EVALUATING OPTIONS FOR ENHANCING TECHNOLOGY DEVELOPMENT AND CONTROLLING COST GROWTH

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ABSTRACT

Given the history of delays for NASA science instruments, a study was conducted to assess the viability of a new development paradigm called Instrument First, Spacecraft Second (IFSS) to reduce cost and schedule growth in future missions. The new paradigm was shown to provide many tangible benefits, including decreased portfolio costs and less portfolio volatility, but there were still questions as to whether it would work within current NASA policy and what options were available for implementing this new development approach. This paper provides a discussion of how the approach fits within NASA, guidance for setting the project schedule and various management options.

Index Terms**—** Cost, Schedule, Instrument development

1. INTRODUCTION

Previous work has shown that the difficulty in developing science instrument has contributed to significant schedule delays and cost overruns for NASA missions [1]. The difficulties are manifested by the late delivery of instruments to the integration and test phase of the mission development which leads to significant "marching army" costs as personnel await the delivery [2, 3]. Anecdotal evidence of minimal cost and schedule growth for missions that were planned around mature instruments led to the postulation that a new development paradigm, called instrument first, spacecraft second (IFSS), might reduce cost growth and schedule delays to provide a less volatile and more manageable mission portfolio. Through a study based on the Tier 2 and 3 missions from the most recent Earth Science Decadal Survey, it was shown through various comparative measures that IFSS can lead to a more stable development environment when compared to the current way of doing business. The next step is then to investigate the programmatic implications of implementing IFSS on actual flight missions.

2. IFSS IMPLEMENTATON IMPLICATIONS

Although the benefits of an IFSS approach appear clear, there is a question on how this approach may be implemented relative to NASA's current development approach. To answer this question, NASA policy was investigated to determine if current NASA policies would have to be modified or separate guidance provided. In addition, implementation recommendations such as schedule guidance are provided. Finally, different organizational constructs are assessed to determine the potential pros and cons of each approach to identify if a single best implementation approach exists.

2.1. NPR 7120.5 Compatibility

One possible issue with implementing an IFSS approach is the compatibility with NASA policy. If NASA policy precludes instrument development prior to full mission development, then this would present a severe obstacle to the implementation of an IFSS approach relative to NASA missions. The primary policy that governs requirements for mission development is NASA Procedural Requirement 7120.5D (NPR7120.5D) entitled "NASA Space Flight Program and Project Management Requirements" [4] and its associated recently released NASA Interim Directive (NID) (NM 7120-97) [5]. Both NPR7120.5D and NM 7120-97 identify the requirements for NASA science missions at specific points in a project's development. Reviewing both documents shows that neither forbids early instrument development leading to a mission implementation. Further, although baseline project-level and system-level requirements are required at the Systems Requirements Review (SRR) in Phase A [5], preliminary subsystem requirements are not required until the start of Phase B. In addition, although the baseline mission and spacecraft architecture is required at SRR [8], the full architecture including payload and ground system are not required until the start of Phase B. It is clear from the documents, however, that the spacecraft design and/or procurement approach must be fully in place by the mission Preliminary Design Review (PDR) leading to the KDP-C (i.e. mission confirmation), mission confirmation milestone decision. This requirement doesn't preclude an IFSS approach as the instrument(s) could still be developed to a heightened level of maturity prior to KDP-C allowing individual projects to make a decision to use an IFSS approach prior to mission confirmation.

Modification to 7120.5 would not be necessary although it may be beneficial to separately identify "IFSS Acquisition Approach" guidance in the form of a handbook or other document. In addition, it may be worthwhile to institute requirements for "demonstrated instrument maturity" and more clearly define guidelines for maturity demonstration such as developing an engineering model demonstrated in a relevant environment. As part of this guidance, the approach to identifying the proper lead time to start instrument development should be outlined to ensure that the IFSS approach is robust.

2.2. Schedule Guidance

To implement an IFSS approach, the timing for instrument development start relative to mission development should be optimized. The development schedule for a mission using an IFSS approach can be based on the duration and variance of historical instrument developments to stagger instrument procurement and spacecraft procurement/mission development. Unique characteristics/challenges of instrument development can also be identified to lay out specific instrument development plans that can then be compared with spacecraft development durations.

Based on the historical instrument delivery and delay data and the analysis results, the typical "IFSS Offset" for instrument development is on the order of two years. This provides instruments with a two year head start prior to a three to four year mission development phase. For most instrument development efforts, this is after the instrument Critical Design Review (iCDR) but prior to instrument integration and test. At this point, the instrument should be fairly mature and most instrument problems should be identified but, even if not, ample time remains to recover prior to delivery to the spacecraft for system environmental test. Instrument CDR should occur prior to the mission KDP-B (i.e. mission preliminary design start) decision so as to ensure that the mission starts with a fairly mature instrument that can categorize its known risks.

2.3. Organizational Implementation Approaches

During the time of early instrument development, it is assumed that mission systems engineers and spacecraft contractors would be involved, at some level, to ensure future mission requirements and potential spacecraft accommodations are considered. To assess this involvement, three organizational implementation approach alternatives were investigated to take any science and instrument requirements, as shown in Figure 1, from conception to launch using an IFSS approach. Alternative 1 represents a Mission Project Office Approach where Directed missions are awarded to a NASA Center and the individual project determines if an IFSS acquisition approach would be best suited for development. Alternative 2 consists of a dedicated Instrument Office Approach where instruments are started within an instrument office embedded in a flight projects division and handed off to a mission project office after instrument CDR. Alternative 3 represents a Stand-Alone Instrument project where a competed instrument is awarded to a supplier, reporting to a larger Program Office, where the spacecraft "ride" may or may not be determined at the time of award. Each of these alternatives represents a different level of involvement from a future mission with decreasing dependence as the alternatives progress from Alternative 1 to Alternative 3.

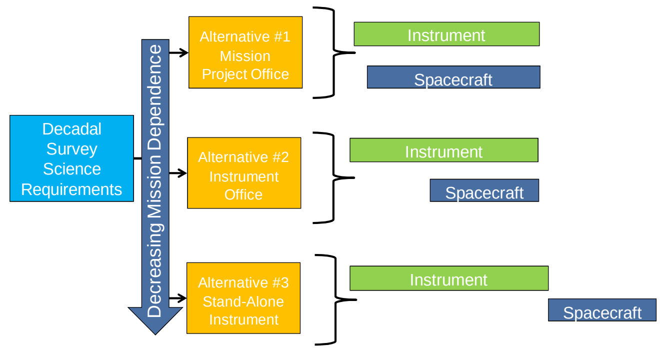

Figure 1: IFSS Implementation Approach Alternatives

2.3.1. Alternative 1: Mission Project Office

Implementing the IFSS approach within the construct of a typical mission would not be a fundamental change from how missions are managed currently. The concept would keep the look and feel of a typical project development while allowing for the early development of the instruments. All the typical functions of a project (Project Management, Systems Engineering, Spacecraft, Instruments, etc.) would be staffed from initiation, but most would be staffed at a minimal level until the instruments reached maturity. Early resources would be used primarily for the development of the instruments. The other functions would be staffed as needed to conduct trade studies/sensitivity analyses to understand the impact of instrument design choices on the mission architecture (e.g., operations complexity, spacecraft mass, spacecraft pointing requirements, etc.). This staffing could either work out of the traditional offices or be part of the systems engineering group. The organizational construct for this type of organization is shown in Figure 2 and follows a traditional project organizational chart.

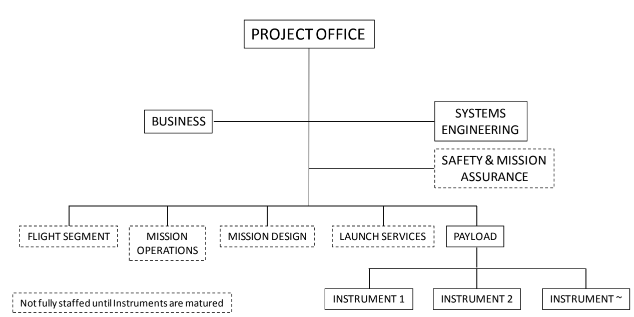

Figure 2: Mission Project Office Organization

A recent example of a mission that attempted this type of implementation was ICESat-2 (an Earth Science Decadal Survey Tier 1 mission). The instrument development started early and a spacecraft vendor was not selected until the time of Confirmation (i.e. KDP-C). The resource allocation for ICESat-2, however, is traditional with time and money spent on other mission functions as opposed to only focusing on the instrument development. This is one potential drawback of the mission project office approach as the mission development approach may revert to a more traditional approach.

2.3.2. Alternative 2: Instrument Program Office

A dedicated instrument program office would be another way to implement the IFSS approach from an institutional perspective. The concept of an Instrument Program Office (IPO) is to allow the development of science instruments outside of a classical flight project environment. It would provide some of the functions of a typical flight project but without the encumbrances and size of a normal flight project. The IPO could be part of the flight projects division of an institution and would consist of a dedicated program office staffed by instrument managers experienced in instrument development as well as systems engineers that would provide mission experience with spacecraft, launch vehicles and mission operations. It is assumed that personnel from the IPO would rotate to the missions as each instrument transitioned to a dedicated mission while others from missions recently launched would transition into the IPO to ensure the proper experience base in each organization. Figure 3 displays a proposed Instrument Project Office organizational chart and shows a much leaner organization as opposed to Alternative 1.

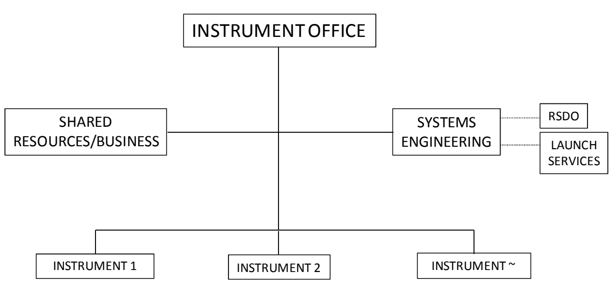

Figure 3: Instrument Program Office Organization

2.3.3. Alternative 3: Stand-Alone Instrument

A third approach for implementing IFSS would be the Stand-Alone Instrument approach. In this case, the instrument development would be led by a Principal Investigator (PI) who would report to a Program Office (PO). The PO would provide business office, safety & mission assurance and systems engineering support. It is assumed that flight selection could be one of multiple opportunities: hosted payload, free-flyer (domestic or international), or a combination of complimentary instruments to comprise a full mission. This approach is typically used for smaller, more resource constrained instruments, but could be used to compete Decadal Survey instruments as well. The primary drawback of such an approach is the possible detachment of the instrument development from future mission and spacecraft requirements that could potentially result in "hanger queen" instruments that cannot find an appropriate mission/spacecraft/launch vehicle on which to fly. Figure 4 displays the reporting of a stand-alone instrument PI reporting to a PO. Depending on the construct, the PI may be reporting into a PO which has both developmental and operational full missions, requiring a sharing of resources between these potentially higher priority missions and the stand-alone instrument development.

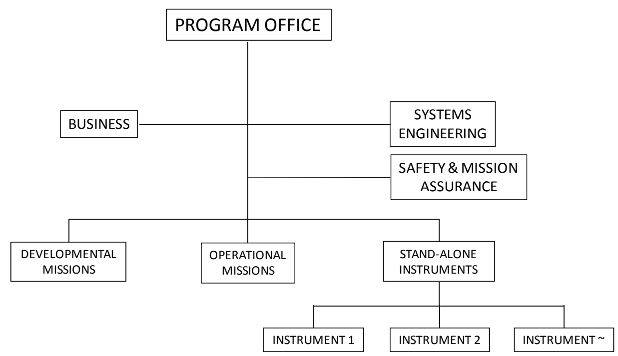

Figure 4: Stand-Alone Instrument Organization

2.3.4. Comparison of Difference Approaches

Each of the proposed alternatives has its strengths and weaknesses relative to meeting an IFSS approach while still providing a robust development plan. Alternative 1 has the benefit of having the familiarity of the current mission project office construct but may make it difficult to break the current paradigm of staffing all mission elements from the outset. Alternative 2 provides the benefit of a separate instrument program office, possibly reporting to a flight projects division, staffed with instrument development expertise as well as spacecraft and launch vehicle shared support which would mature the instrument before handing off for full mission development. Although this organization fully supports an IFSS development approach, it could result in an instrument that may be "gold-plated" and over developed for its mission need if not closely monitored. Alternative 3 would provide the least interface with a future mission and could potentially lead to instruments that are developed that cannot find the appropriate spacecraft or launch opportunity. The pros and cons for each alternative are highlighted in Table 1.

Table 1: Comparison of the Pros and Cons of IFSS Implementation Approaches

Approach	Pros	Cons
#1: Mission	-Looks and feels like typical project -Staff available from all subject matter areas to support work on development issues -Reduced initial staffing relative to traditional mission approach	-Inability to develop integrated mission baseline (cost, schedule, etc.) early on -Standing army for other project elements that aren't necessary to directly support instrument development
#2: Instrument PO	-Avoids large staffing associated with a flight project when only instrument development is going on -Provides a core group with instrument-specific expertise and focus -Provides efficiency as some functions such as CM and scheduling may be used regularly whereas some functions such as the RSDO interface may be very infrequently used	-Being removed from a flight project could provide the chance for unanticipated problems later -Would need to guard against instrument "overdevelopment" to ensure that mission requirements are met without building "gold-plated" instrument
#3: Stand-Alone Instrument	-Competitive process allows "best" science to be selected within program constraints -Allows multiple possible launch opportunities	-May result in instruments without a launch opportunity - i.e. "hangar queens" -Can increase risk as is decoupled from institutional instrument expertise and mission & spacecraft requirements

3. CONCLUSION

An IFSS approach is not precluded by current NASA policy although it would be prudent to develop an "IFSS Approach" handbook to provide guidance in developing a schedule consistent with a robust IFSS development. Multiple organizations could implement an IFSS approach, all with different strengths and weaknesses, although a dedicated instrument program office would provide the most focus for an IFSS approach and would result in the most balanced funding profile of the alternatives considered. The potential for savings warrants a pilot project implementation of an IFSS pathfinder mission to assess if the hypothesized savings and reduction in schedule growth can be realized and if the organizational constructs outlined would provide a robust home for future instrument development.

4. REFERENCES

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