Management approach for Earth venture instruments

Diane L. Hope[a], Sanghamitra Dutta[b],
[a]NASA, Langley Research Center, 9 Langley Boulevard, Hampton, VA, USA 23681; [b]NASA, Headquarters, 300 E Street SW, Washington, DC, USA 20024

ABSTRACT

The Earth Venture Instrument (EVI) element of the Earth Venture Program calls for developing instruments for participation on a NASA-arranged spaceflight mission of opportunity to conduct innovative, integrated, hypothesis or scientific question-driven approaches to pressing Earth system science issues. This paper discusses the EVI element and the management approach being used to manage both an instrument development activity as well as the host accommodations activity. In particular the focus will be on the approach being used for the first EVI (EVI-1) selected instrument, Tropospheric Emissions: Monitoring of Pollution (TEMPO), which will be hosted on a commercial GEO satellite and some of the challenges encountered to date and corresponding mitigations that are associated with the management structure for the TEMPO Mission and the architecture of EVI.

Keywords: Earth Venture Instrument, TEMPO, Earth Venture Instrument -1, EVI, EVI-1, management

1. INTRODUCTION

In 2009 the Earth Science Division (ESD) established the Venture line of mission opportunities, following the general recommendations from the 2007 NRC Decadal Survey (DS) for Earth Science. The DS included a number of mission and flight hardware recommendations, including both directed or strategic missions and a reinvigorated competitive mission line. The ESD elected to implement the fifteen strategic science missions through the Earth Systematic Missions (ESM) Program Office at the Goddard Space Flight Center, and to implement the new competitive mission line, named Earth Venture or Venture, through the Earth System Science Pathfinder (ESSP) Program Office (PO) at the Langley Research Center (LaRC).

The Venture line of mission opportunities is exploratory mission science and is accepted at a higher level of mission risk. The Venture exploratory science measurements are complementary to the ESD strategic missions, and the climate and decadal survey recommended measurements are not dependent on the success of any single Venture mission. The success of the Venture line overall is important, and one element of success is to maintain a regular cadence of solicitations. Consequently, no single mission is allowed to overrun and jeopardize that cadence. The ESD holds Venture projects rigorously to their cost and schedule capped limits. Venture projects that exceed or are projected to exceed these limits will undergo a termination review in order to preserve the Venture solicitation cadence.

The Venture line includes three mission or project types: (1) **EV S**uborbital for sustained airborne science campaigns, (2) **EV M**ission for self-contained, stand-alone science missions, and (3) **EV I**nstrument for instruments to be delivered to a NASA/ESD-provided or NASA/ESD-brokered host spacecraft. The three mission types share many features. Common to all, the selections are science-driven, Principal Investigator (PI)-led, competitively selected, cost- and schedule-constrained, and regularly solicited. There are unique features to the three mission types as well, and these are shown in Table 1.

Table 1. Earth venture program mission types and characteristics.

	Duration from ATP	Cost Cap (FY14$)	Governing NPR	Mission Class	Mission Category	Call Frequency
EV-Suborbital	≤5 years	<30M	7120.8	N/A	N/A	4 years
EV-Mission	≤5 years to launch	<150M	7120.5E	Class D	Cat 3	4 years
EV-Instrument	≤5 years to delivery	<90M	7120.5E	Class C	Cat 3	15 – 18 months

2. EARTH VENTURE INSTRUMENT

2.1 Earth Venture Instrument (EVI)

As indicated in Table 1, Earth Venture Instrument is focused on the development of a flight instrument. The schedule cap is 5 years from selection to delivery of a spaceflight-ready instrument for integration onto a host platform. The cost cap is determined at the time of the solicitation release. Table 1 identifies the cost cap as $90 million in fiscal year 2014 dollars, which was the case for Earth Venture Instrument -1 (EVI-1). The class of instrument is identified as Class C per NASA's Payload Risk Classification in NASA Procedural Requirements (NPR) 8705.4. The classification levels define a hierarchy of risk combinations for NASA payloads by considering such factors as criticality to the Agency Strategic Plan, national significance, availability of alternative research opportunities, success criteria, magnitude of investment, and other relevant factors. Specifically for a Class C instrument this encompasses considerations such as: single point failures which may be permitted but require mitigation by use of high reliability parts, additional testing, or other means; engineering model hardware for new designs; limited flight spare hardware for long-lead flight units; full formal review program; use of previously flown or tested materials or characterization of new materials; formal quality assurance program; and other considerations. The mission category in accordance with NPR 7120.5E, NASA Space Flight Program and Project Management Requirements, is 3, which corresponds to life cycle cost less than $250 million and low priority. The priority is related to the importance of the activity to NASA, the extent of international participation (or joint effort with other government agencies), the degree of uncertainty surrounding the application of new or untested technologies, and spacecraft/payload development risk classification.

The remaining sections of this paper will discuss the specifics of the first solicitation and selection of EVI, the management approach of EVI-1 and associated challenges, and the subsequent solicitation for Earth Venture Instrument – 2 (EVI-2).

2.2 Earth Venture Instrument – 1 (EVI-1)

The first EVI Announcement of Opportunity (AO), NASA's Second Stand Alone Missions of Opportunity Notice (SALMON-2) Program Element Appendix J, was released in February 2012. This solicitation called for developing instruments for participation on a NASA-arranged spaceflight mission of opportunity to conduct innovative, integrated, hypothesis or scientific question-driven approaches to pressing Earth system science issues. The NASA funded PI retains a central role on the instrument or instrument package development, integration and testing, calibration, and science operations.

All investigations proposed in response to this solicitation had to support the goals and objectives of the ESSP Program, be implemented by a Principal Investigator (PI)-led investigation teams, and result in the development of a flight qualified spaceflight instrument ready for integration to a spacecraft (Phase A-C), technical support for integration onto a NASA-determined spacecraft (Phase D), and on-orbit operation of the instrument and delivery of science quality data (Phase E).

Proposals submitted were evaluated and selection occurred through a single step competitive process. The objective of the solicitation was to select an investigation where an instrument would be built and deployed on an existing planned spacecraft followed by production of high quality and highly useful Earth Science data from that instrument. These investigations/instruments were proposed without a firm identification of the spacecraft to accommodate these

instruments. Therefore, selection of proposals from this solicitation had to balance the "accommodatability" of the proposed instruments with the value of the science to be returned from the selected investigations. At the release of the solicitation, it was believed that many satellites would be launched to orbits appropriate for observations of the Earth System and were expected to have excess capacity to accommodate additional instruments. Potential spacecraft developers for the proposed instruments included: NASA (including the International Space Station), other U.S. agencies, national space agencies other than NASA, and commercial vendors. In order to take advantage of payload capacity on any of these platforms, NASA through EVI wanted instruments ready for integration available, or nearly available, for inclusion on these various spacecraft. The available capacity including size, weight, power, thermal control, pointing stability, pointing ability, orbits, and data rates for each potential platform was not specified by the EVI-1 solicitation and explicitly stated that they could vary. In general, it was noted that the instruments provided through EVI-1 would have to work within the available resources, resulting in some constraints on the specifications of the selected instruments. Proposed instruments that could not meet many of the requirements anticipated for most potential platforms would be considered as a higher risk for accommodation than those that have higher specification margin.

The scope of the investigation, with the PI fully responsible, included: (i) development and delivery of the instrument or instrument package; (ii) working with NASA to integrate the instrument on the chosen platform; (iii) commissioning, validating, and operating the instrument and ground systems on-orbit in order to carry out the proposed science investigation; (iv) preparing and delivering appropriate data analysis software, including required calibration data, analyzing the data, archiving the data in a NASA chosen Distributed Active Archive Center (DAAC), and reporting the results of the science investigation in the science literature.

Costs within the PI-Managed Mission Cost were clearly identified in the AO and included: instrument delivery ready for integration onto the selected platform (Phases A-C); development and delivery of functional algorithms and ground processing system (Phases B-D); supporting a science team that contributes directly to the successful implementation of the investigation (Phases A-F); required calibration and validation activities (Phases C-E); operations, product generation, and data analysis during the proposed prime mission lifetime of the investigation (Phases E); and close out of the investigation once the investigation has been concluded (Phase F). The PI-Managed Mission Cost also included the cost of the science team and of key management and engineering staff during Phase D.

For proposal and planning purposes, the host platform was expected to be determined prior to Preliminary Design Review. The proposers were cautioned to account for appropriate budget margin for "minor changes" to the instrument as it may be required once the host platform is selected.

The selected investigation under the EVI-1 solicitation was expected to deliver an instrument for integration onto a selected platform by September 30, 2017.

2.3 Tropospheric Emissions: Monitoring of Pollution (TEMPO)

On November 7, 2012, Tropospheric Emissions: Monitoring of Pollution (TEMPO), Kelly Chance (PI), Smithsonian Astrophysical Observatory (SAO), was selected as the first EVI. The primary objective of the TEMPO investigation is measuring tropospheric trace gases, aerosols, and clouds using temporal and spatial sampling with the necessary precision to resolve diurnal cycle emissions, chemistry, and radiative forcing. The investigation is planned to monitor pollution at urban scales, and provide for monitoring the inflow and outflow of pollution over Greater North America.

Per the selection statement, the "PI is responsible for all attendant obligations. The PI is responsible for the hardware acquisition necessary for successful completion. NASA is responsible for obtaining space and accommodations on an existing satellite platform that has access to space in an appropriate time frame." The host accommodation for TEMPO is on a commercial, Geostationary Earth Orbit (GEO) Host and includes activities necessary to obtain the spacecraft/satellite, instrument integration, launch vehicle, data downlink, and the ground system to transfer the data to the TEMPO Instrument Operations Center. The PI shall interface with NASA and their contractor(s) as necessary to communicate the technical requirements for the host spacecraft for the TEMPO instrument to successfully implement the proposed science.

The ESSP PO, in concert with LaRC Procurement, executed the SAO Contract on March 29, 2013. The scope of this contract included the necessary personnel, expertise, materials, services, equipment, facilities, institutional systems and software, and technical and management processes to accomplish the PI function for the TEMPO Instrument Project, including Science Team, Ground Systems, Instrument Operations, Science Data Processing System, and Core Science

Communication and Public Engagement. Decisions on release of project reserves, exercise of de-scope actions, and materials necessary to communicate the core science are within the scope of the TEMPO PI. The PI delegated the project management, systems engineering, safety and mission assurance and instrument procurement to LaRC.

In April 2013, ESD directed a flight project to LaRC, TEMPO Mission Project, to implement the mission leadership for the host accommodations for the TEMPO instrument. The scope of the TEMPO Mission Project includes the systematic consideration of accommodation interfaces and requirements, host studies, and ultimately procurement of the host mission. Figure 1 shows the implementation of these two distinct yet inter-related projects.

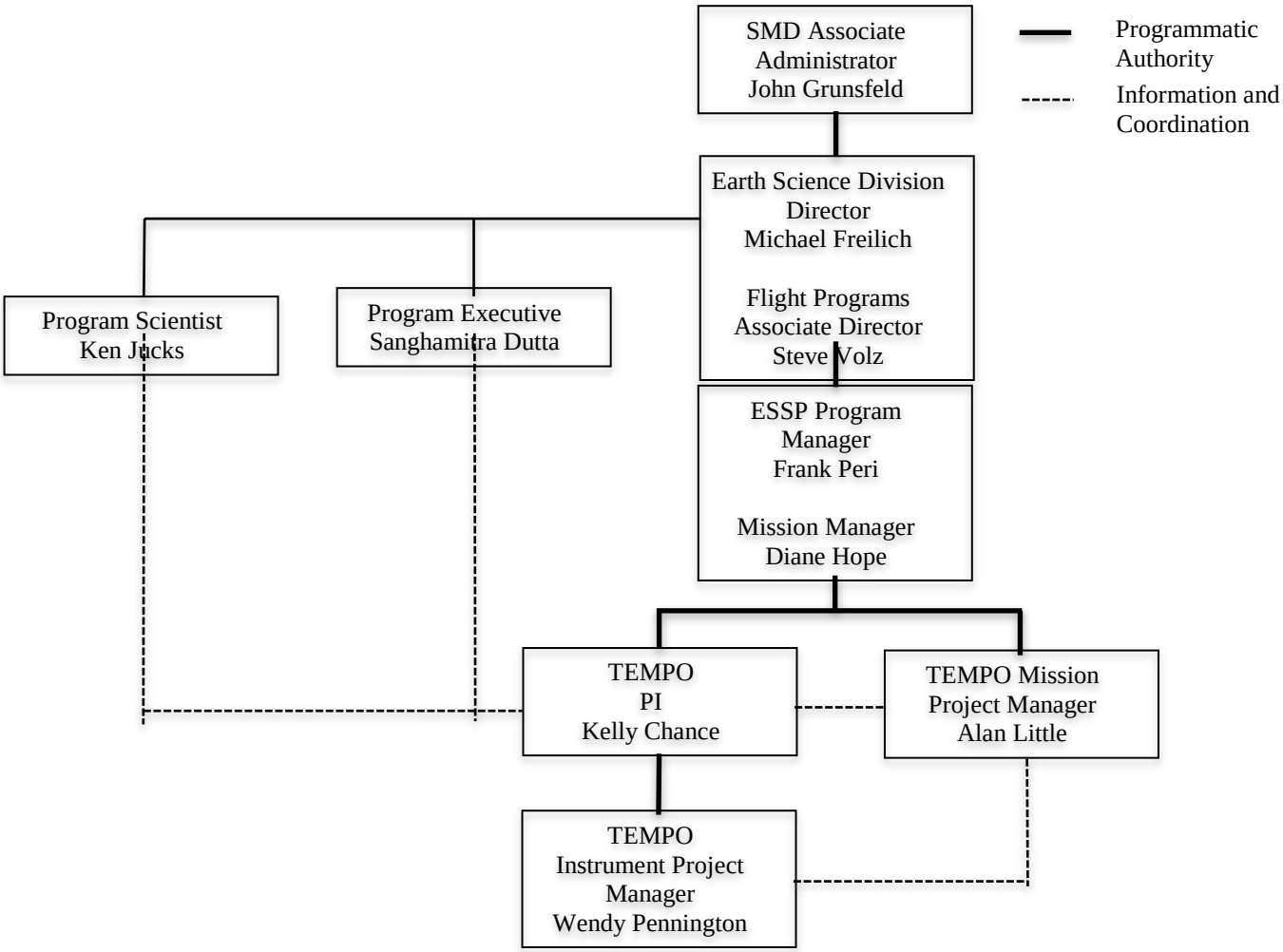

Figure 1: TEMPO Programmatic Authority

The construct of programmatic authority for TEMPO does not follow the typical NASA approach of a single entry point for a mission. Although the PI retains responsibility for the instrument development and science products during operations, he is not directly involved in the host mission procurement. The PI is required to provide his requirements for the host platform to the TEMPO Mission Project. As the requirements are refined for the host spacecraft, all potential impacts to science are worked directly with the PI, as these could impact the PI's ability to deliver the proposed science.

The other point of discussion on the programmatic authority is the delegation of instrument project management responsibilities from the PI to the Instrument Project Manager, allowing PI concentration on the science, instrument operations center, ground support, and overall mission.

2.4 Management Challenges for TEMPO

There are a number of challenges associated with the management and execution of the first EVI. Chief among these is this is the first implementation of this variation on Earth Venture, which requires innovation in applying NASA's rigorous flight project approach in a slightly different manner. Although TEMPO is still in its formulation stage and many of the hurdles are yet to be identified and addressed, to date the challenges have been in the management structure and the EVI architecture.

The management structure for EVI-1 was specified in the AO, calling for a PI-led instrument development with NASA providing the host mission. As noted in Figure 1, in this initial implementation these are two distinct projects requiring extensive coordination and integration to result in a successful mission. This structure was chosen, in part, to maintain the identity of the EVI-1 instrument development and to ensure appropriate insight into this cost-capped $90 million dollar project. For TEMPO, the PI has delegated the day-to-day project management duties to NASA LaRC where a project organization has been established with the requisite disciplines required for execution. The Earth Science Division at NASA Headquarters has directed LaRC to establish a flight project office to manage the EVI-1 mission accommodations (TEMPO Mission Project). The resulting organizations at LaRC are co-located and share some personnel in Safety and Mission Assurance, and support (resources, schedule, risk). In addition, technical working groups have been established in crosscutting areas. All of these efforts have provided an opportunity to work closely together with the intent to ensure cost and technically efficient implementation. Although the projects are separate and report the majority of their status separately to the ESSP PO, the program office works with both of these projects to ensure close coordination, as well as ensuring that each of these projects meets their commitments.

Although the benefit that NASA was seeking from the EVI architecture to obtain cost effective access to space through hosting opportunities, this architecture also leads to many complications that are related to the differing development schedule for the instrument versus the host mission including, designing an instrument without firm host interfaces; obtaining a host mission to accommodate instrument requirements; and conducting reviews that evaluate both the instrument development and the mission. Since TEMPO is schedule and cost capped, it is important that the instrument development is not unduly restrained due to the lack of mission requirements flowing from the host to the instrument. One of the approaches that have been used to mitigate this gap in requirements includes designing the instrument to be as robust as possible to a variety of potential interfaces. The launch environment to be considered in design must be broadly defined to envelope possible environments. The nadir deck space for many satellites is a highly prized real estate and the possibility of mounting instrument control electronics inside the host spacecraft structure is under consideration to improve the ability to accommodate the TEMPO instrument. In addition, in order to minimize the uncertainty in the instrument thermal design, the TEMPO Instrument Project is conducting technical/cost/benefit trades of independent cooling or spacecraft provided cooling. Other areas that will assist in broadening the field of potential hosts is the use of the more typical interfaces for power and data interfaces or planning on interface adapters to address any incompatibilities. Another approach being used by the TEMPO instrument team is to use guidelines that were developed by the NASA Common Instrument Interface (CII) team. The CII project, also implemented by the ESSP PO, had the objectives to develop a set of common instrument interfaces that would improve the ability of an instrument to be accommodated on a commercial geostationary satellite. In the absence of a firm interface definition, the TEMPO Instrument Project has chosen to use these guidelines to inform their design decisions to help improve "accommodatability." Finally, the TEMPO Mission Project is planning studies with potential vendors to better understand the interface requirements early in the instrument development cycle. These definitions are communicated to the TEMPO instrument team on as timely basis as possible, and are anticipated to inform the instrument's preliminary design.

The challenge of obtaining a host mission that meets the TEMPO instrument accommodation requirements including the technical interfaces, orbital requirements, launch date, and operational requirements is difficult and potentially has impact on the instrument performance and ability to meet proposed science. To address the launch date needs, the TEMPO Mission Project has been working with the Air Force Space and Missile Systems Center (SMC) to potentially use their Indefinite Delivery Indefinite Quantity (IDIQ) Hosted Payload Solution (HoPS) contract to minimize the procurement time for host mission selection. Also in support of the host mission procurement focused studies, as previously mentioned and obtained through the SMC HoPS contract, with potential vendors informs the programmatic and technical requirements to ensure a match between the TEMPO instrument requirements and the host provider capabilities.

Finally, defining a formal review strategy for the TEMPO instrument development and host mission represents a significant challenge. Developing a review approach for the TEMPO Mission that addresses the typical NASA requirements while appropriately reflecting the significant difference in the development schedules for the Instrument versus the Host Spacecraft is difficult. The overarching goal is to conduct the mission level reviews as early as possible and to make them truly a mission level review – not an instrument or spacecraft activity. In addition, NASA ESD required that all key decision points (KDPs), those reviews that allow the project to progress into the next phase of maturity, are conducted at the mission level. An important aspect of the review approach is mission confirmation, which follows the Preliminary Design Review (PDR). NASA confirms the total mission following PDR – not an element of the mission. It is also important not to artificially constrain either the instrument or spacecraft development schedules. Finally, it is recognized that the typical expectations for each review have to be adjusted to reflect the phasing of the instrument and spacecraft development. Specifically, the host spacecraft selection does not occur until after the Mission PDR which requires significant adjustment to expected maturity of the mission. This is accomplished through tailoring the success criteria associated with each specific review.

Using these guidelines, the reviews are defined at either the Mission, Instrument, or Host Spacecraft (not NASA led) level as shown in Figure 2 below. The first TEMPO review is the System Requirements Review/Mission Definition Review (SRR/MDR), which is conducted as a combined Instrument and Mission Level review. It is important to do this review at the Mission Level to provide context for the instrument development as well as establishing interface expectations for the host spacecraft. The next review is the Preliminary Design Review, which is also conducted at the Mission Level. The timing for this is consistent with the nominal instrument development and the interfaces with the host spacecraft will be informed by study results conducted by several potential host spacecraft vendors. This provides status information for the TEMPO Mission from which NASA makes the decision in regards to mission confirmation. The remaining instrument reviews are scheduled at the instrument level and follow the normal instrument development lifecycle. After Instrument CDR and prior to the Instrument Test Readiness Review, there is a non-7120.5E review called the Mission Assessment Review (MAR). The purpose of this review is to provide the NASA SMD and ESD with an updated status of the TEMPO Mission. At this point, the Instrument CDR has been completed and the Host Mission contract has been awarded.

The Host Spacecraft reviews follow the nominal development schedule for commercial spacecraft development, which allows 30 months from spacecraft authority to proceed (ATP) to launch and requires that the instrument is delivered 12 months prior to launch. The vendor leads these reviews with NASA participation – assuming one to two people to confirm that the instrument accommodations are being appropriately met. The Host Spacecraft reviews are based on information obtained as part of NASA's CII activities and are updated with information from the vendor studies mentioned previously. It is worth noting the timing of the spacecraft Critical Design Review (CDR) and the Mission CDR. At the spacecraft CDR the instrument interfaces are well defined and this allows a Mission Level CDR to be conducted. At this point, the instrument CDR has been conducted (approximately 19 months earlier) and the instrument is ready for delivery. The instrument part of the Mission CDR consists of a status of the instrument and ground system development and the review focuses on the Host Spacecraft's capability to meet the instrument's interface and operational requirements.

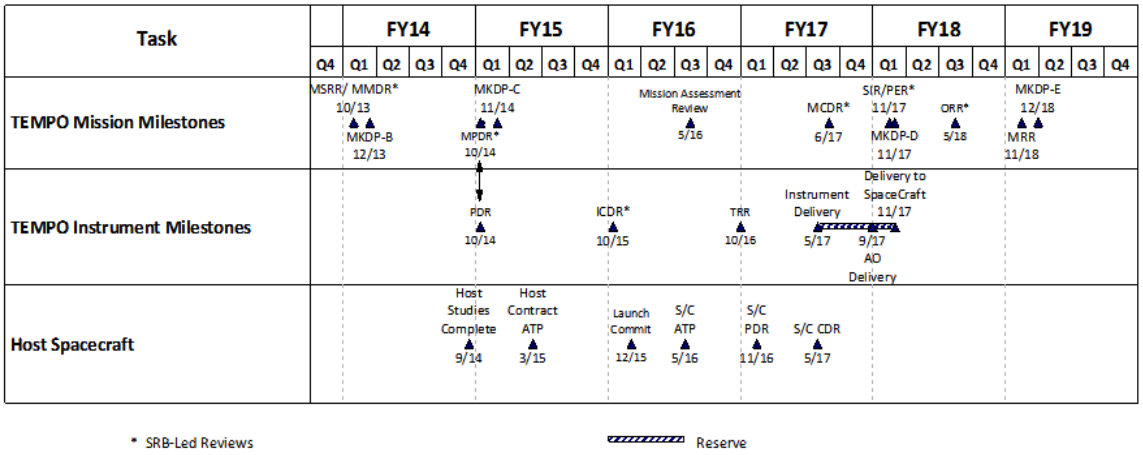

Figure 2: Mission, Instrument, and Host Milestones and Reviews

3. EARTH VENTURE INSTRUMENT -2 (EVI-2)

Selection of the second EVI is anticipated in FY14. The draft Program Element Appendix was released for comment in June 2013 with the final solicitation release expected in August 2013. The draft solicitation, although very similar to EVI-1, allowed proposals for Class D CubeSat investigations in addition to the Class C spaceflight instruments. The cost cap for CubeSats is constrained to $30 million and $94 million for instruments both in FY2016 dollars. The schedule cap for CubeSats and instruments are 4 and 5 years, respectively. Another difference between EVI-1 and EVI-2 is the requirement to provide, 30 days after the solicitation release, a Notice of Intent to propose. There are other minor differences between the solicitations; however, this comparison is between the EVI-1 final solicitation and the EVI-2 draft solicitation, reducing the value of further comparisons.

4. CONCLUSIONS

The EVI element of the Earth Venture Program is a unique opportunity for NASA to obtain Earth science in an approach that develops the instrument in advance of selection of the host accommodations. The objective of this approach is to eliminate the schedule impact of delayed instrument development on a potential host mission. The challenges associated with this architecture lead to potential mismatches in maturity between the instrument and host mission, inadequate definition on interface, and difficulty obtaining a host with the needed accommodations. The approach taken by the TEMPO instrument to has been to maintain the instrument design to be as independent as possible from the spacecraft capabilities. Short of that approach, the method is to design within the guidelines of the NASA Common Instrument Interface. The implementation of the TEMPO Mission using a TEMPO Instrument Project and a TEMPO Mission

Project is a template for EVI. The shared support, co-location, and close interaction of the instrument and mission teams is intended to lead to a cost effective design that serves the science needs. The future implementations of EVI are yet to be determined and the positive outcomes of the TEMPO approach for EVI-1 has the potential to greatly influence future execution.

REFERENCES

[1] Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond, National Academy of Sciences, 2007.

[2] S. Volz, "Implementing the Earth Science Flight Program, Instrument Developments and Earth Venture," presentation, July 2010.

[3] A. Ward and G. Stover, "A New Venture for NASA Earth Science," The Earth Observer, Volume 22, Issue 5, pp. 13 – 18, September – October 2010.

[4] Responding to the Challenge of Climate and Environmental Change: NASA's Plan for a Climate-Centric Architecture for Earth Observations and Applications from Space, June 2010.

[5] NASA Procedural Requirements 7123.1B, NASA Systems Engineering Processes and Requirements, Appendix E, Washington D.C., April 2013.

[6] NASA Procedural Requirements 7120.5E, NASA Space Flight Program and Project Management Requirements, Washington D.C., August 2012.

[7] Science Plan for NASA's Science Mission Directorate, Chapter 4, Section 4.1, Earth Science, July 2010.

[8] J. Wells, G. Stover, and D. Hope, "New Earth Science Opportunities for Small Orbital Instruments and Missions," International Society of Photogrammetry and Remote Sensing Proceedings, April 2011.

[9] Announcement of Opportunity, NASA's Second Stand Alone Missions of Opportunity Notice (SALMON-2), Program Element Appendix J, February 2012.

[10] Draft Second Stand Alone Missions of Opportunity Notice (SALMON-2), Program Element Appendix M, June 2013.

[11] NASA Procedural Requirements 8705.4, Risk Classification for NASA Payloads, Washington D.C., June 2013.