Summary of Open Sessions at the September 21-23 Satellites Panel Meeting for the Planetary Science Decadal Survey

Irvine, CA

Paul Hayne, University of California, Los Angeles

Introduction

The Irvine meeting of the Satellites Panel for the Planetary Science Decadal Survey was a three-day event, organized by the Space Studies Board of the National Research Council (NRC). The purpose of this meeting was to formulate the scientific goals and exploration strategy for the satellites of the outer Solar System. Building on progress made at the previous meeting in Washington, D.C. (August 24-26, 2009), Panel members heard and discussed presentations from NASA, the Applied Physics Laboratory, CNES, and ESA, on topics of practical interest for developing a coherent science and exploration strategy. The panel also reviewed community white papers on topics relevant to this survey.

This report was prepared by a graduate student rapporteur and captures the main topics discussed, but does not necessarily represent the specific views of any individual.

Monday, September 21, 2009

Meeting Overview
Dr. John Spencer, Southwest Research Institute

One of the primary objectives for this meeting is to narrow down New Frontiers-class (NF) missions request for RMA or higher level study. A NF-class RMA study has already been requested. Targets of interest include Io, Enceladus, Ganymede, and the Uranian satellites. Submitted white papers will be discussed in closed session. A total of 66 relevant white papers were submitted, and each Panel Member (PM) has been assigned ~3 of these to review, and will present their impressions and provide a brief written summary to the Panel Chairman. The large number of papers submitted and their overlap means that some will be grouped together during discussion. Scientific merit and community consensus represented in the white papers will inform the recommendations made in the Panel's report.

NRC Study on Radioisotope Power Systems
Ralph McNutt, Applied Physics Laboratory, Johns Hopkins University

A committee co-chaired by Dr. McNutt and Dr. William Hoover, including members from both science and engineering communities (in and out of academia), was formed by the NRC to study the current and future needs for, and availability of radioisotope power systems for planetary exploration. The committee briefed NASA, DOE, Congress, OMB and OSTP on May 5, 2009. Plutonium-238 is the only viable fuel for current radioisotope power systems (RPS), and has not been produced in the United

States since the 1980's, and is not currently manufactured anywhere in the world. NASA currently purchases ^{238}Pu from Russia, and will exhaust all existing fuel by 2020. The RPS study panel therefore recommended that the United States restart production of ^{238}Pu as soon as possible to sustain the current NASA exploration program and address the goals, "enhancing life on Earth and understanding the context of Earth in relation to the Sun and planets." Dr. McNutt explained the basic operations of conventional RPSs, as well as newer Advanced Stirling Radioisotope Generators (ASRGs), which have approximately five times the efficiency of conventional RPSs, but have never been operated in space. Total lifetimes for ASRGs are roughly 17 years, which may limit the types of outer Solar System missions possible.

Current allocations of roles and responsibilities between NASA and DOE are appropriate, and these should be adhered to while developing the infrastructure for restarting ^{238}Pu production. Two different labs exist with the capability of rapidly starting production: Idaho National Laboratory and Oakridge National Laboratory. Projections by NASA administrator's office (April 2008) provide a conservative estimate of future 238Pu needs of 5 kg per year, at a cost of about $10M per year, plus up front infrastructure costs of $150–$300M over seven years. The first ASRG could be ready for a 2014 launch of Discovery 12. Panel members should note that safety approval for use of RPSs on planetary missions is typically about 4 years, based on experience with New Horizons.

<u>Planetary Protection for the Icy Satellites</u>
Cassie Conley, NASA Headquarters

A probabilistic approach is taken to planetary protection, with the COSPAR-adopted standard of 10^{-4} or lower chance per mission for contamination of a planetary body. Each mission has different standards for planetary protection, depending on the chemical and/or biological interest and habitability of the target body. For example, Mercury is considered biologically uninteresting, and therefore no sterilization is required for spacecraft headed there. Europa missions (like any bound for icy satellites possibly containing liquid water) must adhere to the highest risk mitigation standards. Modern biological evidence suggests many different microbe strains are resistant to hazards of the space environment, so diligence is required to detect and remove them.

Dr. Conley presented the Juno mission as an example of the procedures used in planetary protection of a mission to the outer planets, and described a detail study of the risks involved. Since the mission was determined to have a 5% chance of spacecraft failure, the trajectory must avoid Europa until all live organisms are eliminated. In terms of planetary protection priority, Europa ranks highest among the Galilean satellites, with Callisto ranking lowest. An upcoming workshop organized by COSPAR, and sponsored by NASA and ESA, will address planetary protection concerns specifically for Titan and Ganymede.

Planetary protection needs: 1) improved models of material transfer and surface-interior communication; 2) methods for estimating bio-burden and reductions; 3) approaches for sterilizing lander spacecraft at the subsystem and system levels. Panel members asked questions regarding sterilization methods for lander missions to Titan, and were told that the outstanding question is whether and how much interaction exists between the surface and interior. Panel members also wondered whether back-contamination from an Enceladus sample return mission is a problem, and were told that this is generally considered to be a very low-probability event. It was noted that the sterilization facility used for the Viking landers is no longer in existence.

Enceladus Sample-return Missions
Peter Tsou, Jet Propulsion Laboratory

Low cost flyby sample return mission for Enceladus follows Stardust model, with modifications made for capture of volatiles. These mission concepts, collectively called LIFE, must address the following challenges: 1) sample capture velocity of 15-20 km/s, which presents problems for sample integrity; 2) long mission durations (~15 yr); 3) high cost. Some potential resolutions were discussed, including: 1) a new trajectory was found by JPL group, which gives ~3 km/s sampling speed; 2) mission duration can be reduced to 13.5 years, with multiple sampling flybys. Mission cost has not yet been studied in detail. Dr. Tsou's group recommends an in-depth study to assess cost for different mission classes and science return from each. A Baseline mission would keep samples at ambient temperature, but a more sophisticated (and costly) system is probably needed to return volatiles.

Dr. Linda Spilker presented evidence from Cassini that the Enceladus plume contains many volatile ices and complex organic molecules. A liquid water source is implied by the presence of ammonia and salts, which also have the effect of lowering the water melting point. Saturn's E-ring is composed of small (~1-10 micrometer) particles derived mainly from the Enceladus plume, implying that the plume has been active for at least 300 years. Details of a "strawman" payload and launch system were presented. In-situ analysis is recommended to get compositional information on the volatile species. Sample return is very important in order to address scientific questions using the best available methods, now or in the future. A major difficulty for the Enceladus sample return mission is the limited (~14-year) lifetime of RPSs. Finally, a major problem is the high expected re-entry velocity at Earth, which is about 20% higher than Stardust.

The panel expressed concern over the availability of the technology needed to transport volatile samples back to Earth without total sublimation. Questions also exist about how low a spacecraft can go without risk of damage, and how this might generate a sampling bias. Another issue is whether the tracks through the aerogel collector will turn out to be empty if the sample is totally volatilized, and whether large organic molecules will be destroyed.

Mission Architecture Options for Enceladus Exploration
Nathan Strange, Jet Propulsion Laboratory

New astrodynamics techniques open up new possibilities for multiple Enceladus flybys at high inclination, with additional flybys of other Saturnian satellites. It is also possible with current trajectory techniques to orbit two or more moons in one mission, for example Titan and Enceladus. Mission architectures coming out of RMA studies require Titan aerogravity assists (with a heat shield), most launching on Delta IV Heavy vehicles.

Every 19 years (next opportunity in 2018-2019), a Jupiter flyby is available to reduce total mission duration by 2-3 years. Based on available trajectories, the baseline low-cost mission has a duration of about 14 years, or a higher cost mission with proper timing could be as short as ten years. Strange's group at JPL recommends specific funding for development of novel astrodynamic techniques used for finding viable outer Solar System trajectories.

Panel members commented that the studies for the TandEM mission concept had looked at Enceladus in a different way from TSSM, and could be useful for future Enceladus mission studies. It was noted that a Saturn ring sample return mission has also been studied by the astrodynamics group and is possible. Titan atmospheric haze sample return has also been studied, and the spacecraft can safely go down to an altitude of about 800 km. A low cost Enceladus orbiter mission is also possible, but increases the mission duration due to the higher number of damping orbits, which may offset the mass cost savings.

Enceladus Flagship Study
John Spencer, Southwest Research Institute

A summary of the flagship study was presented, emphasizing the scientific merit of a dedicated large scale mission to Enceladus. One of the most compelling reasons to go to Enceladus is that it may represent the most likely place beyond Earth to directly sample a demonstrably habitable environment. Enceladus also sheds light on all icy satellites, being both typical and atypical in many respects. Dr. Spencer outlined the driving post-Cassini scientific questions: 1) Where is the liquid water and how long has it been there? 2) What is the chemistry of the active region? 3) What is the surface and interior composition? 4) What is the nature of the observed activity? 5) How does Enceladus interact with the Saturn system? For example, Enceladus floods the system with neutral ions, damping down the Saturnian magnetic field. A full traceability matrix was generated for the high level science requirements of an Enceladus flagship mission, and is included in the study report.

While Cassini gathered a lot of information about Enceladus, it was not optimized for this, and a future mission would focus on subsurface sounding, plume particle imaging, high resolution mass spectrometry, tidal flexing measurements, and wide-angle imaging with high resolution at close range. Several different mission architectures were studied, including a Saturn orbiter with Enceladus soft lander, or an Enceladus orbiter and hard or soft lander. Unfortunately, polar orbits are only stable for several days, so an orbiter would need to start equatorial and then move to polar plume sampling orbits. Most architectures result in very long (> 15 yr) missions, which is greater than the RPS lifetime, making the baseline mission design not feasible. Panel members noted that cryogenic cooling of the power supply may increase lifetime; this is worth looking into.

Reducing the Challenges Posed by Titan Missions
Kim Reh/John Elliott, Jet Propulsion Laboratory

Titan is a high exploration priority due to its wealth of organics, liquid bodies, channels, and thick atmosphere. Many Titan mission studies have been performed, and most use an orbiter/lander or orbiter/balloon as key elements. Joint NASA-ESA studies focused on a joint mission to Titan and Enceladus, and this resulted in TSSM. The baseline mission has a 2020 launch date, utilizes solar electric propulsion for a nine-year cruise, and a montgolfiere (balloon) or lander released on the first Titan flyby. A two-year Saturn tour includes sampling of the Enceladus plume and Titan haze, before going into Titan orbit. The montgolfiere uses an MMRTG power source, floats at 10 km altitude, with vertical position control only. The prime balloon mission is six months, allowing about two full revolutions around the Titan globe.

Panel members asked whether lander designs besides a lake lander (for example, a dunes lander) had been considered in detail. More study is needed on a dunes lander concept, but NASA and CNES are discussing a joint risk reduction effort directed toward a Titan montgolfiere/aerobot. Fluid dynamics simulations for a Titan balloon are ongoing at CNES and Caltech. Weather on Titan is not expected to be severe enough to be a problem for a balloon, particularly in the tropics.

A risk reduction approach will be implemented with input from both the OPAG Titan Working Group and the Decadal Survey, including comprehensive risk assessment for all viable mission architectures. A separately funded in-depth study of the montgolfiere mission architectures should be funded, since this is the highest-risk component. Panel members asked what it would take to move this mission from the "risky" category to the "technically challenging" category, and were told that deployment and inflation are the most difficult aspects and tests should be done. Addition of active control to the balloon would introduce additional risk, but this is not part of the current plan. Many panel members suggested that recent Titan science from Cassini should inform the mission studies to a great extent; for example, it was generally agreed that a lake lander would generate greater science return relative to the risks than a balloon. A total of $71M has been requested from NASA and CNES for Titan instrument development and risk assessment, and a decision should be forthcoming this winter. There was general consensus that Titan studies ought to be well-funded now, as was done for Europa last decade.

The DSN: Current and Future Capabilities
Barry Geldzahler, JPL

The Deep Space Network (DSN) currently operates in X band (8.4 GHz) for both uplink and downlink to spacecraft, but will soon (approximately 2016) switch to Ka band (33 GHz) to increase bandwidth and avoid the crowding due to communication with multiple spacecraft in X band. Possible modifications on the ground and on spacecraft could allow increase from 6 Mbps to 100 Mbps downlink by 2012: 1) DSN arraying, 2) advanced data compression, 3) increased spacecraft antenna power, 4) larger spacecraft antennas, 5) Ka band deployment on all assets. Not all of these upgrades are currently planned, but switch to Ka band will increase data rate by at least a factor of four. By using both left- and right-circular polarized antennas on spacecraft, transmission throughput is increased by a factor of two.

Panel members asked what the major drawbacks to Ka band are, and were told that weather may disrupt downlink, and a larger region near the horizon is blocked by atmospheric attenuation. The panel asked for numbers on the expected frequency of data loss, but no numbers are currently available. Several possible sites for future antennas are optimal for Ka band: Alice Springs (Australia), White Sands (U.S.), and most of South Africa are good examples. However, no plans currently exist for construction of new antennas or arrays. The presenter noted that all of the current DSN dishes are fitted with S band, which all spacecraft also use, in case of a problem with X or Ka band.

The Panel agreed that communication with NASA administrators is crucial to ensuring that nothing is done to derail the current DSN capabilities. Panel members were assured that there is no reason to worry that current capability will be diminished, and data rates will almost certainly increase. Some suggested that quantitative knowledge of future capabilities could inform mission design, for example, higher data rates could allow higher resolution cameras for EJSM, but less frequent downlink would also modify observation planning.

Uranian Satellite Science
Elizabeth Turtle, Applied Physics Laboratory, Johns Hopkins University

Uranus and its diverse satellites are often overlooked in favor of the Neptune system in planning NASA's exploration strategy, in spite of their relative obscurity and potential to shed light on the broad goals discussed by this panel for outer Solar System satellite science. Dr. Turtle presented data and images from Voyager showing interesting geologic features on many of the Uranian satellites, including evidence for compressional tectonics on Titania, extensional tectonics and possible cryovolcanism on Umbriel, degraded craters and multi-stage tectonism on Ariel, and coronae and degraded craters on Miranda. Some panel members questioned the reliability of geologic interpretations based on such low-resolution data, but agreed that the satellites are tantalizing nonetheless. More detailed study of the Uranian satellites can shed light on major questions in planetary science, for example, as a data point at 19 AU on the abundance of organic molecules. Possible cryovolcanic flows may be the best examples in the Solar System, but higher resolution imaging is needed. The nearly 90-degree obliquity of Uranus means that only a portion of the satellite surfaces are visible during summer or winter; northern summer is 2028, and equinox – the best time to go – is in 2049. The panel discussed the possible constraints on Solar System formation and evolution that a Uranus mission might provide, and it was pointed out that the Uranian satellites might themselves be a product of the giant impact event that knocked Uranus on its side.

The remainder of the meeting was held in closed session.

Tuesday, September 22, 2009

Jupiter Ganymede Orbiter
Michel Blanc, Ecole Polytechnique, France

The ESA component of the putative Europa Jupiter System Mission is called the Jupiter Ganymede Orbiter, and is competing for selection with two other L-class missions within ESA. Dr. Blanc described the science goals of both EJSM and JGO, and placed JGO in the context of the larger mission in relation to the Jupiter Europa Orbiter (JEO), which is NASA's contribution. The JGO mission will build on the success of Galileo and perform an in-depth study of Callisto (multiple flybys) and Ganymede (many orbits). Ganymede is characterized as Europa's "false twin", potentially harboring a subsurface ocean. JGO's science goals for Ganymede include characterization of the ocean, ice shell, deep interior structure, dynamo, magnetic field (and possible dynamo), surface-exosphere-magnetosphere coupling, surface composition and chemistry, surface geology, and thermal-orbital evolution, coupled to geology. Callisto is characterized as a "witness of the early ages" of the Solar System, with an extensive cratering record and surface degradation. Studying Jupiter's atmospheric structure and dynamics, as well as the Jovian magnetic field, is another primary science goal for the mission. Synergistic science between the two spacecraft, including simultaneous magnetic field measurements at two locations, will enable a new level of Jovian system science.

EJSM Jupiter Ganymede Orbiter (JGO) Mission Overview Model Payload
Jean-Pierre Lebreton

The Jupiter Ganymede Orbiter mission architecture has been studied extensively, and the payload is fairly well defined, based on the science requirements driving EJSM and JGO specifically. Unlike JEO, JGO uses an aluminum radiation shield, which allows only ~85 krad through. The model payload has 11 instruments, as determined by ESA Phase 0/A study, with goal of addressing science requirements within power and mass limits. Though the payload does not include a thermal infrared instrument, JGO has a stronger focus on space physics processes than JEO. Ongoing work, mainly in the UK, is studying the feasibility of penetrator (hard lander) systems for both Europa and Ganymede. An Announcement of Opportunity (AO) will be coordinated with that of NASA in early 2011. Panel members worried that the AO will come after the Decadal Survey is already written, so contingencies should be addressed for the event that JGO is not selected. Dr. Lebreton expressed confidence that JGO will be selected by ESA.

CNES's Titan Montgolfiere Studies
Andre Vargas, CNES

Stratospheric balloon launches have become routine at the balloon department of the French space agency CNES, where they have over 40 years of experience in development, construction and operation of stratospheric balloon missions. Dr. Vargas gave an overview of the types of balloons in use and capabilities for R&D toward a Titan balloon at CNES. They also do computer simulation of dynamics and thermal properties, which have been applied to Titan. Venera was a Russian-French collaboration for a Venus super-pressure balloon in the 1980's, experience directly applicable to the Titan problem. A preliminary design for a Titan montgolfiere includes deployment at 40 km altitude at a velocity of 5 m/s, followed by a 10-hour descent to 10 km altitude, with a six month nominal mission. Balloon design challenges include material strength at low 80-90 K temperatures, thermal shock on deployment, and thermal effects of the MMRTG power source. Collaboration with JPL on computer simulation, but lack of a full-scale Titan test chamber presents a challenge for validating materials.

Panel members requested information on funding levels for balloon development at CNES, and were told that the group has about $3M for the full study, titled “Balloon Design Issue Assessment,” through 2013. Other panel members wondered whether a balloon has ever been deployed in mid-air, and were told that no civilian tests have been done, but the U.S. military may have performed many such tests.

Reducing Challenges Posed by a Europa Mission
Karla Clark/Rob Lock, JPL

As the NASA component of EJSM, a detailed mission design has been developed for the Jupiter-Europa Orbiter (JEO). The group from JPL presented the basic design and the present state of risk assessment and mitigation studies. A primary concern is the intense radiation environment likely to be encountered, particularly in Europa orbit. Like JGO, the strawman payload includes 11 instruments including radioscience, but is powered by MMRTGs or ASRGs instead of solar panels. Due to mass requirements, JEO will not use shielding, so only radiation-hard parts capable of tolerating radiation levels about seven times that of Galileo will be used. A great deal of work in testing parts for radiation-hardness has been completed, and more testing is underway. The design of the spacecraft depends not only on the science goals of the mission, but also the radiation environment. Mission risk assessment is being performed according to NASA standards, including radiation effects, internal charging, instrument development, planetary protection, operational complexity, radioisotope power sources, and mission lifetime. The radiation risk mitigation plan is constantly updated in response to peer reviews and input from the science community, and an external advisory board reports to the project management. Extra costs for radiation-hard instruments and re-designs must be included in mission cost assessments.

Panel members were told that about 200 radiation-hard parts have been approved and added to the Approved Parts and Materials List (APML), and an ITAR-restricted list is available. Some Panel members expressed concern that radiation levels could be higher than expected, but were assured that all parts are tested to failure or about seven times the expected levels, whichever comes first. Concern about the radiation tolerance of detectors and sensors was expressed, since these are the main concern for the potential science return. At this stage, little testing of detectors has been done, because no advantage should be given to any one detector design. This year’s EJSM Instrument Workshop was an opportunity for instrument providers to learn about the Europa radiation environment and advertise their instruments; all of this information is now on the web: http:// www.opfm.jpl.nasa.gov. There are expected to be at least two more workshops (one in the U.S. and one in Europe), and input is being solicited on their focus.

Panel members asked how well the true Jovian environment is simulated, and whether or not help can be offered to instrument proposers with testing. The JPL group can simulate the Jovian radiation environment, but not for specific ions, if needed. The Panel wanted assurance that JEO would not run into a situation similar to the Mars Science Laboratory (MSL), in which difficult issues were not addressed on an appropriate time scale; assurance was given that the time line in place will address the radiation hazards and find appropriate solutions in time. Questions were raised regarding the downlink requirements and DSN loading for the nominal mission, and the possibility of more data-rich operational modes was raised, including increased areal coverage.