International Planetary Probe Workshop Report
Contributed by
David Atkinson, Sushil Atreya, James Cutts, Elizabeth Kolawa, Ralph Lorenz

The Fourth International Planetary Probe Workshop was held in Pasadena, California on 19-23 June 2006. The Workshop was preceded by a two day short course on "In Situ Instruments for Planetary Probes and Aerial Platforms". The short course attracted 60 registrations of which 21 were students (6 from Europe), and the workshop was attended by 188 participants, including 42 students (10 from Europe) and 146 regular registrants (30 from Europe). Further details on the workshop objectives and agenda can be viewed at http://ippw.jpl.nasa.gov.

The workshop focused on science missions involving entry, descent and flight in planetary atmospheres. The plenary talks included an address by Jonathan Lunine (Universtiy of Arizona) on NASA's Solar System Exploration Roadmap and by Gerhard Schwehm(ESA-ESTEC) on ESA's Cosmic Vision. Scott Hubbard former Director of Ames Research Center and now at the SETI institute discussed the future of robotic exploration.

Key discussions at the workshop centered on the current U.S. and European Outlook for probe missions, scientific results, , mission concepts and studies, and advanced technologies. Technology sessions focused on entry, descent, and mobility systems, sensors, instruments, thermal control and pressure vessels, and emerging technologies in electronics, communications, and batteries in extreme environments. Discussions covered missions to Giant Planets, Titan, Venus and Mars. For the OPAG audience our focus is primarily on the topics of the Giant Planets and Titan.

Giant Planets The outer planets discussions focused on several key topics, including the scientific justification for probe missions to the giant planets, possible architectures for a Saturn multiprobe mission, the status of key enabling technologies, the value of an integrated systems approach, and potential areas of international collaboration.

To fully constrain origin and evolutionary models of the solar system, it is imperative that comparative planetology studies of the gas and ice giants be conducted. Fundamental questions addressing the formation of the giant planets and the origin of their atmospheres requires that abundances of the heavy element be determined. And, with the exception of carbon in the form of CH_4, this can only be done *in situ* with entry probes at all four of the giant planets. In the near term (5-7 years) the highest priority is given to a Saturn mission comprising a flyby spacecraft, multiple shallow entry probes, and microwave radiometry (MWR). Recent studies indicate that a Saturn flyby/multiprobe mission can be completed under the New Frontiers ($700 million) cost cap.

For the longer term and to continue the philosophy of comparative planetology studies of the outer solar system, Flagship class ($1 billion plus) missions to the ice giants are required. Specifically, the value of a Neptune polar orbiter with probes, with the option of a Triton lander, and a Uranus orbiter with probes was emphasized.

Other discussions focused on Direct-to-Earth (DTE) mission designs, and this was found to be a mission architecture with benefits that are more than offset by high risk and mission complexity. The potential loss of data at the Earth due to single point failures of the Earth receiving systems represents a risk that is impossible to accept. However, to enhance measurements of atmospheric dynamics, DTE techniques have proven to be of significant value when included as communications link that is complementary to a primary probe/carrier link, and in some special cases can represent a redundant telemetry channel.

Titan Exploration: The spectacular imagery of the surface of Titan from both Huygens descent imager and the Cassini radar is motivating an intense interest in future missions to Titan. The Solar System Strategic Roadmap has identified a Titan Explorer mission as the second Flagship mission after Europa Explorer. Several papers included concepts for using lighter-then-air vehicles – one including an extremely long lived Montgolfiere balloon which would fly at airplane altitudes and make repeated descents to the surface. A key issue is whether altitude control is sufficient to meet the goals of future missions or whether lateral mobility will be required. Both types of concepts were presented in the technical sessions.

Other discussions focused on key technologies required, including extreme environment systems and sensors, balloon materials, telecommunications, and system autonomy. Aerial deployment is a potential challenge for the blimp architecture and alternative approaches for reliable deployment were presented.

As with the Saturn probe, Direct to Earth communication is being considered. The great advantage for the Titan Aerial platform is that it can a deploy a large steerable antenna which can provide much higher data rates than for a probe. The aerial platform also operates for months or years as opposed to hours and so the risk from temporary communications interruptions because of equipment failure or weather is much less serious.

International Collaborations Based on the highly successful joint European-U.S. Cassini/Huygens mission, the value of international collaboration on future mission design and implementation, as well as technology development was emphasized. However, ITAR rules make future collaborations highly challenging. A "clean interface" approach may still be possible, for example in the area of solar panels, communication hardware, star trackers, etc. To meet proposal and schedule timelines, such collaborations must be defined and implemented very efficiently and very early in a flight or technology program.

Technologies A number of key technologies for atmospheric probes were highlighted at the workshop, including novel and emerging instrument design, sensor technologies, advanced thermal control and pressure vessels, electronics, power sources and energy storage, and descent and landing technologies. The scope of the workshop was extended to include technologies required for atmospheric mobility systems. The general consensus from the community was the need for new technology developments in order to enable future probe missions. Specific areas identified as high priority for development include:

- Extreme environment system development, including development of test-bed facilities where future flight system components can be tested in realistic planetary environments that they will be exposed to during missions;
- Miniaturization of instrument systems and integration of emerging sensor technologies;
- Sample acquisition systems able to reliably operate in diverse, extreme environments;
- Lightweight, long life pressure vessels and advanced thermal control, including active, for long duration Venus missions;
- High temperature electronics, especially for communication and power systems;
- Autonomous operation of aerial mobility systems;
- Low altitude Venus aerial system;
- Entry probe thermal protection system development and characterization.

Of particular note, except for Saturn probes for which sufficient TPS material remains from the Galileo probe, future outer planet probe missions require that the Giant Planet Facility be reactivated for TPS material testing and characterization.

For all probe missions, more efficient utilization of system resources, minimization of system complexity, and improvement of overall performance and capability strongly suggests that maximally integrated payload system architectures be utilized. There are presently limits to such designs, so early investment in technology development is essential.