# Downselection Results for 2007 Outer Planets Flagship Studies

In 2007 NASA completed a series of studies for flagship missions to Europa, Titan, Enceladus, and the Jupiter system (public versions of the final reports for all four studies are available at http://www.lpi.usra.edu/opag/announcements.html). These studies were intended to inform NASA's decision process regarding the next Outer Planets Flagship mission by defining the science objectives and value, mission architecture(s), implementation readiness/risk, and total mission cost for each of the concepts. Upon their completion, the studies underwent a comprehensive independent review by Science and Technical/Management/Cost (TMC) panels. Based on the results of the studies and their reviews, in December 2007 NASA decided to continue studying three of these missions, the Europa Explorer, Titan Explorer, and Jupiter System Observer. A summary of key findings from the independent Science and TMC review panels is included in the appendix to this document.

NASA and ESA recently agreed to continue studying these Outer Planet Flagship missions under a joint effort. The agencies will study two missions. The first is a Europa/Jupiter mission that will most likely consist of a Europa Orbiter supplied by NASA and a Jupiter/Ganymede Orbiter supplied by ESA. The second mission is a Titan/Saturn mission that will likely consist of a Titan Orbiter supplied by NASA and a Titan in situ vehicle (such as a lander) supplied by ESA. NASA and ESA organized a Joint Science Definition Team (JSDT) for both of these missions. The JSDTs are comprised of scientists from both the United States and Europe and will work with mission design teams at both agencies. The JSDTs are primarily responsible for defining the science objectives for each mission and the multiple spacecraft of which they are comprised.

## Appendix: Key Findings from Independent Review

For the Europa Explorer study, the independent Science and TMC review panels rated the mission concept Excellent/Very Good for science, Medium Risk for science implementation, and Medium Risk for overall mission implementation. The panels noted the following key findings:

- Science objectives defined by the SDT are comprehensive, compelling, and mature; they build upon Galileo's revolutionary findings which pointed toward the next exploratory steps.
- Most science aspects of the mission, in particular the geological and geophysical objectives, investigations, and measurements for Europa and the jovian tour in general, are comprehensive and will provide an important advance in our understanding. However, chemistry science objective, including the portion related to habitability, was not comprehensively addressed. The important questions concerning the chemistry of Europa (and the proposed measurements and associated instrumentation) were not always well identified.
- Although the mission is focused on Europa, the jovian tour preceding Europa orbit insertion offers important advance in comparative planetology.
- The study presented a well thought out and detailed science operations and data acquisition plan that prioritizes science into a series of campaigns.
- A detailed science traceability matrix that identifies scientific goals and objectives, offers methods for investigation, and details measurement requirements supported by the notional payload was provided.
- Details on instrument accommodation were very thorough, giving confidence that the flight system can support the payload.
- The report's assessment of the impact of the radiation environment on nearly every aspect of the mission reflects a sound understanding of the challenge presented by the Europa environment, and the approach is validated by multiple peer reviews as documented in Appendix C of the report.
- The approach to Risk Management demonstrated a good grasp of the major challenges (including the radiation environment) facing the mission and offers risk mitigation efforts that should be effective in controlling risk. This approach includes a comprehensive radiation management plan for the spacecraft and instruments. However, significant risk remains in accomplishing the goals in this plan, particularly regarding instrument detectors. In particular, significant risk remains in accomplishing the goals in this plan, particularly regarding instrument detectors. Radiation-induced effects on the detectors and hence the measurement quality are significant issues that require further analysis and continuous mitigation efforts. Also, the radiation environment introduces significant cost and schedule uncertainty because modifications to all of the electronics (including elimination of all FPGAs due to radiation damage susceptibility) are needed

For the JSO study, the independent Science and TMC review panels rated the mission concept Very Good/Good for science, High Risk for science implementation, and High Risk for overall mission implementation. The panels noted the following key findings:

- JSO offers a unique opportunity to study all four Jovian satellites, including nearly continuous monitoring of Ionian volcanism for 3 years, extensive global mapping data of the Galilean satellites, comprehensive geophysical and geological interrogation of Ganymede; as well as synoptic Jupiter atmosphere measurements with greatly improved spatial resolution and potential spatial and temporal coverage.

- Although the mission captures some of the science accomplished by a Europa orbiter, there is an inherent lack of robustness for the Europa geophysics investigation.
- The report lacks some of the detail describing how this potential will be used. The science objectives are not always well described in terms of actual measurements and expected results, and some science objectives are neglected entirely (for example, the science themes of habitability and solar system formation).
- The general design of the Ganymede orbit phase is an innovative implementation and could facilitate accomplishing a number of major science objectives for Ganymede. However, such different orbits (high altitude elliptical vs. low altitude circular) will require different operational paradigms for the spacecraft and payload, and the report does not address the technical, operational, and cost issues this creates.
- The lack of sufficient detail for some of the scientific objectives and their associated measurements creates problems in other areas: instruments included in the payload are not always well tied to science objectives, instrument capability requirements are not always well stated, and flyby coverage appears to fall out from the tour designed to achieve Ganymede orbit rather than being driven by science requirements.
- While much of the mission does not suffer from severe radiation hazards, key phases of Io and Europa encounters do have that risk, and radiation-induced effects on the measurement quality are significant issues that require further analysis and mitigation.
- As described in the report, it is unlikely that JSO can meet the pointing and stability requirements without significant design and resource impacts.
- Given the identified mass liens relating to delta-v and uncertainty in the structure design, the dry mass margin (<10%) is unacceptable for this stage of development.

For the Titan Explorer study, the independent Science and TMC review panels rated the mission concept Excellent/Very Good for science, Medium Risk for science implementation, and High Risk for overall mission implementation. The panels noted the following key findings:

- The science return from the baseline mission (orbiter+lander+balloon) will be extremely rich, providing a very capable, comprehensive, and large suite of scientific instruments on multiple platforms. Descoping from this full mission to a orbiter plus lander still provides a viable flagship mission with compelling science, and descoping further to just a Titan orbiter still addresses the first of two major objectives (to explore Titan as an evolving Earthlike system) of the mission very well.
- The lack of quantitative measurement requirements for some of the science goals or the lack of demonstrated instrument capabilities in some cases makes it difficult to assess whether or not the payload and mission design will have a reasonable chance to answer some of the posed questions.

- The report provides a complete and thorough concept demonstrating a comprehensive Systems Engineering approach. An excellent analysis of navigation is presented showing the feasibility of landing with sufficient accuracy to achieve a good science mission.
- The mass posture proposed for the flight elements introduces considerable risk (mass margins for each element are ~20%), given that most elements still require significant development.
- The selection of aerocapture for the baseline mission architecture introduces substantial design risk into the Orbiter and dominates the flight system requirements and design while providing only incrementally improved mass delivery. In addition, the entry systems for the Lander and Aerial Vehicle and the Orbiter aeroshell are new designs, and the report does not acknowledge the effort required to bring these systems to flight readiness.
- The arrival scenario at Titan requires all three vehicles to enter the atmosphere in different corridors in a 5 hour period; such a complicated arrival scenario, along with associated command sequence testing and validation for three flight systems at Titan, introduces significant risk.
- The Orbiter, Lander and Aerial Vehicle require extensive development and costs for this effort are significantly underestimated.

For the Enceladus mission study, the independent Science and TMC review panels rated the mission concept Good/Fair for science; risk ratings for science implementation and the overall mission were not determined. The panels noted the following key findings:

- Enceladus is an obvious and tempting target with active erupting plumes providing a unique opportunity to sample extraterrestrial materials that might have been liquid water just a few minutes earlier.
- Plume sampling by an orbiter should be relatively nondestructive of individual molecules due to low sampling velocities, but the desirability of a lander to do chemical analyses is demonstrated in the report as well.
- The science objectives in the report are not always well described in terms of actual measurements and expected results, and the study did not adequately provide traceability from science objectives to measurements needed to resolve key questions.
- For the Enceladus orbiter, the polar orbits contain the high priority science but are too short, too few, and too late in the mission. Among other trades, the subsurface sounder is lost from the Enceladus orbiter in favor of a lander, eliminating a robust method for determining subsurface structure.
- For the Saturn orbiter mission, too much of the anticipated science yield depends on Enceladus flybys whose high velocity plume encounters preclude the use of a Gas Chromatograph Mass Spectrometer, and the improvement over Cassini would be only incremental.
- The report presents only modest attempts to optimize a mission for what is presented as the principal priority, the biological potential of specific areas on Enceladus. The tradespace for selecting a lander is not done in terms of the characteristics of what might be an optimal, or even acceptable, sampling location,

and the value of sampling at an achievable landing site has not been firmly established.

- Chemical analysis instruments optimized for the Enceladus environment need definition and development which take into consideration both the unique environment and the materials to be evaluated; instrumentation and techniques being developed for a Mars sampling mission seem unlikely to adequately support either the necessary chemical protocols or the specific Enceladus environment.
- All three concepts presented have unacceptable mass margins and the Enceladus orbiter concepts have such long mission durations that they are not credible from a reliability standpoint.
- The report also fails to define critical design requirements that would enable assessment of the feasibility of landing on Enceladus, such as requirements for site selection, resources and techniques for landing, and characterization of the landed operating environment and its implication for the Lander design.
- The delta-v and propellant budgets are lacking substance (for example, no trajectory analysis was presented to confirm the delta-v savings derived from multiple (up to 43) flybys of Saturn’s moons).
- The Basis of Estimate for proposed costs has several significant deficiencies adding considerable uncertainty regarding the real cost requirements for this mission.