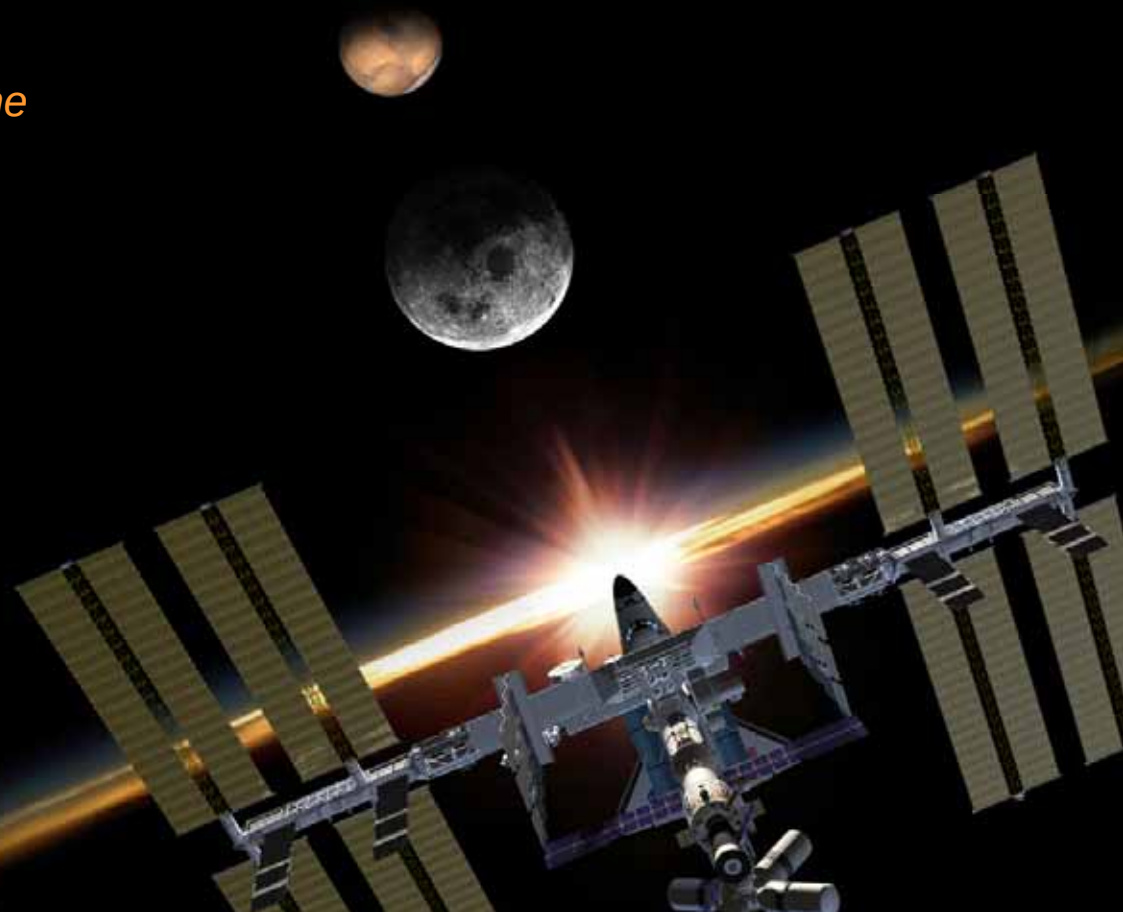
Human Exploration Objectives, Strategy, and Architecture

<u>Objective</u>: To understand individual national strategies, perspectives, interests and plans for space exploration

Earth is the cradle of humanity, but one cannot live in the cradle forever.

K. Tsislovsky



November 18, 2004

Tom Cremins
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Session Participants:

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***Presenter**

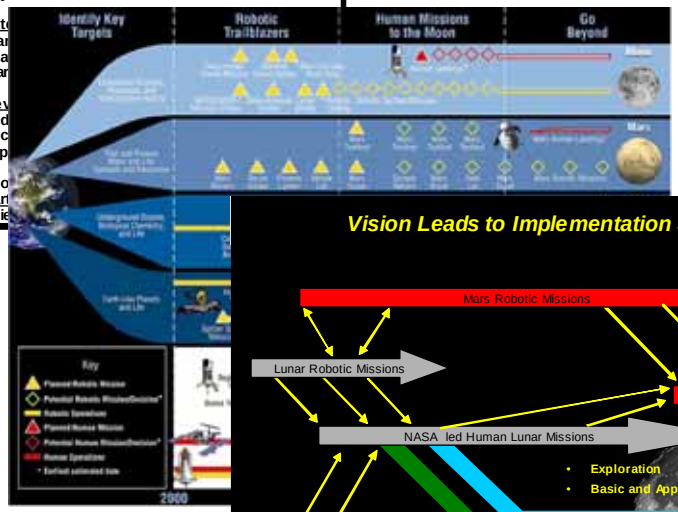
Flow Down from Vision

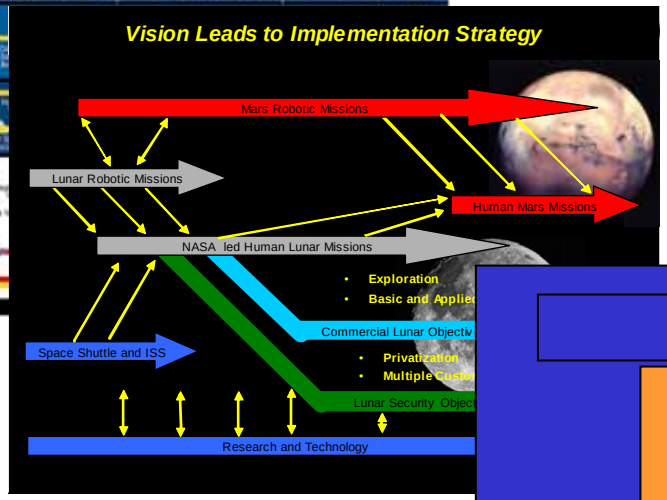
Human Exploration Strategy, Objectives, and Architecture

The Vision for U.S. Space Exploration

THE FUNDAMENTAL GOAL OF THIS VISION IS TO ADVANCE U.S. SCIENTIFIC, SECURITY, AND ECONOMIC INTEREST THROUGH A ROBUST SPACE EXPLORATION PROGRAM

Implement a sustained and affordable human and robotic program to explore the solar system and beyond





Architecture

Requirements

Technologies

Key Questions

- **What are your agency's strategies, objectives and plans for future human space exploration?**
- **What are the driving rationales?**
- **What timetable is your agency projecting?**
- **What is the status of your plans? (Conceptual, approved, funded?)**
- **How do your robotic exploration plans relate to the interests and objectives in human exploration?**
- **How do you relate the Vision for U. S. Space Exploration to your plans and interests?**
- **What space exploration studies has your agency completed in the recent past and what plans exist for future studies?**
- **What are your interests in lunar exploration?**
- **How do you view exploration of the Moon as a testbed for going to Mars?**
- **What other interests do you have for a for human presence on the Moon?**
- **What role will research, testing and demonstrations on the ISS fit into your agency's goals for future space exploration?**

Overarching Strategies

- **Robust human and robotic space exploration program**
- **Sustained human presence**
- **Near-term, visible, relevant milestones, accomplishments, and missions**
  - ISS/human linkage to exploration
- **Align institution and programs to Vision**
- **Apply critical management principles**
- **Hardware compatibility across elements**
- **Economic Interests/ Commercial Participation**
  - **Public offerings/challenges**
- **Science Interests**
- **Security Interests**
- **International Participation**
- **Education Benefits**
- **Technology development**
- **Preparation for Mars and beyond**

Lunar Exploration Strategy

Mission statement derived from the Vision for US Space Exploration:

- **Establish a human presence on the Moon for the purpose of learning to live and work productively and permanently in a planetary environment.**

Apply basic principles:

- **Develop robust architectural capabilities to support multiple strategic goals**
- **Create new opportunities for basic and applied science**
- **Enable economic, security, international, educational objectives**
- **Prepare for transition to a self-sustained presence from the start**
- **Catalyze opportunities for private sector and international partners**
- **Create the institutional framework for non government economic viability**
- **Dramatically improve economics of space transportation**
- **Use lunar resources to create space faring capability**
- **Early accomplishment, early capabilities**
- **Robotic presence first, then integrated robotic and human capability**
- **Incremental building blocks**
- **Cumulative – each step builds on previous one**

Straw Man Strategy

- **Identify site on Moon to use for first human outpost now: South Pole. Allow for expansion to Lunar North Pole and other sites**
- **Characterize this site at a sufficient level of detail to plan for occupation and utilization**
- **Fly robotic missions to collect key data; use data to make architectural decisions, fly additional robotic missions to get follow-up info, (2008-2011)**
- **Communications and navigation, geospatial information, (2008-2011)**
- **Emplace robotic infrastructure on Moon (at single site) to build up outpost prior to human arrival (2011-2015)**
- **Use humans to extend and improve surface and science operations and in situ resource utilization (2015-2020 objective)**

Initial Human Missions

- **<u>Suggested strawman</u>: Crew on surface for increasing durations first, then numbers of crew**

  <u>Activities</u>:
  - **Secure and finalize habitat module emplacement**
  - **Check-out and use pre-emplaced equipment (rovers, loaders, etc)**
  - **Service ISRU equipment and collect harvested products for use on Moon initially, preparing for broader use**
  - **Explore vicinity, augmented by robotics**
- **Enable commercial and international partners in developing/supporting/utilizing basic capabilities**
- **Simulate candidate Mars surface stay in direct support of first human mission to Mars.**
- **Exploit capabilities for *commercial* benefits:**
  - **If payoff is evident, export ISRU products for potential use and/or sale in cislunar space**
- **If interests indicate growing requirements, then provide additional infrastructure**

Human Exploration Strategy, Objectives, and Architecture

Roadmaps

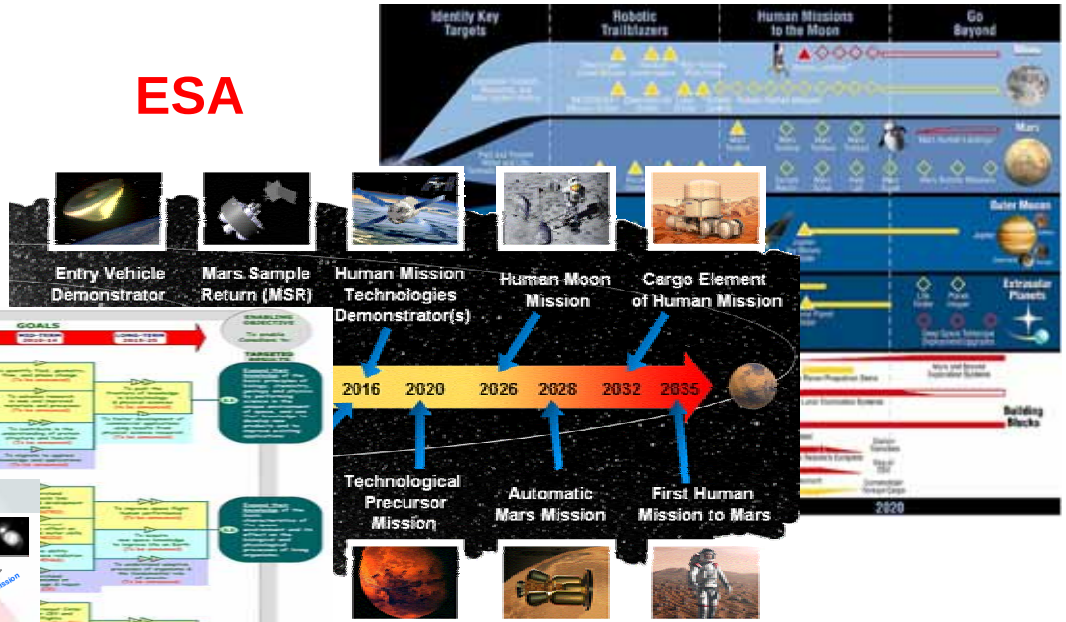
NASA

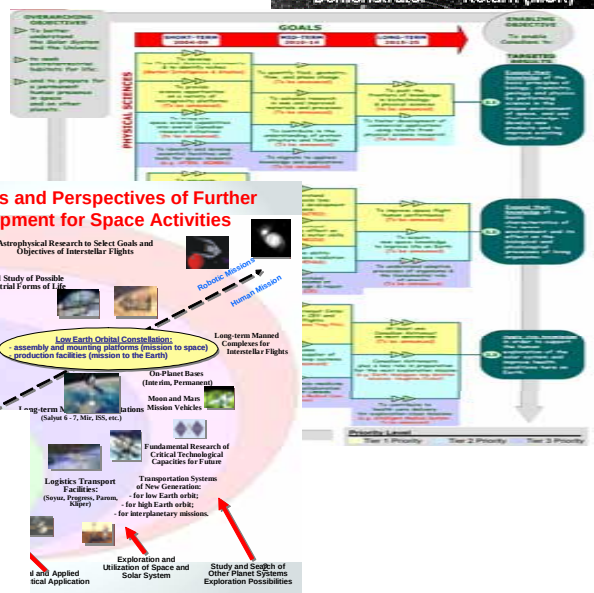
ESA

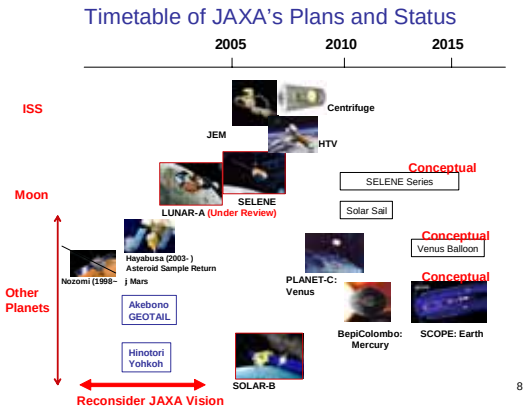
CSA

FKA

JAXA







Individual Roadmaps are being assessed with respect to the US Vision for Space Exploration

Human Exploration Strategy, Objectives, and Architecture

International Cooperation Matrix

Breakout Session Title Human Exploration Strategy, Objectives, and Architecture

Category of Opportunity	Description	NASA	FKA	JAXA	CSA	ESA	INTA	CNES	DLR	ISRO	KARI	ASI	Comments
Transportation													
	Advanced Chemical Propulsion												
	Electric Propulsion												
	Nuclear Thermal												
	Cryogenic Fluid Management												
	Aerocapture												
c	Automated Rendezvous and Docking												
Human Support													
	Radiation Protection												
	Medical Care												
	Life Support Systems												
	Human System Design												
Crosscutting													
	Sensors and Instruments												
	ISRU												
	Advanced Materials												
	Thermal Management												
	Advanced EVA												
	Robotic Human Support												
	On-board Computing												
	Simulation Based Analysis												
	Communications												
	Supportability												
Advanced Space Power													
	Generation												
	Storage												
	Distribution												

DRAFT

The Way Forward for International Participation

- **It is important we get the ISS experience, achieving our commitments and leveraging investments. It is a necessary political and technical goal, and a necessary step in the Vision. We can focus the ISS on the human element in the journey and testing capabilities.**
- **Long term Mars priorities are very common.**
- **There is significant planning in robotic exploration among the partners. We should all collaborate to avoid duplication and maximize complementary objectives.**
- **General support for the Vision as it has been laid out; including Lunar Exploration. Every country is going through an evaluation of what the Vision means to them, their interests, and roadmaps.**
- **Regardless of the outcome of future participation there are a broad set of technologies that partners want to bring to bear. Looking at the larger vision of the Moon, Mars, and beyond there are many opportunities for application of technology and capabilities.**

The Way Forward for International Participation

- **Science: There appears to be a broad set of common science questions and objectives. (e.g., If life exists elsewhere, origin of life, understanding our place in the universe).**
- **We are all focused on the benefits to our societies and society as a whole. Inspiration, education and societal benefits are common motivations for programs around the world. Many technologies needed by society are common with exploration.**
- **There is an interest in the expansion of the human presence in space that relates to the other interests as an objective in itself.**
- **Security: By working together on common space objectives, we are addressing our common security and well-being.**
- **Common standards and compatibility between systems are important and raises the issue of overall governance.**
- **Reduce duplication; be complementary**

Next Steps

- **Continue to evaluate individual roadmaps with respect to the Vision for U.S. Space Exploration and our strategy. Initial by March and final by August**
- **We should develop the needed core competencies for Exploration and all parties should identify areas they are interested in. January**

Riders and Brothers

"To see the Earth as it truly is, small and blue and beautiful in that eternal silence where it floats, is to see ourselves as riders on the Earth together, brothers on that bright loveliness in the eternal cold - brothers who know that they are truly brothers."

-Archibald MacLeish, Poet, 1968.

Earth

Robotic Exploration Objectives to Support Human Missions

Workshop Summary

18 November 2004

Key Messages

- ***Mars is the central exploration focus for nearly all countries***
  - *Most countries haven't identified the Moon as stepping stone to Mars in their strategic planning (with robotic precursors)*
  - *Current planning in countries other than the U.S. is driven by the science priorities developed within their own science constituencies and the global marketplace*
  - *Mars Sample Return was the highest Mars priority in general*

- ***Most countries are application-driven***
  - *their missions and products have to be traced to specific technologies with clearly-defined societal benefits*

- ***A large amount of technology development will be required to enable exploration***
  - *There are a lot of relevant technologies that are planned or being developed that will be extremely valuable to exploration*

- ***Everyone is excited about the potential for true collaboration***
  - *This workshop is a good first step – engaging potential partners before plans are set in stone*
  - *We need to learn the lessons from past collaborative efforts*

Key Messages (con't)

- ***There are many robotic missions planned to both the Moon and Mars***
  - *Collaboration on key missions such as Mars Sample Return is advantageous for all*

- ***Sharing of data from missions is essential to moving forward in a collaborative way***
  - *This is an area where innovative new practices could be of great benefit to Exploration*

Break-out Session Process

- 10 agencies participated
  - ASI — Simonetta Di Pippo
  - CONAE — Roberto Alonso
  - CSA — Pierre Allard, William Harvey
  - CNES — Richard Bonneville
  - DLR — Juergen Drescher
  - ESA — Bruna Gardini
  - JAXA — Kohtaro Matsumoto
  - Roskosmos — Konstantin Pichkhadze, Artem Ivankov
  - UK(BNSC) — David Parker
  - Ukraine — Oleg Fedorov

- 9 agencies presented in addition to NASA
  - Presentations covered each agency's areas of expertise and interest in Lunar and Mars robotic missions as well as space weather monitoring and prediction (NEO's?)

- Summary spreadsheet captured all capabilities, missions, instruments of interest and top 3 items on interest to us/them for Exploration were identified (included in these slides).

- Discussions occurred regarding the measurements, technologies, infrastructure required for robotic precursors. In addition, we discussed the barriers to and potential solutions for collaboration on these efforts.

Russia – Key Areas of Interest (Top 3)

- ***Mars Grunt, Phobos Grunt***
  - ***Mars and Phobos sample return missions with key technologies for inflatables used in entry, descent and landing systems***
  - ***Inflatable technologies maturation and development is of specific interest***

- ***Radioisotope power and heating technologies for long duration missions (Moon and Mars)***

- ***Project Luna-Glob***
  - ***High speed penetrator and sample return from the Moon***
  - ***Penetrator technology maturation and development is of specific interest (also of high interest for Mars)***

Ukraine – Key Areas of Interest (Top 3)

- ***Identifying mechanisms for collaboration, i.e., how to develop a new relationship with NASA and other space agencies***
  - *Getting the science community and industry to understand how to engage with NASA processes*
  - *Defining a complementary relationship with NASA*
  - *Addressing these issues in international working groups*

- ***Developing official framework for ongoing dialogue with NASA***

- ***Key areas of interest to Exploration:***
  - ***Sun-earth connections***
  - ***Space life science***
  - ***Lunar missions***

Italy – Key Areas of Interest

- ***Telecom infrastructure***
  - *Mars Telecommunications Orbiter (near-term), moon-Mars networks (longer-term)*

- ***Remote Sensing and in-situ instrument capabilities for Moon, Mars and beyond***

- ***Robotics***
  - *Drilling*
  - *Sample acquisition and distribution*
  - *In situ analysis (including analyzing samples on Earth)*

- ***Reentry technologies related to inflatables***
  - *General inflatable technologies, i.e. Transhab*

JAXA - Key Areas of Interest

- ***JAXA is still working on their Exploration roadmap and is interested in all areas related to Exploration.***

- ***NASA identified key areas of interest:***
  - *SELENE - Lunar gravity field, mineralogy, chemical elements*
  - *Advanced robotics - automated rendezvous and docking, humanoids, rescue robots*
  - *Penetrator technology development*

UK – Key Areas of Interest (Top 3)

- ***Areas of key science interest that are synergistic with Exploration***
  - *i.e. remote sensing and in-situ payloads for Mars orbiters and landers*

- ***Miniaturization of in-situ payloads***
  - mini-mass spectrometer, '**lab on a chip**' sensor which uses anti-bodies to identify complex carbon chemistry e.g. micro-biology, X-ray spectrometry, UV sensors, miniature stereo cameras
  - May be applicable to some human precursor experiments

- ***Entry, Descent, Landing***
  - Hypersonic modeling, parachutes, radar altimeters, airbags (vented tech.) software and avionics

CNES – Key Areas of Interest (Top 3)

- ***Robotic exploration of Mars strongest interest***
  - *In-situ analysis capabilities were of particular interest*
  - *Implementing a Mars Network such as "Netlanders"*
  - *Participating in MSR*

- ***Planetary Protection for Mars Sample Return (both Mars contamination issues and Earth containments facilities)***

- ***Network science lander project - seismometers, meteorology, atmospheric observations, instrumented entry, descent and landings***

ESA – Key Areas of Interest

- ***Architectural and strategic analysis of Mars program***
- ***Exo-Mars - rover and Pasteur payload (exobiology to search for life)***
- ***Mars Sample Return***
- ***Interest in Lunar activities beyond SMART-1 under consideration***

Canada – Key Areas of Interest

- ***Getting feedback from NASA about the results of this workshop related to Canada's role***

- ***Coordinating NASA / Canadian solicitation processes***

- ***Getting the science value out of the Vision for Exploration (what is the "hook" for CSA?)***

- ***NASA identified key areas of expertise/opportunity related to Exploration:***
  - *LIDAR (for topography, precision navigation, autonomous rendezvous and docking, surface navigation)*
  - *Robotic manipulators (tele-operation and autonomous)*
  - *Canadian Mars mission*

DLR - Key Areas of Interest

- Robotic
  - Maintenance, inspection, on-board autonomy, in-space assembly of large objects
- New collaborative business approaches
- Infusion of results from DLR robotic servicing such as TECSAS into CEV related activities and others
- Avoiding situations without follow-up plans for technology

Next Steps

- *All were interested in reporting back to their agencies and governments the results of the workshop.*
  - ***Action by 12/04: Summarize the capabilities matrix and confirm with each of the agencies. Reassess and review priorities (esp. top 3)***

- *Most agencies indicated a strong interest in the Science Mission Directorate International meeting next March*
  - ***Action by 2/05: Ensure workshop agenda is synergistic with Exploration and we clearly communicate the intersection of the two programs***

- *International Working Groups are and effective mechanism for developing strategies and roadmaps (I.e. Mars Exploration Program Working Group)*
  - ***Action by 1/05: Ensure we have adequate International participation in these groups and that the charters are synergistic with Exploration. Lunar Exploration Program Analysis Group is next step.***

Next Steps (con't)

- *Some agencies indicated a desire for bi-lateral discussions regarding the key capabilities we identified.*
  - ***Action by 4/05: Determine the requirements, schedule, content of bi-lateral discussions regarding key capabilities.***

- *Sharing of data from missions is essential to moving forward in a collaborative way*
  - ***Action by 8/05: Work with Planetary Data System (PDS) community and others to determine strategy for developing common access to mission data.***

- *There are many robotic missions planned to both the Moon and Mars*
  - ***Action by 8/05: Engage key agencies in Roadmapping activities in order to suggest the best near-term mission sets for a collaborative program. (Common action with Session #1).***

International Workshop Session 3: Human Missions and Systems Beyond LEO

Thursday, 18 November 2004

Agenda

- **Administrative Remarks**

- **NASA Exploration Systems Overview**

- **International Program Participation**
  - Agency representatives from Roskosmos, ESA, CNSA, JAXA, and CNES to present their thoughts on human missions and systems

- **Workshop Product Directed Discussions**
  - Discuss key topics

- **Wrap-up**
  - General Summary, Points of Contact, Product (Matrix)

Workshop Product Directed Discussion Scope

- **Discuss missions, including:**
  - Lunar science, Lunar and ISS operations testbeds
  - Lunar commercial services and resource exploration and harvest
  - Near Earth Objects
  - Mars
  - Assembly of telescopes or commercial service depots

- **Discuss functional systems, including:**
  - Transportation stages,
  - Communication and navigation
  - Propellant depots, power
  - Surface habitation,
  - Surface mobility, extravehicular suits and tools,
  - In-situ resource generation

- **Strategy, Architecture, & Requirements**

- **Subsystems discussion planned but deferred to technology session**

Key Discussion Topics

- Present international agency plans for beyond LEO exploration.
- Identify mission(s) of interest to multiple agencies.
- Identify existing systems or major subsystems that could contribute to the functional requirements of the identified missions.
- Identify demonstrated capabilities that could contribute to systems design,
- Identify existing programs and funding that could contribute to the missions, systems, or other capabilities identified above. Identify overlapping goals with each agency's primary and secondary objectives.
- *Deferred:* Identify desired level and mechanisms for collaboration; for example, shared data or experience, contribute subsystems, or contribute major architecture functionality (system or systems). Identify cooperative mechanisms that ensure efficient and effective integration.
- Identify points of contact to mature collaboration formulation plans.

Participants

- **ASI**
  - Andrea Lorenzoni
- **CNES**
  - Francois Spiero
- **CNSA**
  - Meng Hwa
- **CSA**
  - Myriam Dube
  - Nichole Buckley
- **ESA**
  - Loredana Bessone
  - Scott Hovland
- **JAXA**
  - Yoshifumi Inatani
- **ROSKOSMOS**
  - Yuri Grigoriev, RSC-E
  - Leonid Vasiliev
- **NASA**
  - Dave Herbeck – SOMD
  - Bill Jordan – Ext Relations
  - Randy Correl – DoD
  - Bret Drake -- ESMD
  - Mike Lembeck – Session Chair, ESMD
  - Garry Lyles – Session Chair, ESMD
  - Jeff Belanger -- ESMD
  - Roger Crouch – Senior Scientist, ISS Program
  - Kate Maliga, office ext rel
  - Neil Woodward, ESMD
  - Mark Ogles, ESMD

Results

Category of Opportunitiy	Description	NASA	JAXA	Roskosmos	ESA	CNES	CSA	CNSA	ASI	Comment
Missions	Human Lunar	P	I	N	P	C	I		I	
	Robotic Lunar	P	F	C	F	C	P	I	I	
	ISS Utilization-Human Exploration	F	F	C	F	F	F		I	
	ISS Utilization-Basic Research	F	F	C	F	F	F			
	Lunar Commercial	I	I	N			N	I	I	
	Near Earth Objects	F	F	I	F	C	I	I		
	Human Mars	P	I	P	P	I	I		I	
	Human Mars vicinity	P	I	P	P	C			I	
	Robotic Mars	F	I	I	F	P	P		I	
	Assembly of telescopes		I		I		I			
	Planetary Missions beyond Mars	F	F	I	F	I	I		I	
	Commercial service depots	I							I	
Requirements development / coordination	Strategies & Roadmaps	P	I	P	P	I	P		P	First step for everyone
	Architectures & Requirements	P	I	P	I	I	I		I	

F- Funded
P-Proposed
I- Interested
C-Capability exists
N-No Interest

Results

Category of Opportunitiy	Description	NASA	JAXA	Roskosmos	ESA	CNES	CSA	CNSA	ASI	Comments
System provision	Surface Robotics, Rovers	F	P	C	P	P	P		I	
	Orbital Systems and Robotics	F	C	C	F	I	F		I	
	Medical Systems	F	F	C	F	F	P		C	
	Advanced Life Support systems (ECLSS)	F	F	C	F	P	F		C	
	Space Transportation Stages	P	P	P	P	I	N		I	
	Crew Carrier (CEV, Clipper, etc.)	P	I	P	I	I	N		C	
	In-space Cargo Carrier	I	F	C	F	I	N		I	
	Launch Facilities	F	F	F	F	F	N	F	F	Active Facilities
	Advanced Comm & Navigation	P	I	I	I	I	I		I	Advanced= supports Human Mar Missions with wide bandwidth.
	Communication and Navigation	F	C	P	C	C	I		C	
	Human Re-Entry systems	P	I	C	I	I	N	C	I	
	Surface habitation	I	I	I	I	I	I		C	
	In-Space Pressurized Modules beyond	I	I	P	I	N	N		C	
	Inflatable Structures / Habitats	I	I	C	I	I	I		P	
	Advanced Human Surface Mobility	I	I	I	I	N	I		I	
	EVA suits	I	I	P	I	I	N		N	
	Mission Control	F	F	F	F	F	F		F	Current Funding for ISS for all "F"
	In-situ (surface) Resource Utilization	I	I	I	I	I	I		I	
	Propellant Depot (refueling station)	I	I	I	I	N	N		I	

F- Funded
P-Proposed
I- Interested
C-Capability exists
N-No Interest

Results with Notes

Category of Opportunitiy	Description	NASA	JAXA	Roskosmos	ESA	CNES	CSA	CNSA (TBC)	ASI	Comment
Missions	Human Lunar	P	I	N	P	C	I		I	
	Robotic Lunar	P	F	C	F	C	P	I	I	Proposed as part of the Arurora roadmap, mission scope is TBD
	ISS Utilization-Human Exploration	F	F	C	F	F	F		I	
	ISS Utilization-Basic Research	F	F	C	F	F	F			Science Program, No futu plans
	Lunar Commercial	I	I	N			N	I	I	
	Near Earth Objects	F	F	I	F	C	I	I		Under ESA Scientific Program
	Human Mars	P	I	P	P	I	I		I	
	Human Mars vicinity	P	I	P	P	C			I	Roadmap only
	Robotic Mars	F	I	I	F	P	P		I	In work.
	Assembly of telescopes		I		I		I			
	Planetary Missions beyond Mars	F	F	I	F	I	I		I	Follow-on not funded.
	Commercial service depots	I							I	Under Science program
										In work.
										Desires to work with NASA to compare roadmaps.
										Within International Cooperation
Requirements development / coordination	Strategies & Roadmaps	P	I	P	P	I	P		P	Within International Cooperation ne
	Architectures & Requirements	P	I	P	I	I	I		I	With current Exploration Visions

Results (with notes)

ECLSS research funded.

Research is Funded

ISS flight: Improving technologies

Funded with Future Robotics, Study level for orbital systems.

Funded, for either ISS or other programs

ARES, biological regeneration (Melissa program)

Category of Opportunitiy	Description	NASA	JAXA	Roskosmos	ESA	CNES	CSA	CNSA	ASI	nts
System provision	Surface Robotics, Rovers	F	P	C	P	P	P		I	
	Orbital Systems and Robotics	F	C	C	F	I	F		I	
	Medical Systems	F	F	C	F	F	P		C	
	Advanced Life Support systems (ECLSS)	F	F	C	F	P	F		C	
	Space Transportation Stages	P	P	P	P	I	N		I	
	Crew Carrier (CEV, Clipper, etc.)	P	I	P	I	I	N		C	
	In-space Cargo Carrier	I	F	C	F	I	N		I	
	Launch Facilities	F	F	F	F	F	N	F	F	Active Facilities
	Advanced Comm & Navigation	P	I	I	I	I	I		I	Advanced= supports Human Ma Missions with wide bandwidth.
	Communication and Navigation	F	C	P	C	C	I		C	
	Human Re-Entry systems	P	I	C	I	I	N	C	I	
	Surface habitation	I	I	I	I	I	I		C	
	In-Space Pressurized Modules beyond	I	I	P	I	N	N		C	
	Inflatable Structures / Habitats	I	I	C	I	I	I		P	
	Advanced Human Surface Mobility	I	I	I	I	N	I		I	
	EVA suits	I	I	P	I	I	N		N	
	Mission Control	F	F	F	F	F	F		F	Current Funding for ISS for all "F
	In-situ (surface) Resource Utilization	I	I	I	I	I	I		I	
	Propellant Depot (refueling station)	I	I	I	I	N	N		I	

Funding for existing systems onboard ISS

Melissa

In complement to ESA

Design study underway, not funded for development.

Progress capability exists and funded for ISS. Designed multi-use cargo carrier

Proton launch facility usable for Mars-related missions

In cooperation with ESA

Funded for ISS, interested in extended capability.

Funded for ISS cargo, not funded for extension

ALTEC

ATV control center, in cooperation with ESA

Studies are ongoing, depends on architecture

Funded for Shuttle and ISS ops

Existing Capability from Apollo

Summary

- **The future exploration of space will benefit from international partnerships**
- **We need to identify objectives in common (as a basis for cooperation) in order to increase efficiency as prospective partners**
- **Mutual understanding of strategies and architectures is critical for establishing successful partnerships**
- **Table generated is preliminary and will need to be updated by respective agencies. It is a starting point for future discussion**

Points Of Contact

- **POCs Identified**
  - ASI - Andrea Lorenzoni
  - CNES - Francois Spiero
  - CNSA - Meng Hwa
  - CSA - Nicole Buckley
  - ESA - Scott Hovland
  - JAXA - Yoshifumi Inatani
  - NASA - CDR Neil Woodward
  - Roskosmos - Yuri Grigoryev

- **POCs agreed to provide updated contacts within next two weeks for topics listed in results matrix**
- **Allow new POCs to update results matrix by March 05**
- **Roadmaps & Architectures discussion June 05**
- **Discuss common objectives August 05**

Session 3: Human Missions and Systems-Beyond LEO

ECLSS **research** funded.

Research is Funded

ISS flight: Improving

Category of Opportunitiy	Description	NASA	JAXA	Roskosmos	ESA	CNES	CSA	CNSA	ASI	
System provision	Surface Robotics, Rovers	F	P	C	P	P	P		I	
	Orbital Systems and Robotics	F	C	C	F	I	F		I	
	Medical Systems	F	F	C	F	F	P		C	
	Advanced Life Support systems	F	F	C	F	P	F		C	
	Space Transportation Stages	P	P	P	P	I	N		I	
	Crew Carrier (CEV, Clipper, etc.)	P	I	P	I	I	N		C	
	In-space Cargo Carrier	I	F	C	F	I	N		I	
	Launch Facilities	F	F	F	F	F	N	F	F	Active Facilitie
	Advanced Comm & Navigation	P	I	I	I	I	I		I	Advanced= su Mars Missions
	Communication and Navigation	F	C	P	C	C	I		C	
	Human Re-Entry systems	P	I	C	I	I	N	C	I	
	Surface habitation	I	I	I	I	I	I		C	
	In-Space Pressurized Modules beyond	I	I	P	I	N	N		C	
	Inflatable Structures / Habitats	I	I	C	I	I	I		P	
	Advanced Human Surface Mobility	I	I	I	I	N	I		I	
	EVA suits	I	I	P	I	I	N		N	
	Mission Control	F	F	F	F	F	F		F	Current Fundi
	In-situ (surface) Resource Utilization	I	I	I	I	I	I		I	
	Propellant Depot (refueling station)	I	I	I	I	N	N		I	

Funded for Shuttle and ISS ops

Existing Capability from Apollo

Session 3: Human Missions and Systems-Beyond LEO

Requirements development / coordination	Strategies & Roadmaps	P	I	P	P	I	P		P	First step for e
	Architectures & Requirements	P	I	P	I	I	I		I	
Missions	Human Lunar	P	I	N	P	C	I		I	
	Robotic Lunar	P	F	C	F	C	P	I	I	
	ISS Utilization-Human Exploration	F	F	C	F	F	F		I	
	ISS Utilization-Basic Research	F	F	C	F	F	F			
	Lunar Commercial	I	I	N			N	I	I	
	Near Earth Objects	F	F	I	F	C	I	I		
	Human Mars	P	I	P	P	I	I		I	
	Human Mars vicinity	P	I	P	P	C			I	
	Robotic Mars	F	I	I	F	P	P		I	
	Assembly of telescopes		I		I		I			
	Planetary Missions beyond Mars	F	F	I	F	I	I		I	
	Commercial service depots	I							I	

F- Funded
P-Proposed
I- Interested

Session 3: Human Missions and Systems-Beyond LEO

C-Capabilities

N-No Interest

Breakout Session 4:

Exploration Systems Research and Technology Development

Session Report

18 November 2004

Participants:

BNSC (Great Britain)
CNES (France)*
CNSA (China)
CSA (Canada)*
CSIRO (Australia)*
DLR (Germany)*
ESA (Europe)*
INTA (Spain)
ISRO (India)
JAXA (Japan)*
NASA (US)*
Roskosmos (Russia)*

*Made presentation

Breakout Session 4: HSR&T
Identified Technology Areas of Common Interest

Technical Area	Importance	Technical Challenges	Approach	Projected result (what/when)
Challenges for Life support	*Reduction in resupply of resources, increased system efficacy, sustainability, and use of in-situ resources*	**What technology options need to be pursued in order to meet the closure levels of air, water, waste etc. to embark on sustainable missions**	**Build on current partnerships (IALSWG) to identify redundancies, and gaps and focus on symbiotic technology development**	
Challenges for EVA	*Current suit capabilities would not allow for planetary exploration, gaps and inadequacies exist in many aspects of suit development that need to be filled*	**What are the capabilities required to develop sustainable EVA suits for the various missions**	**Exchange of information between Nations currently interested in developing EVA capabilities**	
Monitoring and Controls Challenges	*Limitation of flight based capabilities compared to ground monitoring technologies*	**Various missions will require different fidelity of sensor arrays depending on the mission lengths, the challenges will be developed in accordance with this constraint**	**Build on on-going partnerships to validate sensors in relevant environments.**	
Systems Integration Challenges for Exploration systems	*Integrated testing of subsystem and component technologies in relevant environment to simulate long-duration missions*	**Bring out key challenges such as development approaches, technology interfaces etc...**	**Identify mechanisms by means of which partner nations can participate in tests in current test bed facilities**	

Breakout Session 4: HSR&T
Identified Technology Areas of Common Interest

Technical Area	Importance	Technical Challenges	Approach	Projected result (what/when
Challenges for Radiation Protection	***Inability to undertake long duration missions due to lack of understanding of radiation damages to humans, and protection mechanisms***	**What technology options need to be pursued in order to overcome the deleterious effects of space radiation**	**Coordinate efforts in radiation monitoring, detection, understanding the damages of space radiation and developing protection measures**	
Physiological Changes associated with bone, muscle loss due to reduced gravity	***Gravitational conditions below 1G have resulted in loss of bone and muscle along with other physiological disorders***	**What research needs to done in order to fully comprehend the ramifications of gravity effects on human body and what technologies will mitigate these effects**	**Continue to build on current partnerships (e.g. ISLSWG) to identify activities, redundancies, and gaps and focus research and technology development. Prioritize ground-based and ISS research efforts to answer these questions.**	
Challenges for Autonomous Medical Care	*Remote missions will deem that autonomous medical care capabilities be part of the mission architecture*	**What are the autonomous medical care capabilities should be developed for long duration missions?**	**Concerted efforts to develop complimentary suites of medical care capabilities across partner agencies**	
Behavioral Health and Performance	*Long duration missions will result n isolated environments and will cause disruptions in behavior due to differing psych-social adaptations*	**Tools and techniques need to be developed to deal with psycho-social issues associated with long-duration missions for crews and their families.**	**Build on existing partnerships to develop and validate approaches. Prioritize ground-based and ISS research efforts to answer these questions.**	

Breakout Session 4: HSR&T
Future Work

- Use the technology area matrix as a starting point to further define potential new areas of collaboration - Link to specific agency capabilities - *(Proposal: January 2005 next status check)*
- Shuttle retirement will lead to decreased down mass capabilities. Need to develop on-orbit processing capabilities to decipher research results - (Proposal: *Presentation of preliminary plan at March 2005, International Space Life Science Working Group - ISLSWG- meeting*)
- Identify and strengthen bi- and multi-lateral resource sharing mechanisms to foster relationships that will help answer the critical questions to embark on long duration space missions (*Present plan at March 2005 ISLSWG meeting*)
- Consider the use of alternate platforms with model specimens to understand questions of radiation effects on humans (*NASA preliminary plan - January 2005*)
- Identify research questions and mechanisms to effectively share and use test beds (Successful deployment of MEDES can be used as a guide) *(Proposed completion date: March 2005)*
- Conduct a joint meeting of the ISLSWG, IMSPG (International Microgravity Science Planning Group), and IALSWG(International Advanced Life Support Working Group) focused on exploration technology (*August 2005*)

Breakout Session 4: HSR&T
Issue

- What mechanisms will facilitate in overcoming some of the barriers that exist today for Nations to participate in the Vision for Space Exploration?

Breakout Session 4: ESR&T
Technological Capabilities Presented

- Robotics
- Planetary Entry & Aerobraking
- Thermal Protection Systems
- Aerothermodynamics
- Hot Structures
- Intelligent Structures Health Monitoring
- Large Structures Assembly
- Electric Propulsion
- Hypersonic Propulsion
- Advanced Materials & Textiles
- Communications
- Lunar Resource Extraction
- Mars Environments
- Autonomous Rendezvous
- Sample Return
- Rover Navigation
- Space Flight Operations
- Power Generation
- Wireless Power Transmission
- Fuel Cells
- Lidar
- Remote Sensing
- Space Optics
- Optical Instrumentation

Recommendations

- Form an international technology working group *(January 2005)*
  - Establish a web-based information repository (*February 2005*)
  - Segment future interfaces and work into
    - Human-related technologies, and
    - Non-human-related technologies
  - In the near term, concentrate on identifying relevant information to be shared among participating organizations (*December 2004*)
  - In the medium-term, develop a space technology assessment (*January 2005*)
  - In the long-term, reach agreement on specific and appropriate areas of collaboration (1 *August 2005*)

Session 5
Approaches for International Collaboration

Chairs: Peter Ahlf and Gib Kirkham

POC: Dan Jacobs, NASA, Johnson Space Center, International Partners, ISSP

Presentations

- Alan Cooper, European Commission, Research Directorate
- Graham Gibbs, CSA, Washington Representative
- Dan Reifsnyder, Department of State
- Peter Graef, DLR, Program Scientist, Microgravity Research and Life Sciences
- Raymond Blackburn, NATO Seasparrow Project

Attending

- Jean-Pol Poncelet, ESA, Director of External Relations
- Isabelle Bouvet, CNES, International Office
- Grigory Osipov, Roskosmos, Protocol office
- Masato Koyama, JAXA, Washington DC Representative
- Frederic Nordlund, ESA, Head of the ESA Washington Office
- Micheline Tabache, ESA, International Relations Department
- Marc Haesse, DLR, International Cooperation Department
- Istvan Takacs, Hungary, Science Counselor
- Manon Larocque, CSA, Senior Manager, International Relations
- Jim Sadlier, Director of Strategy at PPARC,
- Giorgio Einaudi, Science Counselor, Italian Embassy
- Mordahai Cohen, Israeli Embassy, Washington, DC
- Yevegney Zvedre, Russian Embassy, Washington, DC
- Wang Cheng, CNSA, Systems Engineering Department
- Thomas Triller, German Embassy, Washington, DC
- Lynn Cline, NASA, Space Operations Mission Directorate
- Al Sofge, NASA, Space Operations Mission Directorate
- Bob Riera, NASA, Exploration Systems Mission Directorate

Approaches for International Cooperation
Scope

- Identify general models or structures that could be applied effectively in promoting international collaboration on human and robotic missions to the Moon and Mars.
- Identify positive and negative aspects of those models in terms of program sustainability and affordability from the perspective of each participant in the breakout session.

Primary Conclusions

- A shared international vision for space exploration is desirable in the long term.
- High-level political engagement is desirable at some point.

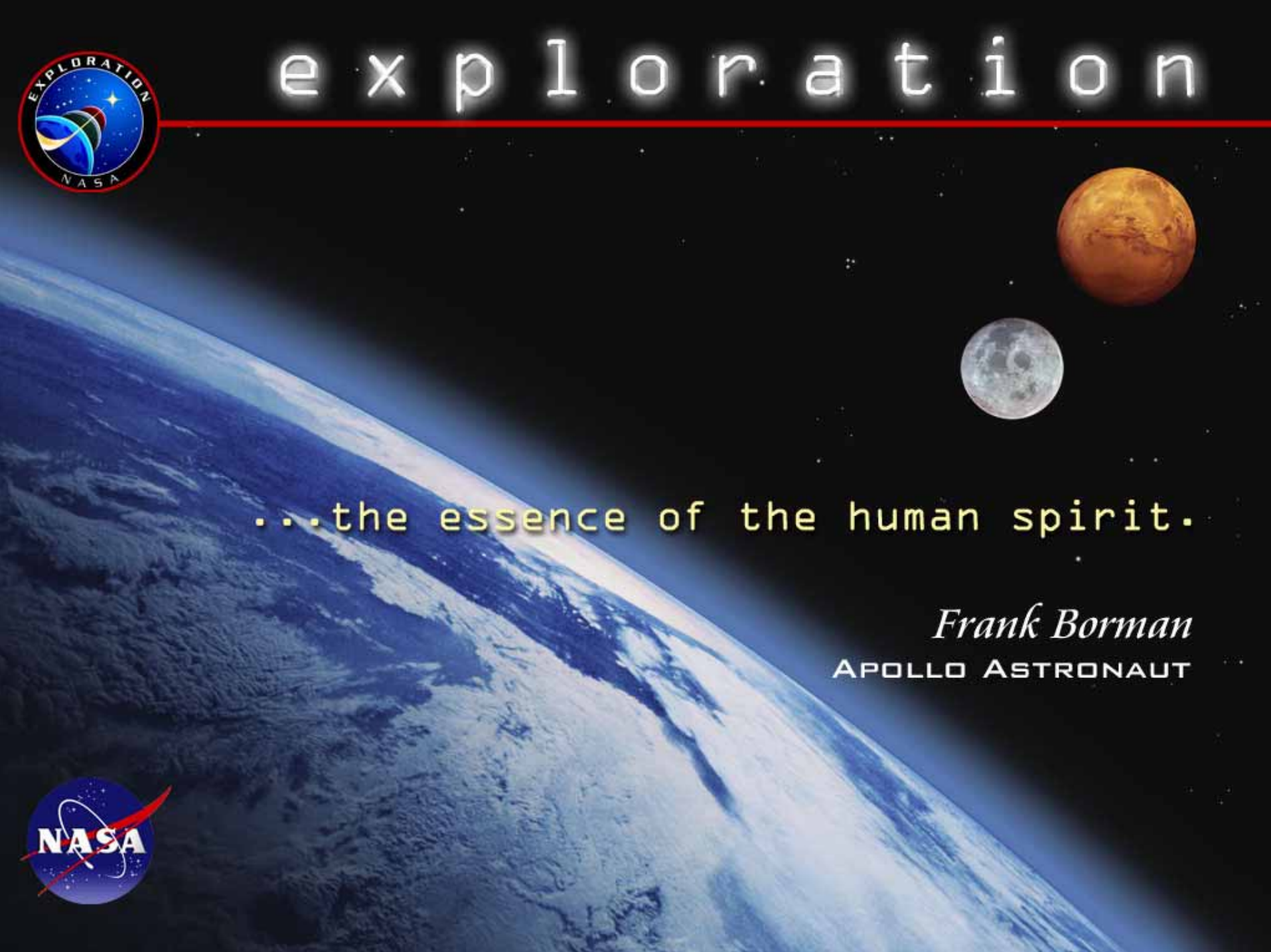
Observations

- Creation of an international coordination mechanism should be considered to provide a framework for ongoing dialogue.
- Several cooperative approaches were discussed and additional models may be considered; a single cooperative approach for all projects is not appropriate.
- Different management structures and instruments of cooperation would be used depending on character of specific project.

Observations (continued)

- Each project could have different cooperative partners and different kinds of contributions and returns.
- Participation by smaller agencies or non-space faring nations could be enabled by assuring timely access to information on space activities and R&D opportunities.
- Pursuit of technical standards or interoperability holds promise and can be pursued in the near term.
- RTF and completion and use of ISS are critical to further cooperation.

exploration



...the essence of the human spirit.

Frank Borman

APOLLO ASTRONAUT

Topics

- Where We Started
- What We Learned
- What Are Our Recommended Next Steps
- Assessing Conference Success

An Historical Event

- **19 space organizations represented:**
  - CONAE (Argentina)
  - CSIRO (Australia)
  - CSA (Canada)
  - CNSA (China)
  - European Community
  - ESA (Europe)
  - CNES (France)
  - DLR (Germany)
  - HSO (Hungary)
  - ISRO (India)
  - ISA (Israel)
  - ASI (Italy)
  - JAXA (Japan)
  - KARI (Korea)
  - Roscosmos (Russia)
  - INTA (Spain)
  - NSAU (Ukraine)
  - BNSC (UK)
  - NASA (USA)

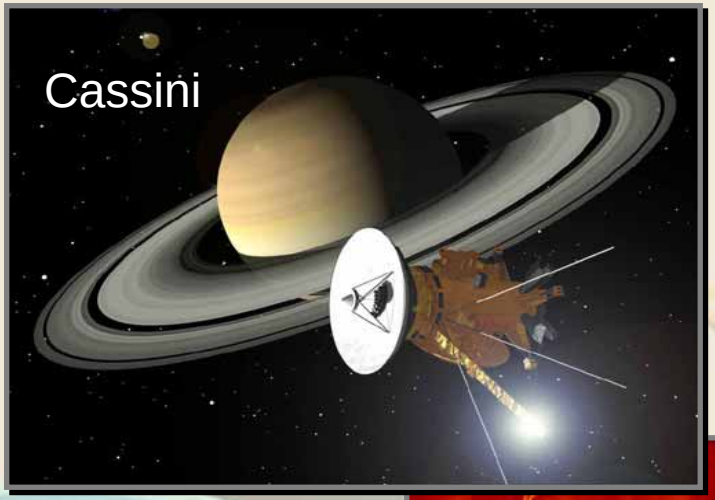
Workshop Goals and Objectives:

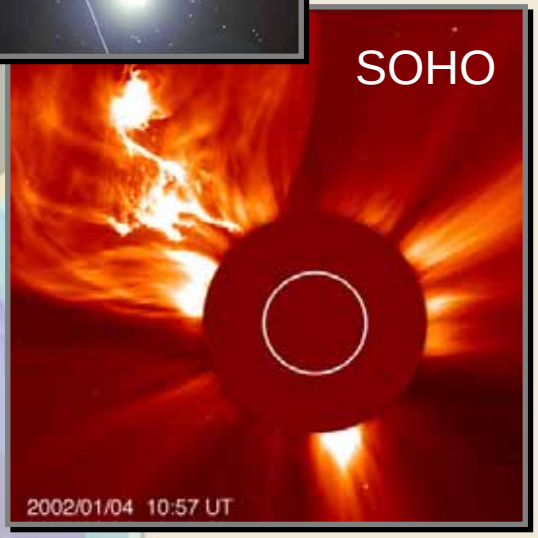
- Provide a forum for NASA and international space agencies to exchange information on their individual plans for human and robotic exploration of space;
- Allow discussion of NASA and international space agency capabilities and areas of interest with regard to cooperation in exploration systems; and
- Identify appropriate mechanisms for follow-on discussions.

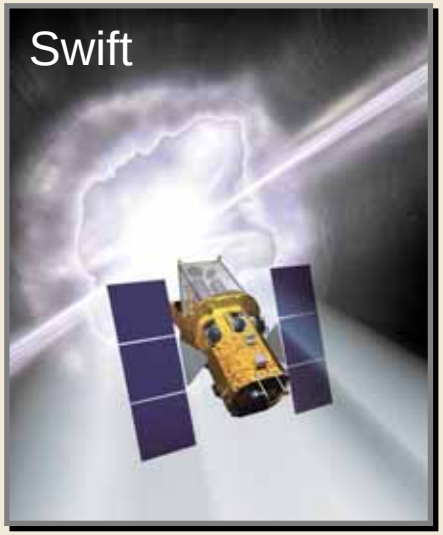
International Cooperation – A Proven Success

We will engage other nations to further our exploration goals

International Space Station







The Process

- Series of briefings from selected agencies
- 5 workshops covering:
  - Human Exploration Objectives, Strategy, and Objectives
  - Robotic Exploration Objectives to Support Human Missions
  - Human Missions and Systems - beyond LEO
  - Exploration Systems Research & Technology Development
  - Approaches for International Collaboration
- Panel discussions and conclusions
- Panel outbriefs

Session 1: Human Exploration Objectives, Strategy, and Objectives

- **Actions**:
  - **Jan 05 -** NASA to develop and populate an Exploration core competencies matrix; all agencies to fill in with areas of interest.
  - **Mar 05 -** Initial evaluation of individual roadmaps for synergy with strategy and Vision for U. S. Space Exploration.
  - **Aug 05 -** Final evaluation of individual roadmaps for synergy with strategy and Vision for U. S. Space Exploration.

Session 2: Robotic Exploration Objectives to Support Human Missions

- **Actions**:
  - **Dec 04** – Summarize the capabilities matrix, and confirm with each of the agencies.
  - **Jan 05** – Assess current working group charters for synergy with Exploration and to ensure adequate International participation.
  - **Feb 05** - Discuss with Science Mission Directorate to ensure that their Mar 05 international workshop objectives are synergistic with Exploration's.
  - **Apr 05** - Identify bi-lateral discussions regarding key capabilities.

Session 2: Robotic Exploration Objectives to Support Human Missions

- **<u>Actions</u> (Con't):**
  - **Aug 05 -** Work with Planetary Data System (PDS) community and others to determine strategy for common access to mission data.
  - **Aug 05** – Engage key agencies in roadmapping activity to suggest the best mission sets for a cooperative program (Common action with Session 1).

Session 3: Human Missions and Systems - beyond LEO

- **Actions**
  - **Dec 04** - Points of contact to be updated.
  - **Mar 05** – Initial update of the preliminary opportunity matrix.
  - **Jun 05** – Initial sharing of roadmaps and architectures.
  - **Aug 05** – Meeting to identify objectives in common (as a basis for cooperation) in order to increase efficiency as prospective partners.

Session 4: Exploration Systems Research & Technology Development

- **Actions**:
  - **Jan 05** – Identify near-term technology opportunities for collaboration.
  - **Jan 05** - Establish an international technology working group to determine human/non-human related technologies.
  - **Feb 05** - Establish a web-based technology information repository.
  - **Mar 05** - Complete a space technology assessment.

Session 4: Exploration Systems Research & Technology Development

- **<u>Actions</u> (Con't):**
  - **1 August 05** - Reach agreement on specific and appropriate technical areas for collaboration.
  - **Aug 05** - Brief joint meeting of International Space Life Sciences Working Group (ISLSWG), International Advanced Life Support Working Group (IALSWG) and International Microgravity Strategic Planning Group (IMSPG).

Session 5: Approaches for International Collaboration

- **Actions**:
  - **Jan 05 -** Explore common terms & conditions for potential future agreements.
  - **Feb 05** – Reconvene for continued dialogue on open items or new issues. Potential subjects for further dialogue:
    - Cooperative approaches / management structures
    - Continued opportunities for collaboration such as industry-to-industry, scientist-to-scientist, etc.
  - **Mar 05** – Investigate an international coordination mechanism to serve as a frame work for ongoing dialogue.
  - **On-going**: Monitor all session action items against established dates.

Next steps: Pursue Promising Opportunities

- All participants will carry home the briefings and products from this workshop for further evaluation;
- The results of this workshop will serve as a guide for all of our agencies in determining promising content and approaches to future collaboration;
- We will assess these opportunities to determine which areas are of greatest interest / Return-on-Investment (ROI); and

Next steps: Expand the Discussions

- Need to open forum to industry who will play a key role in formulating and implementing international cooperation;
- Results of this workshop will be shared with industry and academia at the 1st Space Exploration Conference in Orlando, Florida, 30 Jan - 1 Feb 05;
- Need to maintain a world-wide dialogue and open communication to share:
  - Agency programs, status, and plans;
  - Conferences, workshops, events; and
  - Business and research opportunities, etc
- Need to investigate innovative ways to communicate and stay current:
  - E.g. explore the establishment of an internet web site to access global activities related to space exploration

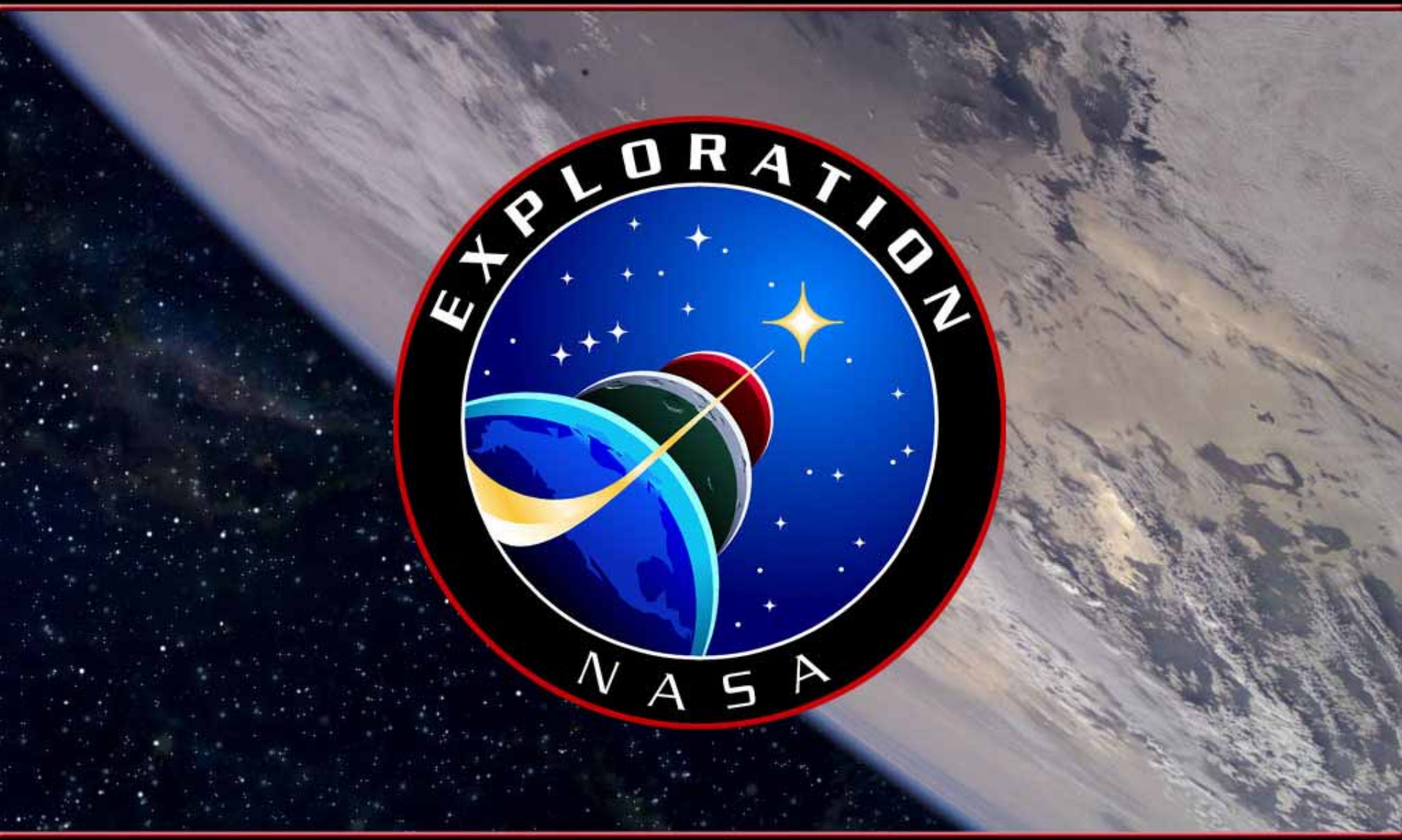
Workshop Goals and Objectives:

- Workshop Goals and Objectives:
  - Provide a forum for NASA and international space agencies to exchange information on their individual plans for human and robotic exploration of space; ✓
  - Allow discussion of NASA and international space agency capabilities and areas of interest with regard to cooperation in exploration systems; and ✓
  - Identify appropriate mechanisms for follow-on discussions ✓

Final Thoughts

- Side discussions were as important, if not more so, then general briefings and discussions;
- “Program-of-Programs;”
- Follow-through is critical to the success of international cooperation;
- We must make this journey together;
- We have the privilege to be working on programs of global importance and interest to all; and
- We are inspiring our children - the next generation that will pick up the baton of exploration.

Explore With Us!



“We Want You as Partners…”

International Workshop on Creating New and Sustainable Space Exploration

Summary

Michael F. O'Brien
Assistant Administrator
Office of External Relations
November 18, 2004

Topics and Issues Discussed

- **Pride in national capabilities and genuine interest in the Vision for U.S. Space Exploration**

- **Strong interest in a mutual understanding of respective space priorities**

- **ISS Partners are concerned about completion and utilization of ISS**
  - **NASA committed to return the Shuttle to flight, complete assembly of the ISS, conduct research in support of exploration goals, and meet its international commitments as a first priority**

Topics and Issues Discussed

- **Desire for long-term cooperation; discussion regarding consequences and benefits of a such a commitment**
  - **Political expression of support for cooperation in exploration is important**

- **Belief that frequent coordination and communication are necessary**

- **Desire to continue dialogue on specific interests within an international coordination mechanism to be defined**

- **Interest in common standards and compatibility**

- **Desire for equal partnership based on mutual respect**

Guidelines for International Cooperation

- **Traditional NASA guidelines for international cooperation**
  - Mutually beneficial exploration goals
  - Clearly defined interfaces and management mechanisms
  - “No exchange of funds” as a general, but not absolute, goal
  - Partners are generally government agencies
  - Consistent with export control framework and foreign policy objectives of each partner

Guidelines for International Cooperation

- **Other desirable characteristics**
  - Avoid unique development costs, where technology and infrastructure already exist elsewhere
  - Maximize advanced technology and development programs through partnership
  - Pool international capabilities and resources

- **Working to improve our approaches**
  - Flexibility in BAA for Human and Robotic Technologies
  - NASA response to potential partner requests for information and clarification.

Additional Desired Attributes of Cooperation

- Long-term involvement in a shared vision
- Clear mutual understanding of objectives
- Coordination among partners on a regular basis
- Some ability for autonomy within a specific project
- Segmentation of roles and responsibilities
- Robustness and flexibility of architecture
- Broad openness and timely access to data
- Political commitment and mandate to cooperate
- Flexibility in cooperative arrangements

Challenges to International Cooperation

- **Management Complexity**
  - Decision-making
    - Complexity grows with number of partners
    - Timing of decisions
    - Who is in charge?
  - Communications challenges
  - Differing specifications, standards, and assumptions

- **Technical and Programmatic Risk**
  - The “Critical Path” issue
  - Interfaces difficult to manage at a distance
  - Difficult to monitor progress and get early warning of problems

- **Other issues**
  - National budgetary and bureaucratic uncertainties
  - Potential linkage to activities unrelated to exploration
  - Cultural approaches may be different

Workshop Goals and Objectives

- **Provide a forum for NASA and international space agencies to exchange information on their individual plans for human and robotic exploration of space**
  - Reviewed the plans for human and robotic exploration of space of eleven space agencies on Days 1 and 2
  - Exchanged views on opportunities and issues for consideration on Days 1~3

- **Allow discussion of NASA and international space agency capabilities and areas of interest with regard to cooperation in exploration systems**
  - Discussed space agency specific interests and capabilities on Day 2

Workshop Goals and Objectives

- **Identify appropriate mechanisms for follow-on discussions**
  - Near-term: Each breakout session proposed next steps on Day 3 and we will follow-up
  - Longer-term: Expect discussion of broad international mechanism at Science Exploration Workshop in March 2005.