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To Kyoto Research Park

In Kyoto Research Park

Conference Program

October 11 (Tuesday)

	Room A	Room B
9:30		
10:00		
11:00	**Opening Ceremony** **Session 1A** Missions in Operation (Part 1)	
12:00		
13:00	**Special Invited Talk (Part 1)**	
14:00	**Session 2A** Missions in Operation (Part 2)	
15:00	**Session 3A** Planetary Mission Studies	**Session 3B** Science Instruments
16:00	**Session 4A** Missions to Asteroids	**Session 4B** Spacecraft Subsystems
17:00		
18:00		

October 12 (Wednesday)

	Room A	Room B
9:30	**Session 5A** Robotic Missions	**Session 5B** Plasmaphysics around Terrestrial Planets
10:00		
11:00	**Session 6A** Interplanetary Missions	**Session 6B** MRO Operation & Data Return
12:00		
13:00	**Special Invited Talk (Part 2)**	
14:00	**Session 7A** Missions in Ready	
15:00		
16:00	**Session 8A** Management Approach	**Session 8B** Plasmaphysics in Jovian System
17:00	**Session 9A** Advanced Propulsion System	**Session 9B** Planetary Atmosphere
18:00	**Banquet** at Kyoto Research Park, Atrium	

October 13 (Thursday)

	Room A	Room B
9:30	**Session 10A** Infrastructures for Planetary Mission	**Session 10B** Interior Explorations
10:00		
11:00	**Session 11A** Experiences & Lessons Learned	**Session 11B** Mission Analysis Low Thrust Trajectory Planning
12:00		
13:00		
14:00	**Discussions**	
15:00		

Get Together Party
October 10 (Monday) 18:00 - 20:00
at Kyoto Tokyu Hotel 2F, Room *"Miyabi"*

October 11 (Tuesday)

Room A

Opening Ceremony 10:00 — 10:50

Session 1A 11:00 — 12:00
Missions in Operation (Part 1)

Hayabusa (MUSES-C) Rendezvous with Itokawa and Proximity Operation Status
J. Kawaguchi (ISAS/JAXA), et al.

Space Maneuver of Microwave Discharge Ion Engines onboard HAYABUSA
H. Kuninaka (ISAS/JAXA), et al.

SMART-1 Lunar Mission: Reducing Mission Operations Costs
J. de Bruin (VEGA GmbH), et al.

Special Invited Talk (Part 1) 13:00 — 13:30

Low-Cost Small-Body Missions: A Personal History
R. W. Farquhar (JHU/APL)

Session 2A 13:40 — 14:40
Missions in Operation (Part 2)

The Stardust Sample Return Mission from Comet Wild2 and the Intersteller Dust Stream: Problems and Lessons Learned
M. E. Zolensky (NASA/JSC)

MESSENGER: A Discovery Mission to Mercury
R. E. Gold (JHU/APL), et al.

Deep Impact: A Simple but Important Experiment **(Invited Talk)**
M. F. A'Hearn (Univ. of Maryland), et al.

Session 3A 14:50 — 15:50
Planetary Mission Studies

ESA Planetary and Solar-Terrestrial Technology Reference Studies
P. Falkner (ESA/ESTEC), et al.

The ESA Jovian Minisat Explorer Technology Reference Study
A. C. Atzei (ESA/ESTEC), et al.

Mission Trade-Offs for an 'Entry-Level' Mars Orbiter and Entry Probe
A. Phipps (SSTL), et al.

Session 4A 16:00 — 17:40
Missions to Asteroids

Study of Post-Hayabusa Sample Return Mission to Primitive Type Asteroids
A. Fujiwara (ISAS/JAXA), et al.

Missions to Binary Asteroids: Trajectory Design, Navigation and Science
D.J. Scheeres (Univ. of Michigan), et al.

Mission Concept of Multiple Near Earth Asteroids Exploration by Miniature Asteroid Interceptors
Y. Kawakatsu (JAXA/ISAS), et al.

Bering – a Deep Space Mission to Study the Origin and Evolution of the Asteroid Main Belt
P. R. Bidstrup (Univ. of Copenhagen), et al.

The Mission Concept of the Small Autonomous Asteroid Explorer "Bering"
John Leif Jørgensen (Technical University of Denmark), et al.

Room B

Session 3B 14:50 — 15:50
Science Instruments

Science from Small Sensors : A Philosophy for Parasitic Instruments and Science from Engineering Data
R. D. Lorenz (Univ. of Arizona)

Low cost, Miniature, Fiber-based Spectrometers for Planetary Surface, Subsurface and Atmospheric Investigations
J. Kang (JHU), et al.

Laser-based Mass Spectrometry for in situ Astrobiology
W. B. Brinckerhoff (JHU/APL), et al.

Session 4B 16:00 — 17:00
Spacecraft Subsystems

Autonomous Guidance & Control for Low-Cost Deep Space Probes
J. van der Ha (Consultant), et al.

Development of Monolithic Ceramic Thruster for Interplanetary Exploration
K. T. Uesugi (ISAS/JAXA), et al.

Numerical Simulation of Film-Cooled Bipropellant Thruster Performances
K. Ohminami (Sokendai Univ./ISAS), et al.

October 12 (Wednesday)

Room A

Session 5A 9:30 — 10:50
Robotic Missions

Lunar Robotics Exploration by Cooperation with Lander and Microrovers
T. Kubota (ISAS/JAXA), et al.

Tiny Rover Missions for Small Body Explorations
T. Yoshimitsu (ISAS/JAXA), et al.

The System and Integrated Guidance and Navigation Strategy of Asteroid Interceptors
O. Mori (ISAS/JAXA), et al.

An Efficient Autonomous Flying Robot for Mars Exploration
G.Savu (National Institute of Turbomachinery - COMOTI)

Session 6A 11:00 — 11:40
Interplanetary Missions

Observations of Zodiacal Light During the Cruising Phase of PLANET-C/VCO Mission
M. Ueno (Univ. of Tokyo), et al.

ASTROD I: A Single-Spacecraft Deep-Space Laser Ranging Mission
W. T. Ni (Purple Mountain Observatory, CAS), et al.

Special Invited Talk (Part 2) 13:00 —13:30

From Rosetta to BepiColombo
R. Schulz (ESA/ESTEC)

Session 7A 13:40 — 15:20
Missions in Ready

BepiColombo Goes to Mercury
R. Schulz (ESA/ESTEC), et al.

BepiColombo Mercury Magnetospheric Orbiter
H. Yamakawa (ISAS/JAXA), et al.

Dawn Discovery Mission: Status Report **(Invited Talk)**
C. T. Russell (UCLA), et al.

PLANET-C/Venus Climate Orbiter of Japan
T. Imamura (ISAS/JAXA), et al.

Global Mapping of Lunar Gravity Field using SELENE Two Small Satellites
T. Iwata (ISAS/JAXA), et al.

Session 8A 15:30 — 16:30
Management Approach

Cost Modeling for Low-Cost Planetary Mission
E. Kwan (JPL/Caltech), et al.

A Quantitative Assessment of Complexity, Cost, and Schedule: Achieving a Balanced Approach for Program Success
R. E. Bitten (The Aerospace Corp.), et al.

Determining When a Mission is "Outside the Box": Guidelines for a Cost-Constrained Environment
R. E. Bitten (The Aerospace Corp.)

Session 9A 16:40 — 17:40
Advanced Propulsion System

A PARIS Mission to the Jovian Trojan Asteroids
R. E. Gold (JHU/APL), et al.

MOSS - The Mission to the Outer Solar System
B. J. Kellett (SSTD/RAL), et al.

Magnetoplasma Sailing: Missions and Technology Requirements
H. Yamakawa (ISAS/JAXA), et al.

Room B

Session 5B 9:30 — 10:50
Plasmaphysics around Terrestrial Planets

ERG Satellite Mission to Study Formation of the Radiation Belts
T. Ono (Tohoku Univ.), et al.

Mission Design of SCOPE –Small Satellites Formation Flying Mission for Magnetospheric Tail Observation–
Y. Tsuda (ISAS/JAXA), et al.

Mars Orbiting Plasma Surveyor (MOPS)
S. Barabash (Swedish Institute of Space Physics), et al.

Magnetic Field Investigation and Development of Magnetometers in Japan for Planetary Missions
A. Matsuoka (JAXA/ISAS), et al.

Session 6B 11:00 — 11:40
MRO Operation & Data Return

The Mar Reconnaissance Orbiter Mission Operations: Architecture and Approach
B. Jai (JPL/Caltech), et al.

Response to Mars Reconnaissance Orbiter's end-to-end Data Accountability Challenges
Y. Lee (NASA/JPL), et al.

Session 8B 15:30 — 16:30
Plasmaphysics in Jovian System

Small Jovian Orbiter for Magnetospheric & Auroral Studies
Y. Kasaba (ISAS/JAXA), et al.

Electric Field Diagnostics in the Jovian System: Brief Science Case and Instrumentation Overview
L. G. Blomberg (Alfvén Lab. RIT), et al.

Cold Plasma Diagnostics in the Jovian System: Brief Science Case and Instrumentation Overview
J. E. Wahlund (Swedish Institute of Space Physics), et al.

Session 9B 16:40 — 17:40
Planetary Atmosphere

Probing Venus Atmosphere with Scientific Instruments onboard the Venus Climate Orbiter of Japan
T. Satoh (Kumamoto Univ.), et al.

Mission and System Design of a Venus Entry Probe and Aerobot
A. Phipps (SSTL), et al.

TOPS: Telescope Observatory for Planets on a Small-satellite
K. Yoshida (Tohoku Univ.), et al.

October 13 (Thursday)

Room A

Session 10A 9:30 － 10:50
Infrastructures for Planetary Missions

A Communication Hub in Lagrange L1 for Opening the Area to Small Satellites
J. Y. Prado (CNES), et al.

Deep Space Quay and Solar Voyage Era
M. Matsumoto (Univ. of Tokyo), et al.

Jovian Outpost Establishment and Operation "Conventional Propulsion Assessment"
R. E. Poetro (Kyusyu Univ.), et al.

Low-Cost Moon Mission Spacecraft Technology
Y. V. Protsan (Yuzhnoye State Design Office), et al.

Session 11A 11:00 －12:20
Experiences & Lessons Learned

PHILAE / ROSETTA LANDER: A New Strategy to Realize Space Systems
S. Ulamec (DLR), et al.

Feedback from Mars Express Lesson Learned on the Venus Express Verification Approach
P. Giordano (ALCATEL ALENIA Space), et al.

Dawn Discovery Mission: Lessons Learned **(Invited Talk)**
T. C. Fraschetti (NASA/JPL), et al.

Low Cost Spacecraft Design Approach for Planetary Missions
K. Kitade (NEC TOSHIBA Space Systems, Ltd.), et al.

13:30 －14:30

Discussion

Room B

Session 10B 9:30 － 10:30
Interior Explorations

Penetration Characteristics of Planetary Penetrator
H. Shiraishi (ISAS/JAXA), et al.

Seismometer Design and its Characteristics onboard LUNAR-A Penetrator
R. Yamada (ISAS/JAXA), et al.

Asteroid Exploration with Pods
E. Asphaug (Univ. of California, Santa Cruz), et al.

Session 11B 11:00 －12:00
Mission Analysis - Low Thrust Trajectory Planning -

On Low Thrust Orbit Control Strategy for Spacecrafts around the Collinear Libration Points
X. Hou (Nanjing Univ.), et al.

Preliminary Analysis of Low Energy Interplanetary Transfer
M. Nakamiya (Sokendai Univ./JAXA), et al.

Use of Solar Sails with Controllable Solar Radiation Pressure for Libration Point Orbits
D. Novikov (IKI), et al.

October 11 (Tuesday) 11:00 – 12:00
Room A

Session 1A Mission in Operation (Part 1)

Kuninori Uesugi (JAXA/ISAS) and Gregg Vane (NASA/JPL)

Hayabusa (MUSES-C) Rendezvous with Itokawa and Proximity Operation Status

J. Kawaguchi, A. Fujiwara, and T. Uesugi (ISAS/JAXA)

Hayabusa, a world's first sample & return attempt to/from an asteroid arrived at the target Itokawa on September 12th, 2005. This is one of the biggest milestones in the mission, while the final destination of the mission is Earth. This success is the first slow speed rendezvous via electric propulsion and demonstrated the Japan's technology in this field, enabling the future versatile types of solar system exploration missions. Hayabusa started its proximity operation including visible, near-infra-red and X-ray spectroscopy observation. This paper, at the same time, shows how the slow-speed rendezvous was accomplished with the optical navigation

Space Maneuver of Microwave Discharge Ion Engines onboard HAYABUSA

H. Kuninaka and J. Kawaguchi (ISAS/JAXA)

Four units of the microwave discharge ion engine "μ10", which generates 8mN thrust and 3,200sec specific impulse with 350W electric power, are dedicated to the main propulsion on the "HAYABUSA" asteroid explorer. The spacecraft was input in the deep space by M-V rocket on May 2003. After vacuum exposure and several runs of baking for reduction of residual gas the ion engine system established continuous acceleration supported by the attitude control system, the power management system, the autonomous control, and so on. New orbit change scheme delta-V Earth Gravity Assist using the electric propulsion was applied to transfer to the asteroid. On September 2005 HAYABUSA succeeded to rendezvous with the asteroid ITOKAWA. During two-year flight the ion engine system generated 1,400m/s delta-V consuming 22kg xenon propellant and achieved the total numbers of space operational time 25,800 hours.

SMART-1 Lunar Mission: Reducing Mission Operations Costs

J. de Bruin (VEGA GmbH), O. Camino-Ramos, D. Milligan(ESA/ESOC), M. Alonso, R. Blake(Science Systems GmbH), D. Gestal, and S. Ricken (LSE Space AG,)

SMART-1 is the first of the European Space Agency's Small Missions for Advanced Research in Technology. The primary mission goal is to demonstrate Solar Electric Primary Propulsion by orbit raising from geostationary transfer orbit to the Moon. SMART-1 was launched in September 2003, as an auxiliary passenger on Ariane 5. After separation from the launch vehicle, the European Space Operations Centre assumed control of the spacecraft, preparing, then initiating, the orbit raising phase. The orbit raising phase has led SMART-1 through the Van Allen radiation belts and a number of Moon resonances to perhaps the most critical phase of the mission, Moon capture. In November 2004 SMART-1 successfully maneuvered into Moon orbit, a major milestone in the mission. At present SMART-1 is in its operational orbit performing scientific operations. Scientific operations will be interrupted only by a one-month reboost phase in September 2005 to optimise the lunar orbit for the mission extension until July 2006. The paper/presentation will present a summary of the operational experience to date, with particular emphasis on how innovative technology has impacted the complexity of Ground operations and on how Ground operations have been organized to minimize cost.

October 11 (Tuesday) 13:00 – 13:30
Room A

Special Invited Talk (Part 1)

Kuninori Uesugi (JAXA/ISAS) and Gregg Vane (NASA/JPL)

Low-Cost Small-Body Missions: A Personal History

Robert W. Farquhar

The evolution of low-cost small-body missions is described from the viewpoint of someone who was closely involved in developing these missions beginning in 1972. The first successful mission of this class was a flyby of comet Giacobini−Zinner that was carried out in 1985 by a spacecraft called International Cometary Explorer (ICE). In 1989−90, the author formed a new NASA program of low-cost planetary missions called "Discovery." Later, while at The Johns Hopkins University Applied Physics Laboratory, the author served as the Mission Director for two Discovery missions, the Near-Earth Asteroid Rendezvous (NEAR) and the Comet Nucleus Tour (CONTOUR). The author's connection with low-cost comet sample-return missions is also discussed.

October 11 (Tuesday) 13:40 – 14:40
Room A

Session 2A Missions in Operation (Part 2)

Kuninori Uesugi (JAXA/ISAS) and Gregg Vane (NASA/JPL)

The Stardust Sample Return Mission from Comet Wild2 and the Intersteller Dust Stream: Problems and Lessons Learned

M. E. Zolensky (NASA/JSC)

Sample return missions are essential to planetary scientists, permitting reproducible, state-of-the-art analytical techniques to be applied to samples, and for future investigations to made on carefully curated material. As the first sample return mission to be launched in three decades, the Stardust Mission is a template for future missions to small bodies. On January 2, 2004, after 5 years in space, the Stardust spacecraft completed a close flyby of comet Wild2 (P81). Flying at a relative speed of 6.1 km/s within 236km of the nucleus, the spacecraft took 72 close-in images, measured the flux of impacting particles, did in-situ compositional analysis of freshly released dust with a time-of-flight mass spectrometer, and collected thousands of coma grains. The flyby was a great success not only in collecting particles from a dangerous environment but also in providing a wealth of information on the comet itself. Images taken during the encounter showed that the 4.5km hamburger-shaped body had surface features unlike those seen on any other solar system body, including 100m tall pinnacles, flat topped mesas, sink hole like depressions with flat floors bounded by vertical cliffs, and crater-like depressions surrounded by mysterious halos. Landslides and normal faults were evidence of a hard crust and mass wasting. The comet surface was dramatically different from typical old cratered surfaces, and the high vertical slopes and even overhanging cliffs indicate that the comet surface has significant strength, and is not the rubble pile of loose material that many had predicted. The comet surface was ejecting dust and gas into space in the form dozens of small active regions, not the single jet that was expected. Efforts have now turned to the recovery of the sample return capsule, which will perform a direct entry of Earth's atmosphere the morning of January 15, 2006. The primary goal of the mission is to collect >500 particles >15μm diameter from the comet. A secondary goal is the collection of interstellar grains streaming through our solar system. All of these particles, ranging in size from under a micron to ~100 microns, were collected in low density silica aerogel. The returned samples will be processed at the curatorial facility at the NASA Johnson Space Center and 5 to 100 micron size extracted cometary particles will be distributed to analysts worldwide following a 9-month period of preliminary sample examination. In the course of this mission, the first sample return mission in 30 years, we have had to reinvent critical aspects of robotic sample return, including spacecraft contamination control, sample recovery procedures, sample preliminary examination, and sample curation for future generations of planetary scientists. We have compiled a list of lessons learned from the Stardust Mission which will be useful to future missions to small bodies.

MESSENGER: A Discovery Mission to Mercury

R. E. Gold (JHU/APL), S. C. Solomon(Carnegie Institution of Washington), R. L. McNutt Jr., J. C. Leary, and D. G. Grant(JHU/APL)

NASA's MErcury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER) spacecraft, was launched on 3 August 2004. The mission is designed to answer six fundamental questions about Mercury that are pertinent as well to our general understanding of terrestrial planets. During the 6.6-year cruise phase, MESSENGER will fly by Earth, Venus, and Mercury. Calibration measurements of the Earth and Moon were made during an Earth flyby, one year after launch. The three Mercury flybys in 2008 and 2009 slow the spacecraft sufficiently for Mercury orbit injection in March 2011 and permit mapping of 90% of the planet. All of the seven instruments have now been successfully operated in space. The cruise phase has been used to commission the spacecraft and instruments and to begin the transition to automated operations with on-board, time-tagged commands. A one-year-long observational campaign in a near-polar orbit is planned for the Mercury orbital phase. A 12-hour period and 80° inclination are maintained while the periapsis altitude is readjusted to 200 km every Mercury year. This orbit enables mapping of the entire planet and acquiring detailed elemental and topographical data over the northern hemisphere.

Deep Impact: A Simple but Important Experiment (Invited Talk)

M. F. A'Hearn (Univ. of Maryland) and The Deep Impact Team

This paper will summarize the results from the Deep Impact encounter with comet Tempel 1, which will have occurred on 4 July. I will provide an overview of the results and discuss aspects of NASA's Discovery Program that bear on the success of missions like Deep Impact. I will also discuss prospects for an extended mission to another comet.

October 11 (Tuesday) 14:50 – 15:50
Room A

Session 3A Planetary Mission Studies

R. Farquhar (JHU/APL) and H. Yamakawa (JAXA/ISAS)

ESA Planetary and Solar-Terrestrial Technology Reference Studies

P. Falkner, A.C. Atzei, and A. Peacock (ESA/ESTEC)

The Sci-A Office at ESA has introduced Technology Reference Studies (TRS) to provide focus for the development of strategically important technologies of likely relevance to future science missions. Several technologically demanding and scientifically interesting missions are studied. Presently Sci-AP has finished four TRSs: VEP focused on in-situ atmospheric exploration of Venus using an orbiter, a relay satellite, an aerobot and fifteen microprobes. DSR returns of one kilogram surface sample material from the low gravity environment of the Martian moon Deimos. IHP aims to travel to the Heliopause and the interstellar medium at a distance of 200 AU from the Sun within 25 years. JME focused on the exploration of the Jovian system and in particular Europa with one relay spacecraft in a highly elliptical orbit around Jupiter and a circular polar orbiter around Europa, including a feasibility study of the delivery of a microprobe on Europa. Current studies focus on magnetospheric and atmospheric Jovian orbiter(s) and entry probe(s). An additional concept investigates an Earth multi-scale magnetospheric constellation and a last one with a Near Earth Asteroid Sample Return.

The ESA Jovian Minisat Explorer Technology Reference Study

P. Falkner, A.C. Atzei, and A. Peacock (ESA/ESTEC)

ESA's Science Payload & Advanced Concepts Office has started a combination of activities under the name Technology Reference Studies (TRSs). The scope is to identify and develop critical technologies that will be required to enable a low resource approach for future scientific missions. The selected solutions are not only driven by technological drivers: cost is a major player in the low resource approach targeted by the TRSs. The use of medium class launchers such as the Soyuz-Fregat 2-1b is one of these approaches, however it also requires a significant effort in resource reduction in order to enable these concepts. Part of the challenge lies in finding the right balance between the development of enabling low resource technologies and the reuse of existing but often less efficient equipment. The Jupiter Minisat Explorer study provided a list of critical technologies required for the remote sensing of Europa. The next phase has now been initiated, focusing on the exploration of the Jovian atmosphere and magnetosphere: by assessing the feasibility of different configurations (single versus multiple spacecraft and probes in various orbits) additional challenges will be identified. The resulting list of critical technologies will help to prepare a technical roadmap for future mission requirements.

Mission Trade-Offs for an 'Entry-Level' Mars Orbiter and Entry Probe

A. Phipps, J. Clemmet, M. Taylor, D. Gibbon, M. Beard, A. S. Curiel, P. Davies, J. King, J. Ward, M. Sweeting (SSTL), A. Smith, and G. Parnaby (Univ. of Surrey)

ESA has established a European goal through the Aurora programme of meaningful exploration of the Martian surface -based upon static & mobile in-situ analysis (Exo-Mars) and also returning samples from Mars to Earth for first-hand study and analysis (Mars Sample Return). Since the costs associated with such programmes are high, the key technologies, techniques and uncertainties should first be verified on rapid, small-scale and affordable technology missions in order to mitigate risk. With this increased emphasis on Mars missions this paper outlines the lowest 'cost of entry' Mars exploration mission capable of technology demonstration (to enable future missions to focus on increased scientific return). While aiming for a repeatable mission capable of demonstrating broad capability, this concept study focus is on Martian dust storm surveying as the science *reference* case. The mission proposed is compatible with the Aurora programmes' recently cancelled Arrow missions - the industrial cost cap for these missions estimated to be around a modest 100 million Euros. The mission is repeatable in subsequent years, facilitating a programme of exploration mission evolving in capability each time. Non-critical mission-enhancing technologies being 'space proven' on each occasion and once successfully proven become the core platform technology for follow-on mission. This research summarises the mission trade-offs to be made, both for an orbiter and entry probe. It details requirements, the principle design drivers, and outlines a mission design philosophy proven for LEO missions, which could be adopted for mission cost and risk minimisation. It assesses low-cost launch options, the modifications required to currently available platforms and describes the entry probe concept design. This study has identified that the technologies required for the mission already exist, but it details key European mission enhancing technologies.

October 11 (Tuesday) 14:50 – 15:50
Room B

Session 3B Science Instruments

M. Simon (JHU/APL) and Y. Kasaba (JAXA/ISAS)

Science from Small Sensors : A Philosophy for Parasitic Instruments and Science from Engineering Data

R. Lorenz (Univ. of Arizona)

When conducting in-situ exploration of planetary environments, even small, simple science sensors are able to provide important information. Examples of modest yet scientifically important instruments are the Surface Science Package (SSP) on the Huygens probe to Titan, and the payload of the VEGA balloons. Another example is the New Millenium DS-2 Mars Microprobes. Science can be done with engineering telemetry such as solar array currents, temperatures, microphones and accelerometers. I will provide a number of specific examples from Mars and Venus missions, and from Huygens - indicating not only cases where scientific results have been obtained, and cases where arbitrary choices prevented data from being useful. I urge spacecraft projects to be receptive to the inclusion of small sensors and to consider the potential scientific return from engineering data and to make housekeeping data available in science archives.

Low cost, Miniature, Fiber-based Spectrometers for Planetary Surface, Subsurface and Atmospheric Investigations

J. Kang (JHU/APL), Harry Shaw (NASA/GSFC), Lin Pu (Univ. of Virginia), Gang Chen (JHU/APL), Paul Mahaffy (NASA/GSFC), and Jeannette Plante (Dynamic Range Corp.)

Fiber optic and fiber laser technology provide opportunities for substantial miniaturization of spectrometers for planetary microsats, nanosats, and balloon-based exploration initiative. This technology can be combined with advanced packaging techniques to reduce circuitry mass and volume within the constraints of low-cost, low risk planetary instrument development. We will discuss some of our designs for fiber based Raman and Fluorescence spectrometers, the technology capability, and advanced packaging techniques for practical low cost miniaturization. Potential missions utilizing stationary platforms, rover-based platforms and flying platforms will be discussed. The sensitivity and detection levels achievable by these science platforms will be discussed. The science potential for combining the fiber based spectrometers with advanced fluorescence detection chemistries will be discussed with regards to the search of extra-terrestrial biomarkers. Miniaturized spectrometers can also be combined with power search techniques such as genetic search algorithms to permit intelligent remote investigations in real time to maximize productivity in extreme environments or in domains where regular communication with earth ground stations is not possible.

Laser-based Mass Spectrometry for in situ Astrobiology

W. B. Brinckerhoff, C. M. Corrigan, T. J. Cornish, S. A. Ecelberger, and A. L. Ganesan (JHU/APL)

We describe laser desorption mass spectrometry (LDMS) methods and instrumentation for combined inorganic and non-volatile organic chemical analysis on *in situ* astrobiology missions. LDMS operates by desorbing and ionizing atoms and molecules, point-by-point, from an unprepared rock sample, ice, or dust. The ions are detected in a miniature time-of-flight mass spectrometer (TOF-MS). At high laser intensity, molecules are dissociated, permitting a basic geochemical assay of the elemental and isotopic composition, correlated to a microscopic image of the sample. At lower laser intensity, a wide range of organics including those representing fragments of macromolecular organic matter are detected to high mass (~10^3 Da). The fine (50 – 100 μm) scale LDMS spectra can provide mineralogical associations for organics, data which are complementary to those from bulk sample analyses. With carefully tuned TOF-MS ion optics, molecular fragmentation and ionization patterns may be investigated by varying laser intensity.

October 11 (Tuesday) 16:00 – 17:40
Room A

Session 4A Missions to Asteroids

R. Farquhar (JHU/APL) and H. Yamakawa (JAXA/ISAS)

Study of Post-Hayabusa Sample Return Mission to Primitive Type Asteroids

A. Fujiwara, A. Fujiwara, M. Abe, Y. Kawakatsu, O. Mori, H. Yano, T. Yoshimitsu (ISAS/JAXA), H. Demura (Aizu Univ.), T. Noguch (Ibaraki Univ.), and Y. Takagi (Toho-Gakuen Univ.)

A new near-earth asteroid sample return mission is being studied. The mission is the heritage of Hayabusa, which is now being in flight. The target asteroids are supposed to be some of primitive type such as C-type. One of the important scientific objectives is to investigate organic materials contained in the sample obtained from the top surface to the interior of depth a few 10cm as well as to clarify the spectroscopic type and meteorite. Some remote sensing instruments and in situ instruments boarded on the spacecraft and the rover, respectively, are planned for the selection and description. of the sampling sites on the asteroid. Possible mission designs have been made up to now. Laboratory experiments to develop the sampling device is underway.

Missions to Binary Asteroids: Trajectory Design, Navigation and Science

D.J. Scheeres, J. Bellerose, and E. Fahnestock (Univ. of Michigan)

Any mission to an asteroid has a reasonable probability of visiting a binary asteroid system. In fact, it may be desirable to send a spacecraft to a binary asteroid, due to the inherent scientific interest that these objects engender. This paper will discuss the challenges of navigating a spacecraft in the vicinity of a binary asteroid, focusing on the unique aspects that missions to such bodies must face. In addition, we will discuss some of the compelling scientific measurements that can be made in the vicinity of these bodies, making them an attractive target for a future mission.

Mission Concept of Multiple Near Earth Asteroids Exploration by Miniature Asteroid Interceptors

Y. Kawakatsu, O. Mori, Y. Tsuda (JAXA/ISAS), Kohta Tarao (Univ. of Tokyo), and Jun'ichiro Kawaguchi (JAXA/ISAS)

Proposed in this paper are the mission concepts of near earth asteroids exploration using miniature Asteroid Interceptors. The Interceptor is an autonomous self-contained interplanetary probe with 10kg mass which is now under development in JAXA/ISAS. It has the capability of navigating itself autonomously to flyby the target asteroid using optical navigation system. The image of the asteroid taken by the camera onboard at the closest approach is the main science output of the mission. The first mission concept discussed is the single use of the interceptor as the piggy back payload of the geostationary mission, which enables the minimum size interplanetary mission. It is shown that the utilization of the Earth synchronous orbit drastically increase the number of the possible target asteroids. The second mission concept discussed is the multiple asteroids exploration with a single launch. An option to overcome the difficulty in performing critical operation of multiple spacecrafts simultaneously is also discussed. The list of the target asteroid candidates, detailed mission sequence and maneuver parameters are shown for the assumed example mission.

Bering – a Deep Space Mission to Study the Origin and Evolution of the Asteroid Belt

P. Bidstrup, H. Haack (Univ. of Copenhagen), A. C. Andersen (NORDITA), R. Michelsen, and J. L. Jørgensen (Danish Technical Univ.)

Using a fully autonomous spacecraft- Bering – we propose to detect and study sub-km asteroids from an orbit within the main asteroid belt. The main purpose of the proposed Bering mission is to detect a statistically significant sample of an expected population of approximately 10^{10} main belt asteroids in the size range 1 m to 1 km. These asteroids are too faint to be observed using Earth-based telescopes. Sub-km asteroids can be detected from spacecraft at close range but due to the high relative velocities and the long communication times this requires a fully autonomous spacecraft. Using theoretical estimates of the distribution and abundance of sub-km asteroids we find that the Bering mission would detect approximately 5 new sub-km asteroids per day. With an expected lifetime for the mission of a few years we expect to detect and study several thousand sub-km asteroids. Results from the Bering mission would allow us to: 1) Provide further links between groups of meteorites and their parent asteroids. 2) Constrain the cratering rate at planetary surfaces and thus allow significantly improved cratering ages for terrains on Mars and other planets. 3) Constrain processes that transfer small asteroids from orbits in the main belt to the inner Solar System.

The Mission Concept of the Small Autonomous Asteroid Explorer "Bering"

J. L. Jørgensen, R. Michelsen (Technical Univ. of Denmark), H. Haack (Univ. of Copenhagen), T. Denver, and P. S. Jørgensen (Technical Univ. of Denmark)

The study of the Asteroids is traditionally performed by means of Earth based telescopes. The scientific scope of interest is both statistical, i.e. flux, orbital, size and taxonomic distribution, and morphological, i.e. surface composition, rotational properties, shape etc.. While the telescope based research offers precise orbital information, it is limited to the brighter, larger objects, and taxonomy as well as morphology resolution is limited. Conversely, dedicated missions offers detailed surface mapping in radar, visual and prompt gamma, but only for a few selected targets. The dilemma is obviously the resolution vs. distance and the statistics vs. delta-V requirements. Researchers from Copenhagen University, Denmark and the Technical University of Denmark have developed an autonomous space mission concept whose goal is to map the flux, size and taxonomy distributions of the Asteroids. This mission has been given the name "Bering" after the famous navigator and explorer. The autonomous operations are centred on the Advanced Stellar Compass (ASC). The ASC is a miniature star tracker, capable of generating accurate attitude information, spacecraft velocity and position information. Since the ASC can autonomously detect any luminous object in its field of view, any Asteroid there will be detected. Equipping a space probe with eight ASC's will provide full sky coverage. This autonomous instrumentation suite also enables automatic communication linkup with Earth. The main instrument of the probe is a precision tracking telescope fitted with a multi-spectral imager. When one of the ASC's has detected an object of interest, the tracking telescope is pointed to the target field via guidance from dedicated ASC mounted on the secondary of the telescope. The mission consists of two identical space probes that will fly in a loose formation. The loose formation flying has the objective to allow for generation of distance information to the target, which otherwise would be constrained only, but also to provide redundancy of the main telescope. Because of the autonomous inter spacecraft link, made possible by the ASC's, only the possibility of stereo imaging of a target is lost, should one of the telescopes fail. The proposed mission profile encompasses a swing-by manoeuvre at Venus. To allow for a comprehensive mapping of Near-Earth Objects, the swing-by will take place on the second perihelion passage, after which the probes will leave for the asteroid main belt. A subsequent kick burn at aphelion will ensure a proper scanning of the Asteroid belt and ensure a mapping of all Asteroid classes. The mission profile, mission stages and the operation of the key technologies are presented. The autonomous operations of the probes are discussed, based on measured accuracies of the ASC instrument already in flight, the ASCFIT telescope guider and the ASCANT link-up algorithm.

October 11 (Tuesday) 16:00 – 17:00
Room B

Session 4B Spacecraft Subsystems

M. Simon (JHU/APL) and Y. Kasaba (JAXA/ISAS)

Autonomous Guidance and Control for Low Cost Deep Space Probes

J. van der Ha (Consultant) and V. Lappas (Univ. of Surrey)

Small Satellites are establishing themselves as important tools for exploring our solar system. Developments in micro-electronics have enabled small and low-cost deep space probes to complement conventional space platforms in long-duration deep space missions. There is obviously an incentive to develop and enhance autonomous and robust guidance and control concepts for low-cost deep space missions. The paper presents a baseline design of an autonomous attitude determination and control system for a spacecraft performing a Near Earth Object (NEO) flyby mission. During the spin-stabilized escape phase, a single low-cost Sun sensor provides all information needed for the autonomous determination of the spin axis attitude pointing. Following the spin to three-axis transition, low-cost gyros in combination with a star sensor deliver the required attitude knowledge. The NEO encounter phase is the most critical mission phase with the attitude control performed by a cluster of Control Moment Gyros (CMG's). The satellite needs to be rotated relatively fast to keep the NEO within its field of view for the imaging. The attitude knowledge is provided by a set of gyros and a star sensor. Simulations demonstrate the practicality and versatility of the proposed concept for low-cost NEO deep space missions.

Development of Monolithic Ceramic Thruster for Interplanetary Exploration

K. T. Uesugi, E. Sato, S. Sawai (ISAS/JAXA), K. Furukawa, H. Mishima, K. Morishima, Y. Nonaka, and M. Kondo (MHI)

Ceramics are one of the attractive materials for the spacecraft on-board thrusters because of their superior performance on heat resistance. However they are brittle, and thus they have not been used in the real flight missions. It might be fractured due to mechanical vibration at launch, or thermal shock at firing. The authors have conducted a series of the ground tests including a number of the firing tests. The test results confirmed the feasibility of the Si-based monolithic ceramic thruster.

Numerical Simulation of Film-Cooled Bipropellant Thruster Performances

K. Ohminami (Sokendai Univ./ISAS), K. T. Uesugi, and H. Ogawa (ISAS/JAXA)

A steady state flow simulation inside a film cooled bipropellant thruster is performed for the purpose of estimating the film-cooling effects. The wall heat flux and its distribution of the chamber wall are numerically obtained by a simplified 3 dimensional axisymmetric CFD (Computational Fluid Dynamics) model. The flow is formed from two kinds of fluid: one is a hot combustion gas and the other is a cold film cooling fuel. The combustion gas is generated by the reaction of hydrazine (N_2H_4) and NTO (nitrogen tetroxide). The properties of those gases are estimated under the assumption of isentropic process using experimental data; oxidizer/fuel ratio of the combustion gas is 1.2 and the chamber pressure is 0.76MPa. The simulation is performed by CFD code with a turbulent model. The film cooling fuel is dealt as cold-vaporized gas in the p model. The present results show that the film-cooling gas reduces the wall heat flux and keeps the chamber wall temperature lower than that in non-film-cooling case. The temperature distribution of the simulated result agrees well with the experimental result.

October 12 (Wednesday) 9:30 – 10:50
Room A

Session 5A Robotic Missions

G. Whitcomb (ESA/ESTEC) and S. Sawai (JAXA/ISAS)

Lunar Robotics Exploration by Cooperation with Lander and Microrovers

T. Kubota (ISAS/JAXA), Y. Kunii (Chuo Univ.), Y. Kuroda (Meiji Univ.), T. Yoshimitsu, T. Okada, and M. Kato (ISAS/JAXA)

In JAPAN, a new lunar exploration mission including a lander and rovers is under studying. The main mission for lunar robotics exploration is to demonstrate the technologies for lunar or planetary surface exploration. They will cover pin-point landing technology, reliable landing scheme with obstacle avoidance, landing mechanism on rough terrain, exploration rover and tele-science technology. Lunar geologic survey will be also performed in the vicinity of central peak of impact craters to investigate the underground materials. The working group has been conducting the feasibility study of advanced technologies for lunar robotics exploration. Unmanned mobile robots are expected for surface exploration of the moon or planets, because rovers can travel safely over a long distance and observe what to see by some scientific instruments. The authors propose a lunar robotics exploration by lander and rover cooperation. Firstly the purpose and outline of the proposed exploration mission is discussed. Next the authors present the design and implementation of a science rover for the near future lunar missions requiring long traverses and rover-based scientific observation. And then a system overview of a developed rover and some experimental results are provided. Teleoperation and autonomous navigation technologies are also presented.

Tiny Rover Missions for Small Body Explorations

T. Yoshimitsu, T. Kubota, and I. Nakatani (ISAS/JAXA)

The System and Integrated Guidance and Navigation Strategy of Asteroid Interceptors

O. Mori, Y. Kawakatsu (ISAS/JAXA), K. Tarao (Univ. of Tokyo), Y. Tsuda, and J. Kawaguchi (ISAS/JAXA)

This paper introduces very small probes ‘interceptor’ which are under developing for flyby mission by Japan Aerospace Exploration Agency (JAXA). The weight of the interceptor is less than 10 kg. It is of great advantage to make a close flyby. The interceptor is a spinning probe whose shape is a cylinder. It observes spectrum, takes close images, and determines mass of an asteroid during a flyby. The interceptor has a narrow angle camera and a wide angle camera. Both cameras can take pictures of the target. The narrow angle camera also measures relative position between the interceptor and the target before flyby. Multicolor filter is attached to the narrow angle camera for observing spectrum of the target. To estimate orbit change due to flyby, a transponder is carried. The combination of the two-dimensional sun sensor and RF sensor can detects the attitude. A new cold gas jet system controls the orbit and attitude. A membrane with solar cells is deployed for power supply. The system of interceptor can be used for the other missions, for example monitor spacecraft. In this paper, an integrated guidance and navigation strategy during high speed flyby is also described.

An Efficient Autonomous Flying Robot for Mars Exploration

G.Savu (National Institute of Turbomachinery - COMOTI)

The Mars-Earth similarity criteria applied for flying vehicles like airplanes or helicopters, demonstrate high power consumption and large geometrical dimensions required for a controlled flight in the martian atmosphere. An ideal vehicle responding to the exigencies of the martian surface exploration (small dimensions, low-power consumption obtained from the martian environment, vertical take-off/landing and long time of exploitation in autonomous regime), is a combination of cold jet propelled machine (Mars Jumper) and a classical airplane. Due to the low density and low Reynolds numbers of the martian atmosphere, the propellers for horizontal moving or rotors for the vertical flight have very poor values of efficiency. The working principle of the vehicle is based on the transformation of the non-chemical in-situ energy existing on the Mars surface in mechanical or electrical energy. The weak solar radiation is transformed by photovoltaics in electrical energy, used to compress the martian atmosphere in a storage tank. The power for the vertical take-off/landing or for the horizontal displacements is obtained by the expansion of the compressed gas through vertical or horizontal nozzles and direct depends by the charging/discharging time ratio

October 12 (Wednesday) 9:30 – 10:50
Room B

Session 5B Plasmaphysics around Terrestrial Planets

A. Peacock (ESA/ESTEC) and *M. Nakamura (JAXA/ISAS)*

ERG Satellite Mission to Study Formation of the Radiation Belts

T. Ono (Tohoku Univ.), M. Hirahara (Rikkyo Univ.), K. Kasaba, A. Matsuoka (ISAS/JAXA), K. Shiokawa, K. Seki, Y. Miyoshi (Nagoya Univ.), and ERG project team

A small satellite mission named ERG (Energization and Radiation in Geospace) was proposed for studying the formation of radiation belts associated with magnetic storms. A comprehensive measurement of particles and fields on-board the satellite of less than 150kg is planned based on the heritage of the achievement of previous and undergoing Japanese scientific satellite missions. To realize definitive evaluation of possible mechanisms for the formation of the radiation belts, instruments to be on-board are characterized as; (1) Distribution functions of electrons and ions. (2) DC electric and magnetic fields. (3) Electric and magnetic components of plasma waves. The ERG project also involves ground-based facilities of optical measurements, Super-DARN HF radars, 210° and CPMN magnetometer chains. Theory and data analysis group compares the comprehensive data set with results from computer simulation to achieve new understanding of the structure, electrodynamics, and wave-particle interactions of the radiation belt plasma. The ERG project team is planning to collaborate with ORBITALS (Canada) and RBSP (NASA) missions, and still searching for collaboration with possible international projects. The presentation will be focused on the scientific aim, strategy of the mission, and present status of the feasibility study.

Mission Design of SCOPE –Small Satellites Formation Flying Mission for Magnetospheric Tail Observation–

Y. Tsuda, K. Maezawa(ISAS/JAXA), H. Kojima(Kyoto Univ.), M. Fujimoto(Tokyo Institute of Technology), I. Shinohara, Y. Saito, K. Higuchi, T. Toda, and T. Takashima (ISAS/JAXA)

Japan Aerospace Exploration Agency (JAXA) is currently planning the next generation magnetosphere observation mission called “SCOPE.”(cross-Scale Coupling in Plasma universE) SCOPE consists of five satellites, one 450kg mother satellite and four 90kg daughters, which are assumed to be launched by JAXA’s M-V rocket at once. Five satellites fly in basically a tetrahedron formation, minimum 5km apart from each other, at their perigee of 30 Earth-radii distance. To obtain the highly accurate spatial distribution of the magnetospheric phenomena, the quality of the clock synchronization and the relative orbit determination between satellites are essential. SCOPE satellites are to be equipped with the intersatellite communication and ranging system, which is now being developed, to realize the accuracy of 5usec as to clock synchronization and 50m as to the relative distance measurement for that purpose. This paper introduces the current system design and the technical challenges of SCOPE to realize the highly accurate magnetotail formation flying mission.

Mars Orbiting Plasma Surveyor (MOPS)

S. Barabash, M. André (IRF), L. G. Blomberg (KTH), R. Lundin (IRF), G. T. Marklund (KTH), P. Rathsman, F. von Schéele (SSC), and J. E. Wahlund (IRF)

Mars Orbiting Plasma Surveyor (MOPS) is a microsatellite mission focused on studies of the near – Mars environment and the planet – solar wind interaction. Despite many previous Martian missions a comprehensive investigation covering simultaneous measurements of particles, fields, and waves has not been so far performed. We propose a spinning spacecraft of a mass of 50-80 with the 10 kg payload which can "rides" on another platform until Mars orbit insertion and then be released on a suitable orbit. The spacecraft design is based on the experience gained in very successful Swedish space plasma missions. The MOPS spacecraft is equipped with its own 1m high gain antenna. The payload includes a wave experiment with wire booms, magnetometer with a rigid boom, electron and ion energy spectrometers and an ion mass analyse, an energetic neutral atom imager and an UV photometer. One of the proposed scenarios is piggy – backing on the Russian Phobos – Grunt mission to be launched to Mars in 2009.

Magnetic Field Investigation and Development of Magnetometers in Japan for Planetary Missions

A. Matsuoka (ISAS/JAXA), F. Tohyama (Tokai Univ.), M. Shinohara (Kyusyu Univ.), and Y. Tanaka (NICT)

For mainly space plasma missions, fluxgate magnetometers have been developed and manufactured in Japan. In this paper we report the properties of three types of magnetometers; MGF onboard NOZOMI (Planet-B), MGF-I for BepiColombo MMO, and a newly-developed digital-type magnetometer for future space and planetary missions. Both weight and power consumption decrease as the development progresses. It is a great merit for future missions, where instruments are required to be light and low power-consumption. For the magnetometer for BepiColombo Mercury project, tolerance for high-temperature and significant radiation is also required. The development of the magnetometer for BepiColombo is a good 'milestone' to challenge more difficult missions.

October 12 (Wednesday) 11:00 – 11:40
Room A

Session 6A Interplanetary Missions

G. Whitcomb (ESA/ESTEC) and S. Sawai (JAXA/ISAS)

Observations of Zodiacal Light During the Cruising Phase of PLANET-C/VCO Mission

M. Ueno (Univ. of Tokyo), M. Ishiguro (Univ. of Hawaii), M. Kimata (Ritsumeikan Univ.), S. S. Hong (Seoul National Univ.), T. Satoh (Kumamoto Univ.), N. Iwagami (Univ. of Tokyo), F. Usui, H. Yano, T. Imamura, and M. Nakamura (ISAS/JAXA)

We present a new observing project using the cruising phase of PLANET-C/VCO (Venus Climate Orbiter) mission. The PLANET-C mission, which is designed to be cruising through the interplanetary space toward Venus, will give us a unique opportunity to observe the zodiacal light from various viewing points in the solar system without any contaminations of the sky light, and will map out the spatial distribution of the dust cloud along the heliocentric distance, the resonance structures, and small clumps of the cloud complex. “IR2” camera onboard PLANET-C, whose main target is to monitor Venusian atmosphere at near infrared wavelength, is designed very carefully to extend its sensitivities toward the faint zodiacal light, and to realize very stable response. We are also developing a PtSi infrared sensor device which is dedicated for the camera, which has a very wide dynamical range covering bright Venusian surface as well as the faint component of the zodiacal light. The current status of the detector development is also presented in this talk. Very significant problem on the zodiacal dust cloud is the origin itself, like the presence of circum-stellar dust in Vega-like star. Since the lifetime of the interplanetary dust under the Poynting-Robertson drag is much shorter than the age of the Solar System, which leads that some supply sources must exist in the present Solar System, as well as the Vega-like stars. PLANET-C capabilities such as good sensitivities for extended sources, unique viewing points, fine spatial resolutions will open new horizon for IPD studies. The birth of Infrared Astronomical Satellite (IRAS) in mid-1980s dramatically changed then smooth featureless picture of the zodiacal dust cloud by revealing numerous bands of asteroidal debris, several narrow trails of cometary dust, and a clumpy dust ring just outside the Earth's circumsolar orbit. The IRAS has thus renamed the used to be featureless zodiacal cloud as interplanetary dust cloud complex. The ring clumps comprise always the same configuration in the frame rotating at rate of the Earth's mean motion. The success of IRAS was largely due to improvements in relative accuracy from then available a dozen to a few percents and in spatial resolution from ten degrees to a tenths of a degree. Most importantly, the IRAS observations of zodiacal IR emission (ZE) are free from the Earth's scattering atmosphere. In the beginning of 1990s the COBE/DIRBE mapped almost entire sky with a 0.7 arc-degree size beam and with established calibration. As far as the IPD cloud complex is concerned, one of the most exciting results of the DIRBE/COBE mission is a full confirmation of the MMR dust ring, and an isolation of the leading and trailing blobs in the MMR feature. Even with the COBE/DIRBE results, the uniform component of the zodiacal dust is still unclear because it is very difficult to distinguish from the extragalactic light. One of the simplest test is to measure the uniform component at various heliocentric distance.

ASTROD I: A Single-Spacecraft Deep-Space Laser Ranging Mission

W. T. Ni (Purple Mountain Observatory, CAS, National Astronomical Observatories, CAS, Tsing Hua Univ.), H. Araújo (Imperial College), G. Bao (Purple Mountain Observatory, CAS, National Astronomical Observatories, CAS), H. Dittus (Univ. of Bremen), T. Huang (Nanjing Univ.), C. Lämmerzahl (Univ. of Bremen), L. Liu (Purple Mountain Observatory, CAS), G. Li (Purple Mountain Observatory, CAS, National Astronomical Observatories, CAS), H. Y. Li (Purple Mountain Observatory, CAS), J. F. Mangin (Observatoire de la Cote D'Azur), Y. X. Nie (Institute of Physics, CAS), A. P. Patón (Purple Mountain Observatory, CAS), A. Peters (Humboldt Univ.), A. Rüdiger (Max Planck Institut für Gravitationsphysik), É. Samain (Institute of Physics, CAS), S. Schiller (Univ. of Düsseldorf), D. Shaul (Imperial College), S. Shiomi (Tsing Hua Univ.), T. Sumner (Imperial College), J. Tao (Purple Mountain Observatory, CAS, National Astronomical Observatories, CAS), S. Theil (Univ. of Bremen), C. F. Tong (Purple Mountain Observatory, CAS, Zhejiang Univ.), P. Touboul (Office National D'Edudes et de Recherches Aerospatiales), F. Wang (Purple Mountain Observatory, CAS, National Astronomical Observatories, CAS), H. Wang (Nanjing Univ. of Aeronautics and Astronautics), Z. Wei (Institute of Physics, CAS), A. Wicht (Univ. of Düsseldorf), X. J. Wu (Nanjing Normal Univ., Purple Mountain Observatory, CAS), Y. Xia (Purple Mountain Observatory, CAS, National Astronomical Observatories, CAS), Y. Xiong (Yunnan Observatory, NAOC, CAS), C. Xu (Nanjing Normal Univ., Purple Mountain Observatory, CAS), J. Yan (Purple Mountain Observatory, CAS, National Astronomical Observatories, CAS), H. C. Yeh (Nanyang Tech.Univ.), Y. Z. Zhang (Institute of Theoretical Physics, CAS), and Z. B. Zhou (Hua Zhong Univ. of Science and Technology)

ASTROD I is a drag-free deep-space laser-ranging mission concept with single spacecraft for improving relativistic gravity, for mapping the solar-system gravity and for precision astrodynamics; it is the first step of ASTROD (Astrodynamical Space Test of Relativity using Optical Devices) with 3 spacecraft. For a launch on March 23, 2012, after two encounters with Venus, the orbital period can be shortened to 170 days. After about 370 days from launch, the spacecraft will arrive at the other side of the Sun for the determination of relativistic parameters. In this paper, we present orbit design and orbit simulation, requirement on acceleration disturbances and analysis of their sources, charge accretion-rate simulation and discharging schemes, optical design, and mission analysis. The required acceleration noise level of ASTROD I is 10^{-13} ms^{-2} at the frequency of 0.1 mHz. We discuss possible sources of local gravity gradients and present the results using simplified models for the current configuration of ASTROD I. We calculate ASTROD I test mass charging rate by cosmic ray protons and alpha particles using the Geant4 toolkit; a charging rate of 24 ± 7 e^{+}/s is obtained; the magnitude of the acceleration noise and the coherent signals associated with charging are estimated.

October 12 (Wednesday) 11:00 – 11:40
Room B

Session 6B MRO Operation & Data Return

A. Peacock (ESA/ESTEC) and *M. Nakamura (JAXA/ISAS)*

The Mar Reconnaissance Orbiter Mission Operations: Architecture and Approach

B. Jai, D. Wenkert, C. Kloss, B. Hammer, M. Carlton (JPL/CalTech), and W. Sidney (Lockheed Martin Space Systems Comp.)

The Mars Reconnaissance Orbiter (MRO) was launched on August 12, 2005 by an Atlas V launch vehicle from Cape Canaveral Air Force Station. MRO will carry a rich set of science instruments to Mars and provide global, regional survey, and targeted observations. In addition, a set of engineering instruments providing optical navigation, Ka band telecommunication and UHF relay services to future Mars missions are part of the MRO payload. During the mission, the MRO operations teams are presented with two major challenges – unprecedented high data rate and data volumes, and complex science planning and resource sharing. MRO has the capability to communicate with earth at a maximum of six Megabits per second (> 50 times any previous Mars missions). With the current Deep Space Network (DSN) contact schedule of 19 eight-hour tracks per week, the baseline mission plan is for MRO to return 34 Terabits of raw science data during the two year primary science phase. Each of the science instruments has its unique requirements for global mapping, regional survey, and targeted observations. Some instruments prefer nadir-only observations, while others require off-nadir observations (especially for stereo viewing). The requirements from these Mars viewing instruments presented a significant challenge for the operations team to design the complex science planning and resource sharing/allocation process. This paper describes what MRO project is implementing to solve these challenges.

Response to Mars Reconnaissance Orbiter's end-to-end Data Accountability Challenges

Y. Lee, B. Allen, W. C. Eggemeyer, L. Gilliam, B. Jai, T. Reeve, T. Specht, R. Wendlandt (JPL/CalTech), R. Reed, and T. Wright (MissionSpace Corp.)

All spacecraft comprised of multiple instruments must face end-to-end data accountability issues during flight. Lost commands, spacecraft anomalies, and problems in spacecraft to ground communications can contribute to unexpected data loss and degradation of data quality. To identify and address these data loss problems in the past, arduous workarounds and last-minute tools are developed during the mission operations phase, resulting in significant cost impacts to the overall project. Projects can achieve significant cost benefits by confronting this problem in a systematic manner during the development phase of the mission. Mars Reconnaissance Orbiter (MRO) is the first JPL/NASA mission to proactively address end-to-end data accountability in the development phase. The MRO spacecraft, due to launch in August 2005, will carry six science instruments and three engineering payloads. The High Resolution Imaging Science Experiment (HiRISE) is expected to create images that require anywhere from a few Gigabits to 28 Gigabits. In addition to providing a platform for several science instruments, MRO will be the telecom relay asset for upcoming Mars missions. Since MRO will produce an unprecedented number of science products that results in a much higher data volume than any other deep space mission, keeping track of MRO products as well as relay products would be a daunting, expensive task without a well planned data product tracking strategy. To respond to this challenge, the MRO project has developed the end-to-end data accountability task by utilizing pre-existing information available from both ground and flight elements. Large data products require multiple days to deliver, passing through complex flight and ground data flow processes. These processes utilize many new flight and ground components. The capability to perform first-order problem diagnosis is essential in order for MRO to answer the question: “Where is my data?” and “When will my data be available?” The main foci of this end-to-end data accountability task are to (1) provide automated end-to-end data product status information from science and relay data product planning through its entire lifecycle until delivered to end-users, and (2) assist the team in performing data analysis and data problem resolution in a timely manner. This paper details the approaches taken, design and implementation of the tools, procedures and teams that track data products from the time they are predicted until they arrive in the hands of the end users.

October 12 (Wednesday) 13:00 – 13:30
Room A

Special Invited Talk (Part 2)

G. Schwehm (ESA/ESTEC) and J. Kawaguchi (JAXA/ISAS)

From Rosetta to BepiColombo

R. Schulz (ESA/ESTEC)

The space science programme of the European Space Agency, ESA, includes two planetary cornerstone missions: Rosetta and BepiColombo. Both missions are devoted to the same ultimate goal, namely, understanding the formation and evolution of our solar system. With the comprehensive examination of a comet, Rosetta will provide crucial information about the origin and very early evolution of the solar system some 4.6 billion years ago, when the planets were assembled from the oldest building blocks, of which comets are believed to be the cold remnants. BepiColombo on the other hand, will investigate Mercury and its environment; hence provide the detailed information necessary to understand the process of planetary formation and evolution in the hottest part of the proto-planetary nebular. Rosetta and BepiColombo tackle the question of how the solar system formed and evolved not only from very different scientific angles, but also with different approaches to the mission scenarios as well as to spacecraft and payload technology. A few examples: Rosetta will reach its target by conventional means and gain Δv through gravity assists, whereas BepiColombo will use solar-electric-propulsion. The Rosetta spacecraft has a total mass of ~1330 kg, which includes 165 kg for 11 scientific instruments and in addition a ~100 kg Lander. BepiColombo consists of 2 spacecraft, the Mercury Planetary Orbiter (MPO) and the Mercury Magnetospheric Orbiter (MMO), which will be in different orbits around Mercury to conduct a detailed study of the planet, and its environment. Together the MPO and MMO will have a mass of ~700 kg with ~90 kg for 16 scientific instruments. While, the Rosetta and BepiColombo payloads consist, for a large part, of instruments with resembling measurement techniques, the BepiColombo payload is significantly lower in mass. This reflects the tremendous progress that has been made in recent years in the development of new technologies and miniaturization techniques. Major effort was also put into optimizing the scientific return of BepiColombo by defining the requirements to be fulfilled by payload complement, at an early stage to ensure that the various measurements can be interrelated and complement each other. A comparison of the Rosetta and the BepiColombo mission will be provided with special emphasis on preparatory work to optimize scientific return and resources.

October 12 (Wednesday) 13:40 – 15:20
Room A

Session 7A Missions in Ready

G. Schwehm (ESA/ESTEC) and J. Kawaguchi (JAXA/ISAS)

BepiColombo Goes to Mercury

R. Schulz, J. Benkhoff, J. van Casteren, R. Carli, B. Gramkow, and M. Novara (ESA/ESTEC)

BepiColombo is the planetary mission of the Cosmic Vision Programme of the European Space Agency (ESA), devoted to the thorough exploration of Mercury and its environment. It will be carried out as a joint project between ESA and the Japanese Aerospace Exploration Agency (JAXA). Planned for launch in 2012, BepiColombo consists of two scientific spacecraft, the Mercury Planetary Orbiter (MPO) and the Mercury Magnetospheric Orbiter (MMO). The MMO studies the wave and particle environment of the planet, while the MPO is dedicated to the characterization of Mercury itself. Both spacecraft will be in dedicated orbits around Mercury that have been optimized for their tasks. The launch configuration consists of a stack of the two spacecraft and the chemical and electrical propulsion modules. The interplanetary trajectory includes flybys at the Earth, Venus (twice) and Mercury (twice), as well as several long thrust arcs provided by solar electric propulsion. The Mercury orbit capture and lowering to the operational orbits will be done with chemical propulsion. ESA is responsible for the overall project, including the mission design, the MPO, the electrical and chemical propulsion modules, the launch, the cruise operations up to delivery of the two spacecraft in their respective Mercury orbits and the MPO mission and science operations. JAXA is responsible for the procurement of the MMO and for its mission and science operation at Mercury. The mission definition has been completed and the scientific payload of both spacecraft has been selected. The MPO payload comprises 11 instruments/instrument packages; the MMO payload consists of 5 instruments/instrument packages. Together, the scientific payload of both spacecraft will provide the detailed information necessary to understand the process of planetary formation and evolution in the hottest part of the proto-planetary nebula as well as the similarities and differences between the magnetospheres of Mercury and the Earth. The MPO will focus on a global characterization of Mercury through the investigation of its interior, surface, exosphere and magnetosphere. In addition, it will be testing Einstein's theory of general relativity. Major effort was put into optimizing the scientific return by defining the payload complement such that individual measurements can be interrelated and complement each other. A detailed overview of the status of BepiColombo will be given with special emphasis on the scientific objectives and the payload complement of the MPO.

BepiColombo Mercury Magnetospheric Orbiter

H. Yamakawa, H. Ogawa, Y. Sone, H. Hayakawa, Y. Kasaba, T. Takashima, T. Mukai (ISAS/JAXA), T. Tanaka, and Masaki Adachi (NEC-TOSHIBA Space Systems, Ltd.)

Mariner 10 made in situ measurements around Mercury about 30 years ago with three fly-by observations. Based on those observations, it is appeared that Mercury has intrinsic magnetic field and its own magnetosphere. The Mercury Magnetospheric Orbiter (MMO), which is a part of the ESA-JAXA joint BepiColombo mission, is designed to solve the open questions of Mercury's magnetic field and magnetosphere. This paper describes science targets, scientific payloads, and spacecraft design of the MMO spacecraft.

Dawn Discovery Mission: Status Report (Invited Talk)

C. T. Russell (UCLA), C. A. Raymond, T. C. Fraschetti, M. D. Rayman (NASA/JPL), J. McCarthy, and A. L. Grandfield (Orbital Sciences Corp.)

The Dawn mission is the ninth spacecraft in the Discovery series, selected for study in January 2001 and approved for development in December 2001. It is now being readied for launch in late June 2006 to rendezvous with and orbit the two largest minor planets 4 Vesta and 1 Ceres. Dawn is the first purely science mission to use ion propulsion as an enabling technology and the first to orbit two planetary bodies other than Earth. This mission is well into its assembly test and launch operations phase. This paper reports on the status of the mission and acts as an index to the literature describing the Dawn mission.

PLANET-C/Venus Climate Orbiter of Japan

T. Imamura, M. Nakamura, T. Abe, N. Ishii, T. Ikenaga (ISAS/JAXA), and M. Ueno (Univ. of Tokyo)

Venus Climate Orbiter (VCO) is the first Venus spacecraft of JAXA and is also called the PLANET-C project. The launch of the spacecraft by M-V rocket is scheduled for 2008-2010. The phase B study of VCO has started in 2004. The most critical part of the development is thermal design, which enables onboard instruments to be maintained in sufficiently cool conditions. At present the thermal design, as well as the designs of subsystems (communication, batteries, attitude control, propulsion, structure, etc.) and interfaces between them, has roughly been fixed. VCO focuses on the meteorology of Venus, which is characterized by the rapid zonal circulation called the super-rotation. The wind speed increases with height, and the atmosphere at the cloud top rotates around the planet within 4 Earth days, although the planetary rotation period is as long as 243 Earth days. To observe the key processes driving this atmospheric circulation, VCO will have 5 cameras covering wide range of wavelength dedicated to meteorological study and an ultra-stable oscillator for radio occultation. The spacecraft is three-axis stabilized and directs cameras toward Venus via attitude control. The orbit of the spacecraft around Venus is a long elliptical one with 30 hours period. The angular velocity of the spacecraft is synchronized with the westward rotation of the cloud-level atmosphere for ~20 hours around the apoapsis, and successive global images will be obtained from this portion of the orbit. Close-up images of meso-scale features and limb images will also be obtained near the periapsis, and the shadow region along the orbit is utilized for observing lightning and airglow. Radio occultation will also be performed regularly to observe the vertical profiles of temperature and sulfuric acid vapor.

Global Mapping of Lunar Gravity Field using SELENE Two Small Satellites

T. Iwata (ISAS/JAXA), N. Namiki (Kyusyu Univ.), H. Hanada, N. Kawano (NAOJ), and T. Takano (ISAS/JAXA)

SELENE (Selenological and Engineering Explorer) consists of Main Orbiter and two small satellites; Relay Satellite (Rstar) and VLBI Radio Satellite (Vstar). Global mapping of the lunar gravity field will be conducted with higher accuracies using these sub-satellites. Relay Satellite Transponders (RSAT) on Rstar and Main Orbiter will perform the four-way Doppler measurements for Main Orbiter aviating above the lunar far side. The orbit of Rstar will be simultaneously measured by two-way RARR. Transponders on Rstar (RSAT-1) relay both ranging signals for two-way RARR and carrier waves for four-way links, and a transponder on Main Orbiter (RSAT-2) relays the four-way links. Our system will establish the first case to track two fully moving links between lunar orbiters. Differential VLBI Radio Sources (VRAD) on Rstar and Vstar will generate signals for multi-frequency differential VLBI observations, which provides the highly accurate positioning of both satellites. Radio sources on Rstar (entitled VRAD-1) and Vstar (VRAD-2) transmit three pairs of S-band and a pair of X-band carrier signals to VLBI radio telescopes where the narrow band-width VRAD terminal will be installed. Rstar and Vstar are restricted to execute selenodesy observation, therefore their systems are simplified and optimized for the mission. Both Rstar and Vstar are spin-stabilized satellites with octagonal prism main bodies which measure 1m x 1m x 0.65m, and the total mass is about 45 kg for each satellite. Neither of the satellites has altitude and active attitude control system, which yields precise measurements of orbital perturbations and enlightens mass of the satellite system. We have designed a simple structured and light weighted release mechanism, and confirmed the release properties by ground and on-orbit tests. Attitude and spin motions of the satellites will be settled by the release properties. Mission analysis shows that these properties affect the selenodetic observation, which has been confirmed to be analytically estimated and calibrated in data processes.

October 12 (Wednesday) 15:30 – 16:30
Room A

Session 8A Management Approach

J. van der Ha (Consultant) and H. Kuninaka (JAXA/ISAS)

Cost Modeling for Low-Cost Planetary Mission

E. Kwan, H. Habib-Agahi, and L. Rosenberg (JPL/CalTech)

Flight science missions often generate observational challenges requiring the use of state-of-the-art technologies and designs. The types of flight science instruments, the associated measurements, and observational data products for remote and in-situ sensing missions are often unique. These requirements drive the designs and technologies being used, frequently with significant cost impacts. Beyond the technology and new engineering challenges to develop a low-cost planetary mission, a key step is to develop a sound business case to secure the budget required for the mission. Credible cost models will play a vital role in performing cost/schedule trade-offs analysis so that senior management can make the appropriate go/no-go decision for the mission. The NASA Jet Propulsion Laboratory (JPL) has been developing life cycle cost models to support the Lab's senior management in achieving this goal. This presentation will provide attendees an overview of the JPL parametric cost models used to estimate flight science spacecrafts and instruments. This material will emphasize the cost model approaches to estimate low-cost flight hardware, sensors, and instrumentation, and to perform cost-risk assessments. This presentation will also discuss JPL approaches to perform cost modeling and the methodologies and analyses used to capture low-cost vs. key cost drivers.

A Quantitative Assessment of Complexity, Cost, and Schedule: Achieving a Balanced Approach for Program Success

R. E. Bitten, D. A. Bearden, and D. L. Emmons (The Aerospace Corp.)

Project success is a function of the suitable balance and potential tradeoffs between cost, schedule, and performance. Recent work developing the Complexity Based Risk Assessment (CoBRA) methodology has linked performance attributes to overall system complexity and has related complexity, independently, to cost and schedule. This paper takes the CoBRA methodology a step further and shows the result of a multi-variable regression analysis performed to determine quantitative relationships between complexity as a function of cost and schedule, schedule as a function of cost and complexity, and cost as a function of schedule and complexity. The authors assert that these relationships between cost, schedule and complexity could be applied at the onset of programs for future budgeting requirements. In addition, a mission case study is examined to test the validity of these relationships. Finally, these relationships are then used to provide guidelines for various program development approaches, such as where the cost and schedule are fixed as in the NASA Discovery Program, or where schedule is fixed due to launch window constraints such as in the Mars Exploration Program, to increase the likelihood of program success. Application of these relationships would assist decision makers with these key tradeoffs and various program development approaches.

Determining When a Mission is "Outside the Box": Guidelines for a Cost-Constrained Environment

Robert E. Bitten (The Aerospace Corp.)

A management and assessment processes for cost-constrained projects must assess if a mission is within the envelope of cost, schedule and technical constraints. The process must identify when a mission falls outside of this envelope and, therefore, would be deemed likely to fail. This envelope has been illustrated previously by both a notional triangle, formed by the three sides of cost, schedule and performance, as well as a notional box. Although these representations are notional, they can be formally quantified using industry standard guidelines. When quantified, these representations become a pentagon in which spacecraft mass reserve, launch mass margin, power margin, schedule reserve and cost reserve are assessed to identify where a mission may be “outside the box”. A survey of industry guidelines are used to form this “risk pentagon” and develop a quantitative template for assessing the risk of a mission based on these five categories. Using the risk pentagon, a project can assess if it has limited reserves and take action to reduce its risk posture by incorporating more reserve into its design. The final result will be a mission with an increased likelihood of meeting cost, schedule and technical constraints, thereby maximizing the likelihood of mission success.

October 12 (Wednesday) 15:30 – 16:30
Room B

Session 8B Plasmaphysics in Jovian System

M. Eiden (ESA/ESTEC) and T. Imamura (JAXA/ISAS)

Small Jovian Orbiter for Magnetospheric & Auroral Studies

Y. Kasaba, T. Takashima (ISAS/JAXA), H. Misawa (Tohoku Univ.), J. Kawaguchi (ISAS/JAXA), and "Jovian Small Orbiter Sub-Working Group" in "JAXA Solar-Sail Working Group"

"Solar-Sail Project" to have been examined by ISAS/JAXA as an engineering mission has a possibility of a small probe into the Jovian orbit. This paper summarizes the basic design of Jovian magnetospheric and auroral studies by this small "chance". The "a large-scale Jovian mission" has been a hope since the 1970s when the examinations of planetary exploration were started in Japan. In the one of plans, "the largest planet in the solar system" would be solved by two main objectives: (1) Structure of a gas planet: the internal & atmospheric structures of a gas planet which could not become a star (following the objectives of Planet-C and BepiColombo). (2) Jovian-type magnetosphere: the process of a "pulsar-like" magnetosphere with the strongest magnetospheric activities in the solar system (following the objectives of BepiColombo and SCOPE). The small orbiter in "Solar-Sail Project" aims to establish the feasibility of such future outer planet missions by JAXA. It aims the former target in its limited resources.

Electric Field Diagnostics in the Jovian System: Brief Science Case and Instrumentation Overview

L. G. Blomberg (Alfvén Laboratory, Royal Institute of Technology), J. E. Wahlund (Swedish Institute of Space Physics), J. A. Cumnock (Alfvén Laboratory, Royal Institute of Technology, Univ. of Texas at Dallas), G. T. Marklund, P. A. Lindqvist (Alfvén Laboratory, Royal Institute of Technology), M. Morooka, M. André, and A. I. Eriksson (Swedish Institute of Space Physics)

The Jovian plasma environment exhibits a variety of plasma flow interactions with magnetised as well as unmagnetised bodies, making it a very nice venue for furthering our understanding of solar wind - magnetosphere / ionosphere interactions. On the overall scale the solar wind interacts with the Jovian magnetosphere, much like at Earth but with vastly different temporal and spatial scales. Inside the Jovian magnetosphere the co-rotating plasma interacts with the inner moons. The latter interaction is slower and more stable than the corresponding interaction between the solar wind and the planets, and can thus provide additional information on the principles of the interaction mechanisms. Because of the wealth of expected low-frequency waves, as well as the predicted quasi-static electric fields in the interaction regions between different parts of the Jovian system, a most valuable component in future payloads would be a double-probe electric field instrument. Recent developments in low-mass instrumentation facilitate electric field measurements on spinning planetary spacecraft, which we exemplify.

Cold Plasma Diagnostics in the Jovian System: Brief Science Case and Instrumentation Overview

J. E. Wahlund (Swedish Institute of Space Physics), L. G. Blomberg (Alfvén Laboratory, Royal Institute of Technology), M. Morooka, M. André, A.I. Eriksson (Swedish Institute of Space Physics), J.A. Cumnock(Alfvén Laboratory, Royal Institute of Technology, University of Texas at Dallas), G. T. Marklund, and P. A. Lindqvist (Alfvén Laboratory, Royal Institute of Technology)

The Jovian magnetosphere equatorial region is filled with cold dense plasma that in a broad sense co-rotate with its magnetic field. The volcanic moon Io, which expels sodium, sulphur and oxygen containing species, dominates as a source for this cold plasma. The three icy Galilean moons (Callisto, Ganymede, and Europa) also contribute with water group and oxygen ions. All the Galilean moons have thin atmospheres with residence times of a few days at most. Their ionized ionospheric components interact dynamically with the co-rotating magnetosphere of Jupiter and for example triggers energy transfer processes that give rise to auroral signatures at Jupiter. On these moons the surface interactions with the space environment determine their atmospheric and ionospheric properties. The range of processes associated with the Jovian magnetospheric interaction with the Galilean moons, where the cold dense plasma expelled from these moons play a key role, are not well understood. Conversely, the volatile material expelled from their interiors is important for our understanding of the Jovian magnetosphere dynamics and energy transfer. A Langmuir probe investigation, giving *in-situ* plasma density, temperatures, UV intensity and plasma speed with high time resolution, would be a most valuable component for future payloads to the Jupiter system. Recent developments in low-mass instrumentation facilitate Langmuir probe *in situ* measurements on such missions.

October 12 (Wednesday) 16:40 – 17:40
Room A

Session 9A Advanced Propulsion System

J. van der Ha (Consultant) and H. Kuninaka (JAXA/ISAS)

A PARIS Mission to the Jovian Trojan Asteroids

R. E. Gold (JHU/APL), C. B. Ensworth (NASA/GRC), R. L. McNutt Jr., P. H. Ostdiek, and L. M. Prockter (JHU/APL)

PARIS (Planetary Access with Radioisotope Ion-drive System) spacecraft enable a new class of missions to the outer solar system. These low-thrust missions are especially effective for exploring objects in shallow gravity wells. They take advantage of high-efficiency radioisotope generators to provide the power for an electric propulsion system. The net power-to-mass ratio enables New-Frontiers class missions to carry a significant science payload to the outer solar system. We consider a PARIS mission that can reach the asteroids in less than 5 years, orbit 624 Hektor, the largest of the Jovian Trojans, and go on to orbit at least one other nearby object. The candidate payload for this mission includes cameras, a UV-Vis-IR spectrograph, gamma-ray and neutron spectrometers, and plasma and energetic particle spectrometers. The power system would generate about 900 W, the launch mass would be < 1000 kg, with < 5 year trip time.

MOSS - The Mission to the Outer Solar System

B. J. Kellett, R. Bingham, B. J. Kent, R. Crowther (Rutherford Appleton Laboratory), and G. R. Tynan (Univ. of California)

The aim of the MOSS mission is to reach the very edge of the solar system and even to go beyond it into true interstellar space – and to do this in less than 8 years. In a normal rocket, both the “fuel” and “oxygen” need to be carried and these are then combined to provide thrust. However, the need to carry a source of oxygen into space in order to be able to combust the rocket fuel adds a great deal of weight and complexity to the space probe. It would be much simpler if we only needed to carry the propellant itself and found some alternative way of turning this into thrust. This is the concept behind MOSS – we plan to use SOLAR THERMAL PROPULSION. The mission scenario is to head for Jupiter first and then use a gravitational sling-shot trajectory to send MOSS very close to the Sun – within 3 or 4 solar radii of the surface. In simple terms we are planning on taking an “ice cube” to the Sun and melting it for propulsion.

Magnetoplasma Sailing: Missions and Technology Requirements

H. Yamakawa, I. Funaki (ISAS/JAXA), K. Fujita (ISTA/JAXA), H. Otsu (Shizuoka Univ.), Y. Nakayama (National Defense Academy), H. Sugita (ISTA/JAXA), H. Ogawa, I. Shinohara, S. Sawai, S. Nonaka, and H. Kuninaka(ISAS/JAXA)

To propel a spacecraft in the direction leaving the Sun, a magnetic sail (MagSail) produces a large-scale magnetic field to block the hypersonic solar wind plasma flow. Based on some theoretical evaluations, a MagSail with plasma jet, consisting of a 10-m-diameter coil and a high-density plasma source, can efficiently increase the size of the magnetic field of the MagSail; hence this concept, what we call Magnetoplasma sail, is shown feasible from both theoretical and engineering point of view. Ultimate performance of the MPS spacecraft and necessary resources to construct it, however, are still under discussion. Accordingly, magnetoplasmadynamic thrust production process as well as spacecraft design should be optimized to realize a fast trip to the outer planes, which requires both high specific impulse and large thrust to power ratio.

October 12 (Wednesday) 16:40 – 17:40
Room B

Session 9B Planetary Atmosphere

M. Eiden (ESA/ESTEC) and T. Imamura (JAXA/ISAS)

Probing Venus Atmosphere with Scientific Instruments onboard the Venus Climate Orbiter of Japan

T. Satoh (Kumamoto Univ.), N. Iwagami, M. Ueno (Univ. of Tokyo), S. Watanabe (Hokkaido Univ.), M. Taguchi (National Institute for Polar Research), Y. Takahashi (Tohoku Univ.), M. Suzuki (EORC/JAXA), T. Imamura, and M. Nakamura (ISAS/JAXA)

Scientific instruments onboard the Venus Climate Orbiter (VCO) altogether sense physical and chemical properties at different levels in Venusian atmosphere. Activities in the highest level (airglow at visible wavelengths on the night-side disc) will be studied by Lightning and Airglow Camera (LAC) which utilizes a linear photo-diode array sensor. LAC also will record yet-to-confirm lightnings in the clouds. At the cloud top level, observations will be performed by Ultraviolet Imager (UVI) to investigate the nature of the UV absorber and to track horizontal motions of cloud features. Local variations in cloud top altitudes will be determined by Long-Infrared camera (LIR), at around 10-um wavelength, which has a 2-D borometer array sensor. With LIR, we expect to detect at best a few hundred-meter difference in the cloud top altitude, useful information to understand the distribution of upwelling/downwelling motions. Variations in cloud top altitudes will be also studied by 2-um Infrared Camera (IR2) with its 2.02-um filter applied to the day-side observations. The vertical resolution may not be compared to what LIR would achieve but the horizontal resolution is expected to be superb. The main target of IR2 at Venus orbit is atmospheric motions in the middle and deep atmosphere. Such observations will be done at 1.73-, 2.26- and 2.32-um wavelengths which are known to be relatively absorption free (so-called atmospheric windows), enabling us to see deeper atmosphere "through" the clouds on the night-side disc of Venus. Distribution of CO will be studied by differentiating 2.26- and 2.32-um images to understand production, circulation and dissociation processes of this molecule. Finally, the deepest level in the atmosphere (almost reaching the surface) will be investigated by 1-um Infrared Camera (IR1) at 1.01-um wavelength. In addition to studies of physical properties of the deepest atmosphere, suspected volcanic activities will be also searched for with IR1. Not only the above imaging-camera suite but also the radio occultation observations are expected to add useful information regarding the structure of the upper atmosphere (temperature profile and stratification). We expect to obtain a new view on the atmospheric dynamics for Venus with these observations.

Mission and System Design of a Venus Entry Probe and Aerobot

A. Phipps, A. Woodroffe, D. Gibbon, P. Alcindor, M. Joshi, A. S. Curiel, J. Ward, M. Sweeting (SSTL), J. Underwood, S. Lingard (Vorticity Ltd), M. van den Berg, and P. Falkner (ESA)

The Venus Entry Probe study is one of the European Space Agency's (ESA) technology reference studies. It aims to identify; the technologies required to develop a low-cost, science-driven mission for in-situ exploration of the atmosphere of Venus, and the philosophy that can be adopted. The mission includes a science gathering spacecraft in an elliptical polar Venus orbit, a relay satellite in highly elliptical Venus orbit, and an atmospheric entry probe delivering a long duration aerobot (aerial robot) which will drop several microprobes during its operational phase. The atmospheric entry sequence is initiated at 120 km altitude and an entry velocity of 9.8 kms^{-1}. Once the velocity has reduced to 15 ms^{-1} the aerobot is deployed. This consists of a gondola and balloon and has a floating mass of 32 kg (which includes 8 kg of science instruments and microprobes). To avoid Venus' crushing surface pressure and high temperature an equilibrium float altitude of around 55 km has been baselined. The aerobot will circumnavigate Venus several times over a 15-22 lifetime analysing the Venusian middle cloud layer. Science data will be returned at 2.5 kbps over the mission duration. At scientifically interesting locations 15 drop-sondes will be released. This paper focuses on the final mission design with particular emphasis on system level trade-offs including the balloon and pressurisation system, communications architecture, power system, design for mission lifetime in a hostile and acidic environment. It discusses the system design, design drivers and presents an overview of the innovative mission-enabling and mission-enhancing technologies.

TOPS: Telescope Observatory for Planets on a Small-satellite

K. Yoshida, Y. Shoji, K. Kawasaki, J. Shimasaki, Y. Takahashi, T. Sakanoi, J. Yoshida (Tohoku Univ.), and M. Taguchi (The National Institute of Polar Region)

A space telescope observatory is free from atmospheric interferences such as wobble or attenuation, thus advantageous in challenging faint stars and materials at ultimate limits of space, higher resolution of fine images, and wider window of wavelength from X-ray to infrared. The Hubble Space Telescope (HST) is one successful example of a telescope observatory in orbit, which has been contributing a great deal to better understanding of our universe with spectacular new images for about 15 years. However, HST is one of the most expensive enterprises in the world in which a huge number of scientists and engineers are involved. From the observation scheduling point of view, the allocated time for a single user is very limited and a continuous long-term observation to a specific target is therefore difficult. The advantages of higher resolution and wider wavelength hold true even with a small telescope such as 0.3 m in diameter, a few 10 million dollars for the development cost, in contrast to HST which has a 2.4 m main reflector mirror and costs over billion dollars. The size of a main mirror, which gives major impact on the development and launch cost, is needed for higher capability of light collection in the observation of faint targets. When we limit the observation targets to brighter ones, such as major planets in our solar system, 0.3 m of diameter is enough in pursuing high quality of science. A group of Tohoku University, Japan, combined with science and engineering members, has been working on such a greatly low cost mission for the space telescopes in the Earth orbit for planetary observation that should fit in an emerging format of small satellite missions. From the planetary exploration point of view, to develop and send fly-by probes or orbiters to each planet is considered typical approach to obtain scientific data with higher spatial resolution from a close vicinity of the target. But those spacecrafts require complicated mission sequence with a long time for interplanetary journey, taking high costs of operation and high risks of possible troubles. On the contrary, telescopes in the Earth orbit dedicated for planetary observation could provide a low cost mission opportunity for high quality of science with relatively lower risks and a longer observation period. As one of advantages, multiple major planets including Venus, Mars, Jupiter, and Saturn could be observed by a single orbital observatory from one to another. Complementary long-term observation could be offered before, during and after a close encountering mission to these planets by fly-by probes or orbiters. This paper presents our preliminary feasibility study on the mission TOPS: Telescope Observatory for Planets on Small-satellite which carries a couple of 0.3 m telescopes but weighs less than 200 kg including the satellite bus system. The main mission of TOPS is to make simultaneous multi-band observation of atmospheric phenomena on Venus, Jupiter and Saturn for some long period continuously, then reveal the three dimensional dynamics of atmospheric flow and the mechanisms behind the phenomena. As for the science, one major focus of the mission is simultaneous multi-band observation by four image detectors from ultraviolet (UV) to infrared (IR) wavelength. For this purpose, the light collected by each reflector is split into two detectors. Two telescopes then produce four multi-band images on the same target simultaneously. Since the specific light (or electro-magnetic) emission or absorption corresponds to the specific altitude in the atmosphere, the multi-band observation brings us the sliced images by altitude, thus significant to understand the three-dimensional behavior of the atmospheric flow on the target planet. The best spatial resolution of the images is targeted at 0.1 arcsec to satisfy the observation requirements, which also fits within the theoretical diffraction limit of a 0.3 m diameter optics. (Note that the apparent diameter of the target plants is in the range from 10 to 60 arcsec.) Another major focus of the mission is continuous and long-term observation. Unlike a snap-shot type of observation, continuous observation is greatly beneficial for the understanding of the flow dynamics. Long-term observation for several months, or years, will reveal seasonality of the phenomena. As for the engineering design, TOPS makes use of the satellite bus system that has been developed for a series of small satellites. The bus system has a zero-momentum three-axis stabilization system with reaction wheels and cold gas-jet thrusters. Solar paddles are equipped to generate 300 W of power at maximum. An S-band communication system for telemetry and commanding, and an X-band system for science data downlink. An 800 km altitude of sun-synchronous orbit is foreseen with a high possibility of piggy-back launch. One of the key technologies dedicated for a telescope observatory is the pointing accuracy and stabilization of the spacecraft. Our mission targets at 0.1 arcsec in resolution, then the attitude drifting rate should be less than 0.1 arcsec per the exposure time of the photo detector. The satellite bus system gives 0.1 degrees in the pointing accuracy and 0.1 arcsec/10 msec in the drifting rate. This capability suggests that the exposure time should be less than 10 msec. For the introduction of the target planet in the field of view, an active mirror control will utilized in the secondary or thirdly mirror of the telescope. Preliminary analyses have been made on possible sources to degrade the image resolution, such as vibrations from the reaction wheels and deflection of the optical system due to thermal expansion/contraction. Details of these analyses are elaborated in the paper. The mission TOPS, which we are looking at a possibility to launch within four or five years from now, will open a new direction of low-cost small-satellite missions which could make new discoveries in planetary science.

October 13 (Thursday) 9:30 – 10:50
Room A

Session 10A Infrastructures for Planetary Missions

C. Stavrinidis (ESA/ESTEC) and T. Iwata (JAXA/ISAS)

A Communication Hub in Lagrange L1 for Opening the Area to Small Satellites

J. Y. Prado, L. Torres, J. Benoist, E. Hinglais, and I. Gibek (CNES)

The Lagrange points L1 and L2 of the Sun-Earth systems, both located at 1.5 million kilometres from the Earth, are the best locations for scientific missions dedicated to solar studies (L1 preferably) or astronomy and astrophysics (L2 preferably). The major drawback of these locations is that they are far from the Earth, which poses severe constraints on the communication system with the ground stations, mainly for receiving the scientific telemetry. Up to now, each spacecraft located at L1 or L2 (SOHO, ACE, MAP and soon HERSCHEL, PLANCK, EDDINGTON, JWST...) is quite an heavy spacecraft (thousands of kilograms) and the receiving stations on the ground are large deep space dishes. To suppress this communication bottleneck and allow these Lagrange points to be used by small satellites, it is proposed in this paper to provide wide band telemetry between small user spacecraft and ground stations through a large communication relay satellite, located on a halo orbit around one the Lagrange L1 point.

Deep Space Quay and Solar Voyage Era

M. Matsumoto (Univ. of Tokyo), and J. Kawaguchi (ISAS/JAXA)

Jovian Outpost Establishment and Operation “Conventional Propulsion Assessment”

R. E. Poetro, T. Yasaka, T. Hanada, and H. Hirayama (Kyusyu Univ.)

In the future, establishment of an outpost in Jovian system is expected. Assessment of the outpost establishment is performed, considering conventional propulsion, with main base location at low Callisto orbit. The base consists of propellant production facilities, nuclear power units, communications equipment, rocket engines, spare parts, and all science laboratories/probes to be dispatched to Ganymede, Europa, Io and Jupiter, with mass up to 1000 ton. The base construction requires multiple launches, distributed in 30 years (2030-2060) with various gravity assist paths involving Venus and Earth. Multiple gravity assist launch opportunities are searched using an automated search program. Without considering any deep space maneuver, low energy trajectories do exist for almost every year with transfer time up to 12 years. A scenario of orbit insertion employing Galilean moons gravity assist enables reasonable number of required flight per year. Frequent transportation from Callisto to Europa as resource of energy with gravity assist(s) from Ganymede is identified. Launch opportunities for some trajectory paths, in 1-year time, determined by similar automated gravity assist search program, are presented.

Low-Cost Moon Mission Spacecraft Technology

Y. V. Protsan (Yuzhnoye State Design Office), A. V. Loyan (Electric-Jet Propulsions Laboratory), K. Murakawa, M. Sugiki (Astro Research Corp.), G. V. Tarasov, V. V. Tolmachev, S. I. Moskalev, and E. P. Zhuravel (Yuzhnoye State Design Office)

The low-cost Moon mission spacecraft technology has been proposed by Yuzhnoye SDO as an alternative approach to existing and developing the Lunar projects in the world. The objective of creation of such spacecraft is to have on the Moon orbit one main and several on-duty spacecrafts carrying out the functions of remote surface observer, micro platforms for specific scientific experiments in the Moon field, placing of specialized spacecrafts onto required Moon orbits, surface lander and also for implementation of reliable communication to the Earth by the main orbital spacecraft.

October 13 (Thursday) 9:30 – 10:30
Room B

Session 10B Interior Explorations

A. Fujiwara (JAXA/ISAS) and T. Kubota (JAXA/ISAS)

Penetration Characteristics of Planetary Penetrator

H. Shiraishi (ISAS/JAXA), K. Suzuki (Univ. of Tokyo), S. Tanaka, M. Hayakawa, A. Fujimura, and H. Mizutani (ISAS/JAXA)

We have developed an acceleration data acquisition system (an accelerometer and its electronics) during the course of development of Japanese LUNAR-A penetrator mission, and we evaluated the performance and calibration properties on a series of impact tests with full size models. The record of accelerometer would give the impact velocity and the penetration path length of lunar penetrator. Some proto-type models carrying the data acquisition system were fired toward the lunar analogue soil, and the three-component acceleration data was obtained at the non-zero attack impact. The measured axial acceleration data indicates that the data acquisition system can provide the impact velocity and the penetration path length with sufficient accuracy, while the normal acceleration data suggests that the lunar penetrator will experience the large shearing forces when it impacts with non-zero attack angle. We have also developed a numerical simulation code describing the penetration dynamics into the soil target, with an emphasis on the influence of the non-zero attack impact. Combining the results of penetration characteristics (penetration path length and inflection angle) and measured acceleration data, we investigate the deceleration history and penetration trajectory predicted from the model calculation.

Seismometer Design and its Characteristics onboard LUNAR-A Penetrator

R. Yamada (ISAS/JAXA), I. Yamada (Nagoya Univ.), Y. Yokota, H. Shiraishi, S. Tanaka, A. Fujimura, H. Mizutani (ISAS/JAXA), N. Kobayashi (Tokyo Institute of Technology), N. Takeuchi (Univ. of Tokyo), H. Murakami (Kochi Univ.), Y. Ishihara (Japan Agency for Marine-Earth Science and Technology), J. Koyama, K. Yomogida (Hokkaido Univ.), and Y. Takagi (MitsutoyoCorp.)

The LUNAR-A mission of ISAS (Institute of Space and Astronautcal Science)/JAXA, Japan will send two penetrators to the Moon to study its internal structure. The seismometer system onboard the LUNAR-A penetrator consists of two short period electro magnetic sensors with a resonant frequency of 1.0-1.2Hz, each of which is aligned orthogonally. It has already been proved that the flight-type seismometers do not show any significant change of their characteristics after penetration into the simulated lunar soil. To verify the dynamic characteristics of the seismometer, we conducted a series of tests to measure the ground motion (micro tremor) at the domestic seismic observatory. We mainly investigated the dynamic response of LUNAR-A seismometers for the quite low amplitude level of micro tremor (about 1E-7-1E-8 m/sec in terms of the velocity of ground motion). In this paper, we describe the details of hard ware design of the seismometer, the characteristics, the experimental obtained dynamic response and the expected performance in the forthcoming LUNAR-A mission.

Asteroid Exploration with Pods

E. Asphaug (Univ. of California, Santa Cruz), D. Scheeres (Univ. of Michigan), and K. Housen (The Boeing Co.)

We present a refined concept for the low-cost, reliable exploration of the interior structure of asteroids, small moons and cometary nuclei – called “asteroids” for the present discussion – based upon a redundant array of simple *pods* which are dropped passively onto the surface by a spacecraft in close proximity. Pods conduct monitored explosion-based seismomechanical, dynamical and compositional experiments. The key design assumption of these experiments is that nothing need be known apriori about the surface or the interior.

October 13 (Thursday) 11:00 – 12:20
Room A

Session 11A Experiences & Lessons Learned

C. Stavrinidis (ESA/ESTEC) and T. Iwata (JAXA/ISAS)

PHILAE / ROSETTA LANDER: A new Strategy to Realize Space Systems

S. Ulamec (DLR), S. Espinasse (ASI), B. Feuerbacher (DLR), D. Moura(CNES), and H. Scheuerle(DLR)

"Rosetta" is a Cornerstone Mission of the previous Horizon 2000 ESA Programme. Its goal is to rendezvous with comet 67/P Churyumov-Gerasimenko and to study both its nucleus and coma through an orbiting spacecraft and a landed platform. The later, named "Philae", after the island where the obelisk was found which helped together with the stone of Rosetta to decipher the Egyptian hieroglyphs, has been designed to land softly on the comet nucleus and is equipped with 10 scientific instruments to perform in-situ studies of the cometary material. The Mission was proposed by ESA as an Orbiter-only scenario. However, some of the key-investigations are only possible by analysing the comet nucleus in-situ. Thus, the announcement of opportunity invited to provide a surface science package in addition to the remote sensing instruments, aboard the main spacecraft. A consortium, consisting of partners from Austria, Finland, France, Germany, Hungary, Ireland, Italy and the UK was formed where mainly Scientific Institutes (partly funded by the respective national agencies) provided the subsystems, instruments and the complete, tested system. The concept followed a "best effort" and "no exchange of funds" strategy; a Steering Committee (composed of representatives of all contributing institutes and institutions) controlled the progress of the project and solved problems, whenever necessary. This concept is continued for the operational phase. Project management is located at DLR in Cologne/Germany, with co-project managers at CNES (France) and ASI (Italy). The scientific lead is at the Max Planck Institute for Solar System Science (Lindau, Germany) and the Institut d'Astrophysique Spatiale (Paris). Despite a largely increased management effort (and overall costs exceeding the original estimate), this strategy proved to be successful, and eventually led to a space system, the Philae Lander, which otherwise could have never been realized. The concept, how the Philae Project has been organized should be seen as a model for future missions, whenever funding constraints lead to large consortia and the involvement of scientific institutes.

Feedback from Mars Express Lesson Learned on the Venus Express Verification Approach

P. Giordano and S. Rustichelli (ALCATEL ALENIA Space)

Mars Express was the first example of ESA "Flexible Missions". It represented a new concept based on maximum reuse of the existing technology that is either "off-the-shelf" or it has already been developed. The objective to launch in a record time, 30% faster than other comparable missions and with reduced funding, could be achieved only with a thorough re-thinking of the model philosophy and environmental tests. The approach to the structural qualification of Mars Express has been dramatically revised to achieve the qualification of the design. The encouraging results of Mars Express are the basis of the Verification and Testing program of the second ESA's Flexible Mission, Venus Express. Highly recurrent of Mars Express, even if with important peculiarities due to the different mission and environment, this Project inherited the qualifications achieved on its predecessor, allowing a single module approach where the Testing campaign started directly on the PFM. This paper presents the innovative concepts implemented, showing the influence of the adopted solutions on the in-flight performances. An overview of Venus Express Test Campaign is also given, focusing on the effects of the previous experience and the lessons learned acquainted both from ground testing and first flight results.

Dawn Discovery Mission: Lessons Learned (Invited Talk)

T. C. Fraschetti, M. D. Rayman (NASA/JPL), C. T. Russell (UCLA), and C. A. Raymond (NASA/JPL)

Dawn is a low-cost planetary mission with high heritage from Deep Space 1 and earlier missions. It uses ion propulsion to rendezvous with and to orbit the two most massive asteroids 1 Ceres and 4 Vesta. The mission is well into its last year of development and will be launched in summer 2006. This paper shares lessons learned by the Dawn team to date.

Low Cost Spacecraft Design Approach for Planetary Missions

K. Kitade, S. Hagino, H. Hihara, K. Baba, T. Yoshida (NEC TOSHIBA Space Systems, Ltd.), K. Shouji (NEC Engineering, Ltd.)

In Japan, several unique planetary missions, such as the Asteroid Sample Return Spacecraft "HAYABUSA" launched in 2003, had been realized and some other innovative planetary missions are being planed. In this kind of missions, not only sophistication and reduction in weight and cost, but realization of low cost is also increasingly required. This paper proposes the spacecraft design approach, which meets the request mentioned above. Proposed design approach aims to realize a versatile and low cost spacecraft also flexible to any kind of missions by building the system with the basic concept composed of three layers.

October 13 (Thursday) 11:00 – 12:00
Room B

Session 11B Mission Analysis - Low Thrust Trajectory Planning -

A. Fujiwara (JAXA/ISAS) and T. Kubota (JAXA/ISAS)

On Low Thrust Orbit Control Strategy for Spacecrafts around the Collinear Libration Points

X. Hou, H. Wang, and L. Liu (Nanjing Univ.)

Collinear libration points play an important role in deep space exploration for their special positions and dynamical characteristics. Since motion around them is unstable, we need to control the spacecrafts to maintain them around the collinear libration points for a long time. Although impulsive maneuvers have been proven successful in this kind of control problem, in this paper we have proposed a low-thrust control strategy, and given out some numerical simulations combining with the orbit design and control of WSO/UV (World Space Observatory of UltraViolet).

Preliminary Analysis of Low Energy Interplanetary Transfer

M. Nakamiya (Sokendai Univ./JAXA), and H. Yamakawa (ISAS/JAXA)

There have been various investigations about low energy interplanetary transfer trajectories for spacecraft (S/C) in recent years. This paper focuses on the initial portion of the interplanetary transfer that is the escape from the Earth gravity leaving from the L2 libration point. Libration points are where solar gravity, Earth gravity and centrifugal force acting on S/C in the Sun-Earth system are balanced. The L2 point located about 1.5 million km away from the Earth in the anti-sun direction. From the L2 point of the Sun-Earth system, a transfer to the interior and exterior planetary region is found easy, which enables the interplanetary transportation system among the solar system by addition of a little energy at the libration points L2. In this paper, a one-impulse escape, which is a direct escape with Δv at L2, is compared with a two-impulse escape assuming Δvs at L2 and the subsequent perigee point. The result shows that the two-impulse approach is more effective than the one-impulse approach at the cost of long flight time.

Use of Solar Sails with Controllable Solar Radiation Pressure for Libration Point Orbits

D. Novikov, R. Nazirov, and N. Eismont (IKI)

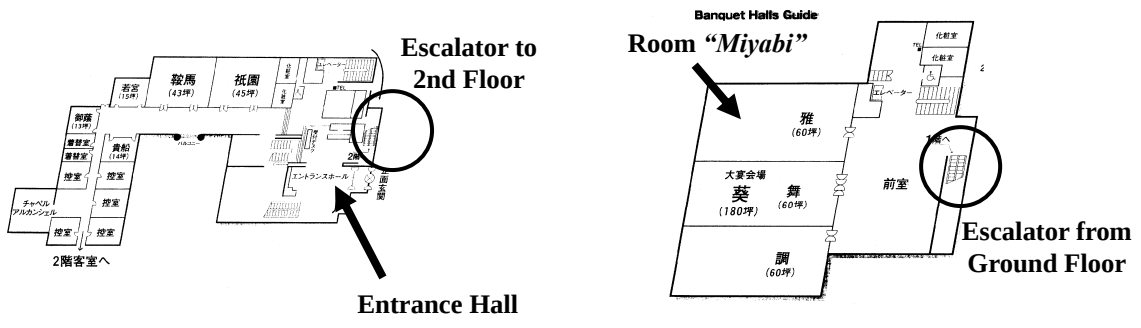
After successful experiments with solar sails deployment fulfilled during rocket launch in Japan this new technology of spacecraft propulsion is becoming quite realistic, especially for small spacecraft. Possibilities to use solar sails as a tool for spacecraft (s/c) orbit control in vicinity of collinear libration points are studied. It was assumed that initial libration point orbits are the ones generated by one impulse transfer from Earth and Mercury satellites orbits. Characteristics of orbits such as orbit amplitudes, position with respect to Earth and periods of motion depend on sails area ratio to s/c mass. The studies are done mainly for the problems of the near Earth solar wind explorations but the same approach was also applied for the Sun-Mercury collinear libration points.

Social Programs

Get Together Party

Held on October 10 (Monday) Evening (18:00 – 20:00)

at Kyoto Tokyu Hotel 2F, Room “Miyabi”.



Ground Floor *2nd Floor*

Kyoto Tokyu Hotel Map

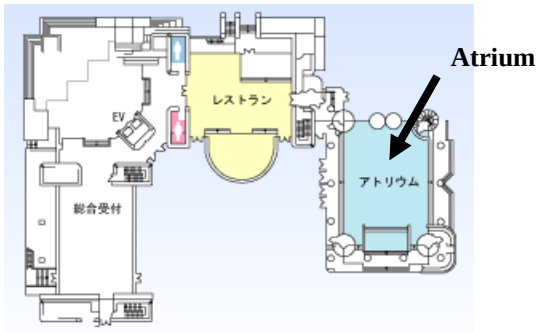
Banquet

Held on October 12 (Wednesday) Evening (18:00 – 20:00)

at Kyoto Research Park, Atrium

with Special Entertainment by geiko/maiko.

(supported by Kyoto Prefecture)



Ground Floor

Kyoto Research Park Map

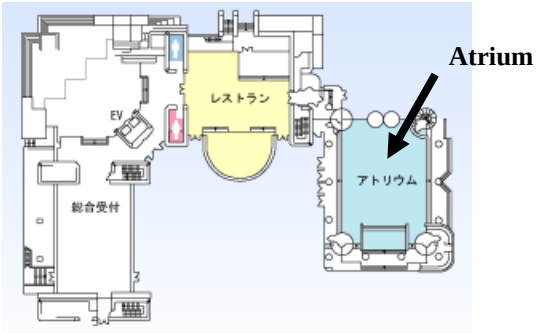
Information

Lunch

from October 11 to 13, noon.

at Kyoto Research Park Ground Floor, Atrium

Free for conference participants



Ground Floor

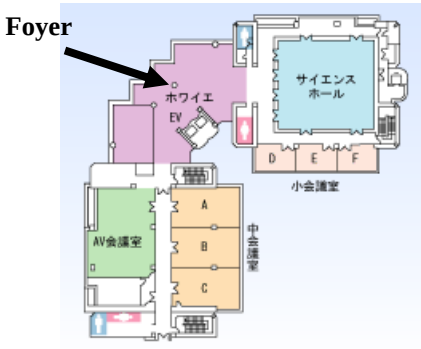
Kyoto Research Park Map

Coffee Service

Every break

at Kyoto Research Park 4th Floor, Foyer

Free for conference participants



4th Floor

Kyoto Research Park Map

Internet Service

PCs and color printer is available

at Kyoto Research Park 4th Floor, Foyer

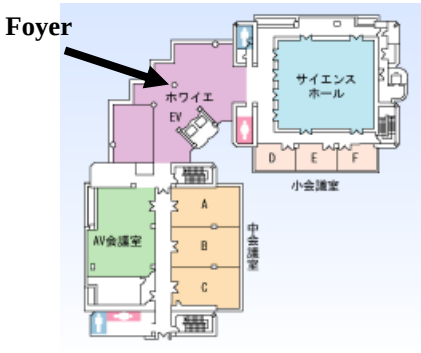
Free for conference participants

Wireless Network Service

Account issued

at Kyoto Research Park 4th Floor, Foyer

Free for conference participants



4th Floor

Kyoto Research Park Map

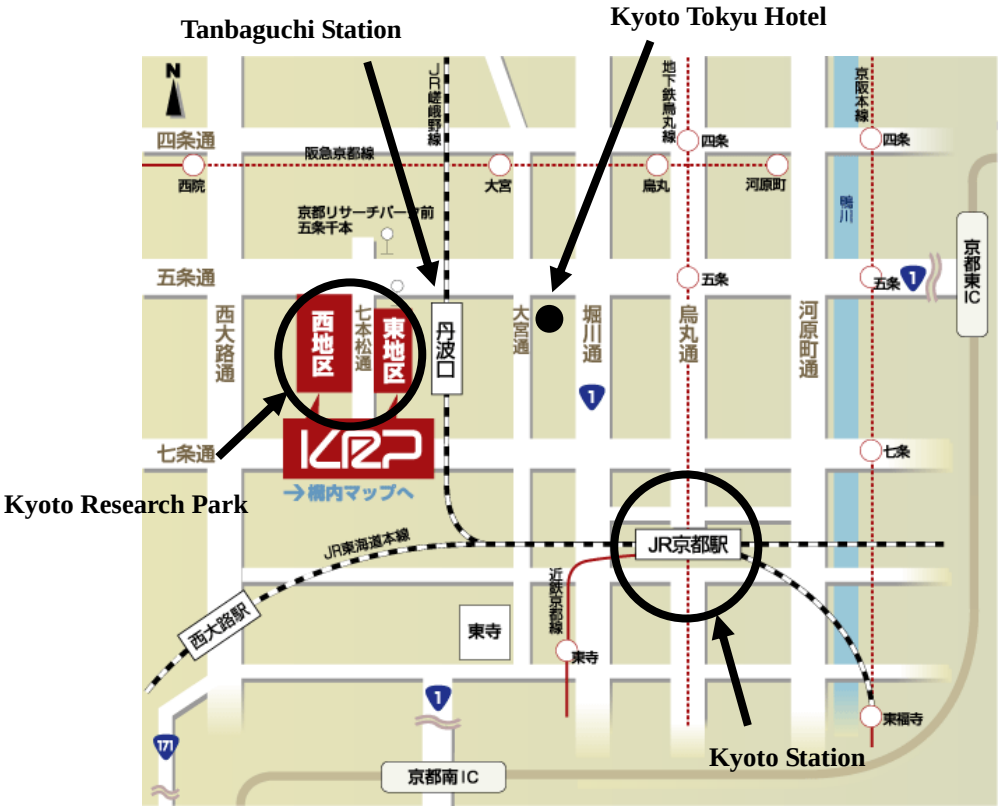
Maps

To Kyoto Research Park

Use JR Sagano line from Kyoto station,

get off at “Tanbaguchi Station”,

walk 5 minutes to west, and Kyoto Research Park



Bus is available from/to Kyoto Tokyu Hotel,

every morning and evening.

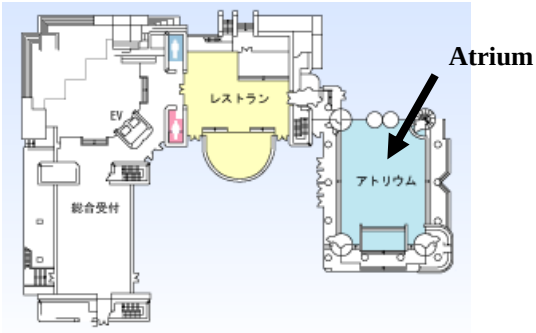
In Kyoto Research Park

Conference is held at “East Area” of Kyoto Research Park

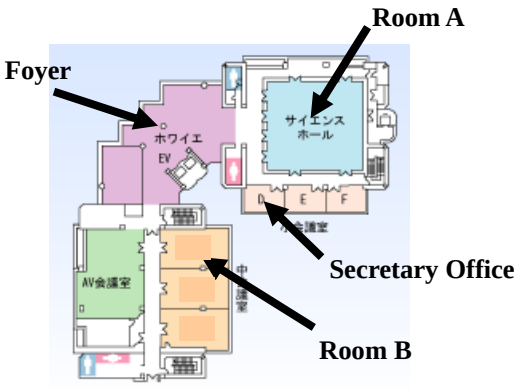
East Area

In Kyoto Research Park

Technical Meeting held at the 4th floor.



Ground Floor



4th Floor

Kyoto Research Park Map