SP-1312

Extract of Laplace/TandEM section

ESA's Report to the 37th COSPAR Meeting

Montreal, Canada
July 2008

European Space Agency
Agence spatiale européenne

5.7. Laplace/TandEM

Two outer planet missions are being jointly studied: The Europa/Jupiter System Mission (based on the ESA Laplace proposal and on the two NASA 2007 flagship studies: Europa Explorer and Jupiter System Observer); and the Titan/Saturn System Mission (based on the NASA Titan Explorer Flagship study performed in 2007 and on the ESA TandEM proposal). NASA and ESA, in coordination with their international partners, will jointly down-select one of the two missions in October-November 2008 for implementation starting in 2009.

5.7.1 EJSM (Europa/Jupiter System Mission)

Introduction

EJSM is to carry out an in-depth study of Europa and the Jupiter system, with special emphasis on studying Europa's habitability in the global context of the Jupiter system.

Is Jupiter's Europa really habitable? To what extent is its possible habitability related to the initial conditions and formation scenario of the Jovian satellites? To what extent is it due to the way the Jupiter system works? The Europa/Jupiter System Mission under study uniquely addresses these key questions.

The exploration of the jovian system and its satellite Europa is one of the priorities presented in ESA's 'Cosmic Vision' strategic document. The jovian system displays many fascinating facets. It is a small planetary system in its own right, built from a mixture of gas and icy material that was present in the external region of the solar nebula. Through a complex history of accretion, internal differentiation and dynamic interaction, a unique satellite system formed, in which three of the Galilean satellites – Io, Europa and Ganymede – are coupled via the Laplace resonance. The coupling implies an exchange of energy and angular momentum among themselves and with Jupiter, with far-reaching consequences for their respective evolution, activity, internal structure and habitability. This unique satellite system is imbedded in its fast rotating magnetosphere – a location where important astrophysical processes concerning the dynamics of magnetised discs and electrodynamic coupling in close binaries can be studied *in situ*. All components of the Jupiter system are themselves coupled to Jupiter's atmosphere via auroral and tidal interactions. Among these satellites, Europa is believed to shelter a water ocean between its geodynamically-active icy crust and its silicate mantle, which would contain more water than all of Earth's oceans combined. Europa is thus one of the most promising targets – if not the most promising one – in the search for habitability in the Solar System.

Mission profile

The mission baseline scenario is based on three spacecraft:

— a Europa Orbiter (EO) (to be provided by NASA, using Multi Mission Radioisotope Thermoelectric Generators MMRTGs),

— a Jupiter Planetary Orbiter (JPO) (to be provided by ESA), and

— a Jupiter Magnetospheric Orbiter (JMO) (to be provided by JAXA).

An alternative scenario is based on two spacecraft:

— a Europa Orbiter (to be provided by NASA), and

— a Jupiter Planetary Orbiter (to be provided by ESA),

For further information, see http://sci.esa.int/laplace with both spacecraft carrying enhanced instrumentation for magnetospheric science. Roscosmos has indicated an interest in independently developing and launching a Russian-developed Europa Lander.

Two possible launch scenarios have been identified for the assessment study. The baseline scenario considers that each international partner would launch its own element. A single launcher scenario (provided by NASA) will also be considered as one of the tradeoffs.

NASA plans to launch the Europa Orbiter in 2016/2017. The launch date of the other two mission elements is currently planned for 2018 or later. Arrival dates depend on the selected interplanetary trajectory. Various options for launch dates, launch scenarios and interplanetary trajectories will be studied. Trade-offs will be made in order to maximise the science during the operational phase at Jupiter. Typical interplanetary trajectory durations are 5–7 years. Operational lifetime at Jupiter will be at least 1–2 years (including 60 days nominal lifetime of the Europa Orbiter once in orbit around Europa, with an extended duration depending on the mitigation approach implemented against the high radiation environment). The single launch option would require that all elements be ready for launch at the same time.

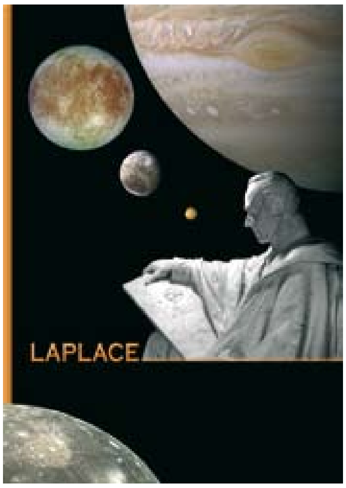
Model payload

The science objectives of EJSM can only be met by a combination of measurements performed with the various instruments on board the different mission elements. The studies will assess the synergies and complementarities among individual instruments and platforms for each of the specific mission targets. The accommodation of the model payloads under consideration within the three spacecraft (baseline) or two spacecraft (alternative scenario) will be studied to optimise the overall complement to explore Europa and the Jupiter System. The distribution of payload among the spacecraft is an important aspect of the science and payload accommodation studies. Several options will be studied. The radiation environment of the Europa Orbiter is expected to be significantly higher than for the other mission element(s). Implementation of mitigation strategies against radiation effects may play a role in the choice of payload accommodation options.

The following main classes of instruments are under consideration:

Internal structure investigations:	Ground-penetrating radar, laser altimeter, magnetometers, micro-gradiometer, radio science experiment.
Remote sensing investigations:	Cameras (narrow- & wide-angle, stereo), spectro-imager, ENA low- & high-energy imager, gamma/neutron spectrometer, sub-mm sounder, thermal IR imaging spectrometer, UV auroral imager, UV imaging spectrometer, V/NIR imaging spectrometer, X-ray imaging spectrometer, radio science experiment
Fields & Particle investigations:	Dust analyser, dust collector/analyser, energetic particle detectors, ion and neutral mass spectrometer, magnetometers, plasma spectrometers, radio and plasma wave instrument, ENA detectors.

Figure 5.7.1.1. Artistic illustration of EJSM predecessor



Concept spacecraft design

The baseline mission configuration is three spacecraft. The EO would use MMRTGs and the JPO would use solar panels as baseline, but an MMRTG (that would be provided by NASA) option may be studied. The JMO, which would be a spinner, would use solar panels. NASA is currently working on launch dates in either 2016 or 2017. The baseline approach would consider that each partner would launch its own element; if the JPO is to use MMRTGs, a NASA launcher for the ESA-provided element will be studied.

EO would be a nadir-pointing platform. It would initially perform Jupiter system science observations once in orbit around Jupiter, and later, when placed in orbit around Europa, would mainly perform remote sensing and *in situ* Europa exosphere observations. The EO payload would be optimised to allow Jupiter System Science complementary to the observations made by JPO and JMO and to address objectives related to Europa once in orbit around Europa.

JPO would be a three-axis stabilised platform optimised for remote sensing observations and *in situ* measurements for Jupiter system science complementing EO and JMO. Its trajectory around Jupiter would include flybys of the four Galilean moons (Io, Europa, Callisto, Ganymede), and possibly of other jovian moons. Its science complement would be optimised for addressing Jupiter System science. The possibility for a final mission phase with the JPO going into orbit around one of the other Galilean moons will be studied.

JMO would be a spinning platform optimised for *in situ* fields and particles measurements and it would monitor the Jovian magnetosphere, the moon exospheres and their interactions, aiming at Jupiter System science observations complementary to those made by EO and JPO.

The initial study activities are focussed on defining the radiation environment and the cumulative radiation doses of the three elements. Mitigation approaches for designing against radiation will include design of trajectory options and operational strategy options.

Operations

The mission operation scenario would mainly depend on the level of international cooperation. As a baseline, each partner would control and operate the spacecraft under its responsibility. Mission operation would be coordinated by a mission operation coordination group. Science operations would also be under the responsibility of each partner. Science operation coordination at mission level would be conducted by a science operation coordination group. Various science operation scenarios will be studied. Further definition of the mission operations and science operations schemes will be derived from the assessment study.

International collaboration

EJSM is being developed as an international collaboration among NASA, ESA and JAXA. The mission concept is based on the ESA 2007 Laplace mission proposal and on the two NASA Flagship missions studied in 2007 (Europa Explorer and Jupiter System Observer). JAXA confirmed its strong interest in participating as already indicated during the Laplace proposal preparation. Roscosmos expressed an interest in separately developing and launching a Europa Lander. Other international collaborations may materialise in the course of the assessment study.

5.7.2 TSSM (Titan and Saturn System Mission)

Introduction

TSSM is to carry out an in-depth investigation of Titan, to investigate Titan, an Earth-like organic-rich world, and the Saturn System, with special emphasis on Enceladus.

Titan, Saturn's largest moon with a diameter of 5150 km and a surface pressure of 1.5 bar, is revealing itself to Cassini-Huygens as a very complex and dynamic world. On a 16-day timescale (the length of Titan's day and also its period around Saturn), tides rise and fall in seas and lakes of hydrocarbons, winds are driven in the atmosphere, and stresses are created deep in the interior. From year to year, seasonal changes are expected in the atmosphere and on the surface, in the atmospheric composition and temperature, in the aerosol concentration, in the clouds, in the wind patterns and in the lakes and seas. Many analogues to the Earth have been found in the organic-rich, icy environment of Titan. Cassini-Huygens has revealed Titan's surface to be eroded by fluvial activity, and in some places precipitation may be torrential enough to cause flash floods. The atmosphere exhibits a greenhouse effect like Earth's. Clouds, dunes, rivers, lakes, seas, possibly ice volcanoes, and stratospheric anomalies analogous to our planet's ozone hole have been observed.

Enceladus, only 500 km in diameter, is also surprising us. To the Cassini instruments, this puzzling little moon revealed dramatic organic-laden jets of water vapour and dust-sized ice particles emanating from its south polar region (which is marred by narrow tectonic rifts called 'tiger stripes', probably containing organics), possibly from liquid water reservoirs just below the icy surface.

The main mission goals are to thoroughly investigate these two most intriguing moons of Saturn and their connection to the overall Saturn system. More specifically, the mission will address the following objectives:

— Conduct a thorough investigation of Titan's environment: atmosphere, ionosphere and exosphere as well as its plasma and magnetic field environment. Of particular

Figure 5.7.2.1. Artist's impression of TSSM

For further information, see http://sci.esa.int/tandem interest is the 800–200 km transition region, a key component in understanding the entire atmosphere and the origin of the organic molecules that it produces.

- Characterise the neutral atmosphere in terms of temperature, pressure, wind fields and CH_4 and C_2H_6 humidity.
- Study the internal structure and evolution of clouds, haze characteristics, evaporation rates and temperature over lakes, surface composition and thermal properties.
- Map Titan's surface from orbit with resolutions <100 m, and at much higher resolution (<1 m) from a number of '*in situ* elements' including compositional context and infrared imaging.
- Explore the interior structure and bulk composition of Titan and Enceladus by quantifying spatial and temporal variations in rotation, topography, gravity field, magnetic field, seismicity and surface properties.
- Obtain constraints on Titan and Enceladus formation and evolution models, in particular isotopic ratios to constrain the origin and cycle of methane on Titan, and isotopic ratios and the origin of the plumes and jets emanating from Enceladus' southern hemisphere.
- Study the potential for astrobiological studies and the potential habitability of these two objects.
- Perform Saturn System science, particularly as it pertains to understanding the formation and evolution of Titan and Enceladus.

Mission profile

The mission scenario under consideration is based on a NASA-provided Titan Orbiter that will carry and deploy some 'Titan *in situ* elements'. The *in situ* elements under study by ESA include a hot air balloon (Montgolfiere) and/or up to three probes/landers. The interplanetary trajectory might include gravity assist manoeuvres at several planets that would allow arrival at Saturn in less than 7–9 years. Upon arrival at Saturn, the Titan Orbiter would first enter orbit around Saturn to perform Saturn system science, with particular emphasis on Enceladus remote sensing and *in situ* measurements. In a second phase, the Titan Orbiter would be inserted into orbit around Titan. Several options will be studied for releasing the Titan *in situ* elements, including release prior to Saturn orbit insertion, release after Saturn orbit insertion, release prior to Titan orbit insertion, and release after Titan orbit insertion. Not all Titan *in situ* elements would be released at the same time.

NASA plans to launch the Titan Orbiter in 2016/2017. This planned launch date is a challenge for ESA to meet. Typical interplanetary trajectory durations are 7–9 years. Operational lifetime at Saturn would be at least four years (possibly including 2 years in orbit around Saturn followed by two years in orbit around Titan).

Model payload

The Science objectives of TSSM at Titan (derived from TandEM and Titan Explorer concepts) could only be met by a combination of measurements performed by the Titan Orbiter payload and the Titan *in situ* elements. While the orbiter payload would be optimised for Titan science, it would be carefully designed and/or operated to optimise the Saturn System objectives either from Saturn Orbit or from Titan Orbit. The assessment studies will look carefully at synergies and complementarities between individual instruments on either the Orbiter or the *in situ* elements, and between the different platforms.

The following main classes of instruments are under consideration:

Titan orbiter payload:	ion and neutral mass spectrometer, thermal IR spectrometer, magnetometer, micro-gradiometer, radio science, UV spectrometer, near IR camera and mapping spectrometer, radar altimeter, SAR imager, subsurface radar sounder, microwave radiometer, energetic neutral analyser, plasma analyser, energetic particles detector, advanced aerosol analyser, dust detector, E-field and plasma waves sensors, accelerometer.
In situ elements payload:	GCMS, Vis and NIR camera and mapping spectrometer, atmospheric structure instrument/meteorology sensor, subsurface radar, advanced aerosol analyser, IR spectrometer, altimeter, gradiometer, nephelometer, radio science, accelerometer, auroral & airglow photometer, atmospheric electricity and waves instrument, acoustic sensor, magnetometer, RAMAN-LIBS spectrometer, gas analyser/chemical sensors, microscope/closeup imager, subsurface mole, heat flow/physical properties, seismometer, sub-critical water extractor & μ-capillary electrophoresis, X-ray spectrometer, optical rain gauge.

Concept spacecraft design

The design of the Titan Orbiter would be Cassini-like, although somewhat scaled down in capability. All instruments would be body fixed (no articulated instrument platform); however the telecommunication antenna would be articulated to allow decoupling of communications from observations. It would have a payload capability of 70–80 kg (goal 100 kg). It could deliver as much as 400 kg of *in situ* elements into Titan atmosphere.

The Titan Orbiter would perform Saturn system science observations once in orbit around Saturn and later be placed in orbit around Titan with the instruments located on the nadir-pointed face. The trajectory around Saturn would likely be designed to include Enceladus flybys. Propulsion options being investigated include chemical and inner Solar System solar electric propulsion. Orbiter electrical power would be provided by Multi-Mission Radioisotope Thermoelectric Generators (MMRTGs).

The *in situ* elements to be studied include a hot air balloon (Montgolfiere) and descent probes/landers. The Montgolfiere appears to be the most appropriate type of balloon for Titan, as its thick and cold atmosphere is the most favourable of all Solar System planetary atmospheres for balloon flight. Initial concepts of a Titan Montgolfiere studied by CNES look very promising. The combined heat source for the local gas of the atmosphere and also the electrical source for the Montgolfiere would be an MMRTG, which would be provided by NASA (to be confirmed). The Montgolfiere would be released from an entry aeroshell after traverse through the atmosphere (much like Huygens parachute was deployed); it would then inflate during descent and reach full inflation above 10 km. Following inflation, the Montgolfiere would float around Titan's globe carried by the winds. At mid-latitudes, it would circle the globe in about 6 months. The Montgolfiere would be designed for a lifetime of at least one year (two circumnavigations of Titan's globe) but could live much longer. The altitude of the Montgolfiere would be autonomously adjusted/controlled by using a vent valve in the top of the balloon and onboard software fed by attitude and altitude sensors. Payload options to be studied for the Montgolfiere range in mass from 10 kg to 30 kg.

Descent probes/landers would provide *in situ* atmospheric and surface measurements in locations not deemed safe or optimal for the Montgolfiere, especially at high latitudes. The TandEM proposal has put forward some mini-probes concepts derived from the Huygens design and also inspired by Beagle-2 miniaturisation technology. Heritage from ExoMars will also be available, especially for the surface phase. Science objectives to be addressed by the probes require that they be designed for a lifetime on the surface of at least two Titan days (equivalent to two Titan orbital periods around Saturn, i.e. 32 Earth days). A combination of primary batteries (for the high-power descent and initial surface phase) and secondary battery/low-power radioisotope-based thermoelectric generators will be studied. Payload options to be studied for the probes range in mass from 5 kg to 15 kg.

Operations

The mission operation scenario would have some resemblance to the Cassini-Huygens scenario while taking advantage of lessons learned to reduce overall mission cost and complexity. During the cruise phase, science and instrument calibration activities would be regularly planned. Targeting and release of the *in situ* elements would be the prime responsibility of NASA, in full coordination with ESA. ESA will take over the operations of the *in situ* elements once they are delivered to Titan. For the entry, descent, inflation and initial operation phases, the *in situ* elements would use the overflying orbiter as a communications relay station. After inflation and initial operation phase, the Montgolfiere would rely on a combination of high-reliability onboard data recording, regular data relay sessions to the Orbiter and direct-to-Earth tracking, and possibly low-data-rate direct-to-Earth transmission. The probes/landers would also rely on high-reliability onboard data recording, regular radio relay sessions with the Orbiter, direct-to-Earth tracking and low-data-rate transmission. While an uplink (telecommand) capability is foreseen for the Montgolfiere, it is not foreseen for the probes/landers. Two uplink designs, through the orbiter and/or directly from the Earth, will be studied.

Mission operations would be coordinated by a mission operation coordination group. Science operations would be under the responsibility of each partner with coordinated operations carried out by a science operations working group. The Orbiter science operations would be based at JPL, Pasadena. The science operations for the *in situ* elements would be based at ESAC, Spain. Further definition of the mission operations and science operations schemes will result from the assessment studies.

International collaboration

TSSM is being developed as an international collaboration between NASA and ESA. The mission concept is based on the NASA Titan Explorer flagship mission studied in 2007 and the 2007 ESA TandEM mission proposal.