Lessons Learned and Recommendations on International Participation from the International Space Station Program

Daniel V. Jacobs

Michael J. See

Lyndon B. Johnson Space Center

Houston, Texas

National Aeronautics and

Space Administration

Lyndon B. Johnson Space Center

Houston, Texas 77058

September, 2004

Table of Contents

1.0 Introduction

This Report expands and elaborates on an earlier edition provided to the Exploration Systems Mission Directorate (attached in Annex 3) in May 2004. For this report, lessons learned were provided from throughout the ISS Program and supporting organizations at JSC, KSC, MSFC, and ARC. A list of the organizations that provided input is contained in Annex 1.

In addition to the primary lessons learned about international partnerships, several useful observations were made about working with International Partners (IPs) in general. Those have been listed separately in Annex 2.

Some assumptions about the Exploration Program were used in writing this report. The key assumption that drives many of the recommendations in this report is that the Program will go through many distinct phases and activities over many years or decades. The will likely increase in complexity over time, and have their own unique characteristics and requirements. Therefore, the approach and mix of IPs will likely be different for each phase.

For that reason it is strongly recommended that the Program should not seek and adopt a single approach toward partnerships. Rather, the partnership arrangements should start simply and evolve along with the activities in the Program. A menu of the various types of partnerships desired, along with the terms, conditions, and requirements of each one, should be developed early in the Program, and the types of partnerships should be selected from this menu for each activity as they arise, with the requirements, roles and responsibilities well understood from the beginning. This paper reflects that approach.

2.0 Policy Lessons Learned

2.1 Agreement Framework

The previous edition of this study discussed the strengths and weaknesses of the ISS IGA and MOU structure, specifically recommending that a multilateral comprehensive agreement should not be developed prematurely and that top-level agreements should not be mission-specific. The following recommendations were made:

- Early on, NASA should establish the legal and policy framework and terms and conditions for partnerships. This core should cover such topics as intellectual property rights, liability, dispute resolution, public affairs, amendments, international and criminal jurisdiction, customs and immigration, and termination. A set of terms and conditions on these topics have already been agreed to by many potential IPs in the ISS IGA and MOU, which can serve as the starting point for a new core. The core should not contain any mission-specific content, but should serve as a stable foundation upon which other documents will be developed. Once the core has been developed, its use in subsequent agreements should not be negotiable. Every agreement should either contain the core or be subordinate to an agreement that contains it. This will provide a stable structure but does not contain programmatic details that will become out of date or obsolete.
- Because of the evolutionary nature of the program, initial activities or projects could be carried out on a bilateral basis. These initial activities will likely be relatively simple, short-lived projects, and their results will serve as the basis for subsequent larger, longer-lived projects. NASA could theoretically decide to continue to utilize bilateral arrangements for larger projects as well. This would assume that the other IPs will not need to interact or exchange information or items with each other under this arrangement, but would go through NASA for everything. However, this will not likely be possible for more complicated projects.

- As the program matures, as the concept of the larger activities becomes more clear, and as the IPs and their relationship with NASA stabilizes, a multilateral framework will likely be most appropriate. The multilateral agreement should primarily consist of the central core of terms and conditions discussed above, along with over reaching long-term goals and objectives for the Program. This agreement should remain largely unchanged through the life of the Program and provide the stability necessary over time. Specific details on contributions, roles and responsibilities, and milestones should be contained in subordinate agreements.
- The subordinate agreements can take a number of forms. In the ISS Program, the various types of agreements evolved over time and were developed ad hoc. They included reimbursable agreements, barters, cooperative arrangements, meeting products, amendments, exchanges of letters, and others. For the Exploration Program, a menu of the types of agreements that are planned for use should be developed up front, along with the criteria for use and terms and conditions for each. As the need for subordinate agreements arises, the appropriate type of agreement can be selected from this menu based on the specified criteria. Users will know up front what the requirements and expectations are for the selected agreement type, eliminating the confusion and delay inherent in developing agreements ad hoc.

2.2 Types of Relationships

As discussed in the first edition of this study, the most important aspect affecting the types of relationships to be used with IPs is a decision on the type of leadership role for the U.S. The expectations placed on NASA by Congress and the American people are that NASA will lead major programs. With true "IPs," this may be difficult, as each has its own expectations of taking a certain leadership role as well. However, it is not obvious that US leadership is always the appropriate or optimal model for all activities. Different structures will likely be appropriate for different phases and projects. NASA should be clear to itself when making these decisions what role leadership role NASA should play versus the role NASA has traditionally played. Compartmentalizing the scope of authority and functionality may allow management to be shared in some areas, while still maintaining NASA leadership in others.

Several options exist below and should be considered. Some options are discussed, starting with the ISS Model. The authors are not endorsing any particular model, but offer them as examples of differing approaches taken in other sectors of society that may have some application here. Each has its own strengths and weaknesses. It is likely that hybrid applications will be most advantageous, mixing various approaches in order to maximize their strengths and avoid their weaknesses. What is important is that a clear decision on the leadership model be made at the outset of the project and that roles and responsibilities be very clearly defined to all participant parties.

2.2.1 ISS Model

The ISS Program was set up to operate using a board and panel structure, each of which functions on consensus. NASA is the first IP among equals, with each board chaired by the NASA representative. In cases where consensus cannot be reached, the NASA representative technically has the right to make a decision for the board; however, this right is rarely used in practice. Nothing in the ISS arrangements confers upon NASA the right or ability to compel another IP to take specific actions against its interests; therefore, occasions are rare in which it is efficacious for NASA to make unilateral decisions. The advantages of this arrangement are that each IP has a voice and that this system, like that of the United Nations described below, allows IPs to abstain when it is politically inconvenient for them to agree to a decision. The drawback is that the system can become paralyzed when no consensus is reached on an issue and NASA cannot progress on it absent the support of the dissenting IP(s). It should be noted that the Russian partner has been reluctant to fully integrate itself into the board structure, preferring to handle most issues on a bilateral basis with NASA.

2.2.2 Science Model

In NASA's long history of cooperation in science, it has participated in cooperative program in a large number of roles and relationships. Science activities traditionally have Principal Investigators (PIs), Co-PIs, and a number of Co-Investigators (CoIs). Parties can serve in leadership roles as PIs in some activities while simultaneously serving as major or minor CoIs in other activities with the same IPs. An IP's science program consists of the aggregate of these activities. As discussed in the section on Critical Path Issues below, this allows any one IP to spread its involvement in a science field more broadly than it could if the IP had to lead every activity. It also minimizes risk, in that a certain amount of redundancy is provided with the multiple activities being performed, and potentially provides for a greater science return on investment

2.2.3 Corporate Model

Another model is that of a single independent "corporation," governed by a standard corporate structure, funded by the countries participating in the project who act as shareholders. The corporation will bear the ultimate responsibility for the project's success. Key political issues will need to be addressed, such as how the work is redistributed back to the individual countries and who the corporate officers are, but the technical and administrative tasks of the project will fall under one entity. Issues of concern such as commonality of crew interfaces, nomenclature, training, and systems could all be managed more effectively by such a monolithic organization. While it is not recommended that the structure of the European Space Agency be copied, some aspects of that system provide a useful model.

2.2.4 United Nations Model

Another approach to management of a multilateral body is the United Nations model, using a central council of members, with the chairman or lead rotating among the members. This central U.N.- style body could focus on issues that are common, such as coordination of science objectives, development of common facilities, and so on. Outside of this central council could be more minor IPs (those not meeting certain criteria), who could participate on an ad hoc basis.

2.2.5 "Berlin" Model

Large-scale projects, like multi-spacecraft armadas or a moonbase, could be organized into distinct sectors, either physical sectors (specific spacecraft or geographic locations) or functional sectors.

1. The physical sectors can be designed to be (1) interdependent, (2) connected but independent; or (3) completely independent. Each IP could have a specific geographic sector, *a la* post-WWII Berlin. Each IP would be responsible for its sector and would make its own decisions as to the development operation and utilization of its sector. Under this model, each IP could decide for itself how independent or dependent it wants to be, and could manage its sector and contributions itself. In areas where the IP decided to be dependent, it would be responsible for coordination with other sectors to obtain resources. A management structure of IPs, like the like the U.N. model above, could then be established that would only address issues of common interest to all IPs, such as research goals, mission objectives, sharing of common facilities, contingency situations, etc.

2. Functional sectors could be organized around functions like oxygen production, materials production, power, ECLSS, habitation, etc., rather than physical or geographic sectors. This organization does result in dependencies, and would not allow IPs to make unilateral decisions on some aspects of their sectors. However, integration and interface requirements could be dramatically reduced and simplified.

The decision on the type of management structure and relationship style to be used is related to other decisions discussed later in this paper, such as critical path contributions, U.S. lead, and so on. This interrelationship should be recognized early, and specific decisions should be made consciously, with a common understanding of all parties as to their implications.

2.3 Critical Path Issues

NASA has traditionally been expected to maintain control of the critical path in major programs. The experience in the ISS Program is that IP contributions will likely be on the critical path at some point regardless of upfront NASA policies against that. For example, the Russians filled critical path roles with crew life support and propulsion and other aspects of the ISS. Planning for that up front and adopting a flexible approach is only prudent, and may allow for a bigger, broader and more productive program in the long run.

The ISS experience also demonstrated that IPs performed better on elements in which they felt some ownership. Responsibility for major elements on systems in the critical path increases that sense of ownership in the Program. The IPs want to be integral, and in the long run, NASA may benefit from that. NASA's history of cooperation in science provides precedents for various critical path options. In different science programs, NASA has controlled the critical path, shared the critical path with others, and contributed off the critical path.

This flexibility in NASA's leadership role in cooperative programs provides the science programs a robustness not possible if NASA were to always be in control of the critical path. This approach allows NASA to implement a broader program, providing more return for the dollar, increased redundancy, and reduced overall risk.

Two important lessons were learned from the ISS experience. Early on in the partnership with Russia, due to evolving definitions of critical path criteria it was unclear whether certain elements provided by the Russians were in the critical path for ISS. This caused confusion and criticism in dealings with Congress and the general public. Therefore, it is important that an up-front definition of what is "critical path" is needed, with defined categories of critical path and IP dependencies. Then for each activity, NASA should decide which category is appropriate/acceptable, based on the size of activity, importance, budget, political issues and abilities, experience and stability of the IP. This decision should be made with risks and implications clearly understood. Further, NASA should be publicly clear and correct about the provision of critical path items.

Secondly, if critical path components are to be provided by IPs, contingency plans should be developed early in the program for the potential non-delivery of those components. Those plans should be included in the decision package for approval of the partnership.

2.4 Types of IPs

As the ISS Program evolved, the types of relationships used by the Program have evolved as well. NASA primarily viewed its relationship with its IPs as cooperative in nature with governmental counterparts. Over time, however, other arrangements were used as well:

- Barter agreements that were more like fixed-price contracts
- Reimbursable agreements, in which cash is exchanged for good or services
- Space Act agreements with foreign commercial firms for specific activities
- Relationships with and between IP and NASA contractors to the ISS Program on issues in export control, proprietary data, configuration management, and so on

Each type of partnership had advantages and disadvantages that were not foreseen at the time they were concluded. For example, basic cooperative partnerships had significant flaws in dealing with issues involving budgets or cost changes, and did not deal well with data exchanges, verification equivalent processes and documents or other areas.

For example, reaching agreement on the implementation of changes desired or required by one IP that have impacts on other IPs was difficult at best on cooperative relationships, and the financial responsibility for these changes was always an issue. Reaching agreement on what type and how much data was exchanged was frequently a problem and enforcement of agreements was non-existent. Agreements on what type and how much testing and verification was necessary for the IP's own elements was contentious, as NASA often wanted more testing than IPs were willing to pay for. Similarly, judgements on whether IPs' own internal testing processes were equivalent to NASA's were difficult. Barter agreements had even more problems with changes or cost issues, requiring almost all to be renegotiated over time, as discussed in more detail with a section on barters. Contracts dealt well with defined data requirements and deliverables, but were inflexible. Contracting directly with foreign contractors rather than going through governmental IPs should also be considered. The greater the number of pass throughs of funds and requirements, the greater the possibility for misunderstandings, delays, and misdirected funds, and the smaller the possibility of political interventions.

For future programs, the types of partnerships that could potentially be pursued include government to government, industry to industry, and NASA to foreign domestic government agencies, to U.S. and foreign industry, and to NGOs and universities.

NASA should identify the various types of partnerships or relationships that it wishes to pursue for the Exploration Program, and develop the pros and cons and criteria to be used in determining which type of partnership is appropriate for various objectives. It should be clear what types of rights and obligations are incumbent upon the parties in each type of partnership and how the different types of partnerships relate to each other.

In addition, the process for accepting IPs into the Program, both initial IPs and subsequent new IPs, should be defined and agreed to at the start. The ISS Program did not initially contain useful guidelines for selecting and approving new IPs, and this became a problem later as new participants were considered and brought into the Program. For example, the IPs have still not formally agreed to inclusion of Brazil years after the Bilateral NASA/Brazil MOU has been signed. The previous edition of this study contained a discussion of the criteria that should be used in selecting the type of IP appropriate for a specific project. There are various options for the process of selecting new IPs later in the Program. They include:

- NASA selects all IPs
- An inner circle of primary or major IPs jointly approves other IPs
- The initial set of IPs jointly approves subsequent IPs
- At any point in time, all current IPs approve all new IPs, whether bilateral or multilateral
- Each subsequent IP pursues additional bilateral arrangements with third parties

Processes need to agree at the outset of the program on the process and criteria for inviting, accepting, or allowing new IPs into the Program, at all levels. The processes should define who has authority to decide, the scope of the decisions, and what kind of IPs may not require approval.

2.5 Barters

A number of fundamental problems arose with the barter agreements used in the ISS Program, some of which are inherent in barter arrangements and some of which resulted from NASA's approach.

- IPs were unable to absorb the inevitable technical changes that occurred in the ISS Program, which flow into bartered elements due to close interfaces and ICDs. Further, the IPs' defined changes include the filling in of TBDs and the clarification of existing requirements.

- A key issue was the difference between NASA's and the IP's views of the arrangements. NASA approached the barters as extensions of existing cooperative relationships, whereas the IPs approached the barter agreements as if they were fixed price contracts. The barters were negotiated based on estimated costs of building hardware. The estimations were often immature and incomplete; however, in some cases the IPs budgeted and let fixed price contracts based on these numbers. They did not take into account the normal risk inherent in development programs and were unable to deal with unforeseen technical challenges.

- The IPs lacked a sense of responsibility for hardware that will eventually be owned by NASA.

These problems arose in the Centrifuge Program with JAXA and in the Nodes Program with ASI and ESA. Recommendations based on the lessons learned from these experiences are:

1. Barter reserves for future changes must be set up in advance by both parties as part of the barter agreement. Groundrules for their use should be agreed to. Frequently, disagreements over changes or perceived changes of impacts to the IPs caused work to come to a halt quickly. Allowing budget margin to cover changes and disagreements would help to keep work moving.
2. NASA should maintain budget flexibility to provide compensation to the IP for any added goods and services outside the scope of the existing barter agreements. This will enable NASA to make unilateral changes to the scope of the deliverable by the IP without affecting the balance of the barter.
3. Do not barter for a piece of development hardware that will be transferred from one IP to another. When one IP transfers ownership of a component to another IP, the sense of responsibility and pride is diminished or removed. Instead, barter for the provision of products or services. For example, oxygen could be provided in a barter instead of an oxygen production facility. Data transmission could be provided instead of a data relay satellite, food instead of a galley, housing services instead of a habitation module. The providing IP continues to own and be responsible for the facility or equipment, and therefore retains all the incentives to make sure they operate effectively, efficiently, and cheaply.
4. NASA should consider alternatives to barters where appropriate:
    a) Where possible, pursue collaborative projects with joint ownership and usage rights rather than bartered hardware or services. If a project is in the national interest and serves the needs of both IPs, the partnership is more fruitful and is more likely to create an excellent product than if one IP has no eventual ownership in the product. It is difficult for a country who is paying to develop a product to do its best job and commit resources to making the best possible product if that product is not, in the end, its asset.
    b) Where costs are well understood and straightforward, cash transactions through contracts are cleaner than barters. Some transactions could be resolved and hardware services and data delivered in a timely manner if they were contract deliverables. There were several examples of this with the Russians. The orbiter docking system and Mir docking module, FGB delivery, and training facility models were all delivered via contracts and problems with deliverables, schedules, changes and quality were minimized. Previously, the training facility models were included under a barter agreement, and they were never completed. When they were shifted to a contract, work immediately proceeded and they were delivered.

2.6 Allocation of Resources and Costs

In the ISS Program, two IPs provided resources that were needed by all IPs. Therefore the use of those resources had to be shared among the IPs and the costs for those resources had to be repaid by those using them. These resources included power, astronaut opportunities, crew hours, raw materials, and communication band-width, among others. This approach spawned a number of other issues and decisions that had to be addressed by the ISS agreements, how resources and costs are to be distributed, how resources and costs are calculated and in what units, and how costs are repaid.

A lot of these have been addressed in the ISS Program, but the process has been difficult, lengthy, tedious and cumbersome, and the accounting process may be burdensome. Other issues can be anticipated from this approach, but have not yet been dealt with in the ISS Program, including:

- What happens when the configuration of the ISS changes, and therefore the proportion of contributions from each IP changes? Do the allocations of resources and costs also change?
- What happens when the artificial unit of calculating costs (kg to orbit) differs dramatically from the actual cost in money of producing those resources or from the value of receiving those resources by other IPs?
- What happens if IPs are not able to agree on a barter to repay common costs, but the receiving IP cannot provide other means of repayment?
- What happens if a IP providing resources upon which other IPs depend (such as upmass) does not provide sufficient resources, after a receiving IP's systems have been developed based on a certain level of resources?
- What happens when schedules are dramatically delayed, raising costs and/or reducing resources? Does that affect the value of the resources or the valuation of the original contributions?
- What happens when the amount of resources provided drops below the level necessary to provide a break-even rate of return on investment to IPs?

For programs in which resources are produced by a few and distributed to many, or in which infrastructure with its subsequent costs is provided by a few for many, an approach such as that used by ISS may be unavoidable. In that case, the lesson learned from the ISS is to simplify the process as much as possible, to develop a means for calculating costs and values early to avoid protracted and painful negotiations later on, and to avoid detailed accounting requirements. However, other alternative approaches should be strongly considered: Aspects of these other approaches may include:

- Bilateral arrangements instead of multilateral ones
- Stable provision of reserves instead of variable proportional allocations
- Partner production of some of their own resources instead of common production
- Commercial provision of resources

Recommendation: NASA and potential IPs should seriously consider alternatives to the current allocation process for resources and costs. The long-term implications of the selected approach are considerable, and the method selected is likely unchangeable once the program has started. Therefore, it is important to select an approach that is as flexible and simple as possible.

2.7 Export Control

Because export control and International Traffic in Arms Regulation restrictions are potentially a huge Program overhead, the export implications of agreements must be well understood before international agreements are made. NASA believed that export policies were understood and addressed at the beginning of the ISS Program. However, new obstacles regularly surprised NASA and the IPs, and significant impacts were experienced as the obstacles were addressed. Export control issues should be examined before making decisions on allowing an IP to provide specific critical path items or making commitments about what NASA may provide to the IPs.

Suggestions for improvements to the export control process include:

1. Benchmark export control processes and policies used by other government agencies with extensive international interactions, such as Department of Defense, Deptartment of State, Department of Commerce, including the Patent and Trademark Office, and Deptartment of Energy, to see where efficiencies can be gained.
2. Have representation from Export Policy and review organizations from the Department of State on the negotiation team of each major international agreement NASA makes so that NASA has buy-in from these agencies and they have a full understanding of the implications of these arrangements.
3. Minimize technical interface and integration requirements to reduce data exchange requirements. To the extent possible, limit data exchange to the sharing of the basic research data.
4. Require support contractors bidding on work to have plans and schedules in place for TAAs. Establish agreements up front calling for the development of TAAs between the affected parties. Include the pursuit of TAAs in contract language. Develop guidelines for TAA content in accordance with U.S. export control rules and regulations.

In order to comply with existing U.S. export control rules and regulations the NASA contractors need to pursue the early development of Technical Assistance Agreements (TAAs) with their IP counterparts. The International IPs need to understand the importance of these agreements and support the development of these agreements. There were repeated instances in which NASA contractors were limited in their ability to discuss or transfer technical information due to the lack of a TAA between the affected parties. In certain cases the IPs (i.e., JAXA) supported the development of such agreements and ultimately concurred with the agreements. In other cases (i.e. ESA) agreement was not reached, which resulted in numerous delays and inefficiencies in the transfer of technical information.

Recommendation: If some components contain elements that may later prevent sufficient exchange of data that verification and certification will become difficult by NASA, for example, they should be removed from consideration for partnership. The State Department and Department of Commerce should be involved early on in the development of options for partnership to help NASA to evaluate these issues. Contractors should obtain TAAs as early as possible.

2.8 Proprietary Data

Similar to export control restrictions, the proprietary data restrictions of various IPs provided numerous obstacles. In some cases, the IP agreed to the proprietary data clauses in the ISS IGA and MOU, but failed to make their contractors sign up to those same agreements. In other cases, unknown national laws were produced that appeared to contradict the proprietary data agreements.

Suggestions for improvement include:

1. Before NASA even enters an agreement, proprietary data policies must be clearly discussed and agreed to.
2. Ensure that IPs pass down proprietary data agreements and requirements in their contracts to their own contractors and subcontractors.
3. Ensure that contractors' structures and policies allow for their employees to sign non-disclosure agreements as normal practice and provide guidelines for quick-turnaround for approval of such agreements during the contracting process.

2.9 Meeting IP Objectives

International contributors owe their nations a return on the investment in the shortest possible time. IPs enter into partnership with specific objectives. They have received approval and budget based on those objectives, including schedule milestones, science results, publicity, and astronaut opportunities. However, once in the ISS Program, IPs had little control over how and whether their objectives would be met. ISS return on investment for ESA and JAXA will come only late in the program and this has been continually delayed as the ISS Program has experienced delays. Their funding constituencies are therefore understandably anxious to see return on investment. This has created considerable friction, has complicated assembly sequence development, and caused some agreements to be renegotiated.

To avoid this, key partnership milestones should come as early as possible in the program, not at the end of the program. "Wins" for all IPs in early stages should be planned into the program. This would keep IP motivation high and inspire partnership to be more collaborative than combative. The nations funding the programs should be able to see return on investment in the earliest timeframe possible.

2.10 Other Considerations for Agreements

2.10.1 Clear Scoping and Definition of Agreements

Setting expectations and scoping the work for each member in the partnership is important to avoid long term issues, cost impact, and delays. However, in order to get programmatic agreements in place (these are the first level agreements below the central policy and legal core discussed in section 2.a), important technical implementation details are often left to lower-level agreements. When negotiating these lower-level agreements, teams often find that each side has significantly different expectations of the scope and format of expected deliverables (such as data or models) listed in the higher-level agreements. They often find that the assumptions that were made at higher levels were not properly scoped or well-understood for implementation. The resulting disagreements can cause subsequent delays and cost impacts.

It will likely be necessary to include vague details in Program high-level agreements to be scoped in later, lower-level agreements, but expectations should be set that both sides will maintain cost and schedule margin to account for expected later disagreements.

2.10.2 Common Understanding on Sharing of Program Risk Reached Early

The philosophy regarding the level to which IPs share overall program risk should be clearly defined and consistently followed. If IPs do not explicitly and knowingly sign up to share in the total Program risk, demands for compensation or concessions may ensue should NASA have a technical failure. The ISS IGA supports the notion that IPs share in Program risk – an IP that has a technical failure is not required to compensate the other IPs for the cost of that failure to them – but could have been more explicit. One way to mitigate this risk is to schedule Partner milestones early, as discussed in section 2.f. If Exploration is to have a true partnership model, this philosophy must be strongly stated and adhered to from the outset.

2.10.3 Tracking and Managing Agreements

Over the course of a program, numerous MOAs, MOUs, protocols, and other agreements are made over a broad variety of topics across several management and technical specialties. Key agreements that affect policy, cost, and schedule have implications for all U.S. Program participants. Knowledge of agreements already made is essential in developing positions for new and on-going negotiations. The methodology for cataloging the agreements in the ISS Program has been inconsistent, and this has at times put us at a disadvantage in our negotiations. In addition to tracking the actual signed agreements, it is important to retain the corporate knowledge of the events surrounding the agreements, so that the agreements are interpreted in proper context and scope.

Relying on personal files/records and website postings is not an effective method to store the data in an easily accessible searchable format. Further, when a change in personnel supporting a job function occurs, sometimes a failure to exchange data occurs. This can put NASA at a disadvantage. On occasion, an IP will produce a copy of a ten year old agreement to support its position (when it is to its advantage). It would be to NASA's advantage to have these as a matter of record to use for Program stability and to support the decision making process at Program Reviews with IPs.

Recommendation: Provide a central repository for agreements, protocols, and Program-level memos that are accessible by all personnel supporting the Program.

2.10.4 Only Designated Negotiators have Authority to Reach Agreements

ISS learned the importance of technical and management teams having 1) negotiation skills training, 2) culture sensitivity, and 3) big picture view of how the outcome of their agreements affected the program position.

As teams enter into meetings and negotiations with an IP, it is important to provide team leaders and disgnated negotiators with negotiation and cultural training, as well ensure that the necessary discussions are conducted prior to signing agreements with the Program leadership as these agreements may have larger impacts. Discussing meeting objectives and potential outlooks prior to meetings as well as after are also important. Individuals who are not team leads or designated negotiators should not sign agreements.

2.10.5 Administrative Burden of Having Partnerships Needs to be Included in Program Budgets from the Beginning

The administrative impact of a multilateral partnership must be examined and planned for up front. The administrative impact of conducting a multilateral partnership is more than directly proportional to the number of IPs; it is more on the order of exponentially related. The scheduling of telecons with the various time zones, the travel required to support meetings, visa requirements, budgets, etc. are all factors in this.

3.0 Technical Lessons Learned

3.1 Technical Management and Integration

3.1.1 Agreement on Expectations

As mentioned in paragraph 2.10.1 above, clear scooping and definition of programmatic agreements is key. Also critical is the ongoing process of exploring and agreeing upon expectations as they develop, at the technical level. Expectations between NASA and its IPs involved a broad range of products, services, and performance, including issues such as requirements, hardware, software, and data deliverables; content, format, and quality of products; performance of technical tasks; standards; processes; schedule performance; and cost. Technical teams learned that expectations between NASA and the IPs could not be defined, communicated, negotiated, documented, and agreed early enough.

Conflicts over expectations often arose because of erroneous assumptions, such as:

1. Use of "standard practices" which were not actually standard

2. Verbal agreements were sufficient
3. Previous agreements on similar subjects still applied
4. Documentation always accompanies work completed

Clarifying and correcting differing expectations often resulted in additional cost and schedule delays. One example is divergent processes for certifying Commercial Off the Shelf (COTS) hardware; a failure to reach an up-front agreement with the IPs led to disputes regarding the tests that were required to be performed on certain batteries, for example.

Practical ways to mitigate the significant cost and schedule risks associated with miscommunicating expectations are:

1. With the IPs, plan and schedule the development and negotiation of detailed agreements on technical expectations so they are completed in sufficient time for the providing partner to obtain the funding necessary to meet the expectation. Integrate the production of these agreements into the project development schedule.
2. Negotiate reasonable schedules for providing the expected product or service, and integrate these milestones logically into the overall integrated project schedule.
3. Account for export control and proprietary data restrictions when planning delivery schedules.
4. If there is a belief that a formal agreement is not required, challenge the assumptions that led to that belief and validate the assumption with the other partner (preferably in writing).
5. Ensure budget and other resources are allocated to producing these agreements.

Even if a program follows this approach, it must also recognize that every technical detail cannot be set forth before work begins. IPs must, at the outset, recognize the risks involved in large space development programs and commit to budget margins for all activities accordingly. The experience in the ISS Program has greatly helped NASA and its IPs to understand one another's processes and expectations, although this understanding has sometimes come through difficult disagreements.

3.1.2 Technical Coordination and Integration Mechanisms

a. Technical Working Group Structure and Composition

   The most successful and productive teams or working groups for facilitating technical coordination possessed many, if not all, of the following characteristics:

   1. Officially chartered, with defined and controlled membership, scope, authority
   2. Scope was limited to project or partner
   3. Included members from all affected and relevant technical specialties in all appropriate Program phases involved in accomplishing the team's mission, within the scope of the charter
   4. Met regularly and frequently, either by teleconference or face-to-face, with agendas and expectations clearly communicated in advance of the meeting
   5. Tracked issues and actions and planned their resolution and closure on a target schedule
   6. Had mechanism for interfacing with and transferring issues to other working groups

In turn, integration across teams and working groups at the project (element) and program (system) level was most successful when bilateral or multilateral integration teams and forums were established with similar characteristics.

b. Technical Coordination and Integration Processes

Technical meetings between IPs were most successful when minutes, agreements, and action items were documented and signed before the meeting was adjourned. At some face-to-face meetings, the partner representatives who had traveled to the meeting did not have the authority to sign the documented results of the meeting, at least without consulting with their management back in their home country. Due to this lack of authority, different time zones and other logistical complications, some meetings would conclude with no formal agreement whatsoever. When attempts were later made to obtain signature from the appropriate authority, new issues were sometimes raised, effectively nullifying the tentative agreements reached during the meeting. Worse, partner management would sometimes fully reverse the position taken by the representatives at the meeting. Occasionally, such instances significantly delayed schedules or otherwise wasted resources.

This difficulty can be limited or avoided by implementing one or more of the following:

1. Coordinate clearly with the partner(s) in advance of the meeting on the meeting objectives and expectations of all parties, Especially when agreement upon resource commitments is desired. Define the authority required of the representatives to the meeting necessary to make those commitments.
2. Prepare documents and presentations in advance and provide them to the other parties for review prior to the meeting.
3. Provide fax, telephone, and e-mail facilities to the visiting partner(s) to facilitate communication between the partner representative and their management during the meeting.
4. Formally require partner management to appoint an official point of contact with authority to sign protocols or otherwise obtain management signatures in a timely manner.

3.1.3 Safety Panel

The ISS Program developed a single payload safety panel with partner participation. Because the IPs often have different approaches to safety processes and requirements, participation in a single panel di more to bring unity to this area than any other action. The participation of the IPs in this process gave added credibility to safety issues and promoted their effective resolution. It is key that cargo safety certification requirements and processes be unified and take all IPs' experiences into account as early as possible in the development of the program and its requirements.

3.1.4 Development Schedule Integration

In a technical development program with numerous, complex interfaces at all levels between international contributors, producing and maintaining integrated schedules incorporating the appropriate IPs' activities at the subsystem, project, and program levels is both essential and challenging. Once again, significant differences in the way each partner does business makes this integration task extremely difficult. These differences include:

1. Development life cycle – some IPs plan and execute the various phases of development (e.g., design, manufacturing, test) differently

2. Schedule margin (float) – some IPs clearly identify and allocate schedule margin in their development schedules, while others never reveal margin in their published schedules
3. Budget cycles – each partner starts its budget cycle, and sometimes even its fiscal year, at a different time of year, sometimes making coordination on content and schedules more difficult.

In addition, generating and reaching agreement on an integrated schedule management process can be quite difficult for the same reasons, as well as due to issues regarding who controls the schedule at what level. In the ISS Program, a formal schedule integration process was established, but not all IPs officially participated (most of those that did not eventually agreed to provide up-to-date schedule data). Also, it was very difficult to enforce the formal schedule change control process with the IPs for Program (Level 1) milestones (e.g. the KSC on-dock milestone for an international element).

The problem can be avoided, at least to some extent, by one or more of the following:

1. Establish a robust schedule integration and management process very early in the program that officially includes all IPs.
2. Provide sufficient resources to the program schedule integration and management task to ensure partner schedule data is fully integrated (logic networked) into schedules at the system, project, and program levels.

3.1.5 Configuration Management and Control

a. Change Process Efficiency

As part of the ISS change review and board approval process, changes that impacted the IPs were required to have approval from all affected IPs' prior to implementing the changes. However, the IPs had their own internal review and board approval processes they had to follow before they could provide their approval to the Program. The IP processes were often quite time-consuming.

In many cases, the U.S. contractors needed authorization to proceed (due to internal cost and schedule pressures) prior to IP approval. When NASA had to pre-implement a change prior to having all partner approvals, this created a "split baseline", and the program accepted the risk that an IP might later disapprove or require modifications to the change.

In addition to the inherently slow nature of the IPs' change review processes, other factors sometimes added even more time to acquiring IP approval on a change:

1. Some of the IP's have a culture that requires that they obtain consensus across numerous organizations, individuals, and levels of management before approving a change.
2. Some changes impacted IPs' contracts, and therefore their budgets, making it difficult for affected IPs to accept the change. In some of these cases, the IPs argued for compensation from NASA to offset these costs, and would not approve the change until NASA agreed to provide the compensation.
3. In some cases, an IP would hold approval of a change "hostage" in order to pressure NASA or another partner into accepting their position on another, unrelated issue. In other cases, one IP was manufacturing elements for another IP under a barter arrangement and since they had not been paid, delayed incorporation of all changes due to non-payment from the third party.

The ISS experience in configuration management has revealed that the critical elements of an efficient change process include well-defined roles and responsibilities, a clear board structure, an integrated change-processing tool, and visibility to management at the IP level. Management visibility and the oversight it brings on potential issues will ensure that changes will not languish. The program must also accept that split baselines will inevitably occur with any process, and that tracking mechanisms need to be in place to accommodate these events. Large, system-wide changes will take more coordination, processing time, and oversight to be successful. A change-processing tool with integrated metrics that will pinpoint problem changes is also crucial. Finally, when issues become un-resolvable at the technical level, an effective decision-making forum at the program management level must be available to address these issues. Often simply scheduling an issue for a program-level board would induce closure. Finally, the Program should consider ways to focus IP review upon important changes; many affected the IPs in some way but may not have been at the level of impact to necessitate a review.

It should also be noted that in the ISS Program, NASA expected and accommodated more requirements and design changes during the development phase than the IPs did. Consequently, the IPs usually resisted NASA-proposed changes because they had not acquired the budget reserves to handle them. This further reinforces the need for early, Program-level coordination with the IPs on program configuration management and control policy and budgets.

b. Application of Configuration Status Accounting and Acceptance Requirements

The ISS Program experienced an evolution and diversification of mechanisms for procuring and contributing hardware and software. In the beginning, NASA contracted with U.S. companies, the IPs contracted with international companies, and both contributed these procurements to the Program. Over time and out of necessity, NASA obtained much of its hardware from international companies through barters with the IPs, and the IPs obtained much of their hardware, as well as hardware to be provided to NASA under barter, through direct and indirect contracts with U.S. companies.

This diversification of procurement mechanisms led to inconsistencies in applying technical configuration status accounting and other acceptance requirements. Many inconsistencies were appropriate given the delegated responsibilities of the IPs, but others were not. These inconsistencies led to some confusion during development, manufacture, acceptance, and operation of hardware. Expectations from the ISS Program of requirements for IP hardware were sometimes miscommunicated and, in some cases, caused varying amounts of re-work.

If NASA configuration and acceptance requirements cannot be levied on all projects consistently, then the IPs' configuration management plans should be reviewed and compared with NASA requirements early in the program. Any significant differences should be used as the basis for negotiating agreements on specific program- and project level requirements and schedules. The agreements should also account for the different contract mechanisms that are anticipated.

3.2 Technical Requirements

3.2.1 Commonality of Requirements

The ISS Program found that a core set of technical requirements was applicable to all elements and systems. This core set included requirements related to basic technical characteristics of the ISS in its completed configuration, policy, and standards (e.g. safety, Shuttle interfaces, human factors). Unfortunately, simply flowing these requirements down from the ISS System Specification did not achieve the uniformity in lower-level requirements that was expected by NASA. Although Segment Specification requirements were intended to be consistent across IP segments, wording changes proposed by the IPs and negotiated by different NASA teams led, in some cases, to significant differences between the IPs on these "common" requirements.

A common set of requirements for certain disciplines should be established as appropriate, followed by all, and implemented into the design.

3.2.2 Providing Rationale for Requirements

In many cases on the ISS, NASA may have used existing requirements from other NASA Programs (e.g. Space Shuttle) as the basis for the equivalent requirements on the ISS. These requirements most likely had some history and rationale behind them as to why they are necessary and why they were written the way they were. The IPs may not necessarily know this background. A requirement may seem clearly written and understandable and its intent clear to NASA, but this may not be the case for a given IP. The rationale for technical requirements levied on the IPs should be captured and documented wherever possible and as resources allow.

3.3 System Engineering and Development

3.3.1 Common Hardware, Software, and Processes

The ISS Program has achieved cost savings for NASA and the IPs by promoting the use of common hardware wherever appropriate. Commonality allows for bulk buys and common pools of spares, which reduce overall program risk as well as cost. In the ISS Program, IPs tended to purchase ISS common hardware to support their elements, though not required, because it spared them the costs associated with developing similar hardware on their own. However, the IPs often acquired only the hardware without providing for its ongoing maintenance support; they later approached NASA to conract for these services on their behalf, on a reimbursable basis. In areas in which commonality was emphasized too late or not at all, the program has often had to incur costs to integrate incompatible hardware and software interfaces – although it must be recognized that some incompatibility is unavoidable.

Commonality in the sense of developing multi-user utilization facilities, tools, and equipment, can also be beneficial in reducing redundancy among the items developed by the IPs. For instance, common-use facilities such as the Microgravity Science Glovebox (MSG) provide a time-sharing capability, obviating the need for NASA and ESA to develop independently a similar capability.

To the extent feasible, the development of common user interfaces saves crew training time and crew time on orbit. There is, of course, some additional overhead in negotiating and tracking the utilization allocations among the IPs.

3.3.2 Dissimilar Hardware Redundancy

While commonality is generally to be emphasized, in some cases, dissimilarity may be preferred. Particularly as regards certain critical and complex functions, the independent development of two or more unique systems can add to robustness. For instance, the Russian Orlan spacesuit provided backup Extra-Vehicular Activity (EVA) capability during ISS Increment 9, when the U.S. EMU spacesuit was non-functional. Particularly in the area of life support, the use of multiple redundant hardware and software can provide an operational robustness to the system. A decision to pursue a stragegy of dissimilar hardware redundancy will depend upon the criticality of the particular system and the Program cost of pursuing multiple independent development activities.

3.3.3 Sustaining Engineering

On many occasions, IPs purchased hardware items that were developed by U.S. contractors as ISS common items. Subsequently, either NASA or the partner made changes to the baseline of its units. Without a mechanism in place to convey the changes from one user to the other, incompatibility issues can arise on-orbit. A remedy is to ensure that contracts which include hardware delivery to NASA and IPs are written to include sustaining engineering for all hardware items provided to the program. Another approach which may be considered is for NASA to contract for all common items and related sustaining engineering and distribute them as required by the IPs. This would ensure commonality, but NASA would assume the responsibility for items which the IPs have found to be defective.

3.3.4 "Meets or Exceeds" Certifications

In order to reconcile different manufacturing processes among NASA and the IPs, NASA instituted a process by which each partner certifies that its processes "meet or exceed" current ISS requirements. Over time, however, the partner process documents have gone through various changes, and these changes have not always been subject to review by NASA. In the first place, it is recommended that, to the extent practicable, NASA makes the determination whether a partner process "meets or exceeds" the ISS requirement, rather than leaving such determination to the partner. Secondly, it should be made clear to the partner at the outset of the program that all future changes to program documentation of all IPs needs to be reviewed thoroughly through the appropriate review process.

3.4 Operations and EVA

3.4.1 Centralization vs. Decentralization

Early U.S. human space flight programs demonstrated the benefit of a strong, centralized management structure to execute the operations planning and execution portions of a program. These benefits include overall program cost savings, more effective and efficient decision-making, and more efficient development of rules, databases, and plans. These tasks become more difficult when multiple IPs are involved. Each ISS partner wanted to have its own control center for its elements. Tremendous leadership is involved in ensuring that both diplomatic and technical agreements are made. Early in the program, decide whether operations planning and execution is to be centralized or decentralized. If one partner is to take a lead integration role, it must have the resources and mechanisms to incentivize the other IPs to work within that leadership. If integration is to be less centralized, expectations should be adjusted to recognize the added complexity. Creative solutions should be considered to meet competing political needs.

While also subject to political drivers, training should be centralized to the greatest extent possible, in order to minimize time lost to crew members and to decrease administrative inefficiencies.

3.4.2 Insight Into Partner Systems

From the outset, the IPs should make a clear commitment to provide one another with insight into their systems, in order to increase operational robustness. If NASA is to serve as the lead operator/control center, it must always maintain a systems and operational cognizance of the other IPs' systems and vehicles, even those under the command and control of the partner. Depending on the partner and the systems involved, an on-site integration group may be required to maintain this situational awareness.

ANNEX 1

ANNEX 1 - Contributors and Acknowledgements

1.0 Contributors

Input was provided from throughout the ISS Program and supporting organizations for this report, and served as the foundation for our recommendations. The following individuals either contributed their own perspectives on international participation, or solicited inputs from their organizations and provided consolidated inputs to us, or both. In addition to the organizations listed below, Ames Research Center, Marshall Space Flight Center, and Astronaut Office staff contributed their thoughts as part of others' input. We are grateful for the extensive amount of work and effort to help us by all those involved and for their valuable insight and ideas.

Particular thanks go to Jim Alexander, who took large amounts of inputs, consolidated and distilled them, and drafted some of the sections of this report. We appreciate his fine work and assistance.

Julio Acevedo/Vehicle Office

Jim Alexander/ISS External Relations Office

Glenn Chin/KSC/Mission Management Office

Jennifer Comella/Payloads Office

Mark Dillard/Mission Integration & Operations Office

Mike Fawcett/ISS External Relations Office

Sean Fuller/Operations Division

Frank Garcia/Vehicle Office

Richard Lee/Vehicle Office, Configuration Management

Damon Nelson/KSC/Operations Division

Gerald Readore/Safety & Mission Assurance, ISS Division

Marianne Ruiz/ISS Procurement Office

Dipak Talapatra/ISS External Relations Office

Jeff Theall/Mission Integration & Operations Office

Allyson Thorn/Avionics & Software Office

ANNEX 2

ANNEX 2 - Other Lessons Learned

This annex describes a number of additional observations regarding specific aspects of working with IPs.

1.0 Liaisons

Due to a multitude of factors (including but not limited to cultural/social differences, geographical distance, time zones, and organizational structure), liaison/consultant teams are necessary to ensure effective communications and coordination among IPs. Therefore, liaison functions must be factored into budget and staffing plans accordingly. Liaisons at multiple levels may be necessary, including programmatic and policy liaisons, technical/systems engineering liaisons, and operations liaisons like those of the Houston Support Group at the Moscow Control Center.

To achieve the maximum benefit from a liaison, it is recommended that the Program should:

1. Initiate liaison early in the program
2. Make a deliberate and sustained effort to update liaisons on developments at the home office – this can be as simple as remembering to cc: liaisons on all e-mails dealing with the liaison's partner
3. Maintain a low rate of liaison personnel turnover; time is required to build relationships and informal information channels
4. Give liaisons culture training or time to learn and adapt to the new culture
5. Provide the liaison with support and information to carry out the function
6. Provide the liaison with sufficient infrastructure to do the job, particularly in terms of telecommunications interfaces

In addition to establishment of NASA liaisons overseas, there are significant benefits to establishing liaisons by IPs at NASA facilities as well. In addition to pure liaison facilities, familiarization and On the Job Training (OJT) tours of duty for International Partner personnel tremendously facilitate future interactions, negotiations, and interfaces.

For example, during the beginning of ISS Program (before ISS operations actually began), several Japanese Partner personnel performed six month tours of duty within the NASA flight operations organization. These tours provided opportunities for Partner employees to "experience" NASA operations thru OJT and familiarization activities of STS, such as flight controller training and other operations forums. These tours were in all areas of operations (systems flight control, payload operations, launch package management, flight director office, etc.) The experiences gained by their personnel have tremendously helped in communicating, understanding and even negotiating policy and requirements, not only at the operations level but has helped at the programmatic level as well.

2.0 Personal Relationships

Relationships built in and out of the work environment are absolutely essential to enabling arrangements to be concluded among IPs. Many ISS IP countries, e.g. Russia and Japan, are "high context" societies. While Americans tend to relate to their colleagues as a function of their position and formal role, individuals from high context societies tend to place a high value on personal relationships. Trust and familiarity usually has to be built between colleagues before these IPs are comfortable working through more anonymous mechanisms (e.g. e-mail).

Moreover, cultural assumptions and ideas about work ethic differ from one culture to another. Individual partner representatives bring these cultural differences with them to the partnership. Overcoming these cultural differences can be much less difficult if some time is spent getting to personally know partner representatives. Reaching out personally to IPs builds trust and team spirit, which allows a program to accomplish common goals in spite of acknowledged differences.

3.0 Meeting Formats

Face-to-face meetings with IPs have resulted in significantly more productive meetings than meetings conducted over the phone. Depending on the specific IP, communication is enhanced by physical observations made during the meeting.

With the FSA and JAXA, limited understanding of English can cause critical misunderstandings that lead to false conclusions, wasting time and money. Breakdowns in communication often go undetected in telecons. Although telecons are far cheaper to conduct and are appropriate to routine work, face-to-face meetings are generally required when major issues requiring commitments are discussed.

ISS meetings should be formatted to address type of issues discussed and the results that are desired:

1. Telecons are a good format to document simple black and white issues or material where consensus is easy to obtain or already exists. The telecon meeting format can be productive where all participants know each other well or have had frequent contact in other settings.
2. Video conferencing is better than telecons when the ability to reference materials quickly is needed and also provides some physical cues in reactions to discussions. These are good when topics can be addressed within a couple of hours.
3. The face-to-face meeting format should be used whenever the participants are unfamiliar with each other, major issues must be discussed, or discussions are expected to extend longer than a few hours. Telecons and other communications should occur regularly leading up to the face-to-face meeting by both sides to ensure the issues are understood, all information required will be available, and the time in the face-to-face meeting can be truly productive. For Partner communications, face-to-face meetings should be utilized whenever difficulty in communications is anticipated.

The ISS meeting coordinator should be able to choose the meeting format based on the meeting material and the relationship established with the participants. Cost reduction, though a major consideration, should not limit face-to-face meetings to the point that overall productivity is impacted. Poor communication cost the ISS Program more than travel money expended.

The following is recommended regarding face-to-face meetings:

- Harmonize schedules for various meetings to allow multiple meetings to be attended on one trip.
- Ensure that the decision makers participate, not messengers that must communicate with the real decision maker.
- Scrutinized face-to-face meetings during the planning phase, based on the proposed meeting materials and the specific participants required.

4.0 Travel

The ISS Program learned that travel to enable face-to-face communication and interaction with the IPs at the technical level was essential to accomplishing its goals. The ISS Program maximized the benefits of travel within agency and government budget and policy constraints. Unfortunately, GSA and NASA travel policies are not well suited for large, complex, international R&D programs that depend heavily on team members' ability to travel. Future programs should seek, through the "Freedom to Manage" initiative, the authority to implement less restrictive travel policies and procedures while still minimizing travel costs.

5.0 Budget Cycle Differences

The cycles and processes for obtaining budgets vary considerably among the IPs. ESA's budget system, for example, is significantly different from that of any U.S. government agency. Since the agency receives funding from a council of members, the council prepares a strategic five-year budget but may for policy reasons freeze large portions of the budget until another infrequent council-meeting. At various times, NASA has had to work with almost every partner to develop understandings helpful to the partner in securing ISS monies from its funding authority. FSA's partial reliance on commercial funding naturally presents unique issues, such as accommodation of space flight participants on Soyuz taxi missions.

NASA must enter into any partnership with a realistic understanding that it must be flexible in assisting its IPs' efforts to obtain program funding. More broadly, recognize that sustained support for long-term international programs is contingent upon uninterrupted political support in a number of countries as governments and parties win and lose power.

6.0 Process Commonality

International partner development and integration processes are often different from those employed by NASA. These differences are driven by their unique experiences and are sometimes significant. In a sense, each partner has its own "engineering culture." In some cases (e.g. configuration management, verification, acceptance, certification), such differences complicated NASA's ability to perform its integration function. When common processes are necessary for efficient and effective integration and exchange of products, these processes and methodologies should be defined to the lowest level possible and agreed to prior to Program implementation.

The ISS Program has found challenges for increasing process commonality in a number of particular areas: software compatibility for command, telemetry, file transfer, and data dump; crew provisioning; inventory management; and integrated logistics tracking. The development and use of common manufacturing standards and processes should be encouraged to the greatest possible degree.

7.0 Scheduling Coordination Activities

IPs must deal with different time zones, national holidays, and traditional vacation schedules. As a result, available workdays for tasks and meetings that require multi-lateral cooperation are relatively limited. Productive collaborative time can sometimes be reduced to 3 half-days per week and is further impacted by 3-day and 4-day holiday weekends which do not coincide from country to country. Traditional vacation periods for the Europeans in the summer and other IPs' vacation customs (e.g., Christmas, Easter, Golden Week in Japan) also limit the number of available days for face-to-face or other coordination meetings.

Some approaches for addressing the problem are as follows:

1. International partner coordination schedules should account for these differences and the inefficiencies caused by working on virtual, remote teams.
2. Technical team members with a reasonable amount of authority should be exchanged between IPs to facilitate efficient and rapid communication and problem solving.
3. Project teams' standard work shift schedules should be altered as a normal part of business to allow for at least some overlap with the necessary time zones.
4. Sufficient travel budgets and streamlined travel policies should be provided to support resident technical staffs and travel to ensure timely resolution of issues. Requirements to request travel thirty days or some other arbitrary amount in advance of an activity can stifle an international team's ability flexibly to solve problems.

8.0 Translation and Interpretation

The cost of interpreters and translators needs to be included in the program budget estimates from the beginning, if significant international cooperation will occur. Whereas the ISS Program was established on the principle of English as the language of the program, when the Russian partner joined the program, it was soon realized that this was a requirement that could not be met by the Russians. A number of significant challenges arose from this situation. Many at NASA believe that the lesson learned was that a single language should be enforced for future programs. However, in an era of increasing international involvement, a single language may not be feasible, or even desirable, if it results in an atmosphere of exclusivity instead of inclusiveness. However, there are significant costs of using interpreters in terms of money, time, and risk. In order to minimize all of these, it is important that a corps of qualified interpreters and translators be developed and maintained.

ANNEX 3 – May Report

Lessons Learned from International Participation in the International Space Station Program

Michael J. See

Daniel V. Jacobs

Lyndon B. Johnson Space Center

Houston, Texas

National Aeronautics and

Space Administration

May, 2004

Introduction

Purpose

This paper was developed in response to a request for information from the Office of Exploration Systems (OExS), NASA Headquarters, through a formal task request to the International Space Station (ISS) Program, titled: "ISS Program Lessons Learned and Recommended General Principles for International Partnership in Space Exploration," delivered on March 17, 2004 (Appendix A). Specifically, this paper responds to Subtask 2 of the above task.

Scope

The scope of this paper is consistent with the scope of the OExS task. In general, this paper provides principles, guidelines, and technical lessons learned by the ISS Program for the formation of international partnerships. This paper is an initial version of lessons learned from ISS, covering some of the most significant lessons at a high level. It will be expanded in both breadth and depth in future versions, and is intended to open an ongoing dialogue between the ISS Program and the Exploration Program on these and other topics as needed.

An important factor to consider is that the Exploration program will continue for an extended period of time, go through various phases, have different and changing objectives and goals, and may involve different sets of partners. Therefore, the lessons discussed in this paper may not be applicable to all phases of the Exploration program. As the Exploration program evolves and matures, individual lessons may become more or less relevant.

Leadership

The ISS Program is structured with the U.S. clearly in the lead. The expectations placed on NASA by the Administration, Congress and the American people are that NASA will lead future programs as well, since the U.S. will likely be spending the majority of the money and will likely be producing the majority of the contributions. It should be recognized that some partners might have similar expectations from their countries' leadership. As with the ISS, some formulation that maintains U.S. *overall* leadership, while allowing for partner leadership *in specific areas*, may be necessary.

Although the ISS program established U.S. leadership, the program was operated on the basis of consensus. NASA had the right to make unilateral decisions when consensus was not achievable. However, on a practical basis, this right was rarely exercised, and for matters that required action by other partners, was not easily enforced. For this reason, the program suffered delays on some specific issues, which was sometimes advantageous for the partner who was less impacted by the delay. A leadership approach that calls for the achievement of consensus will run into the same problems.

Recommendation: The leadership approach selected and agreed to for future programs must have an explicit method of making decisions in the absence of a consensus. This method must be enforceable and must be clearly defined and agreed to by all parties. This is true regardless of the type of organization or leadership style selected.

Agreements

The multilateral ISS Intergovernmental Agreement (IGA) established NASA as the first-among-equals partner, the center of a circle of partners. Bilateral Memoranda of Understanding (MOUs) extended to specific partners on the circle and were negotiated in parallel with the IGA. There were a number of both benefits and problems with this arrangement. Because of the number of parties involved, each of which had to work within its own political processes, and because of the complexity of the agreement in terms of technical and programmatic issues, the negotiation of the multilateral IGA, and of the bilateral MOUs in parallel, was difficult and time-consuming. The documents were by necessity vague in areas, but in other areas, were very specific. Those specific sections have gradually become more out-of-date as the program has evolved. The aspects of the agreements most out-of-date were those that listed the contributions of each partner and program milestones. The agreements also established cumbersome mechanisms for decision-making, which are now difficult to streamline. In addition, the documents did not address some key issues, such as the expansion of the partners, the addition of participants, or commercial partnerships.

On the other hand, key provisions of the IGA and MOUs have aged remarkably well and are still relevant after many years and design evolutions. They have provided the program with a solid policy foundation that remains in place precisely because of the difficulty in changing them and to which all partners adhere without question. The agreements included common goals and the structure of the cooperative program, with agreed-upon programmatic processes and mechanisms, and legal constraints necessary for further implementation. These are the aspects of the IGA and MOUs that have proven most useful to all partners.

The exploration initiative has some unique characteristics that should be considered when deciding on the approach to take concerning agreements. It will be multi-phased, moving from initial spacecraft to uncrewed lunar/Mars bases, to crewed missions to permanent lunar/Mars bases. Each phase may have different sets of partners making different kinds of contributions. The phases are currently relatively undefined in scope and timeframe. The entire initiative has a much longer timeframe and the definition of the program will evolve over time.

Recommendations:

1. ***Bilateral agreements should be used leading up to the multilateral agreement. They should be limited in scope to the definition, initial planning, and perhaps initial minor projects or missions of the exploration initiative. A central boilerplate core of the agreements should be developed by NASA and used in each of the bilateral agreements, serving much of the same purpose of a multilateral agreement later, but without the overhead of negotiating multilateral agreement.***
2. ***The multilateral agreement should not be concluded prematurely. Multilateral agreements should be concluded when the program is sufficiently defined to reach common agreement on areas of common interest, program phases, initial partners, and types of partnerships. When the multilateral agreements are negotiated, they should focus on agreement on the aspects of the IGA and MOUs that have been most useful to the ISS partnership and least subject to change over time: common long-term goals, top-level management forums, the enabling of lower-level agreements, and legal aspects (such as intellectual property rights, liability, and export control). They should not be overly inclusive or comprehensive and not identify specific contributions, milestones, or programmatic structures.***

3. ***Once the multilateral agreement is concluded laying out common interests and necessary details, implementing agreements should be negotiated phase-by-phase, perhaps mission-by-mission, of the exploration initiative. Using the legal and policy framework in the top multilateral agreement, each implementing agreement would identify which partners will be involved in that specific phase, roles and responsibilities, short-term goals, and specific programmatic and management arrangements for that phase. These implementing agreements should be limited in scope and duration to the specific phase or mission, allowing implementing agreements for follow-on or other phases or missions to evolve, incorporate lessons-learned, and include different partners and structures.***
4. ***A set or menu of types of lower-level agreements should be developed up front. For each type of boilerplate agreement, a set of guidelines should be attached, indicating when it was appropriate, signatories required, and processes for concluding, along with a standard format. In addition, a central repository of all concluded agreements should be established and maintained.***

Criteria for Partnership

In the ISS program, NASA considered only other major space-faring nations as candidates for partnership. Ultimately, the partners were chosen largely based on the relevance and value of the contributions they proposed and the likelihood that they would acquire the necessary funding. In addition, Russia was chosen to meet certain US foreign policy objectives. Many years of experience with these partners has, by and large, validated these criteria (with the possible exception of foreign policy, which will not be addressed here) as general indicators of the partner's *potential* for making positive contributions toward Program goals. However, ISS experience has also revealed a number of other criteria (technical and non-technical) that should also be considered in not only selecting partners, but also negotiating the content and scope of the partner's participation. Note also that some non-space-faring nations may be able to contribute to space exploration activities in ways that are not relevant or applicable to Earth-orbiting space stations. A complete list of criteria for selecting international partners for human space exploration should include:

- **Capabilities – Does the candidate possess the means to fulfill its commitments?**
    - **Technical – Is the candidate technically proficient in one or more important disciplines?**
    - **Financial – Does the candidate possess or can it obtain sufficient financial resources to fulfill its commitments?**
    - **Political – Does the candidate possess sufficient public and political support to endure as a partner?**
- Dependability – Can the candidate be depended on to remain on course during a long program?
    - **Economic stability – Is the candidate itself economically stable, and are the priorities of its national budget firmly established?**
    - Political stability – Is the national political situation stable or uncertain?
    - Track record – Does the candidate have a record of completing long-term programs and international commitments?
- **Other Criteria**
    - **Foreign Policy – Are there nations with whom NASA will be required to work as a matter of national foreign policy?**
    - Export Control – Are there candidates with whom export control issues are too difficult or restrictive?
    - **Mix of partners – Is there an advantage to forming a group of partners that are economically, culturally, or otherwise diverse?**
        - Allowances for emerging or non-space faring partners
        - Developed vs. developing countries
        - North vs. South, East vs. West

- System redundancy – Is there an advantage to having redundant systems or components designed by different partners?
  - Two different technical architectures integrated into the spacecraft for a core subsystem function can provide the ultimate redundancy.
  - ISS examples: communications, Motion Control Systems, Docking Compartment, airlocks, Orlan and EMU EVA suits, and the Electrical Power System.

Recommendation: Decide early in the program what categories of partners will be sought, approved or for which allowances will be made, and how they will be evaluated and selected. Threshold criteria should be developed for each category. If some categories are identified as critical, recruitment strategies should be developed.

Critical Path Considerations for Partnership

Definition of Critical Path

Another major consideration in establishing international partnerships is whether a partner's contribution can or should be in the "critical path" toward a Program objective or goal. In the ISS program, the definition of critical path, in this context, appeared to vary over time. At different times, a partner's contribution was considered to be *not* in the ISS Program critical path if:

- The contribution was not needed to continue and complete the assembly of the station.
- Assembly of the station could not be continued without the contribution, but alternate providers existed.
- Assembly of the station could not be continued without the contribution, there were no current alternate providers, but there was sufficient margin in the schedule to develop a recovery plan once it became apparent that the contribution would not be completed.

This apparent variation in the implied definition of "critical path" gave the impression that NASA was not effectively planning for the possibility that a given partner might not deliver its contribution to the program.

Recommendation: In determining whether a partner's contribution will be in the "critical path" of the Program, the definition of "critical path" should be clearly established as early as possible and maintained consistently.

Feasibility

Early in the ISS program, NASA attempted to keep its partners out of the critical path to completing ISS assembly. However, various pressures ultimately drove it to putting several partner contributions on the critical path. Doing so increased Program risk and ultimately caused schedule delays and cost overruns. However, it may not be possible to develop a major program without partners in the critical path, for a number of reasons:

- Budget – the full, potential cost benefits of involving international partners may not be realized without putting at least one partner's contribution on the critical path.
- Schedule – It may be impossible to meet Program schedule goals without a partner developing a critical component in parallel with US hardware development.
- Expertise - A partner may uniquely possess expertise in a critical discipline.
- Condition of Agreement – A partner may demand responsibility for developing components that are in the critical path to justify its budget or as a matter of national pride.

Recommendation: NASA needs to recognize that it may be inevitable that partner contributions will be on the critical path of the Program, even if the Program is initially planned to preclude it.

Barters

The MOUs with the ISS partners state that all parties will try to minimize the exchange of funds between parties, but partners will try to work out barter agreements instead in cases when one partner owes another for a good or service. A number of these barter agreements have been concluded with all the ISS partners, ranging from small arrangements valued in the thousands of dollars, to barters of entire modules or launches.

When barter agreements are negotiated, the two parties normally do not exchange information on costs or prices of items to be exchanged. Opinions on the relative values of the items to be bartered are exchanged. Based on this and the partner's own assessment of value and internal costs, each party to the agreement has to decide for itself if the values and costs of each side are balanced and fair. When exchanging off-the-shelf items or goods and services that are well understood, this is relatively easy and straightforward. However, some fundamental problems were experienced with the barter agreements as concluded in the ISS program.

- Items that were bartered were development projects, like the Centrifuge and Nodes modules, so costs and technical challenges were not well understood. When working with partners who are experienced in human space flight and understand how these things work, both parties understand that these uncertainties need to be taken into account and margins need to be added into the estimation of costs. Instead, some bartering partners did not consider these uncertainties, and, in fact, simply took preliminary costs estimates by NASA contractors and used them without doing their own estimations and without adding margin in schedule or cost. The impacts from these mistakes have resulted in cost overruns, program disruption, schedule delays, and efforts to correct the situation.
- Experienced partners understand the risks inherent in development programs, build in sufficient margin to deal with the risk, and then accept the risk when they make commitments. Some ISS partners did not accept that risk when concluding the barter agreement, either through a lack of understanding or intentionally. The NASA team assumed that both sides were using the same assumptions about risk when concluding the agreements and did not seek enough information to ensure that was the case. When technical problems or budget overruns were later encountered, it was discovered that both sides were approaching the issue of risk in development from completely different points of view, again leading to major disruptions in the program.
- Even though the agreements were barter agreements, NASA assumed that both sides were approaching the agreements as cooperative partners, with all that implies about the working relationship between the parties. When the partners provided contributions to the ISS as partners, they understood that they were responsible for:
    - Fixing design problems
    - Ensuring that the hardware would work as planned; i.e., verification tests, integrated tests, pressure tests, analysis, etc.
    - Optimizing operations to minimize long-term costs and maintenance
    - Long-term sustaining engineering and sparing
    - Monitoring contractors
    - Obtaining necessary data from their contractors

  Under the barter agreements, the partners instead viewed their role in these agreements as distinct from their roles as cooperative partners in the program. When partners built hardware for provision to NASA (Centrifuge, Nodes 2 and 3, MPLMs), they had little incentive to do any of the functions listed above, even when required to by the agreement. They approached their roles as more similar to contractors with fixed-price contracts, and their original valuation of the cost for implementing their side of the barter was the fixed price. Therefore, any changes to original requirements, specifications, or descriptions were viewed as potential "contract" changes requiring negotiation. This was even extended to changes that filled out TBDs or provided clarification to ambiguous language. The contractor-like role also affected the provision of data by the partner, with proprietary data issues becoming more troublesome.

- In barter agreements where items were to be exchanged with a transfer of ownership, both parties often had very different views of how acceptance processes, certifications and transfers would occur. NASA is continuing to deal with this problem for items in which NASA will take ownership and operate over a long period of time, but for which data has been restricted.

Recommendation: Over time, barters are likely unavoidable, because partners will always identify things they need from each other and will not want to provide cash to another nation. When barters are required and where possible, avoid barters in which ownership of a piece of hardware will be transferred to NASA. Instead, attempt to barter for services or resources. If a partner takes on responsibility for provision of a service, like transportation services, oxygen production, logistics, even a research capability, the partner can decide for itself how to build, operate, maintain and sustain that service or product. The partner will be incentivized to ensure that they will be able to provide the service over a long period and that it can continue to provide the product, since the partner itself will be doing it. All of the above issues become internalized to the partner. NASA should have less concern how the partner performs the service or provides the product as long as the service or product meets standards, thus minimizing the oversight required. If NASA does decide to barter for hardware that will be transferred to NASA, clearly identify responsibilities for all phases of development and provide provisions that allow flexibility in responding to the inevitable program changes.

Technical Decision-Making Processes and Structure

ISS Program decisions necessitating resource commitments are required to be made at one of several Program boards. Board responsibilities and budgets are generally allocated by function or project (e.g. subsystems management, avionics and software, operations, program integration, U.S. element, partner element). This board structure has functioned reasonably well for U.S. element and U.S. systems development. The U.S. Prime contractor was organized and funded to support these various boards and integrate across them. However, for the partners, this structure has been more cumbersome to navigate and has required disproportionate resources for the consequent overhead, as a proportion of their total project budget. In addition, this structure has sometimes led to confusion or ambiguity as to which NASA board should fund a change associated with a given partner element's integration. This problem (and others) can be mitigated proportionally as the number and complexity of the interfaces between the partner elements are reduced. However, if significant and/or complex partner interfaces are necessary, options for addressing this problem include:

1. Accept this type of structure as an unavoidable necessity in complex development programs.
    a. When structuring partner participation on future programs, emphasize to the partner that these challenges are unavoidable and stress the need for adequate resources to support them.
    b. Ensure adequate resources are applied within NASA to facilitate navigating each partner through the process.
2. Strictly allocate all partner element-related decisions to an appropriate "partner element" board co-chaired by NASA and the partner.
    a. Require all functional disciplines and interfacing element boards to be represented at the partner element board so that all partner element decisions can be made in that forum.
    b. Multi-element, or multi-partner decisions can be addressed the Program-level board.
3. Consider partner integration projects early in process of defining board structure and build into the infrastructure.
    a. Structure Program boards strictly by project, to include partner element integration as a project.
    b. Require functional teams to support all project boards.
    c. Manage system-level integration across at a higher level through a strong systems engineering process, through which each project is represented.

Recommendation: Carefully consider partner integration early in the process of defining the program decision-making board structure. Depending on the nature and content of partner participation in the Program, select the

most appropriate option above for incorporating partner integration into the decision-making process and infrastructure.

Definition of Development and Integration Processes

NASA development and integration processes are often different from the IPs. These differences are sometimes significant, driven by their unique experiences. It could be said that each partner has its own "engineering culture." In some cases (e.g. configuration management, verification, acceptance, certification), this complicated NASA's ability to perform its integration function.

Recommendation: Where appropriate and necessary, define and agree to standard processes and methodologies to the lowest level possible, prior to Program implementation. Rationale: Some common processes are necessary for efficient and effective integration and exchange of products.

Operations – Centralized vs. Decentralized

Early U.S. human space flight programs demonstrated the benefit of a strong, centralized management structure to execute the operations planning and execution portions of a program. These tasks become more difficult when multiple partners are involved. Each ISS partner wanted to have its own control center for its elements. Regardless of how the early programmatic agreements (such as the Station Program Implementation Plans (SPIPs)) are written, without careful management, operations integration can become more a process of diplomacy and less of leadership. In any event, the "lead" partner for operations integration needs meaningful incentives to ensure cooperation.

Recommendation: Early in the program, decide whether operations planning and execution is to be centralized or decentralized. If one partner is to take a lead integration role, it must have the resources and mechanisms to incentivize the other partners to work within that leadership. If integration is to be less centralized, expectations should be adjusted to recognize the added complexity. Creative solutions should be considered to meet competing political needs.