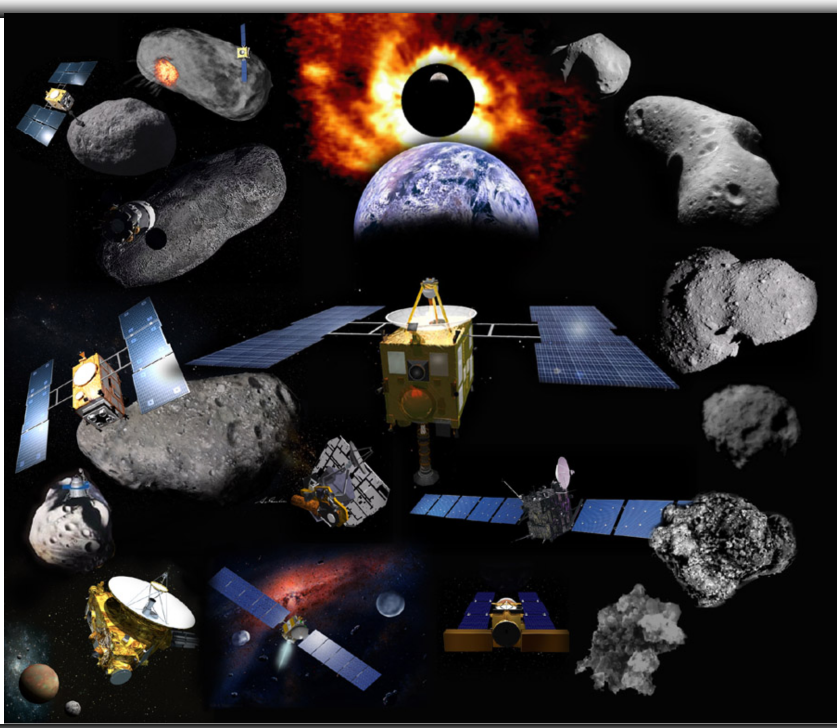
The First Meeting of
The International Primitive Body Exploration Working Group
(IPEWG)

January 13-16, 2008

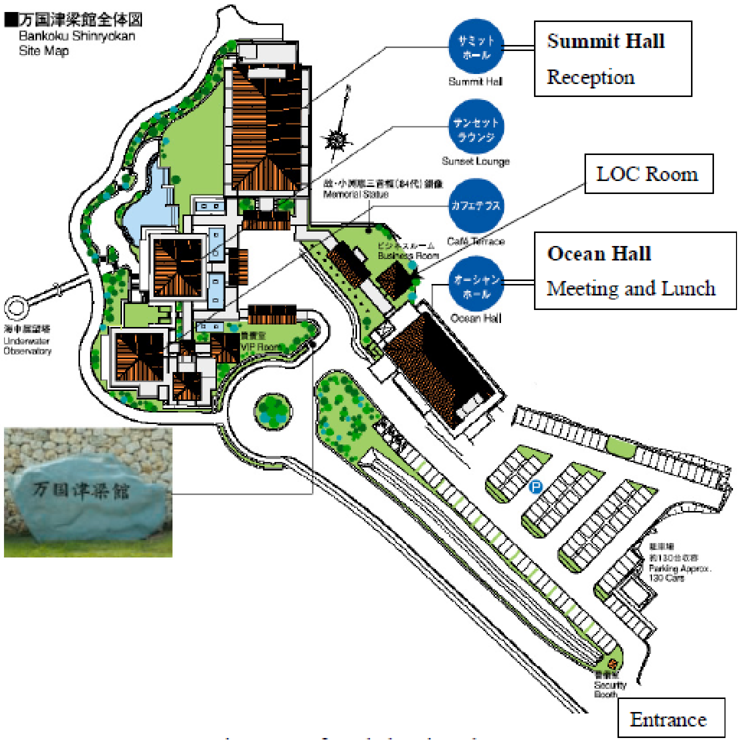
Bankoku Shinryokan
Okinawa, Japan



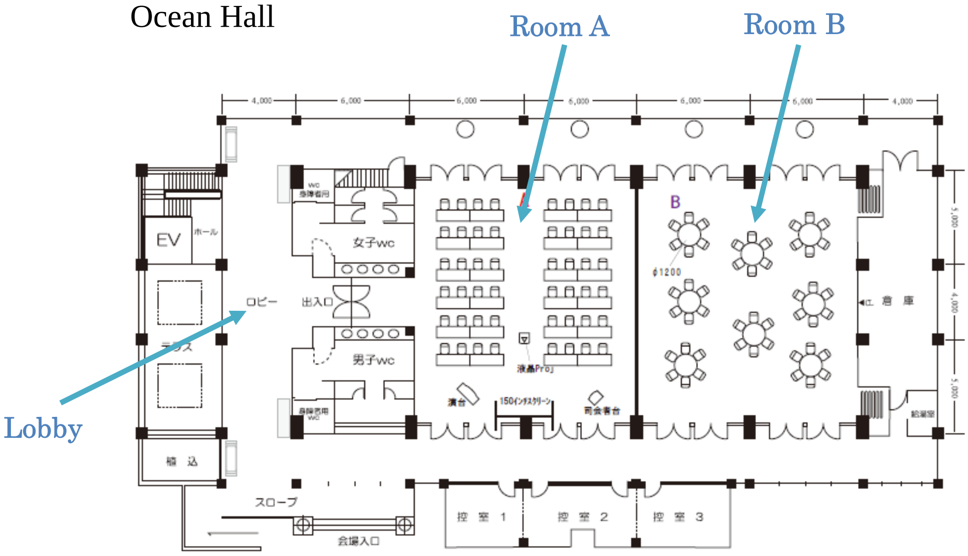
Final Program and Book of Abstracts

Meeting venue

The map of Bankoku Shinryokan



Ocean Hall



Technical Program

*Brackets after the title indicate the duration of each talk in minutes.

January 13th (Sun)

Daytime Participant Arrival at Naha, Okinawa

17:00-20:00 Registration & Welcome Drink @ Okinawa Kariyushi Urban Resort Naha

January 14th (Mon)

Breakfast at hotel

08:00 Room check-out and bus transportation starting from the Okinawa Kariyushi Urban Resort Naha to reach the Bankoku Shinryokan, the meeting venue at Kise Beach.

10:30 **The First IPEWG Meeting Opens: Keynote Speeches**

Chair: Hajime YANO (JAXA, JAPAN)

Opening Address (10)

[K-1] Purposes of International Primitive Bodies Exploration Working Group (IPEWG) (20)

Jun'ichiro KAWAGUCHI (JAXA/JSPEC & ISAS, JAPAN)

[K-2] Lessons Learned from International Halley Armada -Retrospective Overview of IACG Activities- (30)

Kuninori UESUGI (Professor Emeritus, JAXA/ISAS, JAPAN)

[K-3] Spacecraft Visits to Primitive Small Bodies: Results and Outlook (30)

Andy CHENG (NASA-HQ, USA)

12:00 Lunch at Ocean Hall B

13:00 **Session-1: Visions and Plans for Primitive Body Explorations**

Chairs: Jun'ichiro KAWAGUCHI (JAXA, JAPAN) and Gerhard SCHWEHM (ESA/ESAC, Spain)

[S1-1] Italian Activities and Plans in the Field of Exploration (15)

Sylvie ESPINASSE (ASI, ITALY)

[S1-2] UK Aspirations for Space Exploration (15)

Sue HORNE (STFC, UK) and Jeremy CURTIS (BNSC/STFC, UK)

* Presented by Detlef KOSCHNY (ESA/ESTEC, THE NETHERLNANDS)

[S1-3] CNES and France Implications in Small Bodies Missions: Past and Future (15)

Francis ROCARD (CNES, FRANCE)

[S1-4] DLR Vision and Plan (15)

Ekkehard KUEHRT (DLR, GERMANY)

[S1-5] ESA's Missions and Mission Studies to Minor Bodies in the Solar System (15)

D. KOSCHNY (ESA/ESTEC, THE NETHERLNANDS), M. CORADINI (ESA/HQ, FRANCE), D. AGNOLON (ESA/ESTEC, THE NETHERLNANDS), I. CARNELLI (ESA/ESTEC, THE NETHERLNANDS), H. OPGENOORTH (ESA/ESTEC, THE NETHERLNANDS), and R. SCHULZ (ESA/ESTEC, THE NETHERLNANDS), and G. SCHWEHM (ESA/ESAC, SPAIN)

[S1-6] NASA's Vision and Future Plans for Primitive Bodies (15)

James L. GREEN (Planetary Science Division, NASA Headquarters, USA)

[S1-7] JAXA's Primitive Body Exploration Program (15)

Makoto YOSHIKAWA (JAXA/ISAS & JSPEC, JAPAN)

Hayabusa-2 Pre-project Team and Small Body Exploration WG

14:45 Break

15:05 **Session-2: Minor Body Science and Enabling Technologies**

Chairs: Hirohide DEMURA (University of Aizu, JAPAN) and Sylvie ESPINASSE (ASI, ITALY)

[S2-1] Hydrated Minerals on Asteroids (15)

Andrew S. RIVKIN (Johns Hopkins University/Applied Physics Laboratory, USA)

[S2-2] Towards Accurate Mass Determination with Laser Altimeter in the Future Small Bodies' Exploration (15)

Shinsuke ABE (Kobe University, JAPAN)

[S2-3] A Binary Asteroid as a Target of a Space Mission : Scientific Interest (15)

Patrick MICHEL (Côte d'Azur Observatory, FRANCE)

[S2-4] Binary Asteroid System Dynamics and Scientific Exploration (15)

D.J. SCHEERES (University of Colorado, USA), E.G. FAHNESTOCK (University of Michigan, USA), and J. BELLEROSE (University of Michigan, USA)

[S2-5] Deep Interior: Radar Exploration of Asteroid and Comet Interiors (15)

Ali SAFAEINILI (JPL, USA) and Erik ASPHAUG (University of California at Santa Cruz, USA)

[S2-6] Seismology of Primitive Bodies (15)

Erik I. ASPHAUG (University of California at Santa Cruz, USA)

[S2-7] Readiness of Deep Space Exploration by Microwave Discharge Ion Engines (15)

Hitoshi KUNINAKA (JAXA/JSPEC & ISAS, JAPAN)

16:50 Break

17:10 **Session-2 Continues**

Chairs: Fuyuto TERUI (JAXA/JSPEC & IAT, JAPAN) and Francis ROCARD (CNES, FRANCE)

[S2-8] Physical Risks of Landing on a Cometary Nuclei (15)

E. Kührt, J. Knollenberg, N. Gortsas (DLR, Germany) and H.U. Keller (Max-Planck-Institute for Solar System Research, Germany)

[S2-9] Using Very Small Rovers to Explore the Surface of Primitive Bodies (15)

Gregg VANE (Jet Propulsion Laboratory/California Institute of Technology, USA)

[S2-10] Proposal of Micro Rovers on Small Solar System Bodies (15)

Tetsuo YOSHIMITSU, Takashi KUBOTA, Ichiro NAKATANI (JAXA/ISAS, JAPAN)

[S2-11] Active Phased Array Antenna Most Suitable for Primitive Body Explorations (15)

Tadashi TAKANO, Yuio KAMATA, Yasuhiro KAZAMA, and Akira SUGAWARA (JAXA/ISAS, JAPAN)

[S2-12] Marco-Polo Capsule and DASH-II Mission (15)

Tetsuya YAMADA (JAXA/JSPEC & ISAS, JAPAN)

[*S4-1] Stardust-NExT: A New Exploration of Tempel 1 (20)

Karen J. MEECH (Institute for Astronomy, USA) and Joseph VEVERKA (Department of Astronomy, Cornell University, USA)

18:45 **Session-3: Poster and Visual Presentation Session**

* Light refreshments and food will be served

[S3-1] Mission Design and Operation for Deep Space Exploration Program

Mutsuko Y. MORIMOTO (JAXA/JSPEC, JAPAN)

[S3-2] The Need for Observational Support of Spacecraft Missions to Primitive Small Bodies

Paul ABELL (PSI & NASA JSC, USA), Mark SYKES (PSI, USA), and Faith VILAS (MMTO, USA)

[S3-3] Strength Measurement of Carbonaceous Meteorite Fragments Using Micro-Compression Testing Machine

Akira TSUCHIYAMA, Etsuko MASHIO, Yuta IMAI (Osaka University, JAPAN), Takaaki NOGUCHI (Ibaraki University, JAPAN), Yayoi MIURA (University of Tokyo, JAPAN), and Hajime YANO (JAXA/ISAS & JSPEC, JAPAN)

[S3-4] Volatile In-situ Analysis in Asteroid Regoliths

Ernesto PALOMBA (IFSI-INAF, ITALY), Andrea LONGOBARDO (IFSI-INAF, ITALY), Angelo ZINZI (IFSI-INAF, ITALY), Andrea BEARZOTTI (IMM-CNR, ITALY) , Antonella MACAGNANO (IMM-CNR, ITALY), Simone PANTALEI (IMM-CNR, ITALY), Emiliano ZAMPETTI (IMM-CNR, ITALY)

[S3-5] The Drop Tower Experiments as a Tool for Studies of Small Body Surface Phenomena and for Spacecraft Design of Small Body Explorations

Yasuhiko TAKAGI (Aichi Toho University, JAPAN)

[S3-6] MINERVA Rover in Hayabusa Mission

Tetsuo YOSHIMITSU, Takashi KUBOTA, Ichiro NAKATANI (JAXA/ISAS, JAPAN)

[S3-7] Visual Servo Motion Control of an Exploration Vehicle around an Asteroid Using Target Markers

Fuyuto TERUI (JAXA/JSPEC & IAT, JAPAN)

[S3-8] Science and Current Status of the Subgroup of Surface Science Instrument Package (SSP)

Hirohide DEMURA, Yoshio HAMADA, Michihito SUZUKI, Naru HIRATA and Noriaki ASADA (University of Aizu, JAPAN), Hiroshi NARAOKA (Okayama University, JAPAN), Hajime MITA (Fukuoka Institute of Technology, JAPAN), Makoto YOSHIKAWA, Hajime YANO, Tetsuo YOSHIMITU and Takahiro IWATA (JAXA/JSPEC & ISAS, JAPAN), Subgroup of Surface Science Instrument Package (SSP) in Small Body Exploration WG

[S3-9] Crater size-frequency distribution on Itokawa and its implications on asteroids-dust connection

Ryosuke NAKAMURA (AIST, JAPAN), Naru HIRATA (University of Aizu, JAPAN), and Masateru ISHIGURO (Seoul National University, KOREA)

[S3-10] Rosetta Target Asteroids: 2867 Steins and 21 Lutetia

Marcello FULCHIGNONI (University of Paris Diderot, Paris 7/ LESIA, Paris Observatory, FRANCE) and M. Antonella BARUCCI (LESIA, Paris Observatory, FRANCE)

20:30 Session Closed & Hotel Check-in

January 15th (Tue)

Breakfast at hotel.

08:30 **Group Photo Session at the Meeting Venue**

09:00 **Session-4: Currently Operating Missions**

Chairs: Ryosuke NAKAMURA (AIST, JAPAN) and Larry LEMKE (NASA ARC, USA)

[S4-2] Hayabusa - Its Flight and Science Achievements (20)

Jun'ichiro KAWAGUCHI (JAXA/JSPEC & ISAS, JAPAN)

[S4-3] DAWN -- The Mission to the Largest of the Small Bodies (20)

Horst Uwe KELLER (MPI for Solar System Research, GERMANY), Christopher T. RUSSELL (UCLA, USA), Holger SIERKS (MPI for Solar System Research, GERMANY), and the DAWN Science Team

[S4-4] Challenges for the Science Operations for a Minor Body Mission – The ROSETTA Mission to a Comet (20)

D. V. KOSCHNY (ESA/ESTEC, THE NETHERLNANDS) and K. WIRTH (ESA/ ESAC, SPAIN)

[S4-5] EPOXI = EPOCh + DIXI (20)

Michael F. A'HEARN (University of Maryland, USA) and L. Drake DEMING (NASA/GSFC, USA)

[S4-6] New Horizons Pluto-Kuiper Belt Mission (20)

Andrew F. CHENG (NASA HQ, USA) and New Horizons Team

10:40 Break

11:00 **Session-5: Future Missions and Concepts**

Chairs: Yasuhiko TAKAGI (Aichi Toho University, JAPAN) and Marcello FULCHIGNONI (University of Paris Diderot, Paris 7, FRANCE)

[S5-1] Japanese Development of Hayabusa-2 and Marco Polo (15)

Hajime YANO, Makoto YOSHIKAWA, Jun'ichiro KAWAGUCHI (JAXA/JSPEC & ISAS, JAPAN), the Hayabusa-2 Pre-project Team and the Minor Body Exploration Working Group

[S5-2] The Marco Polo NEO Sample Return Mission within ESA's Cosmic Vision Program (15)

D. V. KOSCHNY (ESA, THE NETHELANDS), D. AGNOLON (ESA, THE NETHELANDS), M.A. BARUCCI (LESIA, Paris Observatory, FRANCE), M. CORADINI (ESA, FRANCE), Jens ROMSTEDT (ESA, THE NETHELANDS), M. YOSHIKAWA (JSPEC/JAXA, JAPAN), and the Marco Polo Science Study Team

[S5-3] Science of Marco Polo: Near-Earth Object Sample Return Mission (15)

M.A. BARUCCI (LESIA, Paris Observatory, FRANCE), M. YOSHIKAWA (JSPEC/JAXA, JAPAN), P. MICHEL (OCA, FRANCE), J. KAWAGUSHI (JSPEC/JAXA, JAPAN), H. YANO (JSPEC/JAXA, JAPAN), J.R. BRUCATO (INAF-OAC, ITALY), I.A. FRANCHI (Open University, UK), E. DOTTO (INAF-OAR, ITALY), M. FULCHIGNONI (Univ. Paris Diderot, FRANCE), S. ULAMEC (DLR, DERMANY), H. BOEHNHARDT (MPI, GERMANY), M. CORADINI (ESA, FRANCE), S.F. GREEN (Open University, UK), J.-L. JOSSET (SPACE-X, SWITZERLAND), D. KOSCHNY (ESTEC/ESA, THE NETHERLANDS), K. MUINONEN (Univ. Helsinki Observatory, FINLAND), J. OBERST (DLR, GERMANY) and the MARCO POLO Science Team

[S5-4] Comet Surface Sample Return (15)

Michael F. A’HEARN (University of Maryland, USA) and Harold A. WEAVER (JHU Applied Physics Laboratory, USA)

[S5-5] Comet Nucleus Sample Return: Exciting, Feasible, and Timely (15)

Horst Uwe KELLER (MPI for Solar System Research, GERMANY), Michael KÜPPERS, (ESA/ESAC, SPAIN), and Ekkehard KÜHRT (DLR-Institute of Planetary Research, GERMANY)

[S5-6] CNES Report on “LEONARD” Mission : A Study of In-situ Analysis of a Near-Earth Object (15)

Francis ROCARD, Enmmanuel LINGLAIS (CNES, FRANCE), and Antonella BARUCCI (LESIA, FRANCE)

12:30 Lunch at Ocean Hall B

13:30 **Session-5 Continues**

Chairs: Takashi KUBOTA (JAXA, JAPAN) and Scott MESSENGER (NASA/JSC, USA)

[S5-7] ESA’s Don Quijote Mission Project (15)

I. Carnelli (ESA/ESTEC, The Netherlands), A. Galvez (ESA/HQ, France), P. Michel (Observatoire de la Côte d’Azur, France)

[S5-8] APEX: A Mission Concept to Explore the Physical Properties of Asteroid Apophis and Their Impact on Orbital Evolution (15)

Christian TRENKEL (Astrium Ltd, UK), Paolo D’ARRIGO (Astrium Ltd, UK), Simon BARRACLOUGH (Astrium Ltd, UK) and Andrea CARUSI (IASF, ITALY)

[S5-9] Asteroidfinder - A Proposal for a DLR Compact Satellite Mission - (15)

Ekkehard KÜHRT, Stefano MOTTOLA, Gerhard HAHN, Anko BÖRNER, and Sergio MONTENEGRO (DLR, GERMANY)

[S5-10] Common Modular Spacecraft Bus NEO Rendezvous Mission Concept (15)

Butler HINE (NASA Ames Research Center, USA) and William S. MARSHALL (USRA-RIACS, NASA Ames Research Center, USA)

[S5-11] Piloted Missions to Near-Earth Objects via the Crew Exploration Vehicle (15)

Paul ABELL (NASA JSC & PSI, USA), David KORSMEYER (NASA ARC, USA), Rob LANDIS (NASA JSC, USA), Dan ADAMO (Consultant, USA), Tom JONES (Association of Space Explorers, USA), David MORRISON (NASA ARC, USA), Larry LEMKE (NASA ARC, USA), Andy GONZALES (NASA ARC, USA), Bob GERSHMAN (JPL, USA), Ted SWEETSER (JPL, USA), Lindley JOHNSON (NASA HQ, USA), and Ed LU (Google, USA)

14:45 Break

15:05 **Session-6: Ice Breakers for International Collaboration Discussions**

Chairs: Makoto YOSHIKAWA (JAXA, JAPAN) and D.J. SCHEERES (University of Colorado, USA)

[S6-1] Subaru Telescope's Collaboration with Space Missions (20)

Tetsuharu FUSE (Subaru Telescope, National Astronomical Observatory of Japan, USA)

[S6-2] Future Plans for NASA’s Deep Space Network (20)

Leslie J. DEUTSCH (Jet Propulsion Laboratory, California Institute of Technology, USA), Robert A. PRESTON (Jet Propulsion Laboratory, California Institute of Technology, USA), and Barry J. GELDZAHLER (NASA, USA)

[S6-3] International Planetary Data Alliance: an International Standards Initiative for Compatible Planetary Data Archives (20)

Maria-Teresa CAPRIA (INAF-IASF, ITALY)

[S6-4] The Origins and Evolution of NASA Data Policy and Its Impact on Scientist Expectations (20)

Mark V. SYKES (Planetary Science Institute, USA)

[S6-5] Curation, Spacecraft Recovery and Preliminary Examination for the STARDUST Mission: A Curatorial Perspective (20)

Keiko NAKAMURA-MESSENGER (ESCG/NASA Johnson Space Center, USA), Michael ZOLENSKY (ARES/NASA Johnson Space Center, TX, USA), Jack WARREN (ESCG/NASA Johnson Space Center, USA), Ron BASTIEN (ESCG/NASA Johnson Space Center, USA), Lisa FLETCHER (ARES/ NASA Johnson Space Center, USA), and Thomas SEE (ESCG/NASA Johnson Space Center, USA)

[S6-6] The IPEWG Charter Ideas (20)

Kaori SASAKI (JAXA/JSPEC, JAPAN)

17:05 LOC Announcement for the Splinter Meeting on the 16th and Free Discussion on International Collaboration

18:00 Break

18:30 Reception with Local Attractions

20:30 Return to Hotels

January 16th (Wed)

Breakfast and Check-out at hotel.

(NOTE: Bring all your belongings to the chartered bus if you will return to the downtown or the airport on this day.)

09:00 **Session-7: International Collaboration Splinter Meeting: 1st Round**

* All participants choose one of the following discussion groups to join

* Only Group X lasts for 80 minutes while other groups spend 40 minutes each.

(1) Ground Observation Campaign and Mission Target Coordination

Chair: Paul ABELL (NASA/JSC, PSI, USA)

(2) Deep Space Network

Chair: Leslie J. DEUTSCH (JPL, USA)

(3) Code-Share Payloads and Co-I Invitation

Chair: Erik ASPHAUG (UCSC, USA)

(X) IPEWG Charter Drafting

Chair: Kaori SASAKI (JAXA, JAPAN)

09:40 **Session-8: International Collaboration Splinter Meeting: 2nd Round**

* All participants choose one of the following discussion groups to join

* Only Group X will continue the meeting from the 1st Round

(4) Launcher Provision and Sharing

Chair: Jun'ichiro KAWAGUCHI (JAXA, JAPAN)

(5) Science Instrument Cross Calibration

Chair: Shinsuke ABE (Kobe University, JAPAN)

(6) Data Archive

Chair: Masanao ABE (JAXA, JAPAN)

(7) Sample Quarantine, Curation, and Analysis

Chair: Akira TSUCHIYAMA (Osaka University, JAPAN)

(X) IPEWG Charter Drafting

Chair: Kaori SASAKI (JAXA, JAPAN)

10:20 **Session-9: Panel Discussion on International Collaboration Areas**

Chair: Makoto YOSHIKAWA (JAXA, JAPAN)

*8 splinter meeting group chairs except group X will act as panelists

11:30 Lunch at Ocean Hall B

12:30 **Session-10: Wrap-Up Session**

Chairs: James GREEN (NASA-HQ, USA) and Hajime YANO (JAXA, JAPAN)

* Discussions on Recommendations and Action Items

* Proposal of the IPEWG Charter Draft

* Proposal of the Second IPEWG Meeting Host

* Any Other Business

* Concluding Remarks (Summary of the Meeting)

13:30 Adjourn

14:00 Chartered Bus Leaves from the Meeting Venue to Downtown Naha and then the Airport

[K - 1]

The First IPEWG Meeting in Okinawa, Japan (January 2008)

PURPOSES OF INTERNATIONAL PRIMITIVE BODIES EXPLORATION WORKING GROUP (IPEWG)

Jun'ichiro KAWAGUCHI (JAXA/JSPEC&ISAS, JAPAN)

[Contact E-mail : Kawaguchi.Junichiro@jaxa.jp]

Thanks to successful development of enabling technologies for deep space exploration, missions to the small solar system bodies have revolutionized our understanding of the Solar System's origin. At present, rendezvous, impact, landing and sample return missions to asteroids and comets such as NEAR-Shoemaker, Hayabusa, Stardust, Deep Impact, Rosetta,Dawn, EPOXI and NEXT as well as New Horizons, a fly-by mission to EKBOs, are completed or still in the middle of operation.

At the same time, more challenging, new missions are under development or under concept studies by several space agencies including Hayabusa-2, Hayabusa Mk-II(Marco Polo), Don Quijote, OSIRIS, and Phobos-Grunt.

In addition to scientific and engineering motivations, NEO studies receive increasing interests in the context of planetary defense, deep space human spaceflight and potential in-situ resource utilization.

In 1980's, the inter-agency coordination group for Comet Halley exploration proved that synergy of coordinated individual missions could enrich total outcomes more than each result combined. Since then, international exploration working groups participated by international space agencies have been formed and played key roles for advancing fields of solar terrestrial physics, Moon and Mars missions.

As we are entering the second golden age of the primitive body exploration in upcoming decade, now is the appropriate time to create the International Primitive Body Exploration Working Group (IPEWG) in order to promote international collaborations and to maximize outcomes of each mission. With these in mind, the first IPEWG meeting will be hosted by JAXA at Okinawa, the southern-most, tropical island in Japan. All space agencies, scientists, engineers and other interested stakeholders are cordially invited.

[K - 2]

The First IPEWG Meeting in Okinawa, Japan (January 2008)

LESSONS LEARNED FROM INTERNATIONAL HALLEY ARMADA - RETROSPECTIVE OVERVIEW OF IACG ACTIVITIES -

Kuninori UESUGI (Professor Emeritus / JAXA, Tokyo, Japan)

[Contact E-mail : tono@isas.jaxa.jp]

In 1970s, four space agencies of the world, ESA(Europe), IKI(Russia), ISAS(Japan) and NASA(USA) had independently planned to send their space probes to Halley's Comet which would appear in 1985-86, 76 years after the previous apparition in 1910.

Aiming for success of these missions and to maximize the scientific results, the representatives of four agencies met at Padova, Italy in 1981 and decided to establish a working group, called Inter-Agency Consultative Group for Space Science (IACG). Its task was to **coordinate** all the space missions to Halley's Comet and all remote observations from space, whilst the task of its counterpart, the International Halley Watch (IHW), was to coordinate all observations from the ground.[1]

International cooperation may seem an obvious approach, but is not always easily achievable. All too often good ideas are hindered by political and bureaucratic constraints. Perhaps it was the informal attitude adopted by both the IACG and the IHW that made them so successful.[1]

To coordinate the scientific experiments to ensure the possible data return, to exchange technical information and link wildly dispersed systems and schedules into a common programs while leaving individual freedom for each agency to develop its projects to conform with its own methods and means has called for patience, tact, understanding, and above all trust and goodwill.[2]

After the incredible success of Halley Armada, IACG made the decision to continue its activities; extending them in the following years to other scientific programs of mutual interest, such as International Solar Terrestrial Physics (ISTP) Program. In addition, ILEWG (International Lunar Exploration Working Group) and IMEWG (International Mars Exploration Working Group) were established under the auspice of IACG.

[References]

[1] R. Luest, Opening Address on 20th ESLAB Symposium on the Exploration of Halley's Comet, (1986) ESA SP-250, Vol.1, pp.xv-xvi

[2] R.Luest, Presentation Address to His Holiness Pope John Paul II, (1986)

[K - 3]

The First IPEWG Meeting in Okinawa, Japan (January 2008)

SPACECRAFT VISITS TO PRIMITIVE SMALL BODIES
: RESULTS AND OUTLOOK

Andy CHENG (NASA-HQ, USA)

Abstract is not available.

ITALIAN ACTIVITIES AND PLANS IN THE FIELD OF EXPLORATION

Sylvie Espinasse (ASI, Rome, Italy)

[sylvie.espinasse@asi.it]

The presentation shall be devoted to Italian activities and plans in the field of exploration. Based on the experience acquired through national programmes and international collaborations, Italy is involved in robotic and human missions of exploration.

Currently, the attention for robotic exploration is focussed mainly on Mars. The exploration of the red planet started with the collaboration with Russia on the Mars 96 mission and was followed by the Italian contribution to the ESA Mars Express mission and to the NASA Mars Reconnaissance Orbiter mission. In the mean time, taking advantage of the expertise acquired with the development of the drill and sampling system of the Rosetta lander, several studies were carried-on for in-situ exploration in the framework of the previous NASA Mars sample Return 2003 and 2005 missions, in particular for subsurface samples collecting systems and for in-situ experiments. Italy also supported since the very beginning the ESA Aurora Programme for the robotic and human exploration of Mars. The first mission of the programme, ExoMars, is under development for a launch in 2013 under the leadership of Italy. It will deliver to the surface a rover equipped with a drill and sample collection system and a large scientific payload and a landed platform with scientific instrumentation. Italy is willing to continue to support the exploration of Mars in the ESA context. Italy will participate to the NEXT mission which is to be launched after ExoMars and to the Aurora's technological R&D activities that will enable Europe to play an important role in the future Mars Sample Return mission(s) in a broader international context. In this view, Italy is also ready to contribute significantly to the development of a Mars Telecom Orbiter to provide data relay capabilities for landed platforms at the surface of Mars starting from Exomars but also for NASA rovers if needed. Complementary ground based activities such as Mars GIS development, ASDC enhancement for planetary data, Martian analogues studies and field testing in Morocco are going on.

In parallel to the Mars exploration, consistent resources have been devoted at national level to involve the scientific and industrial communities to identify science driven robotic missions to the Moon based on national capabilities. The outcomes and results of these activities together with human exploration activities will be used in the future to define possible collaborations in the international framework of Moon exploration.

Particular attention is also devoted to primitive bodies such as comets, asteroids and giant planets satellites. Italy contributed to the NASA-ESA-ASI mission to Cassini and Titan, a large number of Italian scientists are leading or are members of several experiments on board the ESA Rosetta orbiter and Italy is part of the consortium who developed the Rosetta lander Philae and an Italian instrument is on-board the NASA Discovery mission Dawn on its way to Vesta and Ceres.
The above missions are mainly science driven but asteroids and primitive bodies are also very interesting bodies for exploration. On one side they represent the former building blocks of our Solar system but they are also very interesting targets for testing new technologies for exploration and they could be in the future target for human exploration and resources exploitation. This is why Italy is strongly involved in missions to asteroids and primitive bodies having contributed to the

CNES led LEONARD mission study (in-situ mission to an NEA) and having supported the ESA Cosmic Vision proposal Marco Polo. Italy is also collaborating with Russia on the Phobos sample return mission. And last but not least, ASI joined JAXA last December to carry on a mission study to assess the possibility to use the VEGA launch vehicle for the Hayabusa-2 mission.

[S1- 2]

The First IPEWG Meeting in Okinawa, Japan (January 2008)

UK ASPIRATIONS FOR SPACE EXPLORATION

Sue Horne (STFC, Swindon, UK), Jeremy Curtis (BNSC/STFC, Didcot, UK)

[Contact E-mail : j.curtis@rl.ac.uk]

This brief paper sets out the main drivers of the UK's space exploration programme, its long-term ambitions in this field and the missions in which it intends to participate.

The UK's main technological strengths are given in order to inform potential international collaborators.

Finally an explanation is given of the mechanism by which future bilateral collaborations will be considered in the UK.

The First IPEWG Meeting in Okinawa, Japan (January 2008)

CNES AND FRANCE IMPLICATIONS IN SMALL BODIES MISSIONS: PAST AND FUTURE

Francis Rocard (CNES, Paris FRANCE)

[Contact E-mail : francis.rocard@cnes.fr]

CNES and France implication in small bodies missions has started through the VEGA and GIOTTO missions to comet Halley in 1985 with several instrumental participations (camera, infrared spectrometer, mass spectrometer for grain analyses, size and mass of grains ...

This implication continues with an important involvement in the ESA ROSETTA mission. We contribute on numerous instruments of both the orbiter and the lander Philae. For this lander, CNES was involved in the system aspect of the vehicle in a consortium led by DLR. We also provide the telecom and the power (primary and secondary batteries) sub-systems. After the launch, CNES is in charge of the Science Operation and Navigation Center (SONC) of the lander located at CNES Toulouse.

We are currently developing instrumental contribution for the PHOBOS GRUNT mission of Roscosmos. This mission intends to land on the Phobos moon of Mars, to pickup samples and to bring them back to Earth. The launch is schedule for the end of 2009.

For the future, CNES and the French scientific community is interested to participate to a NEO sample return mission like MARCO POLO. Beyond instrumental participations, CNES could contribute at sub-system level like on ROSETTA mission. This will be discussed during the IPEWG meeting.

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DLR VISION AND PLAN

Ekkehard KUEHRT (DLR, GERMANY)

Abstract is not available.

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ESA'S MISSIONS AND MISSION STUDIES TO MINOR BODIES IN THE SOLAR SYSTEM

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The European Space Agency (ESA) has a long tradition in exploring small bodies in the solar system. The first images of a comet nucleus ever were obtained by ESA's Giotto mission to Halley's comet in the year 1986. One of the current flagship missions of ESA is Rosetta, a 2.5-ton spacecraft which is currently on its way to comet Churyumov-Gerasimenko where it will arrive in 2014.

Several studies to small bodies in the solar system have been performed within ESA, including the Don Quichote mission which studies the capabilities for the deflection of a Potentially Hazardous Object (PHO) to avoid an impact onto the Earth, and the currently ongoing Marco Polo mission, a collaboration with JAXA to return a sample from a Near Earth Object as part of ESA's Cosmic Vision programme.

Future plans also include building up observing and warning capabilities for Near Earth Objects as part of new programme proposal called Space Situational Awareness.

This presentation will summarize previous and existing small bodies missions and give an outlook for the future.

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NASA's VISION AND FUTURE PLANS FOR PRIMITIVE BODIES

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In exploring any particular solar system object, the Planetary Science Division has followed a general paradigm of flyby, orbit, land, rove, and return. This prescription has been followed most completely for investigations of the Moon and Mars. A complete campaign may not be performed for each interesting object in the solar system, since not all our scientific questions can be studied at all objects, and there are high technological and financial hurdles to overcome for some missions and certain destinations. Recently launched flyby or reconnaissance missions to primitive bodies include: New Horizons, a mission to Pluto and its moons (encounter July 2015), Dawn, a mission to orbit Vesta (fall 2011) and then onto orbit Ceres (summer 2015), both in the asteroid belt. In addition, NASA has also approved the use of its older Deep Impact (DI) and Stardust spacecraft to new targets. The EPOXI mission will use DI to flyby Comet Hartley 2 in October 2010, while Stardust NExT will complete the exploration of Comet Tempel-1 in February 2011. Tempel-1 was initially observed with DI but Stardust NExT will perform its flyby after that comet has pass perihelion. In addition to these future missions, PSD is also performing a variety of sample return studies that may eventually lead into a strategic or Principal Investigator lead mission.

In 1998 NASA initiated the Spaceguard Survey Program designed to observe 90% of Near Earth Objects (NEO) greater than one kilometer in size by the end of 2008. During this time period, NASA has found over 730 one kilometer or larger Near Earth Asteroids and 65 Earth approaching comets, as well as ~4,200 smaller NEOs. Our current estimate is that there are roughly of 940 one-kilometer NEOs. At the current discovery rate, we will have discovered about 50 more large NEOs by the end of 2008, bringing us very close to achieving our 90% discovery goal. NASA currently uses four survey teams that operate eight ground-based telescopes of mostly one-meter class apertures dedicated to searching the sky and detecting NEOs. All NEO observations that are collected are sent to an international "clearinghouse" for small body observations, called the Minor Planet Center.

The next phase of the NEO Survey program will be designed to discover 90% of all NEOs that are potentially hazardous objects (PHO) 140 meters and greater. To accomplish this phase of the program NASA will continue to look for opportunities using ground-based telescopes, spacecraft, and partner with other space agencies as feasible. For example, we are actively planning to use the Air Force Panoramic Survey Telescope and Rapid Response System (also referred to as Pan-STARRS) after it becomes operational with its first telescope next year. When Pan-STARRS is completed with its intended four-telescope configuration by 2010, this system alone could discover about 70% of the PHOs larger than 140 meters by 2020.

In summary, the future of NASA primitive body research efforts will contain a mixture of science missions (ie: Discovery, New Frontiers), leverage ground-based observatories and radar assets, and fund supporting Research and Analysis programs that continue to pursue the understanding of primitive bodies as building blocks of our solar system.

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JAXA's Primitive Body Exploration Program

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More than two years has passed since the exploration of Itokawa by Hayabusa spacecraft. For the first time, we saw real appearance of a very small solar system body, whose size is only about 500 m in length. We had a lot of scientific results form the observation of Hayabusa, and we got many clues to know the origin and evolution of the solar system. At present (January 2008), the daily operations of Hayabusa are being done for its earth return in June 2010.

As working for Hayabusa, we have also considered post-Hayabusa missions. Since the Itokawa is an S-type asteroid, next target should be a C-type asteroid, because these two types are abundant in the main asteroid belt. The next mission to Hayabusa is "Hayabusa-2", which will explore C-type asteroid. The spacecraft is quite similar to Hayabusa, so we can save time for manufacturing it. The current target asteroid of Hayabusa-2 is 1999 JU3, which is intensively observed in 2007 and 2008. At the same time, we were also considering much more advanced mission after Hayabusa-2, and this mission is called "Hayabusa-Mk2." The target of Hayabusa-Mk2 should be much more primitive objects such as P-type or D-type asteroids, CAT, and comets, and the spacecraft is a newly developed one. In this way, we (=JAXA) are considering programmatic missions for the exploration of primitive bodies. Since there are many small bodies in the solar system, we should have such strategic approach.

From 2006, Hayabusa-Mk2 is also considered under the scheme of Cosmic Vision of ESA with the European study group for small bodies of the solar system. And it was proposed to Cosmic Vision with the name of "Marco Polo." It has passed the first selection so now we are in the assessment phase. The spacecraft, for which Japan is responsible, is based on the idea of Hayabusa-Mk2, but we reconsider it to have a large lander and a new sampling system from Europe.

There are three principal purposes for asteroid exploration, that is, science, spaceguard, and resources. The science is the main target and we want to know the origin and evolution of the solar system and the life. And now, the other purposes, spaceguard and resources, are becoming important, too. The long-ranged exploration plan and international collaborations will be more important from now on.

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HYDRATED MINERALS ON ASTEROIDS

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Water has been an important driver in planetary science research. The search for water has been a central goal of US Mars missions, and its possible presence at the lunar poles is a critical factor for future human bases on the Moon. It is also of great importance for small bodies, found in many carbonaceous chondrite meteorites bound into clay minerals, interpreted as evidence of parent-body aqueous alteration [1]. It is a sensitive tracer of thermal history in meteorites and is associated with primitive objects such as comets and outer-belt asteroids [2]. The dwarf planet Ceres has a global subsurface ice ocean [3], and the difference in water abundances between Ceres and Vesta is one of the major science questions Dawn seeks to address [4].

Since the 1970s, telescopic spectra have been used to detect and study hydrated minerals (here defined as both OH- and water-bearing) on asteroids [5,6,7]. These observations have mostly been done in the 3-μm region, where water and OH have strong absorption bands, though a correlated absorption near 0.7-μm has also been used for these studies [8].

These studies have found that there are few hydrated asteroids in the inner belt, and few in the outer belt, with the mid-belt containing most of the asteroids showing 3-μm bands. This is related to findings that asteroid spectral classes range from few hydrated members (like the S class) to mostly hydrated members (like the C class) [2]. In the past several years, in-depth investigations of individual objects and statistical studies using large datasets have all provided new insights, helped along with additional models of aqueous alteration and new attempts to quantify water/OH content from spectra [7,9-16]. I will present an overview of the current state of knowledge about hydrated minerals on asteroids, including future directions and outstanding issues.

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TOWARDS ACCURATE MASS DETERMINATION WITH LASER ALTIMETER IN THE FUTURE SMALL BODIES' EXPLORATION

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Mass determination of small and irregular objects using spacecraft motion measured by laser altimeter onboard Hayabusa will be discussed[1,2,3]. In order to investigate interior structure by shaking locations and their frequencies, observed boulder locations [4] compared with slope distribution calculated using asteroid Itokawa's shape model is investigated.

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A BINARY ASTEROID AS A TARGET OF A SPACE MISSION: SCIENTIFIC INTEREST

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The Near-Earth Object population is estimated to be composed of 15% binary asteroids, among which a good fraction is of primitive (dark) taxonomic type. Therefore, binary objects can also be considered as target candidates for a space mission (in situ and or sample return). At least one of them, 1996 FG3, a C-type, is found to have an easy access (low Detla V to reach it) and we can expect that new ones will be discovered in the close future, hopefully also of other dark taxonomic types.

Although all primitive targets are interesting, as we know so little about these small bodies, binary objects offer the advantage to let us make a first determination of the mass of the primary before measuring it with the spacescraft, which is never an easy task. Then, our current understanding of their formation suggests that the primary and secondary originally belonged to a same body which was disrupted by rotational break-up or tidal disruption, and this has some consequences on their internal structure that could be tested by investigating them with a space mission. Finally, we can also expect that part of the recently formed surfaces of the primary and secondary originally belonged to the interior of the progenitor so that, if the formation scenario is correct, investigating the surface of these objects gives us the chance to probe the former interior of a larger object without having to drill at great depth.

I will briefly present some recent studies on the formation of binary NEOs by numerical simulations, which can justify the motivation to keep such objects as potential target candidates for a space mission. The aim is not convince that these objects should be considered as prioritary but just what original information they may provide, as it is clear that no matter which primitive target a space mission will go to, we will learn a lot, as it has always been the case with small body space missions.

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BINARY ASTEROID SYSTEM DYNAMICS AND SCIENTIFIC EXPLORATION

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Binaries are ubiquitous in the asteroid population, comprising at least 15% of the NEA population [1] and a significant fraction of the MBA population. Thus, it is likely that a future mission will visit a binary asteroid. More important, binary asteroids represent unique scientific targets that can address several fundamental questions related to asteroids and primitive bodies in general. These include a better understanding of the chronology of space weathering, the origin and physical nature of porosity in asteroids, the fundamental physics controlling the evolution of asteroids, and the morphology and size distribution of blocks on asteroids.

According to current theories of formation, a binary asteroid has been ripped apart or spun to fission at some point in its past. Thus, a binary asteroid should have material from both its original surface and interior distributed on the surface of the body, and thus should present surfaces of different "weathering ages''. This provides an opportunity for comparative weathering studies and sample collection from different strata of an asteroid. The usual asymmetry in the component asteroid sizes and their different spin rates also allows for comparative studies of asteroids under the same helio-centric conditions. The strong coupling between the rotational and translational motion of the bodies enables estimation of the mass distribution of the bodies by observing the dynamics of the system at close range. These observations can provide strong constraints on internal density distributions and can help resolve fundamental questions on the nature of porosity in small bodies. Finally, long-term monitoring of a binary system can test recent hypotheses on the time-scale of evolution of these bodies and better constrain formation and destruction rates of binaries in the solar system [2,3]. A scientific or exploration mission to a binary asteroid provides a compelling opportunity for answering such fundamental questions about asteroids and primitive bodies in general.

In pursuit of such a mission we have carried out a series of studies and analyses on the topic of binary asteroid system dynamics and on the motion of spacecraft and natural particles in this environment [4-10]. The system dynamics of these bodies are complex and involve non-trivial interactions between the rotation state of the components and their mutual orbit [4,5]. These lead to generalizations of well-known dynamical phenomenon such as Cassini states, as there are non-trivial interactions between the rotational angular momenta of both bodies and their mutual orbit, the sum of which must be conserved. Such dynamics internal to the system allow an observer to infer gravity coefficients without directly measuring gravitational attraction via Doppler measurements [5]. This is significant as it implies that it is not necessary for a spacecraft to orbit a binary system to estimate mass distribution and opens the possibility for a hovering mission design [6]. Similarly, if the secondary is in an excited orbital state, as is believed for the binary asteroid 1999 KW4 [7], it is possible to directly estimate the moments of inertia of that body based on imaging alone.

It is also possible to apply a more aggressive approach to exploration using spacecraft in closer proximity to these systems. The navigation of spacecraft in a binary system is challenging, as the gravitational attraction of each body must be accounted for – defining a mini-restricted 3 body problem with non-spherical primaries [8]. The design of navigable spacecraft trajectories in these systems is feasible, although there are strong constraints on orbital geometry. Surface exploration of these bodies opens additional opportunities. Beyond the advantages of the surface exploration of a single body, it is feasible for a surface vehicle to "hop" from one member of the system to the other, as such transfer speeds are generally only on the order of centimeters per second [9].

Starting from these considerations, a suite of possible missions to binary asteroids can be envisioned. Ranging from simple missions that achieve significant scientific goals by merely being "in the neighborhood" and taking pictures, to more challenging missions that may orbit within the binary system or explore the surfaces of the bodies. Thus, for the exploration of an asteroid or primitive body of any type, observation of a binary of that type should yield the highest priority as it can provide the most complete picture of the object's history and morphology.

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DEEP INTERIOR: RADAR EXPLORATION OF ASTEROID AND COMET INTERIORS

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The exploration of asteroid and comet interiors can be achieved in a number of ways, but by far the simplest in terms of flight readiness is the technique of penetrating radar during a several month spacecraft rendezvous, deployed in reflection mode with no landers. This is the *Deep Interior* concept, which will be described in terms of its science goals, its stand-alone mission status and technological readiness, and its feasibility as a mission of opportunity. Its science goal is to tell us about the compositions and structures of primitive bodies.

Our mission's radio reflection tomography technique is analogous to doing a "CAT scan" from orbit. Closely sampled radar echoes are processed to yield volumetric maps of mechanical and compositional boundaries, and to measure interior material dielectric properties. The flight heritage of appropriate hardware applied to ice, rock, and rock-ice mixtures has been demonstrated by two radar experiments at Mars, MARSIS on Mars Express (Picardi et al., *Radar Soundings of the Subsurface of Mars*, Science 2005; Plaut et al., *Subsurface Radar Sounding of the South Polar Layered Deposits of Mars*, Science 2007), and SHARAD on MRO (Seu et al., *SHARAD Sounding Radar on the Mars Reconnaissance Orbiter*, JGR 2007). These have discovered subsurface structures on Mars to 3.7 km depths in south polar region and to 1 km depth in non-polar areas.

Apart from ongoing development of higher fidelity radar instruments, a MARSIS-class radar deployed in orbit about a primitive body will enjoy the following significant simplifying benefits compared to using the same instrument for Mars science:

(1) The proximity of operations leads to a much higher signal to noise, +30 dB or more.

(2) The lack of an ionosphere makes for far simpler data modeling and analysis, compared with what is being required at Mars.

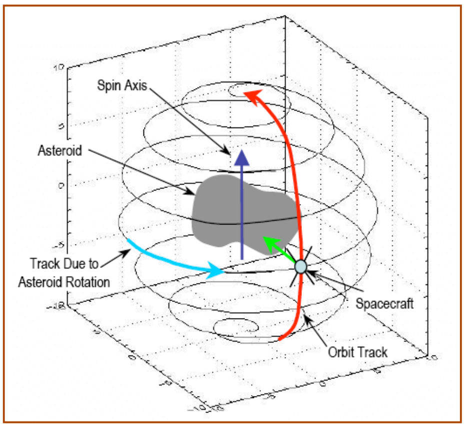
(3) The asteroid or comet is globally illuminated during every data acquisition, meaning that the data return can be correlated directly with the asteroid shape model, with no ambiguities regarding internal versus surface reflectors. Moreover, with sufficient a posteriori navigation accuracy, the data can afterwards be inverted for a unique model of internal structure.

Laboratory measurement of dielectric properties for a suite of meteorite materials (Heggy et al., *Dielectric Properties of Chondrites and Their Implication in Radar Sounding of Asteroid Interiors*, LPSC 2007) show that a ~10 MHz spacecraft radar is appropriate for global illumination of chondritic asteroids ~5 km diameter, for imaging at a scale of a few meters, whereas ~100 MHz radar can globally illuminate asteroids ~1 km diameter. The trade is that there is a close correspondence between the navigational accuracy, and the resolution of the tomography (or the radar wavelength).

A mission benefit is that the dielectric properties of chondritic meteorite types can be discriminated from one another, so that radar reflection can be used not only for structural analysis, but also for interior compositions. There will be challenges; for instance it may prove difficult to discriminate porosity from composition. Moreover, larger asteroids and comets may prove to be globally impenetrable, especially those containing high proportions of salty clays or metals. M types, which may be hydrated and/or metallic, may therefore not be good target choices. The mesosiderite and chondrite asteroid types, though containing free metal, would be very well suited, as would basaltic/melted V- and related types. Deep Interior can investigate most, if not all, of the known small asteroids, and all short-periodic comets.

Deep Interior utilizes a polar orbit about a nominal ~km-sized asteroid (see Figure), with a period of weeks, while the asteroid or comet spins below with a period of hours. (The shorter the rotation period, the shorter the rendezvous.) The result is to obtain thousands of radar looks, providing global interior coverage at a spatial scale that is well-sampled and accurate to within a fraction of the wavelength. At small (sub-km) comets or asteroids, or active comets, or binary systems – wherever long-term stable orbits may prove elusive – a station keeping (Hayabusa) approach is preferable to orbiting, in which case long, slow arcs above the rotating asteroid will provide similar coverage.

Our team has found that optical imaging is sufficient for the *a posteriori* reconstruction of positioning and pointing. Radar provides rock-solid but relatively low-resolution starting points for the spacecraft position and asteroid shape reconstruction, which are ultimately based upon the images (Gaskell et al., *Landmark Navigation Studies and Target Characterization in the Hayabusa Encounter with Itokawa*, AIAA 2006). The only instruments required for Deep Interior are a radar (including antenna) and a high-resolution camera. The mission fits comfortably inside of modest cost parameters, including repeated investigations at multiple bodies. The technology is expected to evolve into a very low cost flight package that could be flown routinely on small spacecraft to near-Earth objects.



Peeling the Apple of a Primitive Body

Deep Interior performs a "CAT scan". It enjoys simplifying advantages over Mars radar observations, which are otherwise similar: cleaner signal, no ionosphere, no clutter, and global illumination. Processing occurs at a variety of levels, from radargrams to full-on tomographic reconstruction. For tomography, data must be acquired at a high spatial fidelity, requiring quality navigation.