PAPERS

History, Practices, and Future of Earned Value Management in Government: Perspectives From NASA

***Young Hoon Kwak**, Department of Decision Sciences, School of Business, The George Washington University, Washington, DC, USA*
***Frank T. Anbari**, Goodwin College of Professional Studies, Drexel University, Philadelphia, PA, USA*

ABSTRACT

The goal of this research is to explore the history, practices, and future of the earned value management (EVM) method in government, and seek opportunities and suggestions for wider implementation of EVM for managing, measuring, and controlling project performance and progress. First, this study reviews the historical background and evolution of EVM implementation in government. Then, current practices for implementing EVM are discussed through examination of EVM adoption and implementation at NASA. The research shows that NASA receives substantial project management value from its implementation of EVM, promotes consistent practices across the agency, and provides effective training on leadership, scheduling, EVM, and data analysis. This study also provides recommendations to improve and broaden the applications of current EVM and project management practices to other government programs and projects. Findings of this research contribute to the management of performance of future projects and programs and encourage the project management community to review and advance the application of EVM.

KEYWORDS: earned value management; government; NASA; performance measurement; lessons learned

Project Management Journal, Vol. 43, No. 1, 77–90

Published online in Wiley Online Library (wileyonlinelibrary.com). DOI: 10.1002/pmj.20272

INTRODUCTION

Why Apply EVM?

Earned value management (EVM) is a management methodology for integrating scope, schedule, and resources, and for measuring project performance and progress (Anbari, 2003; Project Management Institute, 2008). Historically started as cost/schedule control system criteria (C/SCSC) by the U.S. Department of Defense in the 1960s, it is now mandated for many U.S. government programs and projects (Abba, 1997, 2001; Christensen, 1994; Kim, 2000; Kim, Wells, & Duffey, 2003). The interest in and demand for applying and implementing EVM has increased in recent years in government agencies where organizations and auditors are required to report on the adequacy of the organization's internal control over financial reporting (Fleming & Koppelman, 2003, 2010).

The emphasis on performance measurement in government continues to increase steadily, supported by mandates imposed by government laws and public pressure. Specifically, management of government projects, programs, and portfolios—and the related expenditures of public funds—are major, visible areas of concern (Lipke & Henderson, 2006). Despite a growing understanding of the determinants of success, increasing maturity, and a stream of successful programs and projects, project failures continue at an alarming rate (Anbari, 2003; Kwak & Anbari, 2006).

There are visible examples of failure in major public programs and projects. *Analytical Perspectives, Budget of the United States Government, Fiscal Year 2008* (Office of Management and Budget [OMB], Executive Office of the President, 2008a) points out that, of the 840 major information technology (IT) investments (about $65 billion) in the U.S. federal IT portfolio in fiscal year (FY) 2008, there were 346 major IT investments (about $27 billion) that were not well planned and managed, reflecting investments on the "Management Watch List" as well as those rated "Unacceptable." It states: "346 of 840 projects valued at $9.9 billion are on the 'Management Watch List.' These projects still need to address performance measures, implementation of earned value management, security or other issues before obligating funding in FY 2008."

Project and program failures deprive the sponsoring organization and the public from the anticipated benefits of the projects selected for deploying organizational strategy, and divert resources and funds from what might have been more promising endeavors. This ultimately weakens the society's competitive position, well-being, and security (Kwak & Anbari, 2006).

Research Approach

This study explores current EVM practices at the National Aeronautics and Space Administration (NASA) to identify emerging performance measurement

trends, seek improvements, and suggest recommendations for applying EVM practice to other government programs and projects (Henderson, 2003, 2004, 2005). The content includes a brief history of EVM evolution in government, explores and discusses current EVM practices at NASA, and examines the challenges and opportunities of implementing EVM to manage projects and programs. This study also explores key practices in the performance measurement of government programs and projects. This is addressed through interviews and discussions with leaders and experts in NASA programs and projects and through reviews of various government documents and data. The findings of this research contribute to the management of future projects and encourage the project management community to review and advance the application of project management and EVM to government.

A brief discussion of the research approach, which is exploratory in nature, is necessary. Initially, the research design intended to use very structured interviews that include descriptive statistics. Because the interviewees work for the government and anonymity was key, however, revealing that information was not appropriate. Instead, we received contact information from a NASA representative and started asking open-ended questions related to EVM practices. This resulted in interviewees responding to the general questions related to EVM or referring us to review relevant information and articles. Interviewees were very sensitive to answering any specifics that were not in the public domain because they were concerned about conflicts of interest or being identified in any way. The authors endeavored to conduct the study in an objective and neutral manner without criticizing specific projects or programs or revealing the identities of the interviewees. As a result, the applied research methodology is more of an exploratory approach than the structured approach. In the end, we were able to collect valuable insights and recommendations that could apply to NASA as well as other government agencies that are involved in managing projects and programs.

Research Questions

The following questions related to EVM applications in government projects were asked:

- What are the historical evolutions of EVM principles in government?
- How is EVM applied and implemented at NASA?
- What are the challenges and lessons learned from adopting and implementing EVM at NASA?
- What are the key success factors for successful EVM implementation?
- What improvements to current EVM standards might make them more applicable to government programs and projects?

Earned Value Management in Government

Historical Background

EVM is a project management methodology for measuring financial and project performance. A basic form of EVM can be traced back to industrial engineers on the factory floor in the late 1800s. In 1967, EVM was introduced by the U.S. federal government as an integral part of the Cost/Schedule Control System Criteria to understand the financial aspects of programs and to be used in large acquisition programs in an attempt to establish a consistent methodology based on best practices. The method and its variations have been used under several names, such as earned value project management, earned value method, earned value analysis, and cost/schedule summary report (Fleming & Koppelman, 2003, 2010; Kim, 2000; Kim et al., 2003).

To encourage wider use of EVM, the federal government decided to discard C/SCSC by the end of 1996 and turned toward a more flexible EVM system (EVMS). The American National Standards Institute (ANSI)/Electronic Industries Alliance (EIA) published guidelines for EVMS initially in 1998. The Project Management Institute's (PMI's) *A Guide to the Project Management Body of Knowledge (PMBOK®* Guide) provided the basic terminology and formulas of EVM. The terminology was simplified and more details on EVM were provided starting in 2000 and in subsequent editions of the *PMBOK®* Guide (PMI, 2008) and in a separate *Practice Standard* (PMI, 2011). The private sector has also shown greater interest in applying EVM in recent years thanks to numerous publications promoting EVM principles and advanced project management software packages that incorporate EVM methods and analysis (Anbari, 2003; Antvik & Philipson, 2009; Fleming & Koppelman, 2010; Humphreys, 2002; Marshall, 2005, 2007, 2010; Marshall, Ruiz, & Bredillet, 2008; PMI, 2005).

EVMS guidance developed by ANSI/EIA identifies 32 criteria that reliable EVM systems should have. These criteria are organized into the following five categories:

- *Organization:* Activities that define the scope of the effort and assign responsibilities for the work
- *Planning and Budgeting:* Activities for planning, scheduling, budgeting, and authorizing the work
- *Accounting:* Activities to accumulate the costs of work and material needed to complete the work
- *Analysis:* Activities to compare budgeted, performed, and actual costs; analyze variances; and develop estimates of final costs
- *Revisions and Data Maintenance:* Activities to incorporate internal and external changes to the scheduled, budgeted, and authorized work

These five categories address specific areas in which to manage large, complex projects effectively with a commonsense approach. The criteria have been streamlined and simplified over the years so much that some leading practitioners suggest the use of

Year	Event
1967	Cost/Schedule Control System Criteria (C/SCSC) introduced by U.S. Department of Defense (DOD).
1972	First C/SCSC Joint Implementation Guide issued to ensure consistency among military departments.
1991	DOD Instruction 5000.2—Defense Acquisition Management Policies and Procedures issued reaffirming use of EVM.
1996	DODR 5000.2-R—Mandatory Procedures for Major Defense Acquisition Programs and Major Automated Information System Acquisition Programs issued. Draft industry guidelines accepted by Under Secretary of Defense and C/SCSC revised from 35 to 32 criteria.
1998	American National Standards Institute/Electronic Industries Alliance published industry guidelines for EVM Systems (EVMS; ANSI/EIA-748-98).
1999	Under Secretary of Defense adopts ANSI/EIA-748-98 for DOD acquisition.
2000	Simplified EVM Terminology published by Project Management Institute.
2005	*Practice Standard for Earned Value Management* published by the Project Management Institute (revised; second edition published in 2011).

Note. Details of important milestones in the progress of EVM implementation can be found in several sources, such as http://www.acq.osd.mil/pm/historical/Timeline/EV%20Timeline.htm.

Table 1: EVM progress timeline.

"EVM Lite" (Fleming & Koppelman, 2007; Oracle Corporation, 2009; Pakiz, 2006). An EVM progress timeline is shown in Table 1.

Legislation and Regulations

Legislation and regulations have driven the implementation of cost control techniques such as earned value management within the government sector since the early 1990s. Legislation relating to controlling and measuring performance began as early as 1993, with the Government Performance and Results Act. Today, regulations, policies, and guidelines continue to be refined to describe how to implement an EVMS on government projects based on the industry standard.

Title V of the Federal Acquisition Streamlining Act (FASA) requires that agency heads must define and approve the cost, performance, and schedule goals for major acquisitions and achieve, on average, 90 percent of the cost, performance, and schedule goals established. The Clinger-Cohen Act requires the director of the Office of Management and Budget to develop, as part of the budget process, a process for analyzing, tracking, and evaluating the risks and results of all major capital investments for information systems that encompasses the entire life of the system. Table 2 summarizes the main government legislation and regulations as they relate to cost control techniques and EVM.

Policies

The Office of Management and Budget (OMB) required the use of EVM for reporting performance for ongoing federal projects. The *Planning, Budgeting, Acquisition, and Management of Capital Assets* guide (OMB, Executive Office of the President, 2008b) states, "If any of the cost, schedule, or performance variances are a negative 10 percent or more you must provide a complete analysis of the reasons for the variances, the corrective actions that will be taken and the most likely estimate at completion (EAC). Use the EVMS system to identify the specific work packages where problems are occurring." In order to receive federal funding, projects were evaluated based on the business case submitted. The business case included the use of a performance-based management system, specifically an EVMS. Projects were scored based on whether or not an ANSI/EIA-compliant EVMS system was in place for the project (OMB, Executive Office of the President, 2008b). Table 3 shows some of the policies and orders from different governmental agencies.

Guidance Documents

Guidelines for using and establishing an EVMS were published to support the policies implemented for government agencies and industry standards. The *Office of Management and Budget Circular A-11, Part 7: Planning, Budgeting, Acquisition and Management of Capital Assets* (OMB, Executive Office of the President, 2008b) and the *Capital Programming Guide* (OMB, 2006) were written to meet the requirements of FASA and the Clinger-Cohen Act. These documents set the policy, budget justification, and reporting requirements that apply to all agencies of the executive branch of government that are subject to executive branch review. They address capital acquisition, require the use of EVM consistent with the American National Standards Institute ANSI/EIA 748 (ANSI, 2007) for both government and contractor work,

Date	Title	Information
1993	Government Performance and Results Act of 1993	"Requires organizational strategic planning and use of performance measurement for any program using U.S. federal dollars."
1994	Title V of the Federal Acquisition Streamlining Act of 1994	"Requires agency heads to achieve, on average, 90% of the cost and schedule goals established for major and non-major acquisition programs of the agency without reducing the performance or capabilities of the items being acquired."
July 2006	Federal Acquisition Regulation (FAR), Major Systems Acquisition, 48 CFR part 34, subpart 34.2, Earned Value Management System	This regulation applies to the Department of Defense (DOD), General Services Administration, and National Aeronautics and Space Administration. The regulation was based on the OMB Circular A-11. The FAR states that "an Earned Value Management System (EVMS) is required for major acquisitions for development, in accordance with OMB Circular A-11. The government may also require an EVMS for other acquisitions, in accordance with agency procedures." The Civilian Agency Acquisition Council and the Defense Acquisition Regulations Council set forth the following rules. • "EVMS application should be based on the particular agency facts and circumstances rather than specifying a threshold in the FAR." • "It is not appropriate to exclude certain contract types from EVMS requirements in the FAR." • "Agencies have significant discretion in determining the size and complexity of projects that meet the criteria for a major acquisition set by the agency."
April 2008	Defense Federal Acquisition Regulation Supplement; Earned Value Management Systems	This rule is a supplement to the FAR and documents DOD-specific EVM requirements. The requirements for an EVMS include: • Cost or incentive contracts and subcontracts equal to or greater than $20 million are required to use an EVMS that complies with ANSI/EIA-748. • Cost or incentive contracts and subcontracts equal to or greater than $50 million are required to use an EVMS system that has been validated as being in compliance with ANSI/EIA-748. • Cost or incentive contracts and subcontracts less than $20 million are not required to use an EVM. EVM is optional and should be assessed by determining project risk. • Firm fixed-price contracts and subcontracts are not required to use EVM. The use of EVM on these types of contracts is discouraged.

Table 2: Legislation and regulations related to EVM.

and are the genesis of the EVMS requirements for the Federal Acquisition Regulation (FAR). Table 4 summarizes current guidelines.

Implementation of EVM at NASA

Historically, space programs are financed by government funds. However, the business model is changing somewhat with the inception of more commercial space projects. NASA's annual budget is over $18 billion for FY 2010. For the cases examined regarding NASA's use of EVM, these government programs spend taxpayer dollars. It is for this reason that such programs use EVM to more effectively track project expenditures and schedule performance.

In February 1997, the agency issued *NASA Policy Directive (NPD) 9501.3—Earned Value Performance Measurement* to establish the basis for applying EVM to NASA contracts (NASA, 2002). Before issuance of the directive, NASA centers used their individual policies on performance measurement systems. The 1997 directive required NASA project managers to ensure implementation of EVM in contracts. Regularly, NASA's Office of the Inspector General and the Government Accountability Office conduct audits of current projects and provide recommendations for EVM-related integration and improvements. Some of these reports illustrate the benefits and shortcomings of projects in which EVM has been applied at NASA.

NASA's Organization and Projects

To better understand NASA's project management practices, it is worthwhile to have an overview of NASA's organizational structure, as shown in Figure 1. At NASA, organizational structure is based on two primary levels of management responsibility—agency management and strategic enterprise management, which includes managing centers and programs. Internal

Date	Title	Information
June 2002	OMB Circular A-11, Preparation, Submission, and Execution of the Budget (Part 7, Planning Budgeting, Acquisition & Management of Capital Assets)	"EVMS is required for those parts of the investment where developmental effort is required. This includes prototypes and tests to select the most cost-effective alternative during the Planning Phase, the work during the Acquisition Phase, and any developmental, modification or upgrade work done during the Operational/Steady State Phase. EVMS is to be applied to both Government and contractor efforts and regardless of contract type."
March 2005	DOD, Revision to DOD Earned Value Management Policy	This policy change was made to help improve and streamline consistency in the use of EVM in DOD. The policy led to the DFARS revisions in 2008. The changes to the DOD policy included: • Cost or incentive contracts, subcontracts, work agreements: –Equal to or greater than $50 million shall have a validated EVMS based on ANSI/EIA-748. –Equal to or greater than $20 million are required to use an EVMS that complies with ANSI/EIA-748. –Less than $20 million are not required to use an EVM. It is optional, based on risk. • Firm fixed-price contracts and subcontracts are not required to use EVM. The use of EVM on these types of contracts is discouraged. Note: This is in conflict with the OMB policy. DOD allows exemptions based on contract type. • Integrated baseline reviews are required when EVM is required.
July 2006	DOE O 413.3A	This order sets the following thresholds and requirements for use of an EVMS in the Department of Energy: • Projects with a total project cost greater than or equal to $20 million must have an ANSI/EIA-748-compliant EVMS (self-certified) by CD-2. • Projects with a total project cost equal to or greater than $50 million must have an ANSI/EIA-748-compliant EVMS certified by the Office of Engineering and Construction Management.

Table 3: Policies and orders related to EVM.

Date	Title	Information
December 2005	A Framework for Developing Earned Value Management Systems (EVMS) Policy for Information Technology Projects (IT)	This document was developed to provide "a model EVMS framework for the development of agency EVM policy," as required by OMB Memorandum M-05-23.
June 2006	Capital Programming Guide Version 2.0: Supplement to Circular A-11, Part 7, Preparation, Submission, and Execution of the Budget	This guide was originally published in 1997 to assist federal departments, agencies, and administrations in establishing an effective capital programming process based on OMB Circular A-11.
November 2006	National Defense Industrial Association Program Management Systems Committee (PMSC) Earned Value Systems Intent Guide	The guide provides further clarification on the 32 criteria outlined in ANSI/EIA-748. The guide assists government agencies and industry in documenting compliance of their EVMSs with ANSI/EIA-748.

Table 4: Guidance documents related to EVM.

integration is ensured through a number of management councils and boards that coordinate activities and planning among the individual enterprises and between the agency and enterprise management levels (NASA, 1996). NASA also has a unique organizational entity called the Academy of Program/Project & Engineering Leadership (APPEL) that contributes to NASA's mission by promoting program/project management and engineering and providing curriculum, knowledge sharing, performance enhancement, and research (NASA, 2011).

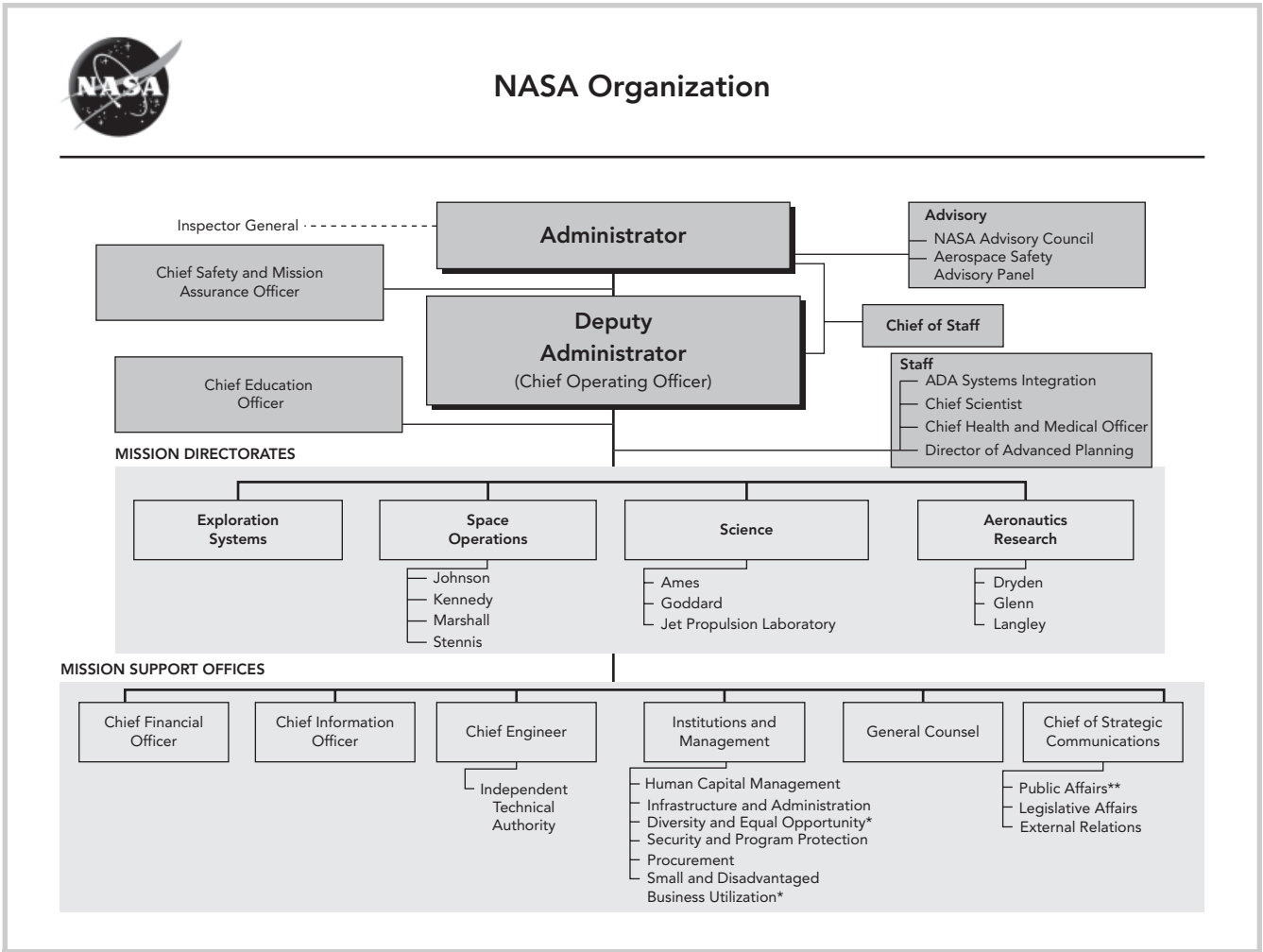

Figure 1: NASA's organizational structure (adapted from NASA, 1996).

Everything NASA does is essentially related to managing programs and projects. NASA divides its missions into five categories: (1) science, (2) aeronautics and space research and technology, (3) exploration, (4) space operations, and (5) education. Science missions and space operations are the two largest portions among the five categories and are generally led by scientists. All missions are defined within the context of project management at NASA, with a strong emphasis placed on developing professionals who can examine and lead projects from a total system perspective.

When Does NASA Apply EVM?

NASA currently has a significant infrastructure of processes and requirements in place that enables robust program and project management. *NPD 7120.5—NASA Space Flight Program and Project Management Requirements* (NASA, 2008a) and *NPD 7120.7—NASA Information Technology and Institutional Infrastructure Program and Project Requirements* (NASA, 2008b) dictate the use of an EVMS on NASA projects:

- For contracts and subcontracts valued from $20M to $50M, the contractor will have an EVMS compliant with the ANSI/EIA-748 Standard.
- For contracts or subcontracts above $50M, the contractor will have an EVMS formally validated and accepted by the federal government.
- An EVMS is applied at the discretion of the project manager for nondevelopmental programs, steady-state operations, support services, and janitorial/ground maintenance services, as well as for basic and applied research projects.
- The Defense Contract Management Agency (DCMA) office shall be used by contractors to determine the adequacy of their EVMS plans (DCMA, 2009).

Solicitation provisions and contract clauses within the *NASA Federal Acquisition Regulation (FAR) Supplement* must be used to provide guidance on contracts as well the government notice of intent to implement EVM. It is interesting to note that a project manager must apply to the NASA chief engineer for a waiver to be granted permission to *not* use an EVMS on a NASA project (NASA, 2010).

Training in EVM at NASA

NASA provides a training curriculum that supports project management processes and promotes consistent practices across the agency for all of its staff members. This includes an agencywide training curriculum, providing courses and schedules for training, and project management courses on leadership, scheduling, EVM, and data analysis. NASA developed an *EVM Implementation Handbook* (NASA, 2010) that provides implementation procedures, processes, and detailed instructions for applying EVM to NASA programs and projects. It includes clear definitions of requirements and responsibilities for the implementation process. It serves as a guideline for EVM implementation and addresses pre- and postcontract award procedures.

Steps in EVM Implementation at NASA

NASA uses a five-step approach to implement EVM, as outlined next.

- *Step 1. Integrated Baseline Review*
  This aspect specifies standardized guidance for the NASA Integrated Baseline Review (IBR) process by providing project managers, project staff, and EVM experts with a standard guide for conducting the IBR as a technical review, ensuring that the project manager has ownership of the process, and defines IBR responsibilities (Kerby & Counts, 2008). Requirements for the IBR can be found at http://evm.nasa.gov/.
- *Step 2. Schedule Health Assessment*
  This process allows the project manager to conduct a project schedule review, internally referred to as a schedule health assessment that evaluates the soundness and validity of project schedules. The schedule health assessment is a quantitative, evaluative methodology that helps determine the credibility and practicality of the schedule for project management purposes. It improves the EVM process by evaluating life-cycle plans and estimates that lay out the schedule baseline, provides a methodology that supports schedule health assessments for IBRs, and monitors project health during the execution of the project (Kerby & Counts, 2008).
- *Step 3. Integrated Information System*
  This information system is used to apply project review concepts through the use of an in-house EVMS. By utilizing an enhanced EVM server and database configuration, NASA provides its project managers with a practical in-house EVMS that enhances the planning, execution, and performance management of NASA programs and projects. The system also provides smaller in-house projects with basic performance management tools, a user-friendly interface, scheduling capability and interface, analysis and reporting functionalities, and standardized software integration (Kerby & Counts, 2008). The *NASA Data Requirements Document* incorporates the use of the Cost Performance Report and formalizes the reporting structure. A NASA EVM focal point is assigned where surveillance is delegated (NASA, 2010).
- *Step 4. Automated Data Analysis*
  This capability allows for continuous review of data through the use of an automated data analysis system. Through the automated analytical capability that performs EVM calculations by utilizing the previously mentioned integrated information system, timely and routine analyses of EVM data are facilitated that enable real-time project-related decision making. Thus, the automated data analysis capability allows for the quick identification of cost and schedule drivers, provides independent estimates at completion, generates data for the centralized database that supports and facilitates agencywide implementation of proprietary software and other initiatives, and provides a capability for standardized report generation (Kerby & Counts, 2008). The *NASA EVM Handbook* also mentions that project managers can delegate EVM monitoring to the DCMA, but must provide resources and assistance in the joint monitoring agreement. It is further stipulated that continuous EVM monitoring is maintained closely at all times. In order to facilitate the tracking and management of the risk-mitigation process, the integration and correlation of EVM data with the project's risk management plan are also emphasized. EVM data are to be included in all management and Project Management Council reviews (NASA, 2010).
- *Step 5. Organizational Investiture*
  Overall, the directives that NASA uses are adopted with flexibility depending on the size and complexity of specific projects. The degree of alignment to NASA project management practices is generally left up to the project manager. The expectation is that project managers will remain within the established NASA framework, but that determinations must be made in order to understand the context of the mission and how to best be successful within that context (E. J. Hoffman, personal communication, 2008). But in terms of results or the approach of the organization, it is vital to NASA that viable results are achieved within budgetary constraints and that public perceptions are maintained, showing that NASA's overall approach to managing projects falls within the confines of the law and demonstrative successes are achieved, ready to display to the public. An entire department has been created for the use of EVM at NASA, which clearly delineates the level of investiture in this best practice.

Three Cases of Successful EVM Implementation at NASA

Three NASA cases in which EVM was implemented successfully in planning, management, and control were identified. They are the Habitat Holding Rack (HHR), the Jet Propulsion Laboratory (JPL), and the Constellation program. In this review, the implementation of EVM principles and tools at NASA is discussed, and some of the major steps and challenges are highlighted. These cases demonstrate that it is important that EVM be introduced at the beginning of projects to get the most benefit out of it. Using EVM provides enough groundwork and discipline to maintain schedule and cost baselines—and allows project managers to take the appropriate actions when project performance starts to slip, because EVM helps keep track of the trends of scope, cost, and schedule. EVM gives project managers the tools and techniques to manage risks proactively and to make better management decisions.

Habitat Holding Rack Project of the International Space Station

One example of successful EVM implementation at NASA is its application to the biological studies involving various habitat construction efforts of the HHR project of the International Space Station (ISS). A subteam of the ISS project (biological studies) undertook the construction of the HHR in 2004. During the "mini-IBR" to establish the performance measurement baseline, it was determined that the contractors, while having identified critical paths for specific aspects of the project, did not have a high-level schedule to tie all aspects of the HHR deliverables together. As a result, the high-level schedule was developed, the true project critical path was identified, and needed changes were made to provide a realistic end-date forecast for the project.

The value of EVM was realized when the existing schedules were integrated. Although contractor personnel had established critical paths for every piece of the project schedule, an overall, high-level schedule did not exist to integrate them. Creating a single, uniform project schedule and linking all the major pieces of the project together empowered the staff with the ability to predict a date for completion of the work, as well as to develop a true critical path for the project. Integration of the schedule also allowed for schedule changes and updates to be made.

These changes helped to identify clear critical paths for the project, and also helped the team to pinpoint an end date that was tied to the impact of those changes (J. G. Kerby, personal communication, 2009). This experience highlighted that even when NASA contractors use EVM, they often apply it inconsistently and even interpret or deliver the status incorrectly. With good EVM tools, solid up-front planning, and effective implementation of these tools, project managers can be better informed to make effective management decisions during the entire life of the project (J. G. Kerby, personal communication, 2009). Through the use of EVM, contractors and NASA were able to ascertain how the project had progressed to that point, the direction it was taking, and what the true cost and schedule drivers were to get the project to where it needed to be. It was through this application of EVM that the HHR project was brought back in line.

EVM at the Jet Propulsion Laboratory

JPL is a not-for-profit, federally funded research and development center located at the California Institute of Technology in Pasadena, California. JPL is the NASA center for the unmanned exploration of the universe and conducts work for NASA; the Departments of Defense (DOD), Transportation (DOT), and Energy (DOE); and other federal agencies. JPL has adopted the cost management/earned value management (CM/EVM) system to use EVM not only to keep track of financial reporting requirements, but also to use it as a management methodology that helps to integrate project management principles. Specifically, project teams develop, manage, and analyze budgets, costs, and variances, as well as forecast and measure performance and facilitate project reporting by using CM/EVM.

Numerous factors have affected the environment within which the CM/EVM system was conceived, developed, and deployed at JPL (Jansma, Gibby, Chambers, Joines, & Egger, 2000). They are:

- JPL's shift to process-based management;
- major reengineering activities at JPL in 1995 and ISO 9000 certification in 1999;
- publication of requirements for implementation of NASA program and project management process in 1998;
- NASA's prime contract for JPL in FY 1999; and
- a previous failed attempt to implement EVM systems at JPL.

In the early 1990s, JPL failed to implement a full criterion-based EVMS. The primary reasons were that the organizational culture at JPL was not ready to adopt and implement project management principles, and a lack of technical capability and compatibility to integrate with the existing system. Interestingly, mini-implementations of EVM were done independently with JPL flight projects, which led to success. However, there was a series of shortcomings, including:

- a lack of full EVM system implementation;
- a lack of integration with JPL's institutional business system; and
- a mediocre tool set that was not capable of supporting complex funding and cost accounting models (Jansma et al., 2000).

In short, there was no well-defined project management process in place to adopt and implement such principles, tools, and practices at JPL.

In the late 1990s, JPL developed a three-phase strategy for achieving the goal to implement an EVMS (Jansma et al., 2000). The first phase was to build a system that integrated EVM methods with the existing business system. The second phase was to involve users and receive feedback by using a prototyping development approach to ensure acceptance among team members. The final phase was to adopt a project resource management process before system implementation, test different scenarios, and provide relevant training. The three-phase approach helped JPL to have a smooth transition to the new process and tools, and to implement EVM successfully.

The Constellation Program

The Constellation Program is a human spaceflight program with a purpose to gain experience in operating away from Earth's environment, to develop technologies needed for opening the space frontier, and to conduct fundamental science. One of the Constellation Program's goals is to integrate, view, and analyze project data to keep track of the project's whereabouts. Implementing EVM was necessary to manage and monitor various Constellation projects successfully. The following steps were used to effectively apply and implement EVM principles:

- Conduct solid communication with all stakeholders.
- Develop process documentation and maintain an implementation schedule.
- Define requirements and expectations for projects using existing tools and guidelines.
- Understand the organizational culture and remain flexible when implementing the EVM system.
- Demonstrate the benefits to key stakeholders.
- Keep strict deadlines to deliver the product, service, and data.

Challenges still remain for a few elements of the Constellation Program, such as the integration between financial systems and EVM techniques, because the data are not fully compatible. Also, education and training in basic EVM principles for the project management team and other stakeholders will be necessary to gain organizational support. The current goal is to build a process that will help project managers and team members have access to the best EVM data possible to analyze project performance, manage risks, and make appropriate decisions (McCann, 2010).

Discussions of EVM Implementation and Project Management Practices at NASA

There are numerous excellent implementations of EVM in organizations throughout agencies in the federal government, private industry, and other countries. Examples in the U.S. government include the DCMA, the DOD, the DOE, the Federal Aviation Administration (FAA), the U.S. Coast Guard, and many others. Details of some of these implementations can be found at the respective agency's website, such as http://guidebook.dcma.mil/79/EVMIG.doc.

One of NASA's leaders specified that, to assure mission success, people who are familiar with processes are needed to ensure adherence to disciplines and provide a decision-making point. As a result of good decisions, better customer relations can be attained (Davis, 1974), and there will probably be a better project return on investment (Kwak & Ibbs, 2000). These are all aspects of providing value: results can be measured, performance can be monitored and quantified, situations that need to be managed have a defined focal point, and overall direction and leadership are defined by the participant's role within the organizational structure. One of NASA's leaders specified that value is also achieved by creating a wealth of institutional knowledge and in enabling managers and directors to share stories of their successes and failures for all to examine and from which the entire organization can learn. NASA's leadership emphasized that NASA should be in the leading role of developing new generations of project managers who possess the senses of leadership, of understanding of complex systems, and of people management and clear communication. In other words, NASA is looking for a person with "project sensibility."

This research raised some concerns about the applicability of the processes defined by NASA to specific types of projects/missions. As one of NASA's leaders pointed out, science projects, technology projects, and human exploration projects all have varying degrees of budgetary, scheduling, and safety constraints, which in turn influence the level of complexity of the project. Getting the right people at the very beginning of the project, following and implementing project guidelines that are key to success (cost, time, and quality), being knowledgeable about the overall aspects of project performance and status, and being honest about progress reporting are the key values of project management at NASA and are the primary reasons why NASA has been so successful in applying and implementing project management since its formation. The approach that NASA uses to scale the extent of the policies and procedures used to create value through projects is effective.

NASA is a project-driven organization that is applying project management to all of its dynamic endeavors. NASA complies with relevant U.S. federal government regulations that require the use of monitoring and control tools in projects and programs. NASA is effectively applying its own policies and procedures related to project management to accomplish its objectives, strategies, and missions. This study argues that NASA is receiving substantial value from its implementation of project management in terms of an extremely

high project success rate and the achievement of organizational goals. Adapting NASA's approach to project management and its implementation of EVM should prove useful in other government agencies.

Recommendations for Improving EVM at NASA

- *NASA should consider applying EVM use to projects of $20 million or less.* NASA stipulates the use of EVM for projects over $20M, and requires the approval of the chief engineer to deviate from this mandate. By developing methods to use EVM for lower-cost projects that may not be considered high-visibility projects, NASA would have standardized processes and procedures for all of its projects.
- *NASA should consider applying EVM to firm fixed-price projects.* Applications of EVM are usually conducted within cost-plus or incentive-type contracts. Typically, firm fixed-price contracts are not managed using EVM because these types of contracts are seen as a risk transfer to the contractor and not to NASA. In reality, NASA is still exposed to risk in terms of quality, schedule, and the ability to complete the project, which ultimately can impact the agency's objectives. Therefore, a modified EVM approach may have meaningful applications to protect NASA from this exposure (Marshall, 2005, 2007, 2010; Marshall et al., 2008).
- *NASA should consider developing a scope management indicator as part of EVM.* Currently, NASA EVM measures only cost and schedule constraints. It may be possible to incorporate a scope management indicator to capture information on the stability of this important constraint (Yu, 1996).
- *NASA should consider including a variance in time using EVM data.* Current EVM metrics are expressed in terms of dollar cost and not in terms of the actual time. While schedule variances need to be stated in terms of dollar cost, it may be useful to express these variances in terms of time, or represent them in terms of duration as well. The schedule variance in terms of dollars may not effectively highlight the true requirement to realign the schedule (Lipke, Zwikael, Henderson, & Anbari, 2009).

Recommendation of EVM to Other Agencies Across Government and Industry

The value of project management to organizations has been established globally in extensive studies (Thomas & Mullaly, 2008). Understanding of project management and its applications in government continues to grow (PMI, 2006). Government agencies can successfully utilize proven principles of project management and tools of earned value management to achieve their goals and enhance the well-being of society.

EVM is a management methodology that gives the manager the ability to visualize a project's status at various points during the project life cycle and consequently manage risks more effectively. EVM has given managers greater confidence in making evidence-based inferences about project resources and scope management; hence, it has allowed more project control and oversight. EVM also brings other innovations into projects. It calls for a project-oriented management structure, a learning culture in the organization, the recognition of specialized skills and expertise, and more interface and interdependence across reporting lines.

EVM has been instrumental in supporting stronger cash flow management capacity, improving transparency and governance, facilitating prevention or mitigation of conflicts, and above all helping bring several large-scope projects to completion on time and within budget. EVM helps provide objective project assessments when applied appropriately and clearly quantifies the opportunities to maintain control over cost and schedule aspects of various projects and programs.

EVM as a methodology has proven merits and continues to expand to several sectors. It advocates for more rigor in project planning and implementation, which are undeniably prerequisites for any successful project. The use of EVM, or parts of it, or tailoring it to specific situations, has allowed managers to enjoy its benefits, including better cash flow management, improved relationships with clients, and successful management of project constraints. Knowledge, skills, applications, and maturity in EVM continue to grow as this powerful method is being used more widely (Antvik & Philipson, 2009; Solomon & Ralph, 2007; Stratton, 2006). EVM will continue to grow as long as more of its weaknesses are known and turned into opportunities for improvement. Table 5 summarizes the primary components of this study and the main linkages between them.

Despite the increasing awareness of the value of EVM and the growing acceptance and use of EVM by government agencies and contractors in the United States and abroad, prior research shows that EVM is substantially less frequently used outside the public sector (Kim, 2000; Kim et al., 2003). While acknowledging the potential benefit of EVM to project management, research further indicates that EVM is significantly less widely used in various industries than other popular tools and techniques in project management, such as the work breakdown structure, bar charts, analogous estimating, and the critical path method (Patanakul, Iewwongcharoen, & Milosevic, 2010). The established value of EVM compared to its relatively limited use in industries other than the public sector draws the attention of the project management community to the importance of considering the use of EVM, or parts of it, or tailoring it to specific projects and situations to allow project managers to enjoy its demonstrated benefits.

Table 5: Primary components of the study and their linkages.

Research Question	Case Study Findings	Interview Findings	Recommendations for NASA	Recommendations for Other Agencies
What are the historical evolutions of EVM principles in government?	• Started as Cost/Schedule Control System Criteria by the U.S. Department of Defense in the 1960s • Now mandated for many U.S. government programs and projects	• The 1997 NASA Policy Directive required its project managers to ensure implementation of EVM in contracts • NASA's Office of the Inspector General and the Government Accountability Office conduct audits of current projects and provide recommendations for EVM-related integration and improvements	• Continue to define all missions within the context of project management, with an emphasis on developing professionals who can examine and lead projects from a total system perspective • Continue to grow knowledge, skills, applications, and maturity in EVM	• Continue to deploy legislation and regulations that have driven the implementation of EVM in government since the early 1990s • Utilize proven principles of project management and EVM to achieve agencies' goals and enhance the well-being of society
How is EVM applied and implemented at NASA?	• NASA's Integrated Baseline Review • Schedule Health Assessment • Integrated Information System • Automated Data Analysis • Organizational Investiture	• Getting the right people at the very beginning of the project • Creating institutional knowledge • Enabling managers to share stories of their successes and failures for all to examine and from which the entire organization can learn	• NASA may wish to consider applying EVM use to projects of $20 million or less • NASA may wish to consider applying EVM to firm fixed-price projects	• Consider implementing EVM to give managers the ability to visualize projects' status at various points during the project life cycle and consequently manage risks more effectively
What are the challenges and lessons learned from adopting and implementing EVM at NASA?	• Build a system that integrates EVM with existing business systems • Seamless integration between financial systems and EVM	• Implementing project guidelines that are key to success • Being knowledgeable about the overall aspects of project performance and status • Being honest about progress reporting	• NASA may wish to consider developing a scope management indicator as part of EVM • NASA may wish to consider including a variance in time using EVM data	• Consider using EVM to give managers greater confidence in making evidence-based inferences about project resources and scope to enhance project control and oversight
What are the key success factors for successful EVM implementation?	• Introduce EVM at the beginning of projects • Involve users to ensure acceptance among team members • Adopt a project resource management process • Provide relevant training • Conduct solid communication with all stakeholders • Develop process documentation • Understand the organizational culture and remain flexible	• Directives that NASA uses are adopted, with flexibility depending on the size and complexity of specific projects. • The degree of alignment to NASA project management practices is generally left up to the project manager.	• Use EVM to allow projects to be kept or brought back in line • Continue to implement a project-oriented management structure, a learning culture in the organization, recognition of specialized skills and expertise, and more interface and interdependence across reporting lines	• Consider using EVM to bring innovations into projects • Consider using EVM to advocate for more rigor in project planning and implementation • Consider the use of EVM, or parts of it, or tailoring it to specific situations to allow managers to enjoy its benefits

(*Continues on next page*)

Table 5: (Continued)

Research Question	Case Study Findings	Interview Findings	Recommendations for NASA	Recommendations for Other Agencies
What improvements to current EVM standards might make them more applicable to government programs and projects?	• Define requirements and expectations • Develop implementation schedule • Keep strict deadlines to deliver the product, service, and data	• The expectation is that project managers will remain within the established NASA framework • Determinations must be made to understand the context of the mission and how to best be successful within that context	• Continue to demonstrate the benefits of EVM to key stakeholders	• Consider enhancing knowledge, skills, applications, and maturity in EVM • Continue to identify weaknesses in EVM and turn them into opportunities for improvement

Conclusions

This study explores the evolution of EVM and explores current EVM practices at NASA to identify emerging performance management techniques and suggest recommendations to improve current EVM practices for government programs and projects. It shows that NASA is a project-driven organization that is applying project management to all of its dynamic endeavors and applying EVM effectively to enhance the success of its projects and programs. NASA receives substantial value from its implementation of EVM, promotes consistent practices across the agency, and provides effective training for all staff members involved in project management processes. Findings of this research are expected to contribute to the management for performance of future projects and to encourage the project management community to review, rethink, and advance the application of EVM to other government agencies.

Acknowledgments

The authors would like to thank anonymous interviewees at NASA. This study was partially funded by a research grant from the IBM Center for the Business of Government and the Project Management Institute (PMI), whose leadership and support are greatly appreciated. Any opinions, findings, conclusions, or recommendations expressed in this study are those of the authors and do not necessarily reflect the views of NASA, IBM, or PMI.

References

Abba, W. (1997, January–February). Earned value management—Reconciling government and commercial practices. *Program Manager, 26*, 58–63.

Abba, W. (2001). How earned value got to prime time: A short look back and glance ahead. *The Measurable News.* Retrieved from http://www.pmforum.org/editorials/2003/earnedvalue-primetime_abba.pdf

American National Standards Institute (ANSI). (2007). *ANSI/EIA 748: Earned value management systems.* Washington, DC: Author.

Anbari, F. T. (2003). Earned value project management method and extensions. *Project Management Journal, 34*(4), 12–23.

Antvik, S., & Philipson, E. (2009). *Earned value management: An introduction.* Stockholm, Sweden: Philipson Biz.

Christensen, D. S. (1994). A review of C/SCSC literature. *Project Management Journal, 25*(3), 32–39.

Davis, E. W. (1974, March). CPM use in top 400 construction firms. *Journal of the Construction Division, Proceedings of the American Society of Civil Engineers, 100,* 39–43.

Defense Contract Management Agency (DCMA). (2009). *DCMA website agency data.* Retrieved from http://www.dcma.mil/about.cfm

Fleming, Q. W., & Koppelman, J. M. (2003, September). What's your project's real price tag? *Harvard Business Review, 81*(9), 20–22.

Fleming, Q. W., & Koppelman, J. M. (2007). *Earned value lite: Earned value for the masses.* Bala Cynwyd, PA: Primavera. Retrieved from http://www.nu-solutions.com/downloads/earned_value_lite.pdf

Fleming, Q. W., & Koppelman, J. M. (2010). *Earned value project management* (4th ed.). Newtown Square, PA: Project Management Institute.

Henderson, K. (2003, Summer). Earned schedule: A breakthrough extension to earned value theory? A retrospective analysis of real project data. *The Measurable News,* pp. 13–23.

Henderson, K. (2004, Spring). Further developments in earned schedule. *The Measurable News,* pp. 15–22.

Henderson, K. (2005, Spring). Earned schedule in action. *The Measurable News,* pp. 23–30.

Humphreys, G. C. (2002). *Project management using earned value.* Orange, CA: Humphreys & Associates.

Jansma, P. A., Gibby, L. B., Chambers, C. R., Joines, J. S., & Egger, R. (2000). *When serious project management is a critical business requirement.* Retrieved from http://www.projectp.com/demos/index.cgi?product=oaug

Kerby, J. G., & Counts, S. M. (2008). *The benefits of earned value management from a project manager's perspective.* Retrieved from http://www.nasa.gov/pdf/293270main_ 63777main_kerby_counts_forum9.pdf

Kim, E. H. (2000). *A study on the effective implementation of earned value management methodology* (Doctoral dissertation). George Washington University, Washington, DC.

Kim, E. H., Wells, W. G., Jr., & Duffey, M. R. (2003). A model for effective implementation of earned value management methodology. *International Journal of Project Management, 21*(5), 375–382.

Kwak, Y. H., & Anbari, F. T. (2006). Benefits, obstacles, and future of six sigma approach. *Technovation: The International Journal of Technological Innovation, Entrepreneurship and Technology Management, 26*(5–6), 708–715.

Kwak, Y. H., & Ibbs, C. W. (2000). Calculating project management's return on investment. *Project Management Journal, 31*(2), 38–47.

Lipke, W. H., & Henderson, K. (2006). Earned schedule: An emerging enhancement to earned value management. *CrossTalk—The Journal of Defense Software Engineering, 19*(11), 26–30.

Lipke, W., Zwikael, O., Henderson, K., & Anbari, F. (2009). Prediction of project outcome: The application of statistical methods to earned value management and earned schedule performance indexes. *International Journal of Project Management, 27*(4), 400–407.

Marshall, R. A. (2005). The case for earned value management with fixed-price contracts. *Contract Management*, *45*(10), 30–34.

Marshall, R. A. (2007, September). The contribution of earned value management to project success on contracted efforts: A quantitative statistics approach within the population of experienced practitioners. *Journal of Contract Management,* pp. 21–33.

Marshall, R. A. (2010). Earned value management: Does the Obama administration's latest policy announcement on contracting obviate its use? *Contract Management*, *50*(3), 16–20.

Marshall, R. A., Ruiz, P., & Bredillet, C. N. (2008). Earned value management insights using inferential statistics. *International Journal of Managing Projects in Business, 1*(2), 288–294.

McCann, L. (2010). *Implementing an EVM system for the Constellation Program.* Retrieved from http://pmchallenge.gsfc.nasa.gov/docs/2010/Presentations/Lisa%20McCann.pdf

National Aeronautics and Space Administration (NASA). (1996). *NASA strategic management handbook.* Retrieved from http://www.hq.nasa.gov/office/codez/strahand/roles.htm

National Aeronautics and Space Administration (NASA). (2002). *Earned value management (NPD 9501.3A).* Retrieved from http://www.ksc.nasa.gov/procurement/kics/docs/npd95013a.pdf

National Aeronautics and Space Administration (NASA). (2008a). *NASA space flight program and project management requirements.* Retrieved from http://nodis3.gsfc.nasa.gov/npg_img/N_PR_7120_005D_/N_PR_7120_005D_.pdf

National Aeronautics and Space Administration (NASA). (2008b). *NASA information technology and institutional infrastructure program and project requirements.* Retrieved from http://nodis.gsfc.nasa.gov/displayDir.cfm?Internal_ID=N_PR_7120_0007_&page_name=main.

National Aeronautics and Space Administration (NASA). (2010). *Earned value management (EVM): Implementation handbooks.* Retrieved from http://evm.nasa.gov/handbooks.html

National Aeronautics and Space Administration (NASA). (2011). *Academy of Program/Project & Engineering Leadership (APPEL).* Retrieved from http://www.nasa.gov/offices/oce/appel/about/about_appel.html

Office of Management and Budget. (2006). *Capital programming guide: Supplement to Office of Management and Budget Circular A-11, Part 7: Planning, budgeting, and acquisition of capital assets.* Retrieved from http://www.whitehouse.gov/omb/assets/a11_current_year/part7.pdf

Office of Management and Budget, Executive Office of the President. (2008a). *Analytical perspectives, budget of the United States government, fiscal year 2008.* Retrieved from http://georgewbush-whitehouse.archives.gov/omb/budget/fy2008/pdf/spec.pdf

Office of Management and Budget, Executive Office of the President. (2008b). *Circular A-11, Part 7: Planning, budgeting, acquisition and management of capital assets.* Retrieved from http://www.whitehouse.gov/omb/circulars/a11/current_year/s300.pdf

Oracle Corporation. (2009). *Earned value lite: Making earned value management work for every project.* Retrieved from http://www.oracle.com/applications/primavera/earned-value-lite-white-paper.pdf

Pakiz, J. J. (2006). *The EVMS light book I.* Long Beach, CA: Program Management Systems.

Patanakul, P., Iewwongcharoen, B., & Milosevic, D. (2010). An empirical study on the use of project management tools and techniques across project life-cycle and their impact on project success. *Journal of General Management, 35*(3), 41–65.

Project Management Institute (PMI). (2006). *Government extension to the PMBOK® Guide* Third Edition. Newtown Square, PA: Author.

Project Management Institute (PMI). (2008). *A guide to the project management body of knowledge* (*PMBOK® Guide*) (4th ed.). Newtown Square, PA: Author.

Project Management Institute (PMI). (2011). *Practice standard for earned value management* (2nd ed.). Newtown Square, PA: Author.

Solomon, P. J., & Ralph, R. Y. (2007). *Performance-based earned value.* Hoboken, NJ: Wiley.

Stratton, R. W. (2006). *The earned value management maturity model.* Vienna, VA: Management Concepts.

Thomas, J., & Mullaly, M. (2008). *Researching the value of project management.* Newtown Square, PA: Project Management Institute.

Yu, K. (1996). Project controls: Cost /schedule/progress management on the NASA Wind Tunnel Restoration Project. *Cost Engineering, 38*(4), 25–32.

Young Hoon Kwak is a faculty member at The George Washington University School of Business in Washington, DC. He earned his MS and PhD in engineering and project management from the University of California at Berkeley. He is a four-time recipient of research grants sponsored by the Project Management Institute, and two-time recipient of the IBM Center for The Business of Government's research stipend. He is the recipient of the 2008 International Project Management Association Outstanding Research Contribution Award. His primary research interests are strategic issues in project management and engineering, construction, and infrastructure project management.

Frank T. Anbari, PE, PMP, holds a PhD in project management and quality enhancement, an MBA and MS in engineering, and is an ASQ-Certified Six Sigma Black Belt. He is a clinical professor of project management at the Goodwin College of Professional Studies at Drexel University, Philadelphia, PA. He served as a faculty member and director of the Project Management Program at The George Washington University, Washington, DC, and taught in the graduate and executive development programs at Pennsylvania State University and the University of Texas at Dallas. Previously, he held leadership positions in industry in the United States.