

**Outer Planets Assessment/Analysis Group
October 19–20, 2011 Meeting
Pasadena, CA**

The Outer Planets Assessment Group is a NASA-supported forum for scientists, engineers and other interested parties to strategize current and future exploration of the outer solar system and to enhance communication between the outer planets community and NASA. Major findings of OPAG as informed by the October 2011 meeting are outlined below, followed by a meeting description and additional details on the individual findings.

I. Summary of OPAG Findings

1. The Cassini spacecraft should be funded and supported through the planned 2017 end of mission. OPAG strongly urges that NASA fund the Cassini Solstice Mission at the level the Cassini Team requires to safely operate the spacecraft and to obtain and analyze the data that are required to accomplish the science objectives of the Cassini Solstice Mission.
2. OPAG urges NASA's Consolidated Senior Review to involve clear two-way communication between NASA and affected flight projects.
3. The Europa flagship mission should move forward with a detailed design study for possible launch later in this decade. Studies for a descoped Europa Orbiter element and Multiple-Europa-Flyby element have been completed, with independent technical reviews and cost estimates to come, and a study for a Europa lander will be completed in early 2012. Provided the technical reviews are positive and cost estimates meet NASA requirements, one or more elements should be chosen for detailed study, with the aim of choosing the best option for flight.
4. Study should begin on a Uranus flagship mission, the Planetary Science Decadal's third-ranked flagship after Mars 2018 and Europa. Identification of key technologies and strategies to reduce risk, cost, and travel time are priorities.
5. OPAG strongly endorses the recommendations of the Planetary Science Technology Review Panel, and urges their timely implementation.
6. Relevant government agencies should do what is necessary to make sufficient amounts of plutonium (Pu-238) available for outer solar system (and other) missions. OPAG strongly supports PSD efforts to have DOE restart Pu-238 production with funds appropriated by Congress.
7. OPAG is encouraged by recent increases to the budget and selection rate for the Outer Planets Research program (OPR). We urge NASA to maintain these increases so that the program can be funded at their stated goal of a 30% selection rate.

II. Meeting description and details of major priorities

OPAG met this fall for two days (attendance 94/67), with a major emphasis on hearing **the reports of the new Europa Science Definition Team**, which was charged with responding to the recommendations of the Planetary Science Decadal Survey. The ongoing, Cassini Solstice Mission was also extensively discussed, with an emphasis on the major negative impacts to the mission that would result from further budget reductions. After OPAG wrapped up, the floor was given over to an open community forum on a possible, future Europa lander.

Presentations were heard as follows:

Wednesday 19 October

Planetary Science Division Update

Jim Green, NASA Headquarters

Outer Planets Program Update

Curt Niebur, NASA Headquarters

Cassini Status Report

Linda Spilker, Jet Propulsion Laboratory

Jupiter Icy Moon Explorer

*Michele Dougherty, Imperial College, London
Olivier Grasset, University of Nantes*

Outer Planets Research Program

Terry Hurford, Goddard Space Flight Center

NASA Europa Mission Study Update

Headquarters Perspective

Curt Niebur, NASA Headquarters

Science

Bob Pappalardo, Jet Propulsion Laboratory

Orbiter Element

Brian Cooke, Jet Propulsion Laboratory

Flyby Element

Ken Hibbard, Applied Physics Laboratory

Wrap Up

Bob Pappalardo, Jet Propulsion Laboratory

Thursday 20 October

Titan Airplane (AVIATR)

Jason Barnes, University of Idaho

TIME Science

Ralph Lorenz, Applied Physics Laboratory

Uranus Working Group Report

Mark Hofstadter, Jet Propulsion Laboratory

Planetary Science Technology Review Panel

Tibor Kremic, Glenn Research Center

Ballon-based Planetary Observatory Workshop

Tibor Kremic, Glenn Research Center

Outer Planets Colloquium Series

Steve Vance, Jet Propulsion Laboratory

Presidential Early Career Awards

Curt Niebur, NASA Headquarters

Given the emphasis on the Cassini Solstice mission at the meeting, and the overall threat to Outer Planets exploration in the coming era of fiscal austerity, our first finding concerns this mission.

1) Cassini Solstice Mission

Cassini will be the only Outer Planet Flagship mission flying this decade, and OPAG is gravely concerned that further budget cuts will cause significantly more science loss in an already “descope,” extended mission. A presentation by the Cassini Project (Linda Spilker, Project Scientist) stated that further reductions on the engineering side would be difficult to implement without taking undue risks to continued spacecraft operations. The Project further stated that this would imply most further budget reductions would necessarily come from science, which would likely drastically compromise one or more of the goals of the Solstice Mission, including:

- seasonal and temporal studies until Saturn system solstice;
- the capability to address new discoveries;
- the end-of-mission, Juno-like orbits to both characterize Saturn's gravity and magnetic fields; and
- measure the mass of Saturn's rings.

Putting the Cassini Solstice mission at risk is counterproductive to NASA’s high-priority science goals to understand the interiors and formation histories of the giant planets. These science goals form the primary rationale for the recently launched Juno mission to Jupiter and for the Planetary Decadal Survey recommendation of a Saturn Probe mission in the New Frontiers mission set.

In this regard, completion of the Cassini end-of-mission’s Proximal Orbits is critical. Cassini is poised to perform these orbits near the end of its Solstice Mission, making measurements not possible from previous orbits. These measurements will be a key component of a broad multi-mission data set needed to reveal giant planet and solar system formation and evolution processes from comparisons of the gas giants Jupiter and Saturn, followed by future comparisons of the gas giants to the ice giants Uranus and Neptune. This knowledge is especially critical to understanding the different planetary systems now being found around other stars. Additional information is in the attached *OPAG Statement On The Cassini Mission’s Proximal Orbits*.

OPAG strongly and unequivocally agrees with the Planetary Decadal Survey in support for funding of Cassini through the planned 2017 end of mission, and at a level that will maintain the current scientifically rich tour, keep all of the science instruments on, continue healthy international collaboration, and return synergistic data as only a Flagship can do. Specifically, we strongly endorse the science of the Cassini Solstice Mission, particularly the Juno-like final orbits. We strongly urge that NASA fund the Cassini Solstice Mission at

the level the Cassini Team requires to safely operate the spacecraft and to obtain and analyze the data that are required to accomplish the science objectives of the Cassini Solstice Mission.

Cassini is a joint project between NASA, ESA, and European national space agencies. OPAG is deeply concerned about the potentially harmful effects of NASA funding reductions on our European partners. Recently, the ESA Space Science Extension Working Group (SSEWG) considered Cassini and other ongoing European planetary missions. Their recommendation is repeated below:

SSEWG Recommendation on continued funding of satellites in operation

[ESA's] SSEWG saw the reports on the results from the satellites in orbit and is impressed with the excellent science delivered by all the missions. In particular, the Cassini-Huygens extended Solstice mission (see recommendation : SSEWG(2010)3), an important collaborative ESA-NASA mission in which about 130 European scientists are involved, is continuing to return new scientific discoveries on the Saturnian system. The SSEWG was concerned to learn about discussions on potential budgetary cuts on the US side that would endanger the mission's science return and might even find an echo within the European Space Agency and the national funding agencies. The SSEWG urges ESA and the European national agencies to maintain the funding level without which this excellent mission in operation might be forced to terminate its investigations. The SSEWG believes that satellites in orbit demonstrating excellence in science return should be maintained and encouraged.

ESA SSEWG, October 19, 2011 (Athena Coustenis, Chair)

2) Consolidated Senior Review

Much of the concern related to further budget cuts to the Cassini Solstice mission stems from the runup to the Consolidated Senior Review of extended missions that is scheduled for the spring of 2012, and related communications between NASA HQ and the Cassini project. While OPAG understands that there are no entitlements based on history, at the same time it should be understood that a mission that has been pared down already cannot necessarily absorb a new cut as well as a mission in its primary phase can, without disproportionately affecting science. OPAG notes that PSS could play a constructive role in the Senior Review process if it were more transparent.

Regarding the Consolidated Senior Review process for extended missions — For fairness and balance among the disparate missions being considered, the following steps should be implemented as part of the process: 1) budget cuts should be generated in consultation with the relevant projects; 2) rationales for all cuts should be clearly specified; and 3) due consideration should be given to previous cuts and the impacts of further cuts on science specifically. Important elements in these steps are a) a need for greater communication and feedback between HQ and the various flight projects and b) increased transparency in the process between NASA, the affected projects, PSS, and the community.

3) Europa Flagship Descope

The Planetary Decadal Survey recommended a Europa mission as its second-highest priority flagship mission, but only if costs could be markedly reduced from that estimated for the Jupiter Europa Orbiter mission. Accordingly, a Science Definition Team was formed and at this OPAG meeting Bob Pappalardo and Brian Cooke reported the findings and recommendations of this SDT.

To achieve the highest priority JEO Europa science objectives, the SDT recommends using two spacecraft: 1) an *Orbiter element* to perform geophysical measurements (“Ocean” science) that can only be achieved from Europa orbit, and 2) a *Multiple-flyby element* to perform remote measurements (“Chemistry” and “Energy” science) that can be achieved from Jupiter orbit. Each element achieves key science objectives, and each has very high science value of its own. Each element is estimated to cost in the neighborhood of ~\$1.5B (FY15). The complementary elements would not have to operate simultaneously; they could fly separately, and staggered in time. The SDT anticipates that one element would fly this decade, if funds allow, and that the second element would be presented to the next Decadal Survey for consideration. In addition, a third, landed element is now being studied by the Europa SDT at NASA’s request.

OPAG found the Europa SDT report to be highly responsive to the Decadal Survey. The two-element approach is both comprehensive in its scientific architecture and an elegant and practical engineering solution. That is, the instruments on the Orbiter are kept to a minimum, while the Multiple-Flyby platform has the more power- and data-intensive instruments. By splitting the original JEO mission into two elements, the cost of each element is significantly reduced and the funding requirements over time are more easily accommodated in a difficult budgetary

environment. Radiation risks are also much reduced through judicious use of shielding, with each mission element designed using only existing, commercially available radiation-hard parts. Independent technical reviews and estimates of mission costs for each element, similar to those recently done for the Decadal Survey, are presently underway.

With the virtue of hindsight, it could be argued that the two-element design is what the next step in Europa exploration should always have resembled. Looking ahead, OPAG envisions that future outer planet flagships may also embrace a similar multi-element (or modular) and fiscally constrained approach. A modular approach (for example, orbiter and probe), if properly designed, also has the virtue of opening a natural pathway for international collaboration.

OPAG finds the Europa SDT report to be highly responsive to the Decadal Survey, and either element (Orbiter or Multiple-Flyby) would make a scientifically compelling Outer Planets Flagship mission. OPAG looks forward to hearing from the Europa SDT in the spring on the results of the Landed element study. With all three Europa mission element studies completed, and with independent technical reviews and cost estimates for all three, OPAG anticipates endorsing going forward with a detailed design study of one or more mission elements, with the aim of choosing the best option for flight.

OPAG strongly encourages selection and a new start of a Europa mission ASAP after the independent reviews are completed, assuming the technical reviews are positive and the cost estimates meet NASA requirements.

4) Future Missions Planning and Funding

OPAG has previously stated a need for activities to support future missions. These include focused technology development, focused mission studies, and planetary environment model definition. The “foci” should be aligned with the findings of the Planetary Science Decadal survey, and would be most effective if it at least portions were competed.

OPAG heard presentations on two Titan mission concepts, TiME (Titan Mare Explorer), a Discovery concept presently undergoing a Phase A study for a capsule to splash into and float across Ligeia Mare, and AVIATR, an airplane concept which a Team-X costing suggested would be <\$1B. These concepts underscore that a range of exciting, standalone Titan mission concepts exist, but has not been fully explored,

which can address parts of the rich portfolio of science at Titan.

Prior to the OPAG meeting, OPAG's Uranus Working Group met under the limited charter "*This group will meet for two days preceding the next OPAG meeting, with the objective of assessing and coordinating Earth-based observing campaigns to best address Uranus science questions.*" Results were presented to OPAG by Mark Hofstadter and were well received. OPAG anticipates a proposal from the ice giant community to extend the charter of the Uranus Working Group, and will take up the next steps for an Ice Giant Mission at the next OPAG. A Uranus mission is on the Decadal Survey's list of potential flagship missions in the decade 2013-2022 (after Mars 2018 and a Europa mission).

Funding for an "Outer Planets Flagship" is included in the recently passed FY12 NASA budget. OPAG wishes to be kept informed as to the disposition of this funding (the operating plan) so that it may provide appropriate and useful input to NASA.

Study should begin on a Uranus flagship mission, with identification of key technologies and strategies to reduce risk, cost, and travel time as priorities. There is also a current need for Titan technology efforts — several technologies have been identified that would be applicable to future situ missions, and they all have long lead times.

5) Planetary Science Technology Review Panel

OPAG heard a detailed final report from the PSTR Panel chair, Tibor Kremic. Technology development and strategy are clearly keys to future exploration of the Outer Solar System. The goal of the PSTR is to assist PSD in developing a coordinated and integrated technology development plan that will better utilize technology resources. The final report clearly articulates issues that affect technology development and utilization across PSD and presents 11 major recommendations in the areas of Management, Strategy, Process, Culture & Communications, and Resources. Given that PSD resources overall will be more limited in the next several years, an efficient and targeted use of technology funding will be all the more important.

OPAG strongly endorses the recommendations of the Planetary Science Technology Review Panel. In an era of tight fiscal constraints, judicious implementation of the panel's recommendations (such as a dedicated

Technology director within PSD) would ensure the best use of technology resources overall.

6) Plutonium-238 Shortage

As in all other recent OPAG reports, we reiterate the central importance of radioisotope power systems for deep space exploration.

OPAG continues to express its deep concern over the shrinking Pu-238 supply, and strongly urges all relevant governmental agencies to extend the steps they have so far taken to produce or otherwise make available sufficient plutonium for future outer planets (and other) missions. OPAG in particular strongly supports PSD efforts to have DOE restart Pu-238 production with funds as appropriated by Congress.

7) Outer Planets Research Program (OPR)

The Outer Planets Research program (OPR) is a critically important funding source that supports diverse scientific investigations that contribute to the understanding of the outer Solar System, including the giant planets, their satellites, and smaller solid bodies including comets, asteroids, and the Kuiper belt. The program includes both data analysis from NASA missions and fundamental research. This program is heavily over-subscribed, with 2010 seeing 123 proposals submitted and a 24% selection rate. OPAG is encouraged that the selection rate has improved from the previous two years (17% in 2008 and 20% in 2009). However, the selection rates remain below NASA's stated goal of a 30% funding rate. Low selection rates lead to a proposal generation burden on the community, threaten the ability to attract talent and retain hard-won experience in the field, and pose a substantial review burden on NASA and the community.

OPAG lauds PSD's decision to maintain an overall level R&A budget in the years ahead, even as the total PSD budget is set to decline. This is in keeping with the spirit of the priorities laid out in the Planetary Science Decadal Survey. At the same time, the OPR program has shown strong and sustained proposal pressure from the outer planets community.

OPAG encourages NASA to take measures to continue increase the OPR program's selection rate to 30%. This will permit continued high quality work

to be accomplished, while reducing the burden of proposing and review. Should the PSD budgetary outlook worsen, OPAG urges the PSD to make every effort to engage the planetary community (through the AGs) to preserve the health of its research community.

The next OPAG meeting will be held March 29-30 in Saint Louis.

OPAG Statement On The Cassini Mission's Proximal Orbits: Critical Data for Giant Planet & Solar System Origins

Completion of the Cassini mission's Proximal Orbits is critical to multiple high-priority planetary science objectives. Cassini is poised to perform these orbits near the end of its Solstice Mission, making measurements not possible from previous orbits. These measurements will be a key component of a broad multi-mission data set needed to reveal giant planet and solar system formation and evolution processes from comparisons of the gas giants Jupiter and Saturn, followed by future comparisons of the gas giants to the ice giants Uranus and Neptune. This knowledge is critical to understanding the veritable zoo of different planetary systems now being found around other stars.

Comparative planetology of gas giants is a high priority objective for research into giant planet and solar system formation and evolution [1,2]. Fundamental aspects of these areas are currently unknown, including processes and materials that deliver volatiles such as water and organics to giant planets and terrestrial planets, and time scales for planetary formation and protoplanetary disk evolution. Comparisons among giant planets, beginning with comparisons of Jupiter and Saturn, are a tool for examining the results of these processes and thus the processes themselves. A meaningful comparison of Jupiter and Saturn requires knowledge of elemental and isotope composition in the well-mixed atmospheres of both planets, and knowledge of gross interior structure to provide context for the compositional information [3,4].

The data set needed to provide this knowledge is being assembled using data from multiple past, present, and future NASA Flagship and New Frontiers missions. The Galileo Probe provided the elemental and isotope composition measurements at Jupiter, except for oxygen. NASA's Juno mission, part of the New Frontiers Program, is en route to Jupiter to make the interior structure measurements needed there. This objective, together with composition measurements (ammonia, and the water the Galileo Probe missed), comprises a significant part of the Juno mission's science and the mission budget, and completes the comparison data set for Jupiter. The recently completed Planetary Science Decadal Survey recommends a NASA New Frontiers Program mission, a Saturn atmospheric entry probe mission, to make the elemental and isotope composition measurements needed at Saturn [1]. Interior structure measurements at Saturn, equivalent in science value to that of Juno's interior structure measurements at Jupiter, would round out the data set. Without these, the comparisons would be inadequate for unambiguous models of planet formation.

It is precisely these Saturn interior structure measurements the Cassini Proximal Orbits would provide. The cost of acquiring the data with Cassini is a relatively small fraction of the Solstice Mission budget. If Cassini does not acquire that data set, the task of acquiring it would fall to a new, future Saturn orbiter mission. Such a future mission is not within NASA's planning horizon, so it would be decades in the

future. This would delay understanding fundamental giant planet and planetary system formation processes in our own solar system, and notably in other planetary systems now coming to light as a result of NASA-funded exoplanet search programs.

REFERENCES

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- [3] Saturn Exploration Beyond Cassini-Huygens, T. Guillot, S. K. Atreya, S. Charnoz, M. Dougherty, & P. Read, in *Saturn From Cassini-Huygens* (M. K. Dougherty et al., eds.), Chapter 23, pp 745-761, 2009, DOI 10.1007/978-1-4020-9217-6_23, Springer Dordrecht, Heidelberg-London-New York.
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