

INTERNATIONAL PARTNERING FOR MOON, MARS, & BEYOND

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While a high level of international cooperation exists today and its importance for future space endeavors is recognized, the current models of cooperation are not sufficient to support an international exploration program. It is important to realize that future exploration begins today with discussions and planning for how countries interested in space exploration can work together to make that dream a reality. The most plausible model for the development of international partnering relationships and agreements suitable to support exploration beyond Low Earth Orbit is one that builds these relations incrementally. The long lead-time of this approach places it on the critical path and calls for near term action. This paper provides a recommendation for international partnering that joins the best practices, capabilities, and resources of space agencies in order to effectively collaborate for future space exploration. A recommendation for structuring international partnering, from a management and organizational perspective, is provided and outlines how multiple space agencies can effectively collaborate to reach the Moon, Mars, and Beyond.

Acronyms

ASI	=	Italian Space Agency (Agenzia Spaziale Italiano)
CEOS	=	Committee on Earth Observation Satellites
EC	=	European Commission
ESA	=	European Space Agency
EU	=	European Union
GJU	=	Galileo Joint Undertaking
GNP	=	Gross National Product
GPS	=	Global Positioning System
HMM	=	Human Mars Mission
IAA	=	International Academy of Astronautics
IGOS	=	Integrated Global Observing Strategy
ISO	=	International Organization for Standardization
ISU	=	International Space University
ISS	=	International Space Station
JSF	=	Joint Strike Fighter
LEO	=	Low Earth Orbit
MEO	=	Medium Earth Orbit
MOU	=	Memoranda of Understanding
NASA	=	National Aeronautics and Space Administration
OE	=	Operational Experience
PB	=	Program Boards
PPP	=	Public-Private Partnership
UK	=	United Kingdom
US	=	United States

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I. Introduction

The Vision for Space Exploration in the United States (US) and the Aurora program in Europe are representative of a shift in space policies worldwide towards the goal of human and robotic exploration. Although some details differ, these plans share a common theme of expanding human presence across the solar system. In particular, the plans involve near-term exploration of the Moon in preparation for eventual human missions to Mars. Given the current relevance of the topic and the international nature of space exploration as expressed in these policies, a group of post-graduate students and professionals at the 2004 International Space University (ISU) Summer Session Program undertook the task of evaluating the Moon as a test bed for Mars exploration. Upon identifying the enabling concepts that can be rehearsed in the context of near-term lunar exploration, the group proposed a set of lunar missions and the political, legal, and social context in which the effort should be undertaken¹.

International partnering, although just one element of the ISU project, is a crucial component to make human exploration beyond Low Earth Orbit (LEO) a reality. The US vision specifically calls for the pursuit of international collaboration and commercial opportunities. International cooperation means enhancing the effectiveness of each nation's contribution to the future use of space. International cooperation implies sharing risks, resources, both technical and financial, and reducing the costs of exploration for all partners². The Aldridge Commission, established by the U.S. President, reported that international technologies would significantly benefit the successful implementation of the broader space exploration activities².

International cooperation for planetary and robotic missions has taken place for many decades. The most recent example is the success of the Cassini-Huygens mission to Saturn and Titan, using one of the most complex spacecraft ever built. Three space agencies formed an international partnership; the National Aeronautics and Space Administration (NASA) Jet Propulsion Laboratory, the European Space Agency (ESA), and the Italian Space Agency (ASI). Cassini was built by NASA, the Huygens Probe by ESA, and the high-gain communication antenna by ASI³. In addition, seventeen nations contributed to the manufacturing of the spacecraft and 250 scientists worldwide study the data on a daily basis returning from Cassini. Proposed in 1982, the concept of sending a spacecraft to Saturn, following the mission by Galileo to Jupiter, was originally discussed in the 1970s⁴.

In July of 2004, the United Kingdom (UK), ESA, and NASA showed that international cooperation is the key to future success in space⁵. Lord Sainsbury stated "space has enormous potential to improve our lives...and can be realized most effectively by working together with international partners." As set out in the UK Space Strategy 2003-06, the UK is focused on developing satellite technology, earth observation, and space exploration using cutting edge robotic technology. Jean-Jacques Dordain, the Director General of ESA, said that ESA has already engaged itself in a strong cooperation with NASA as shown through the successes of SMART-1, Mars Express, Cassini-Huygens, and Rosetta in addition to the upcoming launches of Venus Express and the James Webb Space Telescope. In addition, Mr. Dordain said he was convinced that if ESA was not in charge of a manned mission to Mars, that he was certain that passengers and components will have the label "Made in Europe." This paper examines how the optimistic vision of cooperation that this statement reflects can be brought to reality from an organizational point of view, by comparing existing international partnering models and proposing a flexible model for international cooperation.

II. Existing Program Models

Human space exploration beyond LEO is a concept that has been proposed by a number of countries. As a result, there are a number of approaches to space exploration with both parallel and diverging goals. These programs do not consist of the development of a single end product, such as the International Space Station (ISS), Galileo Program, or Joint Strike Fighter (JSF) described below, but are successive steps that result in the building of a suite of capabilities needed in order to advance to the next step of exploration. The following five examples will examine existing international space cooperative efforts with respect to their suitability to serve as models for an international space exploration program (hereafter referred to as exploration program), and determine successful concepts and methods that could be integrated into an exploration program.

A. International Space Station

The ISS program is one of the largest international cooperation efforts ever attempted and has been a tremendous accomplishment in terms of design, integration, and operation through the involvement of sixteen cooperating nations. The framework for cooperation among the ISS partners began with an Intergovernmental Agreement that allowed four Memoranda of Understanding (MOUs)⁶. These MOUs have led to Implementing Arrangements, which can be multilateral or bilateral agreements. The purpose of this international partnering framework was to "establish a long-term international cooperative framework among the partners, on the basis of genuine partnership, for

detailed design, development, operation and utilization of a permanently inhabited civil International Space Station for peaceful purposes, in accordance with international law⁷.” This agreement identifies the partners and their internal relationships, ownership of equipment and elements, use of Space Station assets, a high-level management structure, and other high-level structural issues. The agreement assigns the lead role for management and coordination to the US, and generally describes the rights and obligations of each of the partners.

Due to the nature and size of an exploration program over multiple decades, the program will require lead integrators for specific missions and this is where the lessons learned from ISS will be beneficial. Specifically for ISS, where the integration is physical mating of modules, it is paramount that one country lead the integration efforts and oversee the program. However, it may not be advantageous to have one country lead the overall exploration program due to the desired international interaction and cooperation identified in the 2004 ISU Exploration Report¹. It may be advantageous to take the positive aspects of the ISS partnerships and incorporate them into a framework that will meet the larger and broader requirements of the exploration program. The most important lesson learned from the ISS partnering framework is that a future exploration framework should allow partners the flexibility to adjust to changing political situations and country needs⁷.

B. Galileo

Europe has embarked upon the Galileo program, an independent European satellite navigation system. It will be interoperable with other satellite global positioning systems such as the United States’ Global Positioning System (GPS) and Russia’s GLONASS. Galileo will provide a highly accurate, guaranteed global positioning service under civilian control. It will use a constellation of 30 satellites in medium earth orbit (MEO) linked to a network of terrestrial command stations and centers required for the provision of services.

To date Galileo is the biggest and first Public-Private Partnership (PPP) attempted within the European Union (EU). The reason that the Galileo founders (ESA/EU) decided to use this form of cooperation is that the program offers commercial opportunities for the private sector.

The program is divided into the following three phases: development, deployment, and commercialization. The development phase (2001-2006) is mainly conducted by ESA through ESA contracts, using the ESA rules such as the “fair return” principle, which provides geographical return through contracts to businesses in contributing countries. The development phase is 50-50% funded by ESA and the European Commission (EC). A special legal entity, called the Galileo Joint Undertaking (GJU) was established to manage the development phase. Both ESA and the EC transfer the money to the GJU, and the GJU is in charge of managing the EC 6th Framework Program Calls, and the ESA procurement, using the specific EC and ESA rules, respectively. Finally, the GJU will choose the consortium that will form a PPP to manage the deployment (2006-2007) and commercial operation (2008) phases. Since Galileo will also draw on public funds and impact fields of public relevance, the EU through a Galileo Supervisory Authority will regulate and supervise some of the activities of the Galileo PPP. The selection process for public procurement of the consortium is nearly completed. The consortium will be the owner of the service warrants and satellites.

The entire Galileo concept of financing, provision of services, and operation is based on the PPP concept where the initial investment is made by the public sector and the private sector (concessionaire) takes over the operational phase. A private financing approach brings several positive aspects to the private sector outweighing the drawbacks due to the higher cost of money compared to government financing and the longer lead time for producing a contract. Advantages for the private sector due to private financing are:

- Unlimited availability of capital in the private sector
- Balancing of early capital expenditure with long-term operational revenue and expenditure

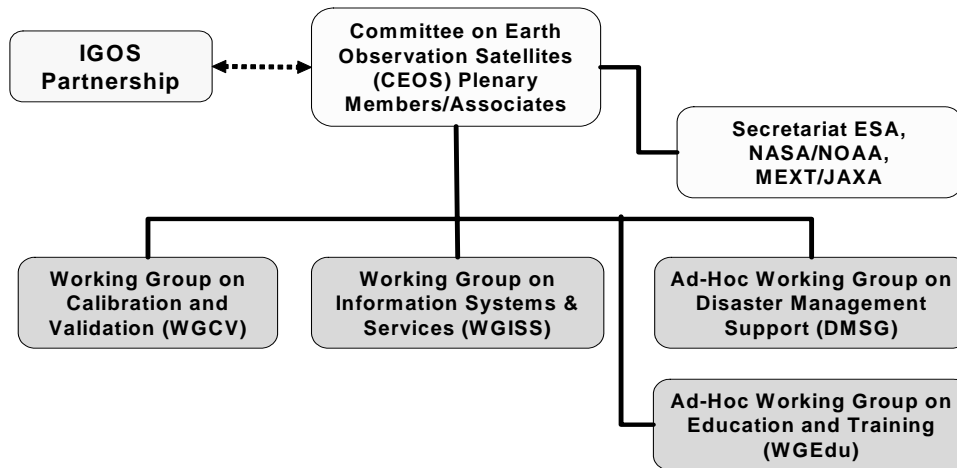
The Galileo management structure and the PPP are good examples of how a supranational organization (EC), an intergovernmental institution (ESA), and the private sector can work together to complete a mission. This type of cooperation could be used for a future exploration mission if some aspect of the mission or program ignites commercial interest.

C. Committee on Earth Observation Satellites (CEOS)

The International Academy of Astronautics (IAA) in its Cosmic Study “The Next Steps in Exploring Deep Space” lists CEOS as an example of multilateral coordination⁸. CEOS is an international organization, which pursues the goal of enhancing earth observation capabilities and benefits gained from the use of gathered data, by coordinating individual activities of its members such that gaps are identified and closed and duplication of effort is minimized. Activities also include the technical tasks such as harmonization and standardization of data formats to enhance interoperability and ease of data exchange, or educational tasks such as training of a skilled workforce that is aware of the potential of earth observation technologies and can exploit, develop and advocate them. CEOS members consist of both national organizations (e.g. NASA) and international organizations (e.g. ESA, EC), that

have an interest in Earth observation, and must maintain a certain level of space based observation activity as well as be willing to grant nondiscriminatory data access to the international community. Associates can be national or international entities that are pursuing earth observation goals on a smaller scale or are undertaking programmatic activities that aid the cause of CEOS. Members and Associates periodically convene in a Plenary to determine an agenda for the organization based on the input from members as well as a number of working groups specialized for instance on technical, political or educational details. Votes of Associates are not required to reach a plenary consensus. A permanent secretariat provides coordination between plenary sessions, serves as a point of contact, and carries out administrative tasks. Figure 1 illustrates the top-level structure of CEOS⁹.

Figure 1: Structure of the Committee on Earth Observation Satellites (CEOS)⁷.



CEOS differs significantly from the two previously described program management approaches, insofar as it does not serve the purpose of completing a specific mission or product but rather seeks to achieve a broad programmatic goal, encompassing multiple joint and individual missions, without previously defining a particular implementation strategy.

D. Integrated Global Observing Strategy (IGOS)

The chart in Figure 1 also contains a reference to an Integrated Global Observing Strategy (IGOS) partnership, which is an interest group that seeks to promote the establishment of a global observation system including both space-based and terrestrial systems. The partnership is a coalition of international organizations including United Nations Organizations, Space Agencies, Global Observing Systems, and International Science and Research Programs¹⁰. Created in June of 1998, the partners of IGOS continue to build upon existing international global observing program strategies "...in seeking to improve observing capacity and deliver observations in a cost-effective and timely fashion. Efforts are directed to those areas where satisfactory international arrangements and structures do not currently exist¹¹." The CEOS chair serves as one of the Co-Chairs of the IGOS Partnership, while the other chair is nominated by Partner consensus. Each Co-Chair is nominated for a period of one year.

IGOS partners work to strengthen cooperation within the partnership. These efforts can be divided into two categories: IGOS internal cooperation and external cooperation. The internal cooperation is focused on exchanging information on partners' relevant activities, identifying gaps and requirements to strengthen the capability and capacity to make integrated global observations, demonstrating the value of IGOS through projects, and carrying out activities to develop individual components of the strategy. To aid external cooperation, the partners work to promote dialogue between the space agencies and the observation communities as well as promote the IGOS implementation among national and international agencies and user groups.

The interesting aspect of the IGOS Partnership is their themed approach to supporting a global observation system. Not all partners participate in every project and this is a benefit to the strategy. Partners participate in projects in which they have expertise and resources to provide beneficial research and outcomes. An example of the themes and partner involvement is located in Figure 2.

Figure 2: Integrated Global Observation Strategy (IGOS) Theme Partnership Involvement¹¹.

THEMES	Lead Partner	Other Involved Partners	Involved Space Agencies	Observing System(s)
Ocean	CEOS, GOOS	IOC, WMO, others	NASA, CNES, others	GOOS
Carbon	IGBP	GTOS, GOOS	NASA, others	GTOS, GAW, GOOS, TBD
Water	WCRP	CEOS, others	NASDA, ESA	TBD
GeoHazards	UNESCO, CEOS	others	ESA	TBD
Atmospheric Chemistry	WMO	CEOS	ESA, NASA, others	GAW, TBD
Coastal	CEOS, GOOS, GTOS	IGBP, UNEP	NASA, NOAA, others	GOOS, GTOS
Coral Sub Theme	UNEP (Coral)	CEOS, others	NOAA, others	GOOS, GTOS

IGOS may serve as an example of how a coordinating body can, under certain circumstances, promote its cause by being a member of another organization or partnering with other entities.

E. Joint Strike Fighter

Although not a space program, the Joint Strike Fighter (JSF) program is described here because it has been suggested in the “Aldridge Commission” report as an alternative structure for international participation in the recently proposed US space exploration program¹².

The goal of the JSF program is to produce an affordable, common family of strike fighter aircraft that is interoperable among the operating countries¹³. The structure of the program is such that partners “buy in” to the program as a Level I, II or III partner, or as a Security Cooperation participant. There is no guarantee to any of the partners or participants of a geographical return of their investment with respect to domestic contracts. The US prime integrator, Lockheed Martin, selects subcontractors (foreign and domestic) on the basis of technical merit and affordability, with the overarching goal of making the JSF an affordable aircraft. The arrangement between the partners is governed by Memoranda of Understanding between the US government and each of the partners.

Recently, however, Europe refused to participate in this type of cooperation, so it is not considered to be an option for the future. It appears unlikely that Europe will participate in a cooperative venture where “fair return” cannot be guaranteed, and where the integration leadership belongs to any single private company. This may serve as an indication that some form of guaranteed return will likely be an essential prerequisite for countries to enter into cooperative efforts. The prime example of an organization which has implemented this principle is ESA, where the contracts a national industry receives within a project, reflect the financial participation of the country. The European example shows that the basic principle can be successful. However, it also shows, that for an exploration program it would require modification in order to mitigate a number of problems associated with distributing contracts primarily based on a quota rather than on merit.

III. Program Management Proposals

The previous examples described can be categorized in two major groups: the public-led type of international cooperation (ISS), and the Public-Private Partnership type (Galileo, JSF, CEOS, and IGOS). The following sections examine these two types of cooperative ventures in order to find the most efficient structure for successful international cooperation serving the purpose of promoting an exploration program.

A. Public-Led Exploration Programs

To manage the exploration program effectively, a highly integrated and cooperative international organization is needed. Two types of public-led organizational structures were evaluated and include an International Space Agency and a Virtual Program framework.

The ISS experience illustrates that a more international management approach is required to effectively organize, integrate, and execute such a broad exploration program as the Vision for Space Exploration constitutes. The first framework examined is an international space agency that would combine the efforts of all agencies into one body. One benefit of this concept is that it would be effective at executing the exploration program and maintaining

continuity in the development of the various robotic and human exploration technologies and missions. Such an agency would be able to integrate the best technology, manufacturing capabilities, and skills of member countries into one cohesive exploration program.

An international space agency could incorporate concepts from the ESA model that integrates certain space activities of member and cooperating countries through one coherent intergovernmental agency. The intergovernmental nature means that all the member states participate in the decision-making process of the agency through representatives to the decision-making bodies. The highest decision-making body of ESA is the Ministerial Council. The next levels are the Program Boards (PBs) followed by the Committee (PC) level. Every ESA program has a Program Board containing the delegates from the participating states (participating states are those that participate in the given program). ESA has four permanent Committees (Science, Administrative, Financial, and Industrial Policy) that act as horizontal committees over the ESA programs. ESA programs are divided into two parts: mandatory and optional programs. The mandatory programs (such as Science, Future Studies, and Education) are funded according to a percentage of the Gross National Products (GNPs) of the member states. Participation in the optional programs (via funding) is subject to national decision. All these elements are contained in the Program Declaration. ESA has special rules related to procurement, contractual, financial, and intellectual property rights matters.

Many questions exist about the criteria that would be used to evaluate a state's entrance to an international space agency. These questions include the deposit and allocation of finances, and how to accommodate individual state needs (political, financial, technological, and social). As a consequence, the timing does not appear right for the creation of an international space agency because issues of national security and technology transfer, funding, and political needs would likely prevent agreement. Furthermore, nations' current lack of a multi-country integrated vision of an exploration program also contributes to making this a difficult task.

A more realistic scenario is to create a more flexible system. The Working Group on "International Cooperation in the Context of a Space Exploration Vision" at the 7th AIAA Workshop on International Space Cooperation held May 3-6, 2004 suggested the concept of "A Virtual Program of Programs" for structuring international cooperation in the exploration program. This paper suggests integrating the various national exploration programs into a Virtual Program through the formation of an international coordination council for the purpose of facilitating coordination of the exploration program. This Virtual Program, "rather than trying to develop a cooperative concept for exploration as a whole, would be comprised of a coordinated set of individual activities, each activity employing the most sensible international arrangement as determined by the specific parties involved." Not all partners would be involved in all activities, and not all activities would necessarily be cooperative. This framework would incorporate the lessons learned from the ISS experience along with aspects that would be beneficial from the International Space Agency concept. The results of council deliberations would guide progress and would promote sustainability and continuity of the Exploration Program in the face of changing commitments over the span of the program. The council, though it would have no directing or funding authority, would have the ability to merge the best aspects of space programs from around the world on a mission basis. This allows countries to participate and finance missions in which they have interest, and allows them to develop new technologies of greatest interest to them.

B. Public-Private Partnerships (PPP)

Based on the experiences with Galileo and the Joint Strike Fighter, PPP can be used if the partners can identify clear commercial interest in a mission. This identification may be initiated from the private sector, so it is not necessary that the space agencies supply the commercial plan—in fact, such an approach would likely fail. Agencies are responsible for the announcement and request of commercialization plans, and then the private sector can submit their commercial plans.

If a commercial interest can be identified, and if the public sector and the program management find it acceptable, a component of a mission can be structured as a PPP, combining public and private funding in that mission part. This structure requires solid legal solutions, since public and private funding are incorporated, and both would require specific legal treatment.

C. Comparison of Public vs. PPP

The basic difference between the two cooperation types concerns the partners. The public-led program can be applied if there is no private interest in the program management or the services offered by a program implementation scheme. Where there are commercial opportunities in a mission, the involvement of private companies may be realistic. From a legal point of view, the two types of activities differ in the formulating and implementing documents, because monetary commitment and transfer, liability, and management must be different. At present, it cannot be determined whether a public-led, PPP type, or an efficient combination of the two would be

preferable. However, the determination of the mission structure should not be made prior to identification of participating partners and mission objectives.

Providing a framework for cooperative space exploration is a complex subject. Various factors such as the legal structure, program and mission plans, and public participation and ownership must be considered and accommodated in order to successfully carry out space exploration efforts on a cooperative basis. Certain factors such as the political and economic motivations for engaging in space exploration change over time and cannot be prevented from changing. Therefore, the model selected for implementing space exploration among multiple entities, and the participants themselves, must recognize and accommodate such circumstances.

The ISS, Galileo, and JSF programs provide concepts that may be applied to cooperative missions in the context of an exploration program. However, a strong framework must be provided at the exploration program level. Due to its programmatic rather than mission based character, CEOS may serve as a starting point and a model for the creation of such a framework. The global and political climate surrounding the exploration efforts proposed by multiple countries, dictates the creation of an exploration forum for two primary reasons. First, to avoid duplication of effort and, second, to ensure that when participants commit funds toward exploration missions, such funds are committed with the knowledge of what is occurring in other countries and projects. Membership of this forum should consist of countries interested in lunar and martian exploration. It is based on modifications to the Virtual Program concept that take advantage of high-level design concepts (such as evolutionary design and public-private partnerships). This forum would coordinate the exploration program, consisting of a coordinated set of individual activities employing the most sensible international arrangement as determined by the partners. If wished by parties involved the exploration forum could play a role in guiding decisions, and the arrangement of partnering agreements for individual missions, by providing non-binding recommendations.

IV. Selection of a Program Management Framework

The framework suggested in the following is aimed at ensuring that interested nations minimize duplication of effort while accomplishing their space exploration objectives. In doing so, it is intended to lay the groundwork for future, closer international cooperation on a global scale.

The Virtual Program concept¹⁴ should be implemented with modifications that take advantage of high-level design concepts (such as evolutionary design and public-private partnerships). The proposed structure for the exploration program is to implement a loose coordinating body called the Space Exploration Forum.

Initially, the primary role of the Space Exploration Forum will be to maintain a database in which participating nations will register their lunar and martian exploration activities. Nations wishing to participate in exploration activities can register those activities with the Forum to limit duplication of effort and allow for synergies among countries. Such a structure will allow nations to coordinate their space exploration activities while still maintaining a national space identity.

Forum membership will be open to any nation willing to participate in long-term human and robotic lunar and martian exploration and to develop capabilities and technologies within a framework of international cooperation. Implementation of the Forum's information-sharing program will be based upon the maintenance of a registry of space exploration activities. This registry will be part of the public domain and will store five critical types of knowledge: high-level (non-sensitive) technical information, all scientific information, the location of exploitable resources, operational and procedural routines, and catalogues of human experience¹⁵. The Forum will allow for adaptability to a changing political environment over the long-term by "providing its members a forum for communication, consultation and coordination, leading ideally to an alignment of national exploration programs¹⁴."

Management of individual missions is accomplished by the agency or partnership and is supported by the Forum. The Forum will not have the authority to manage the missions; however, agencies are encouraged to follow the Forum's recommendations. The space agencies are responsible for implementing a management structure that will meet the goals of the mission. For example, a specific mission may be managed through a PPP if the private sector has a specific interest in the mission or some aspect of it.

Despite the fact that ultimately the organizations participating in any single project will determine the technical, legal and political terms upon which it is carried out, the Forum should reduce the lead time and overhead required to implement the legal, political, and management framework required. This is achieved by providing a set of proven approaches that can be applied according to the type of project and the parties and interests involved. The initial set of approaches will be derived from experience with previous projects both space and non-space related as well as from theoretical considerations. As the exploration program progresses, they must be refined and augmented through the lessons learned from individual projects. Effective mechanisms of feedback to the forum therefore

should be inherent to the top-level management structures. This also allows the Forum to function as a means of amassing collective experience, allowing parties without previous experience to benefit from it, thus lowering the level of inhibition for participation.

Providing such a set of ‘templates’ for program management and cooperation, which can be adopted with minor changes to the particular circumstances, ideally should constitute a form of standardization in the political, legal and management regime. As with other forms of standardization, benefits will grow with the extent and duration of the exploration program. Success will also depend on keeping the Forum as lean as possible and continually reassessing whether it is still serving its primary purpose of making the overall exploration effort more efficient and sustainable.

A. Forum Substructure

It is recommended that three Advisory Boards be established: one for legal and ethical issues, one for societal outreach, and one for technical issues which will make recommendations to the Forum on standardization, technology harmonization, and overall mission operations coordination. These recommendations are not binding given the structure of the Space Exploration Forum; however, if space exploration is to be implemented in a sustainable manner, space-faring nations should make maximum use of pre-existing equipment, data, and capabilities. Forum recommendations will facilitate this endeavor.

1. Role of the Technical Advisory Board

Standardization, a major responsibility of the Forum’s Technical Advisory Board, will involve implementation of an evolutionary design process through interoperability and compatibility of technical components (e.g., technical interfaces, data formats⁸). To facilitate cooperation on a technological level, a common family of technical interfaces should be established for connecting space system elements. These technical interfaces would specify the way in which spacecraft or space systems physically interact with each other. An international organization may establish these common interfaces.

Definite economic advantages of standardization exist for agencies and industry, as indicated by a general study performed by the German Institute for Standardization¹⁶, with a summary provided by Business Link¹⁷. Standardization has served as a cost-reducing mechanism for other industries, as indicated by the DIN¹⁶ and could be an enabling element in the reduction of mission cost and the modularity of space systems as suggested by the Air University¹⁸. Standardization promotes sustainable access to space through easy replacement of system elements, assistance of one spacecraft to another spacecraft or rescue of spacecraft. Benefits for cooperation and international subcontracting between international space industries and agencies are an aspect deserving further study. This study should include the effect of standardization on space commercialization and competition between companies: some companies may be able to develop a competitive edge by focusing on certain space hardware. For example, a company might focus on manufacturing space tugs, space tankers or resource utilization plants.

A space standardization organization could start up as an offshoot of the International Organization for Standardization (ISO). This strategy has definite advantages. Industry, which has both a space branch and a terrestrial branch for operation, may already be affiliated with the ISO. Within the ISO both an organizational structure and expertise already exist. Some start-up funding may be available in ISO and the ISO affiliation will add credibility to the organization. Starting up as a separate entity has an advantage that solutions can be tailored specifically for space applications. Structure of bodies like ISO can be studied, adapted and improved; however, starting up as a separate entity may lead to difficulty in deciding on a structure and would take much more time. An intermediate solution would be to start up as a separate entity loosely affiliated with ISO or to establish an alliance between the ISO and the space standardization organization.

In summary, it is recommended that a spacecraft standardization organization be formed and that this body starts up through or is closely affiliated with the ISO. The Technical Advisory Board would be responsible for the implementation of this recommendation.

2. Role of the Social Outreach Advisory Board

The Social Outreach Advisory Board’s role is to inspire the public and to enable their sustained participation and support for both Moon and Mars exploration missions. In doing so, it will provide to the Forum recommendations that are aimed at highlighting the human element. The Social Outreach Advisory Board will promote programs that foster a sense of ownership and participation in Moon/Mars exploration activities by the public.

The Social Outreach Advisory Board will also serve as a source of Moon-Mars information to the media and to the public, thereby helping to keep the public well-informed of exploration activities. The implementation of a space exploration mission registry that is part of the public domain serves as an example of such an information

source. Since the Forum is an international organization, any person around the world will be able to take part in the Social Outreach Advisory Board's activities.

One of the Social Outreach Advisory Board's roles to coordinate with existing space advocacy groups, such as the American Astronautical Society, the British Interplanetary Society, The Planetary Society, and the Students for the Exploration and Development of Space to provide outreach activities for their own constituents.

The Advisory Board will also play a role in the inspiration of children throughout the world, including those in developing countries. For example, the large-scale international implementation of programs such as The Planetary Society's "Red Rover, Red Rover" program¹⁹, would be an ideal outreach activity for children. This program allows children to build toy rovers and operate others' rovers tele-robotically through the internet.

3. Role of the Legal Advisory Board

Since the legal aspects of individual lunar and martian missions and their management structures will have to be defined individually by participating states, there will be more than one international agreement to define the legal basis for the whole program. The legal structure of individual missions will depend on the participants' needs and desires for that mission (for example, whether or not industry is directly involved through a PPP). It will be the role of the Legal Advisory Board to facilitate the creation of legal agreements between countries that wish to cooperate on a joint mission.

The Legal Advisory Board will define recommendations for the individual missions' legal documents and their basic legal structure. In particular, some basic rules related to the methods of retaining commitment and the Intellectual Property Rights will have to be defined by this Advisory Board.

In general, the three Advisory Boards will submit their findings in the form of a proposal to the Forum. Upon approving a proposal, the Forum will submit these findings as mission recommendations.

B. Timeline

Membership in the Forum will be voluntary. Representatives of the signatory states, agencies, or other organizations that express an interest in participation in the Forum will define the rules that the Forum will approve at its first meeting. Representatives from industry and societal organizations (e.g., space advocacy groups such as the Planetary Society) will be welcome as observers and advisers.

At its first meeting, the Forum will accept its rules of procedure defining detailed member voting rights. After approval of the rules of procedure, the Forum will have to approve a document that establishes the three Advisory Boards, including their own rules of procedures and funding.

Given the current political scene, in which the future of space exploration is still uncertain within most governments and agencies, establishment of a commitment by most space-faring nations to the Space Exploration Forum as described herein is premature. In the near-term it is recommended that regular meetings should occur between space agencies at the administrator level so as to encourage future coordination. These meetings should become progressively more formal, culminating in the eventual formation of the Space Exploration Forum. The Forum, with all three Advisory Boards, should be fully formed as described above by the time preliminary conceptual designs for the first human lunar mission are being carried out. The first highly publicized act of the Forum should therefore be the first international human mission to the Moon.

C. Exit and Transition Strategies for Lunar Engagement

If a lunar engagement is primarily intended to serve the purpose of rehearsing a Human Mars Mission (HMM), it must be insured that it does not simultaneously bog down humanity on the Moon by consuming all available resources. Depending on the available budget, conceivable scenarios range from abandoning the Moon completely, followed by a period of financial recovery, to funding both a Moon and a Mars program in parallel. Since the latter seems unlikely, any lunar engagement with the ultimate goal of reaching Mars should incorporate an exit strategy²⁰ or transition strategy, enabling a smooth shift of resources towards the Martian goal, once the Moon has yielded the desired experience.

Such a strategy need not terminate all support of lunar activity, but must free up sufficient resources. This issue does not appear to be addressed sufficiently in current exploration road maps. The strategy chosen to address this deficiency will ultimately depend on the total available resources as well as on the desired timeframe and the policy concerning long-term lunar objectives. Several major conceivable strategies are characterized in Table 1.

Table 1. Lunar exit and transition strategies.

Strategy	Description	Pro	Con
Minimum engagement strategy	Mission and hardware are designed solely around Martian rehearsal objectives; only semi-permanent infrastructure is deployed; Moon is completely abandoned once desired experience is gained	Cheapest in the short run; fastest route to Mars	No long run benefit to lunar development; if Martian program fails investment is lost; danger of losing operational experience (OE) if transition is not made quickly
Privatization strategy	Pass on/sell lunar infrastructure to private entity	Lunar development without expending government resources	A lunar engagement must be commercially attractive by this time; could be hard to maintain ethical standards
Self-sustaining presence strategy	Lunar presence is built up to the stage where it becomes economically self-sustaining and no or only little public support is required; e.g. through mining, energy production, manufacturing of space hardware, tourism, He3 export	Sustainability; OE is maintained	HMM is delayed almost indefinitely; huge investment; no proven approach to achieve economic self-sufficiency
Inheritance strategy	Lunar infrastructure tailored to long term presence and is built up and exploited for Martian rehearsal; once Martian program is scaled up the infrastructure is passed on/sold to second generation space powers; gradual transition possible	Possibility for second generation powers to “earn their wings”; gradual transition possible; OE is maintained	Questionable whether politically attractive; assumes that not all nations are fully involved in Martian effort
Staging point strategy	Moon is actively used in the launch of a HMM; most likely through propellant production by lunar ISRU; launch of complete mission from lunar surface unlikely	Possibly cheaper for a long term Martian effort; OE is maintained	Long lead time; large investment
Parallel strategy	Both a Martian and a lunar program are supported at full scale; resource demand is likely prohibitive in the foreseeable future	Both Lunar and Martian development; OE is maintained	Large investment.
Mothball strategy	Lunar infrastructure is designed for long term use and for unattended survival in dormant state over years; once Mars program is scaled up lunar base is temporarily abandoned or only sporadically used until eventually new funds become available	Compromise between minimum engagement and more sustainable approach	Challenging in terms of creating autonomous survivability

Such a strategy would also contribute to achieving a firm commitment to an exploration program by participating parties. Having a strategy and timeline in place that clearly define how and when participants in a program can terminate, change or reevaluate their contribution, will make such a commitment more attractive than an open-ended program with a non-defined total commitment.

The strategy chosen will have implications for most aspects of program design, ranging from lifetime of hardware to the political framework. Therefore, making a decision on how to proceed in a lunar engagement once its primary objective has been achieved should take place at an early stage of the program. Likewise, it is recommended to consider transition options between all of the numerous steppingstones within an exploration program once the respectively associated primary objectives have been achieved.

V. Conclusion

Mankind is on the edge of a new adventure, one that will return humans to the Moon and venture out to Mars. An exploration program of this magnitude and of a multi-decade duration will significantly benefit from international partnering. The Space Exploration Forum recommendation is one that allows for flexibility to changing political environments and provides a mechanism for communication among the national space agencies. Through the forum's guidelines and non-binding recommendations, agencies can decide to work with other agencies and/or to work with private industry through PPP arrangements. Communication and organization is the key to success, and with a properly structured forum, the technological and engineering challenges of sending humans to Mars will be overcome through international collaboration.

The study of current international cooperation approaches both in space and terrestrial projects shows that no existing cooperation concept is fully suited to support and coordinate the worldwide multi-decade effort that a sustained exploration effort represents. However, the examples of CEOS and IGOS show there are some existing models that should be considered as starting points for the design of the exploration cooperation framework. The overarching conclusion to be drawn is that the cooperation concepts employed by projects such as CEOS that pursue broad programmatic goals rather than the construction of a single end product are more suitable to serve as models for international cooperation. They come closest to representing the understanding of exploration as a long-term undertaking that at a top level does not dictate any single mission, program, or technical implementation.

At the highest level therefore the cooperation and coordination mechanisms put into place must be flexible enough to accommodate various technological and political constellations that might occur during the implementation of specific missions or programs. The coordinating framework established now cannot anticipate the specifics of how exploration will progress at the mission level, nor must it ultimately depend on the success of any single component. Rather it must endorse and promote the idea of human expansion into the solar system, whatever the means, the participants or the pace will turn out to be.

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