sample Return
- Marco Polo: NEO Sample Return Mission
- DuneXpress : looking for dust populations in the solar system
- TANDEM: Titan and Enceladus
- KRONOS: Saturn atmospheric probe
- LAPLACE: A Mission to Europa and the Jupiter System

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/

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**

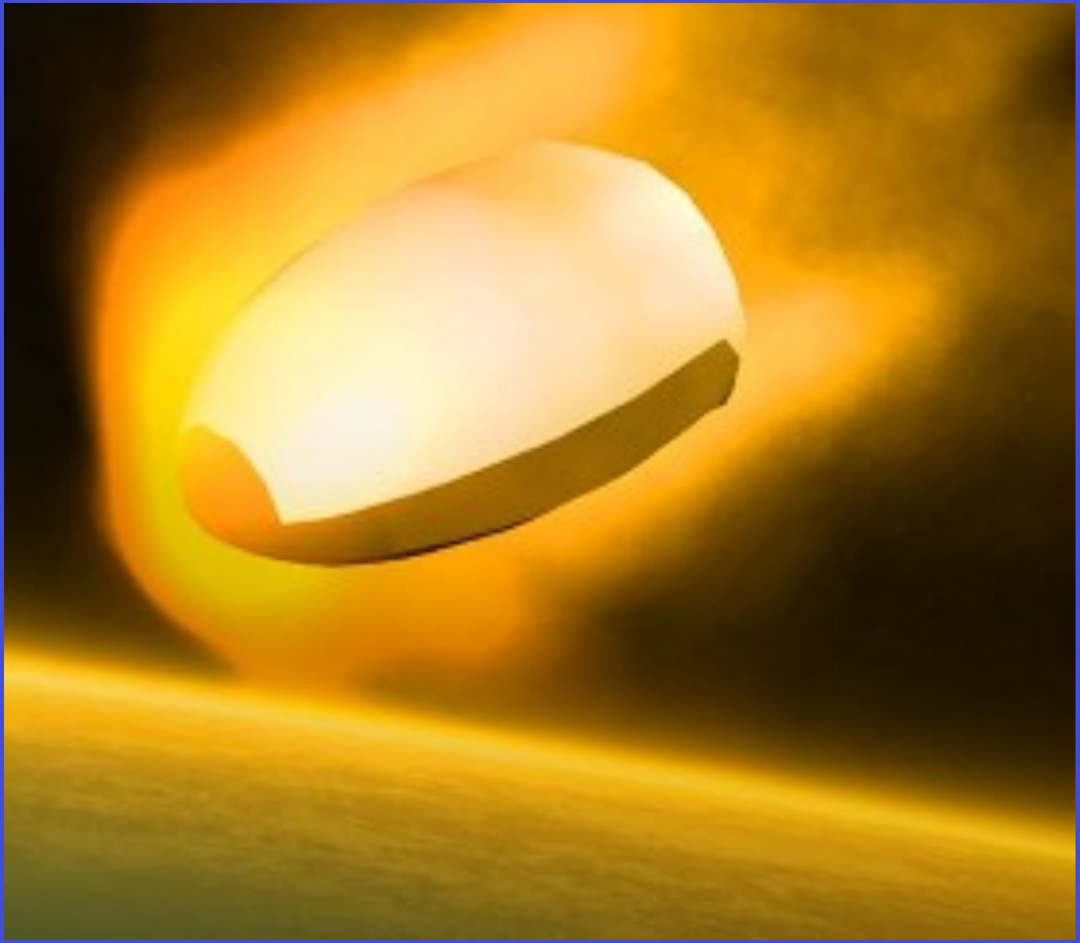
and/or Landers with surface package

- **Penetrators/Landers for Enceladus**

Balloon on Titan floating within a few km above the surface

Sample return with a tether and drill

Surface package



KRONOS :

ESA contribution to a NASA-led New Frontiers mission.

In situ studies of the Saturnian atmosphere

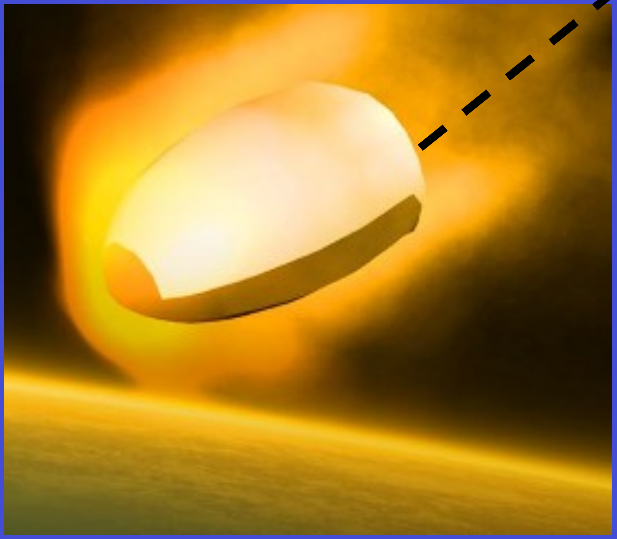
Lead: B. Marty
Co-leads : T. Guillot
A. Coustenis

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

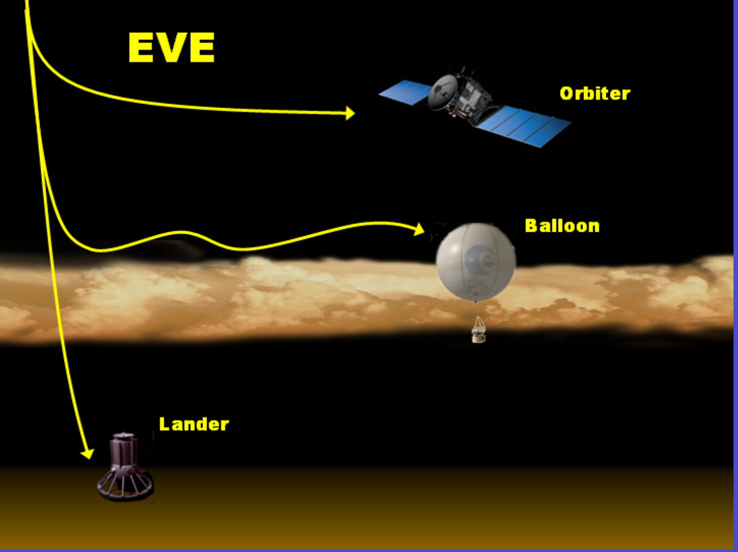
Preferred mission scenario

A combination of

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



Microwave probe entering Saturn's atmosphere



EVE : a European Venus Explorer

The baseline M-size EVE mission consists of :

- one balloon platform floating at an altitude of 50-60 km,

- one descent probe provided by Russia, and

- an orbiter with a polar orbit which will perform science observations as well as relay data from the balloon and descent probe.

→ The minimum lifetime of the balloon, carrying a 15 kg payload, is 7 days (one full circle around Venus)

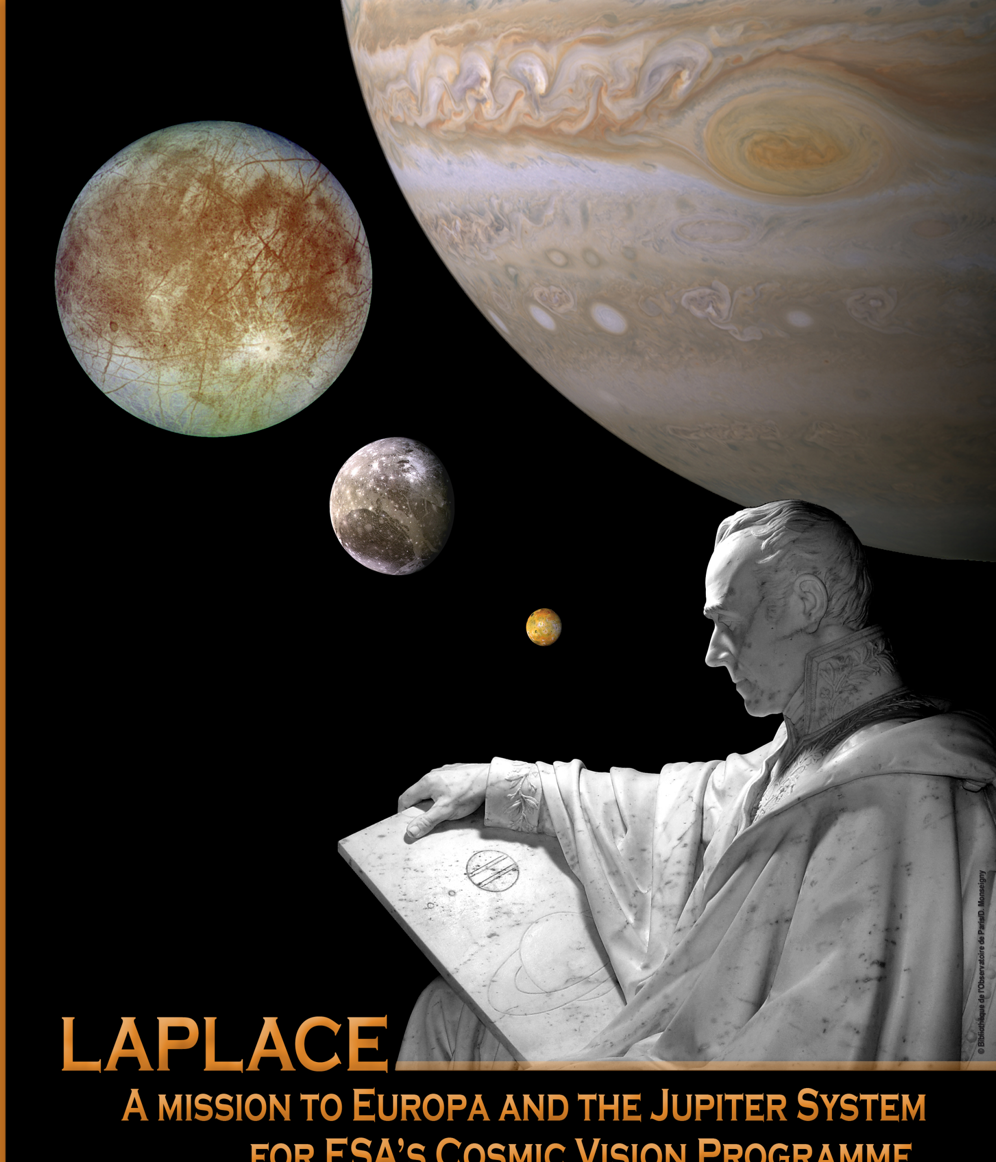
→ The descent probe's fall through the atmosphere is expected to last 60 minutes, followed by a lifetime of 30 minutes on the surface

→ The orbiter, equipped with remote sensing instruments including a radar, is first on a VeX-type orbit, then its orbit is lowered by aerobraking

EVE science goals

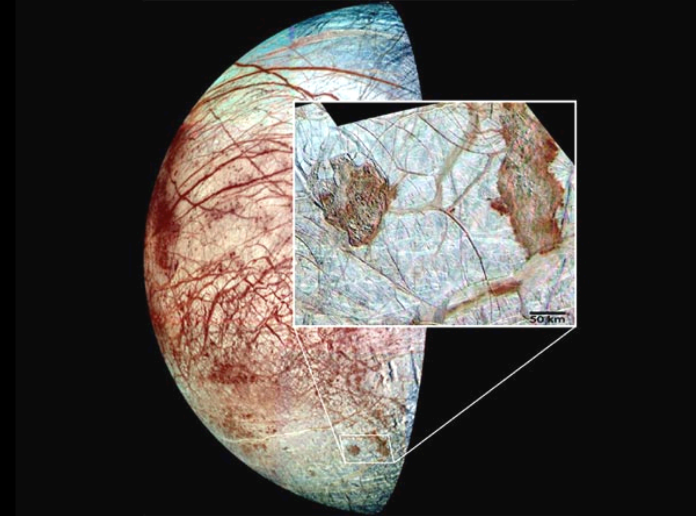
- To derive **a unified model of the formation and evolution of terrestrial planets**, by studying for the first time the complete record preserved in the elemental and isotopic composition
- To study the **stability of the current climate on Venus**, by quantifying exchange of atmospheric constituents with the surface and interior of the planet, and at the interface with space.
- To study the **cycling of water and sulphur compounds in the complex cloud environment**, by simultaneously studying chemical, radiative, and dynamic processes.
- To **re-construct the geological history of Venus**, by mapping the structural elements on the shallow subsurface to better understand volcanic episodes and formations, and anomalies in the ionosphere that can be correlated to present subduction activities.
- To study the **dynamics of the super-rotation** of the lower and middle atmosphere and transition to the solar-antisolar regime in the upper atmosphere, by obtaining in situ measurements at a range of altitudes, longitudes, and latitudes as well as remote wind measurements.
- To study the **role of electrical processes in the atmosphere**, by studying their chemical, electrical, acoustic, optical and possible gamma-ray signatures.

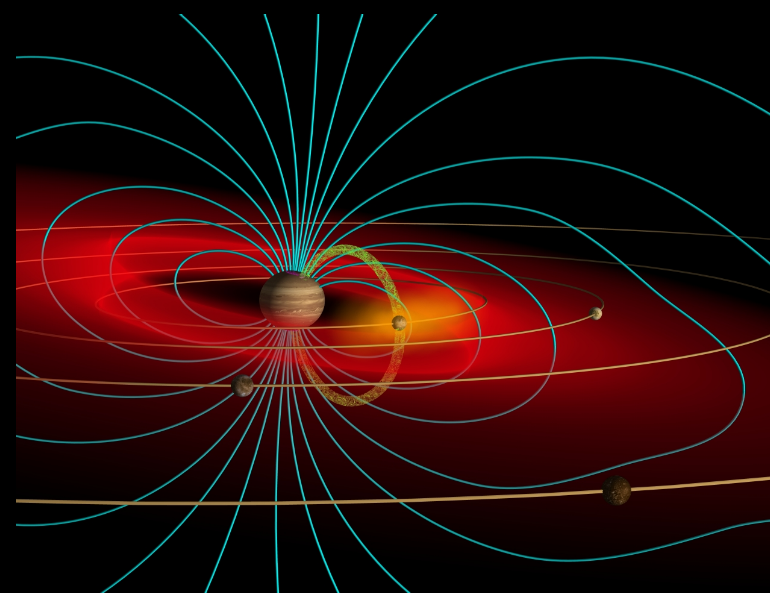
Considered together, these science investigations will contribute to the central theme of the mission, which is ***to understand the evolution of Venus and its climate***, with relevance to terrestrial planets everywhere.

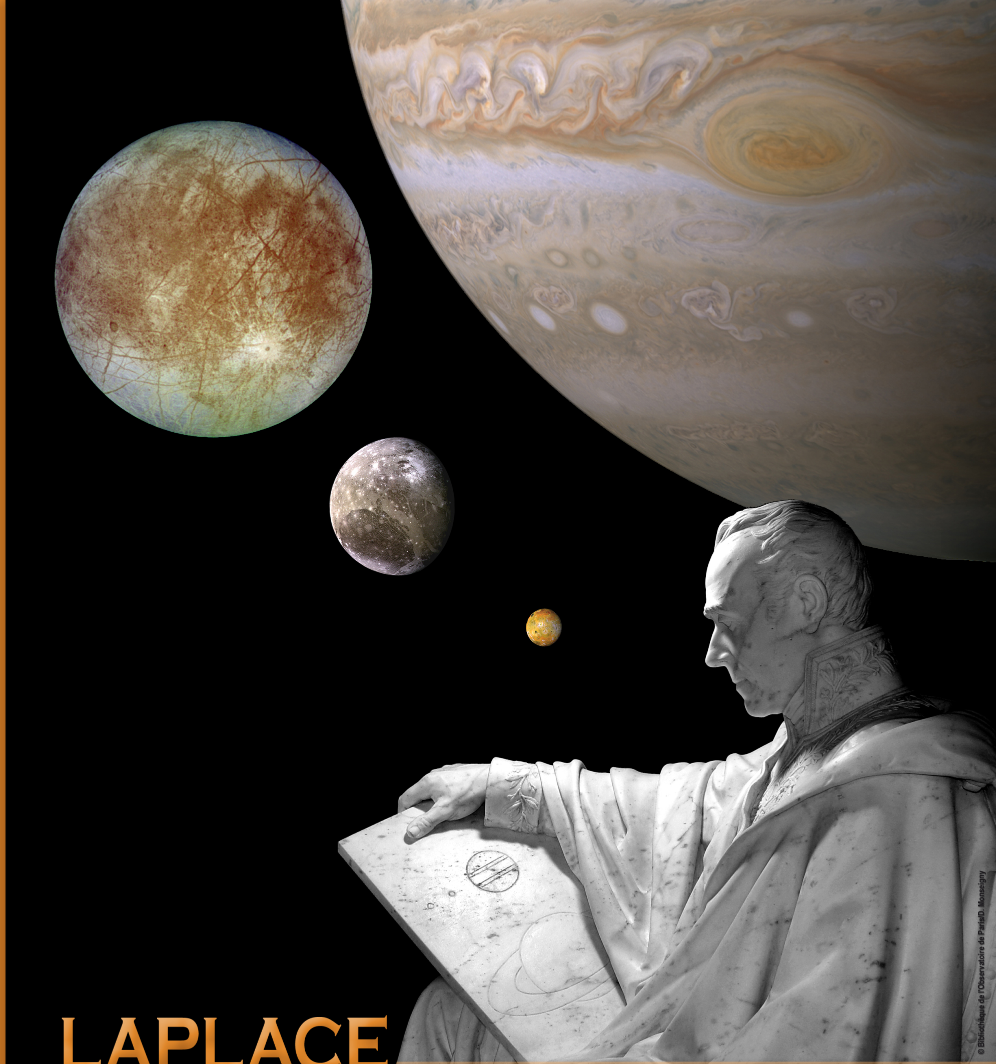


Michel Blanc et al.

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

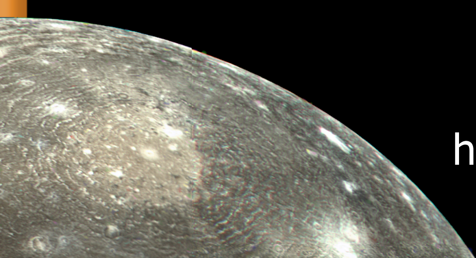






LAPLACE

A MISSION TO EUROPA AND THE JUPITER SYSTEM FOR ESA'S COSMIC VISION PROGRAMME



Michel Blanc et al.

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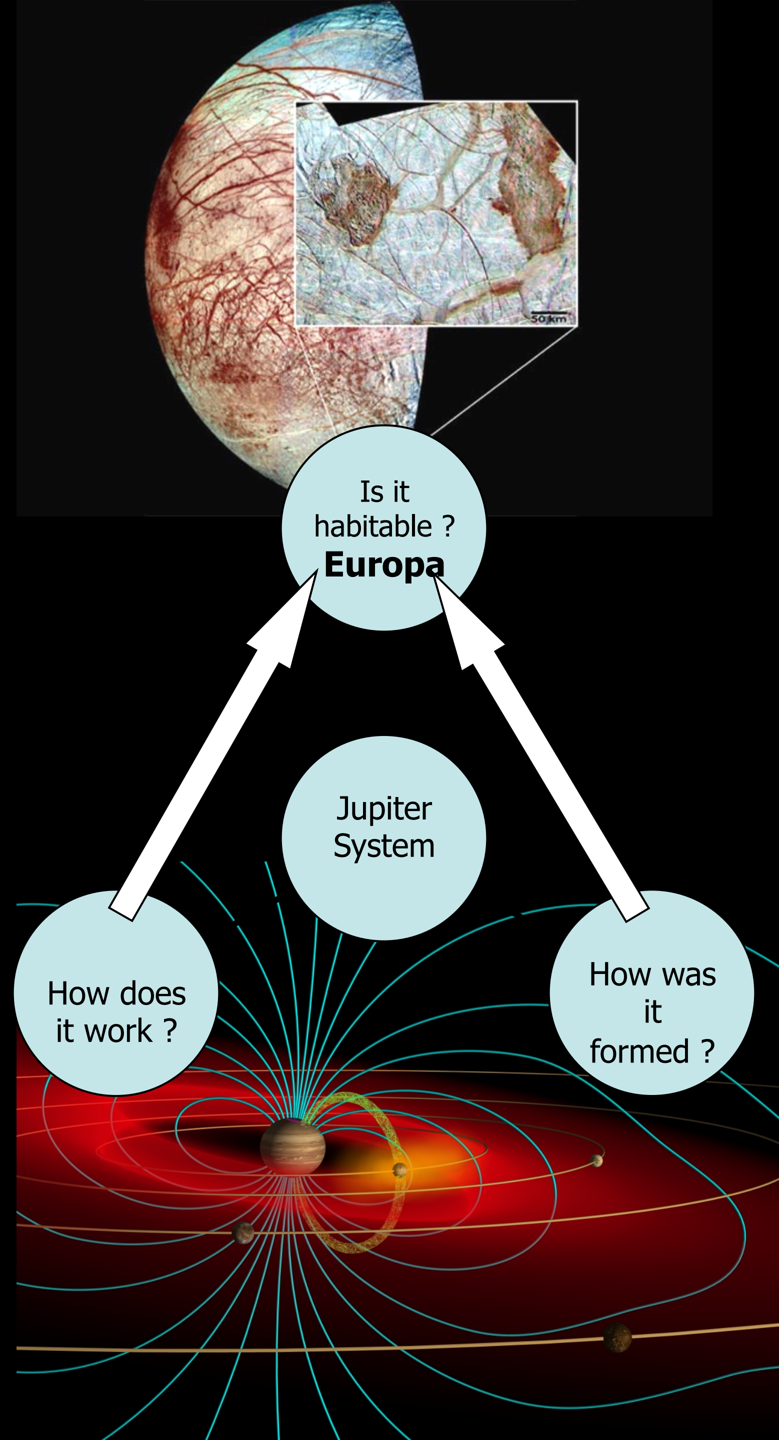


Science Goals

How does the sytem work? How was it formed? Is it habitable?

Mission targets

1 - Europa

2 – satellites

3 Magneto-sphere

4 Atmo-sphere

Earth-based observations

- JWST, ALMA, VLT, ELT’s, radioastronomy
- VLBI (includes interaction w. space segment)

Interplanetary orbit

V/E fly-by science, Seismology, gravity, Dust streams, radio emissons, electron beams etc. (IP)

Jovian orbit

JEO

JPO

JMO

Satellite orbit

Europa Orbiter (JEO)

Surface

Surface element ? (SE)

LAPLACE

Mission Architecture

International collaboration

Example of LAPLACE

NASA	ESA	JAXA	RosCosmos
Flagship missions:			
Europa JSO	} LAPLACE	Jovian Magnetospheric Orbiter	Europa surface element ? (stand-alone mission using ESA relay)
Titan Enceladus	} TANDEM		
New Frontiers			
Saturn Probe	KRONOS		

The strength of International Collaboration

- Broad scientific scope, mission complexity, technological challenges and cost REQUIRE international collaboration to reach to-day's key targets of planetary sciences

- In return, the next generation of planetary exploration missions is a fantastic platform for international collaboration

- The next L-class / flagship missions to the outer planets, to small bodies (with sample return), to Venus and Mars, 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

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

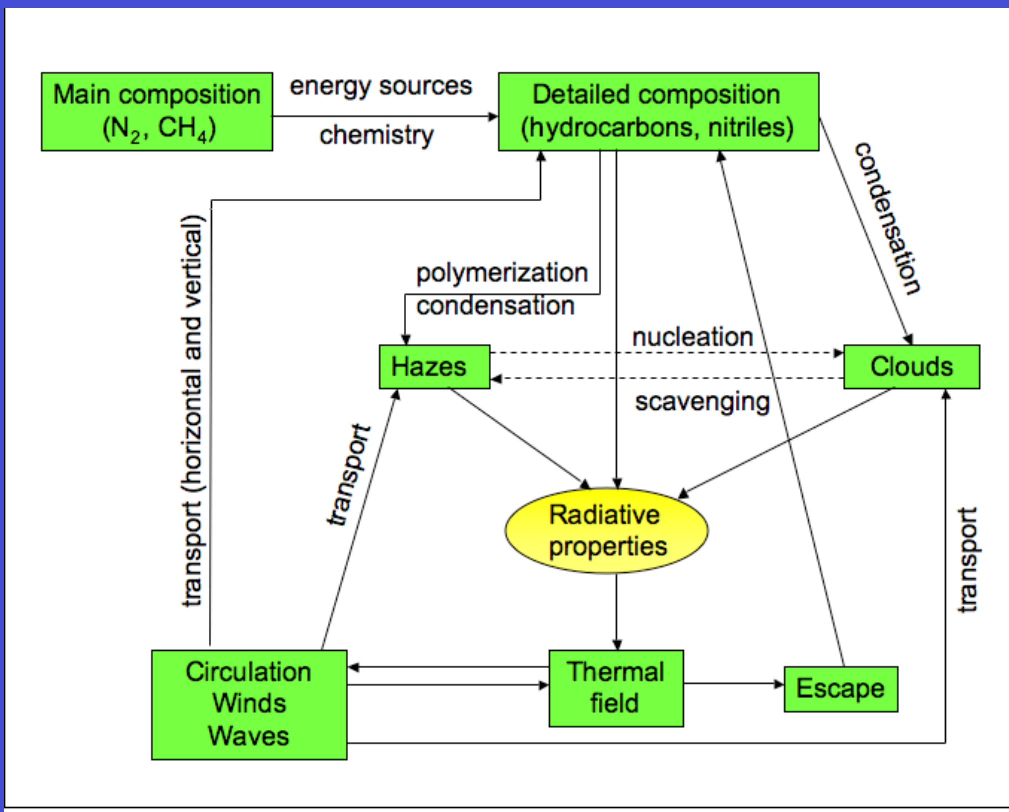
- Working together is more fun, more efficiency, more science return !

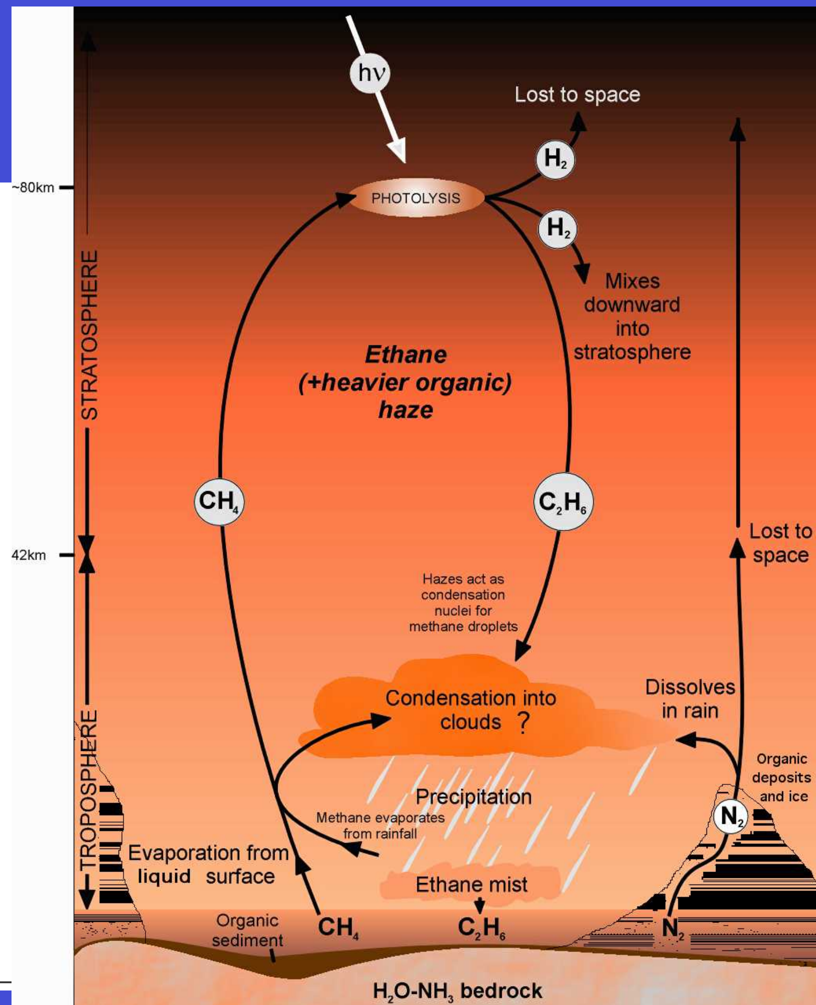
The true algebra of planetary exploration: 1+1 > 2 ; 1+1+1 >> 3 …

Additional slides

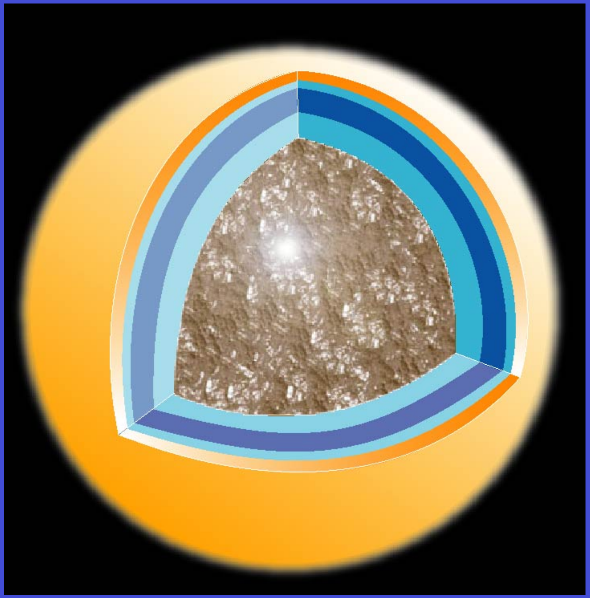
Scientific objectives for Titan's atmosphere

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





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 mechanismes ?

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 1000km 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

Example of science vs payload for interiors

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

ESLAB symposium inputs
April 2005

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

TRACING THE ORIGINS OF THE SOLAR SYSTEM

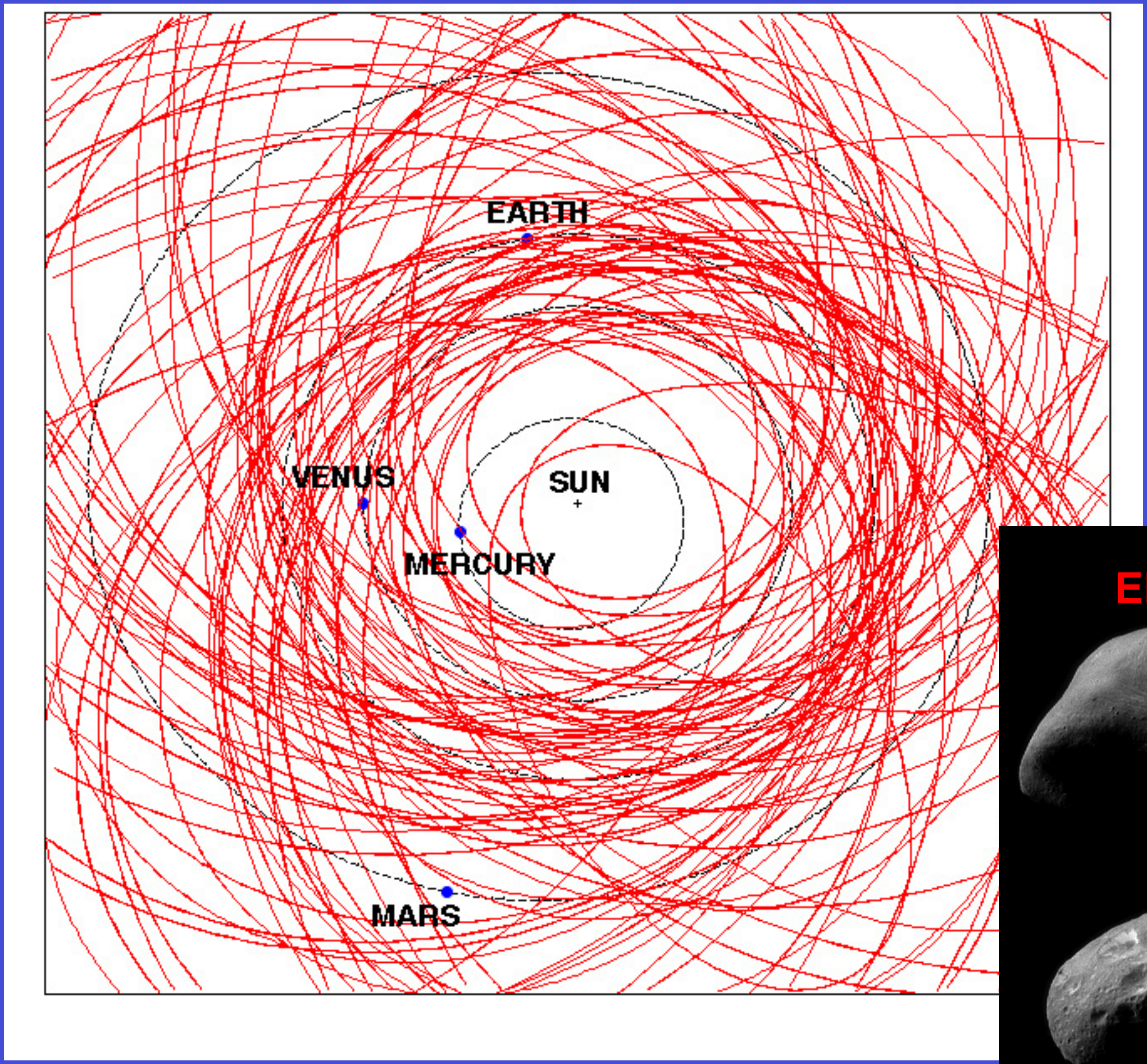
M. Blanc[1], D. Moura[2], Y. Alibert[3], N. André[1], S. K. Atreya[4], I. Baraffe[5], M. Barthelemy[6], A. Barucci[7], R. Beebe[8], W. Benz[3], B. Bézard[7], D. Bockelée-Morvan[7], S. J. Bolton[9,10], R. H. Brown[11], G. Chanteur[12], L. Colangeli[13], A. Coradini[14], A. Doressoundiram[7], M. Dougherty[15], P. Drossart[7], M. Festou[16], E. Flamini[17], M. Fulchignoni[7], M. Galand[15], D. Gautier[7], T. Gombosi[4], E. Gruen[18,19], T. Guillot[20], R. Kallenbach[21], S. Kempf[18], T. Krimigis[22], N. Krupp[23], W. Kurth[24], P. Lamy[25], Y. Langevin[26], J.-P. Lebreton[27], A. Leger[26], P. Louarn[1], J. Lunine[28,14], D. Matson[10], A. Morbidelli[20], T. Owen[29], R. Prangé[7], F. Raulin[30], C. Sotin[31], R. Srama[18], D. F. Strobel[32], N. Thomas[3], H. Waite[4], O. Witasse[27], P. Zarka[7], and J. Zarnecki[33]

Key missions	Comets	TNO's	Jupiter	Saturn	Uranus	Neptune
Low periapsis polar orbiter			X JUNO (NASA)	Cassini		
Entry probe			Galileo (?)	X	X	X
Satellite orbiter	X		X			X
Satellite in situ probe	X		X	x		
Magneto-spheric explorers			X	Cassini		x
Mission Concepts	Post-Rosetta Sample return	Earth Observations first	Europa Orbiter + Magnetosphere Explorer	Post Cassini Titan/ Saturn mission	Uranus Orbiter and probe	Neptune Orbiter and Probe

Tracing the origin of the Solar System

Pierre Lebreton, Alain Leger, Dennis Matson, Alessandro Morbidelli, Toby Owen, Renée .Prangé, Christophe Sotin, Darrell F. Strobel, Nicolas Thomas, Philippe Zarka, Yann Alibert, Nicolas André, Isabelle Baraffe, Reta Beebe, Willy Benz, Gérard Chanteur, Michele Dougherty, Enrico Flamini, Marina Galand, Tamas Gombosi, Tom Krimigis, William Kurth, Yves Langevin, Philippe Louarn, Jonathan Lunine, François Raulin, Ralf Srama, Hunter Waite, Olivier Witasse, John Zarnecki.

A unique opportunity : NEO’s



- offer some primitive objects
- easily accessible

SUMMARY

SMALL BODIES

- ASTEROIDS
- COMETS
- TNOs
- SATELLITES

Pristine material characterization

Surface evolution

Internal structure

Orbiter

Surface element

Sample return

GIANT PLANET SYSTEMS

- SATELLITES
- INTERNAL STRUCTURE

• Surface characterization
• Internal structure & dynamics
• Size of core

Satellite orbiter

Low periapsis polar orbiter

- ATMOSPHERE

Key chemical and isotopic composition

Entry probe

- GIANT PLANET DISKS/ NEBULAE

Structure/composition Dynamics, coupling to central body

High eccentricity equatorial orbiter +Low periapsis polar orbiter

Mission Concept	For immediate study/design By ESA (and partners)			Following steps		
	NEO Sample return	Europa Orbiter + Magnetosphere Explorer	Neptune Orbiter and Probe	Post C/H Saturn mission	Post Rosetta Comet sample return	TNO Mission
International Cooperation level	ESA	ESA or International	International	International		
Enabling Technologies	Large european Heritage Entry vehicle/ planetary protection	Solar cells or RTG's ——— Radiation resistance	RTG's ——— Entry probe	RTG's		
	Resource minimization (mass,power,data)					
Cost level	*	**	***	***		
Additional science		Comparative Planetology Plasmas, Astrobiology	Comparative Planetology Plasmas			

CONCLUSIONS

A major objective for a strong, multi-decadal international cooperation

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

Next steps: class M (<300 M€)

Activity	Date
ESA Internal Assessment Phase	November 2007 - end May 2008
Industrial Assessment Phase (emphasis on payload, cost and risk)	June 2008 - August 2009
Open presentation of study results & Working Group recommendation for Definition Study Phase	September - October 2009
SSAC down selection to 2 missions for Definition Phase	October 2009
SPC confirmation of 2 missions for Definition Phase	November 2009
2 missions in competitive Definition Phase	April 2010 - September 2011
Working group/SSAC evaluation and recommendation for adoption of one mission	September 2011-October 2011
SPC Confirmation of one mission for ITT release *	November 2011
SPC mission adoption (CaC and Payload Formal Agreement)	July 2012
Mission enters Implementation Phase	September 2012
Mission Launch	mid 2017

Next steps: class L (< 650 M€)

Activity	Date
Internal Assessment Phase, focused on identification of key technology areas (up to 3 proposals)	November 2007 to May 2008
Industrial Assessment Phase and definition of TDP (3 proposals)	June 2008 - June 2009
Working group evaluation and recommendation for down-selection from 3 to 2 Class L concepts to compete with LISA for Definition Phase	July 2009 – September 2009
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	October 2009
Two missions confirmed by SPC for entering Definition Phase	November 2009
Two missions in competitive Definition Phase	January 2010 – June 2011
Working group/SSAC evaluation and prioritisation	July 2011 – October 2011
Confirmation by SPC of first mission for ITT release *	November 2011
SPC mission adoption (CaC and Payload Formal Agreement)	July 2012
Start of industrial Implementation Phase	September 2012
Mission Launch	October 2018