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EVALUATING WIN-WIN ASPECTS OF TECHNOLOGICAL COOPERATION IN SPACE EXPLORATION

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ABSTRACT

As the world space community renews its exploration efforts and places increased emphasis on missions to the moon and Mars, new models of cooperation between nations are needed. These new models should take into account the complexity and design of the technical systems that will be necessary for exploration, in addition to the policy concerns of participating nations. This paper explores international cooperation in space exploration programs, with an emphasis on technological cooperation. An original framework is set forth for identifying and evaluating win-win aspects of technological cooperation in space exploration between nations. This framework is then exercised using the case of space exploration programs. Specific recommendations are made for how nations should think about cooperation in space exploration for the mutual benefit of technological and policy concerns. Through such cooperation, benefits beyond improvements to technical system performance, cost, and schedule may be realized, to broadly include domestic and foreign policy gains of individual nations.

INTRODUCTION

International cooperation is becoming an increasingly important part of today's space programs. Nevertheless, today's space-faring nations lack a systematic framework for evaluating international cooperation proposals. Such a framework should have both technological and policy components, so as to capture the effects of international prestige in this high-tech enterprise. By simultaneously considering technology and policy, a more informed decision may be made so as to improve future cooperative schemes.

A literature review of international cooperation in civil space exploration found that papers fall into three main categories: 1) papers that argue for a particular mode of cooperation[1,2,3,4,5], 2) papers detailing the transaction costs of international cooperation and suggesting means of avoiding these costs[6,7,8,9,10], and 3) papers analyzing past instances of cooperation and seeking to explain the rationale for the cooperation seen[11,12,13]. Such approaches to international cooperation have not explicitly considered technology and policy together. The result has been cooperative schemes such as that found on the International Space Station (ISS), which are politically attractive but technically untenable. On the other hand, those schemes that are not politically feasible will never reach fruition regardless of their technical feasibility. This paper proposes a framework for evaluating the feasibility of, and incentives for, international cooperation by analyzing the costs and benefits of various cooperative schemes. The resulting framework is unique because it considers both technical and political concerns in the evaluation process, allowing for an effective trade-off between the two.

This paper hopes to fill a void in the literature by suggesting modes of cooperation appropriate under different sets of techno-political circumstances. The following framework for international cooperation is intended to provide an analytic construct to assist in evaluating various schemes of cooperation with a foreign partner nation. To accomplish this, the framework defines three technical parameters, two policy parameters, and six types of international cooperation. Choice among types of international cooperation should be informed by both the technical and policy parameters so as to construct a partnership that is both viable and productive. A case study lends concreteness to the framework by illustrating the process by which recommendations for international cooperation are derived.

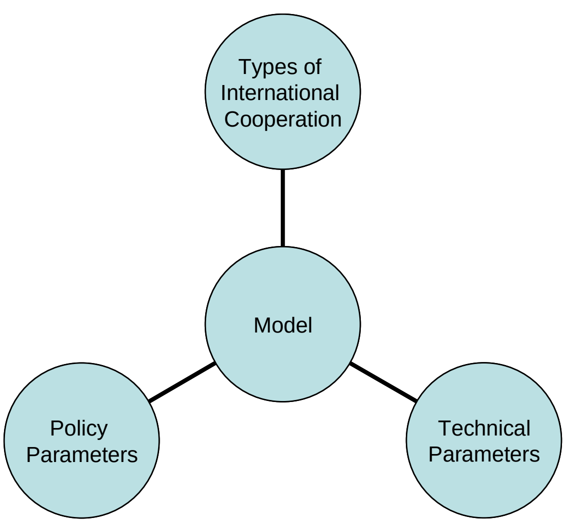

Figure 1: The framework is informed by three separate types of parameters – Types of International Cooperation, Technical Parameters and Policy Parameters

FRAMEWORK DESCRIPTION

Use of the framework has been broken into six discrete steps, aimed at creating a systematic approach to evaluating international cooperation schemes. In implementing this approach, we have identified three types of parameters that are required to inform the framework; namely, technical parameters, policy parameters, and types of international cooperation.

Each of these steps is described in order of execution below.

Step 1: Choose Countries to Analyze

The first step in applying any model of international cooperation is to choose at least two countries for which a particular cooperative arrangement will be analyzed. This framework can be used by any country considering cooperative arrangements for their space projects.

Step 2: Collect Data on Technology Capabilities, Policy Goals for Each Country

Once a set of nations has been selected for analysis, the next step is to determine the reason and ability that each nation possesses for engaging in a cooperative endeavor. Lacking the appropriate policy drive, a nation will be unwilling to cooperate. Similarly, the lack of any substantial technical contribution from a potential partner will preclude cooperation. The primary purpose of this data collection is to determine the capability and incentives that each nation might have to cooperate.

Step 3: Identify Feasible Cooperative Schemes

Once data has been collected regarding the goals and technological abilities of each nation under analysis, this information may be applied to inform the choice of cooperative scheme. In particular, those schemes infeasible because of a dearth of technological capability or because of substantial policy opposition may be eliminated from consideration. This requires a systematic and mutually exclusive list of cooperative methodologies.

Cooperation Level	Type	Description
0	Non-collaboration	In this limiting case, there is no collaboration.
1	Short-term niche	Short-term acquisition of a “niche” capability from a country that can contribute to a particular area.
2	Long-term niche	Long-term attainment of a niche capability from a country that has a recognized expertise/interest in a particular area.
3	Critical Path	Collaboration on vital parts of the space exploration architecture.
4	Parallel Missions	Involvement in a mission or series of missions developed by a foreign partner for mutual benefit.
5	Institutional	All participating nations contribute resources to a world space organization that sets priorities and assigns responsibility for development and delivery.

Table 1: Six types of international cooperation aimed at representing varying levels of contribution from participants.

This paper investigated six different cooperative methodologies based on past experience and proposals made in the literature. Each type represents a degree of contribution from the partner nation, as shown in Table 1.

Step 4: Assess Effects of Feasible Schemes

After identifying appropriate cooperative schemes, the effect of those schemes on technical and policy parameters is evaluated. The technical parameters are those that result from the chosen architecture and design of the system and which are important to technical program managers, namely system performance, cost, and schedule. The policy parameters are the domestic policy utility and foreign policy utility of the cooperative scheme.

Technical Parameters	Policy Parameters
1. Cost 2. Schedule 3. Performance	1. Domestic Political Utility 2. Foreign Political Utility

Table 2: Technical and policy parameters considered in the framework

Step 5: Identify Each Nation’s Preferred Schemes

Each nation is likely to possess a preferred approach to international cooperation with a given partner nation, identified by those approaches which achieve superior technical and/or policy gains. Nations will often have very different ideas of the ideal way to cooperate with each other.

Step 6: Identify Win-Win Cooperation Schemes

In an ideal situation, a cooperative scheme that improves both the technical and policy parameters for each cooperating nation would be selected. In practice, some schemes will favor some parameters over others. In this case, the framework as presented allows decision-makers to explicitly identify and choose between technical considerations and policy considerations so as to make a well-informed choice.

By combining technical design issues and political concerns, this approach to analyzing the effects of international cooperation is of use to both the policy-maker and the program manager. In addition, synergies between the technical and political realms may allow for the identification of win-win cooperative scenarios.

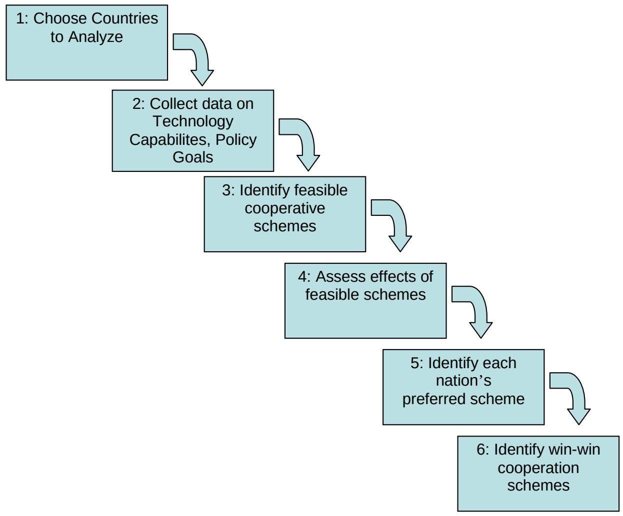

Figure 2: This flow chart captures the six steps required to implement the framework for evaluating international cooperation.

CASE STUDY

So as to lend concreteness to this methodology, we present a case study to analyze potential cooperation between two countries using the framework just described. The evaluation is described in the six steps presented above.

Case Study Step 1: Choose Countries to Analyze

We chose to analyze cooperation between the United States of America and Italy, and to do so from the viewpoint of the United States as it embarks upon its new Vision for Space Exploration (VSE), a long-term plan that explicitly calls for international cooperation[14]. The Italian Space Agency (ASI) has a history of cooperation with the United States on projects ranging from scientific missions to the International Space Station[15]. Italy was therefore considered an appropriate candidate a case study to evaluate potential cooperation. Italy will be referred to as the partner nation.

Case Study Step 2: Collect Data on Technology Capabilities, Policy Goals for Each Country

Both the US and Italy have credible technical capabilities in space, and expect to use space exploration to further their domestic and foreign policy goals.

American Technical Capabilities

With its extensive history in space, the US has much of the technical capabilities necessary to carry out the Vision for Space Exploration. Among the VSE's major milestones is completion and servicing of the International Space Station (ISS) through 2015. The Space Shuttle will support this mission until its retirement in 2010. The completion of the ISS mission will occur in parallel with the development of the next generation launch and exploration vehicles: the Crew Launch Vehicle (CLV) and the Crew Exploration Vehicle (CEV). In addition, a first lunar landing of the VSE is planned for 2018. The return to the Moon is intended to lead to the creation of a lunar outpost that will be used, among other things, to develop and test technologies for an eventual human mission to Mars.

American Policy Goals

American space exploration policy, governed by the Vision for Space Exploration, calls for a "sustained and affordable" exploration of space with commercial and foreign involvement. The VSE explicitly calls for NASA to seek international participation[16].

More broadly, American domestic and foreign policy objectives include:

- High-profile demonstration of solidarity with allies
- National security
- Pride and prestige
- Shaping international policy
- Maintaining a capable technical workforce

Italian Technical Capabilities

Italy has significant technical capabilities to bring to a cooperative project. Its construction of the Multi-Purpose Logistics Module (MPLM) for use on the International Space Station (ISS) gives it credible experience in building flight modules for use in human spaceflight. Italy also has strong competencies in communications systems design, gained through experience with the Cassini Saturn orbiter[17]. Italy has recently focused efforts in favor of the development and deployment of habitation technologies for the ISS, rather than on basic research.

Italian Policy Goals

The primary goals of the Italian Space Agency include fundamental research, development of economic strength and industrial activity, encouragement of growth within the space sector, balance between national Italian space activities and participation in ESA, and international cooperation in space development activities[18].

More broadly, Italian domestic and foreign policy objectives include:

- National pride and prestige: Demonstrating high-tech ability
- National security
- National economic well-being: Developing niche high-tech specialties (pressurized modules, inflatable structures, etc.)
- Shaping international policy: Improving industrial and diplomatic relations with the US
- Maintaining technical capabilities: Maintaining existing capabilities (habitat modules in particular)

Case Study Step 3: Identify Feasible Cooperative Schemes

Of the six cooperative schemes presented in this framework, three are not feasible due to technological or political considerations, and may therefore be ruled out. This restricts the analysis to the remaining three cooperative schemes, aiding in tractability.

Non-Collaboration

This type of cooperation represents a degenerate case because of the stated interest from both nations and the history of cooperation between the United States and Italy. Barring a major change in the political or technical environments of these nations, Non-Collaboration can be effectively ruled out.

Short-term Niche

This type of cooperation with Italy might involve the deployment of an Italian instrument on an American scientific mission. An example of this type of cooperation is the Italian Drilling and In-Situ Experimentation System on NASA's Phoenix Lander, which takes advantage of experience gained by Italy during ESA's Rosetta Mission. A short-term Niche cooperation similarly takes advantage of an existing competency to fill a non-recurring need in an existing mission.

Long-term Niche

This type of cooperation with Italy might involve the Italian construction and/or operation of a supporting component on a multi-mission American program. An example of this type of cooperation is the Italian Multi-Purpose Logistics Module (MPLM), used to re-supply the ISS. Long-term Niche cooperation similarly takes advantage of an existing recurring but non-critical need that develops, or takes advantage of a local competency in the partner nation.

Critical Path

This type of cooperation with Italy might involve the Italian construction of a necessary component on a multi-mission American program. A hypothetical example of this type of cooperation is the Italian construction of a pressure-vessel for the American CEV based upon MPLM-derived technology. Critical path cooperation similarly takes advantage of an existing recurring and critical need. As seen in this example, the earlier development of a particular niche competency could eventually evolve into future, closer cooperation.

Parallel Projects

With Italy lacking its own independent large-scale human space exploration program, it is unlikely that Italy and the United States would engage in parallel projects. We therefore rule out this type of cooperation as infeasible on technical grounds.

Institutional

Today's political climate or foreseeable future climates do not allow for an over-arching organization that could simultaneously regulate American and Italian space exploration policies. We therefore rule out this type of cooperation as infeasible on political grounds.

Case Study Step 4: Assess Effects of Feasible Schemes

Now that we have identified three feasible cooperative schemes, we need to explore their effects on the technical and policy parameters defined in the framework.

Cost

Conventional wisdom holds that international cooperation increases overall mission cost, while decreasing per-partner cost. This is largely due to the fact that current cooperation occurs on a “no exchange of funds” basis. Less cooperation will also incur lower costs by reducing the overhead associated with coordination between partners. These coordination costs include the costs of international travel, communications, hardware shipping and testing, and regulatory overhead. Technical inefficiencies associated with cooperative efforts also raise costs. These inefficiencies result from requirements flow-down, interface definition, and language and cultural barriers.

Overall, the no-exchange-of-funds principle ensures that any of the three feasible cooperative schemes discussed above provides a net-reduction in cost to a cooperating nation. The only situation in which this might not be the case is the one wherein coordination costs exceed the cost of developing a domestic technical capability. Given that the US and Italy are allies, and that coordination costs would thus generally not involve a large diplomatic component, we may conclude that cooperation is beneficial for both nations in reducing costs.

Schedule

Coordination efforts will generally have a negative impact on the overall schedule for a project. However, these negative effects may be partially offset by employing coordination schemes using technology that has already been developed by the partner nation, which thus requires a shorter development schedule. Also, better systems integration and design coordination can mitigate additional schedule impacts. These general impact patterns upon the schedule hold regardless of the type of cooperation under examination.

Given that neither the US nor Italy is involved in a space race, and if there remain no other external drivers forcing a quick schedule (e.g. China decides to send humans to the moon), the effects of schedule delay due to cooperation are unlikely to deter cooperation.

Performance

Italian technical expertise largely overlaps with US technical expertise. Thus, performance is likely to be affected neither positively nor negatively, regardless of cooperation scheme. For example, although the Italians possess proven extraterrestrial drilling technology, such as would be provided in the Phoenix Lander example, acquisition of a similar capability is under development by the United States. Similarly, the specific knowledge about the ISS pressure module, which was gained during the MPLM program and could be applied to the CEV, is similar to the US experience derived from the Apollo, Skylab, Space Shuttle and ISS programs. Thus, in general, cooperation between Italy and the United States is unlikely to significantly alter performance.

American Policy Goals

Cooperation with Italy will benefit several American policy objectives mentioned earlier, including the ability to demonstrate solidarity with US allies. Having allies in Europe also has positive derivative effects for national security, pride and prestige, and for shaping international policy. On the other hand, cooperation with Italy may inhibit US employment and limit the development of technical capabilities in the United States. However, the Phoenix Lander situation is effective in generating the positive policy effects of cooperation without incurring significant costs. This is a result of the limited employment opportunities and technical capabilities required to engage in this collaboration. Cooperation on a Pressurized Cargo Module will demonstrate solidarity with Italy and allow for continued shaping of Italian policy. However, as the number of people employed by the program grows, maintaining a technical US workforce may be harmed. Finally, the use of an Italian pressure vessel on the CEV is likely to have particularly negative domestic policy consequences. In addition to the jobs and technological capabilities that would otherwise be provided domestically, the US will have to accept strategic and critical path dependence on a partner nation.

Italian Policy Goals

Based on the Italian foreign policy objectives stated previously, cooperation between Italy and the US strengthens the alliance between the two nations. In addition, Italy's ability to claim technological prowess on the world stage is increased. For example, cooperation on the instrumentation systems of the Phoenix Lander is likely to be slightly beneficial for Italian foreign policy. This type of cooperation allows for the maintenance of existing Italian technical capabilities. In addition, the collaboration sends a signal to the world, indicating alliance with the United States. Cooperation on an MPLM-style pressurized Cargo Module for the ISS will not only generate the benefits described above, but will also cause economic benefits due to the increased workforce size. In addition, participation in a high-visibility project allows the Italians an opportunity to shape international policy. Finally, cooperation on an Italian pressure vessel for the CEV is particularly beneficial to the Italian government since all of the foreign policy objectives are met. This cooperation scheme also enables Italy the ability to claim high technological capability.

Case Study Step 5: Identify Each Nation's Preferred Schemes

Although cooperation of the short-term niche type (e.g. provide instrumentation systems of the Phoenix Lander) provides the US the most technical and policy benefits in its interactions with Italy, Italy sees the most benefits from the critical path cooperation type (e.g. Italian pressure vessel for the CEV). This is largely because American policy objectives can be achieved by nominal cooperation, while also avoiding expensive administrative overhead and the outsourcing of jobs and capabilities to Italy. On the other hand, all Italian policy objectives are met most strongly when cooperation is on the critical path.

Step 6: Identify Win-Win Cooperation Schemes

With three distinct feasible cooperative schemes available between Italy and the United States, opportunities exist for a techno-political win-win situation. By employing the evaluation framework, the US realizes that cooperation involving a short-term niche capability provided by Italy provides technical cost benefits while achieving a net positive domestic and foreign policy utility.

CONCLUSIONS AND RECOMMENDATIONS

This paper introduced a framework of international cooperation that aims at integrating two realities of space programs: technological considerations and policy considerations. The often-competing needs of these two realms are reconciled when a win-win situation may be found that implies a certain cooperative scheme. As such, the framework presented in this paper is intended to identify precisely those cooperative scenarios that provide technical as well as policy benefits. The framework was exercised on a case study of US and Italian cooperation on the Vision for Space Exploration.

Planned future work will focus on detailed case studies between the United States and a wide array of traditional and non-traditional partner nations. The framework presented in this paper will be used to evaluate American cooperation opportunities across these nations, and identify a combination of cooperative projects that will provide both technical and policy benefits.

While the planned future work focuses on the US, the framework presented in this paper can be applied by any country seeking to engage in cooperation with another nation. The authors would encourage interested parties from other nations to employ such a framework to evaluate potential project's from their own nation's viewpoint.

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