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Agile and Evm for the Dod: a Review of the Challenges and a New Approach to Solve them

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AGILE AND EVM FOR THE DOD: A REVIEW OF THE CHALLENGES AND A NEW APPROACH TO SOLVE THEM

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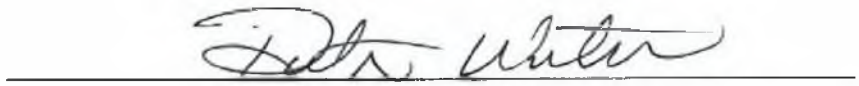

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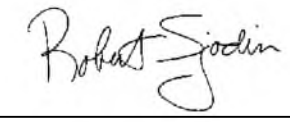

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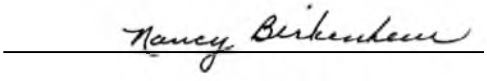

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Abstract

Department of Defense (DoD) acquisitions must improve program performance while working within budgetary constraints. The DoD community shows an interest in utilizing Agile methodologies, but struggles to reap Agile's benefits. They encounted challenges including the historically built up processes that enforce heavy-weight oversight, the outdated, manufacturing focused Work Breakdown Structures (WBS) provided in DoD Handbook: Work Breakdown Structures (WBS) for Defense Material Items (MIL-STD-881C), and the inability of the traditional waterfall based processes to accommodate iterative development. The author used the scientific method to review the documented issues encountered when using Agile on a DoD program within the constraints of Earned Value Management (EVM). The author developed the hypothesis that the currently available WBS options in MIL-STD-881C are in conflict with attempts to implement Agile software development methodologies and Agile Earned Value Management (AgileEVM) on DoD acquisition activities. Modifying MIL-STD-881C to include an iterative-based software development focused WBS would provide the DoD environment with a foundation to begin an overhaul of the current procedures and best practices to better support Agile methodologies and increase the adoption of Agile techniques. Based on the findings in this paper, additional research topics include: developing and defining the new WBS structure, determining what modifications are needed to other military standards, documented procedures, and best practices, and discussing the cultural changes needed to support and encourage greater use of Agile development methodologies in the DoD.

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Thank you first of all to my husband, Scott. You've tolerated many evenings of being ignored for my schoolwork and you never doubted I'd eventually complete my degree. To Carol, Bob, Barb, and Bill, thank you for your constant encouragement and positive thoughts. To all my friends and colleagues who have encouraged, cajoled, and sometimes chastised me to complete this paper, thank you. To my thesis advisor, Rob Sjodin, thank you for your patience during this process. And finally to Nancy Birkenheuer, thank you for your boundless encouragement over the last couple of months.

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Chapter 1 – Introduction

Software development projects have a long history of problems of not being completed on time and within budget. As Anderson (2003) explains, "It is common, to the point of being accepted as industry standard practice, for information technology projects rarely to follow the plan, to be late and over budget and fail to deliver what was promised." Humphrey (2005) indicates "less than 30 percent" of software projects are able to claim successful completion. His definition of successful completion is delivering all "intended functionality" and not exceeding cost and schedule goals by 10 percent. Over a number of years, the Standish Group has published the Chaos report providing statistics on software project success rates, among other data. Kannenberg & Saiedian (2009) compared the Chaos reports from 1994 and 2006. There is obvious improvement with the percent of failed projects dropping from 53% to 19% and the percent of successful projects increasing from 16% to 35%. However, the percent of challenged projects increased from 31% to 46%. While the improvement in the percentage of successful projects is encouraging, this level of performance across the industry would still be considered failing.

The recent economic crisis coupled with the current budget disputes between the United States (U.S.) presidential administration and the Congress are increasing the pressure within the U.S. Department of Defense (DoD) acquisition process to achieve more results with fewer funds. In addition, unfavourable government reports such as the one published by the United States Government Accountability Office (U.S. GAO) in 2012 function to ratchet up the pressure already in place from the political squabbles to improve the DoD acquisition process and achieve more with less. On top of this, section 804 of Public Law 111-84, formerly known as the

National Defense Authorization Act for fiscal year 2010, provides new direction for the DoD information technology (IT) system acquisition process to utilize:

- "Early and continual involvement of the user
- Multiple, rapidly executed increments or releases of capability
- Early, successive prototyping to support an evolutionary approach
- A modular, open-system approach" (Public Law 111-84, 2009)

This pressure is forcing government agencies and, by default their contractors, to re-evaluate how they acquire and perform on government funded projects. As Knausenberger & Shah (2012) point out,

> In an era of looming budget cuts, expanded oversight, and increasing demands on limited resources, government agencies have found that their ongoing initiatives must incorporate three new realities. First, agencies must do more with less by increasing efficiency, cutting waste, and maximizing return on investment. Second, agencies must respond quickly and effectively to changing stakeholder needs by delivering functionality to mission users in shorter timeframes and ensuring that programs remain closely aligned with evolving stakeholder requirements. Finally, through strong, accountable control, agencies must minimize program risk and ensure that expected results will be delivered when promised and for the expected cost.

Earned Value Management (EVM) has been a favoured method for tracking DoD program performance for over 35 years. Fleming and Koppelman (1998) point out, "In its formal application, it has been found to be an effective device to oversee and manage major new systems acquisitions by U.S. government agencies." There are a number of governing and reference documents which either explicitly dictate or provide guidance defining what situations

in which EVM must be used and outlining the preferred implementation that should be used to apply EVM to a program or project. The following list includes some of the primary documents applied to DoD awarded contracts:

- the Government Electronics and Information Technology Association (GEIA) Standard for Earned Value Management Systems (EVMS) American National Standards Institute (ANSI)/Electronic Industries Alliance (EIA)-748-B
- the National Defense Industrial Association (NDIA) Program Management Systems Committee (PMSC) ANSI/EIA-748-A Standard for Earned Value Management Systems Intent Guide
- the Defense Federal Acquisition Regulation (DFAR)
- the Federal Acquisition Regulation (FAR)
- the DoD Handbook: Work Breakdown Structures (WBS) for Defense Material Items (MIL-STD-881C)

For all of EVM's benefits, there are concerns with the amount of oversight and reporting required and a recognition that "a way must be found to scale back the full requirements to meet the needs of most projects – even small software projects" (Fleming & Koppelman, 2006).

As Alleman, Henderson, & Seggelke (2003) mention in their article, most government contracts have been executed using a "linear development process" such as waterfall or spiral development due to the contractual requirements for artefacts to document program process compliance or to support Defense Contract Management Agency (DCMA)/Defense Contract Auditing Agency (DCAA) review/oversight and program reporting to the customer agency. A review of articles in "Crosstalk", a U.S. DoD publication specifically focused on software engineering for the defense industry, as well as recent reports from the U.S. GAO and the

Software Engineering Institute (SEI) reveals that Agile software development has been receiving increasing attention over the last few years as a way to provide more responsiveness to industry changes and to more quickly deliver working products to the end user. However, as noted by Alleman, Henderson, & Seggelke (2003), "Introducing agile development processes into this environment is a challenge. Not because of the processes themselves, but because the financial reporting, CMM compliance, and operational security requirements of the contract." These authors also point out the lack of tools available to support project management and forecasting (Alleman, Henderson, & Seggelke, 2003). An attempt to resolve these dilemmas has been made with the conception of Agile Earned Value Management (AgileEVM).

AgileEVM was developed to help bridge the chasm between the flexibility offered by Agile software development methods and the oversight required for EVM (Sulaiman, 2007a). "AgileEVM is an adaptation of the traditional project management practice of measuring actual value of integrated cost, schedule and scope against a baseline plan using Earned Value Management (EVM) metrics." (Sulaiman, 2007b). Sulaiman and her colleagues investigated and documented an alternative approach to calculating traditional EVM cost and schedule performance metrics. While the modified calculations resolve the challenge of applying EVM metrics to Agile software development, this solution addresses only a part of the quandary surrounding the use of Agile on DoD awarded programs. Another facet of this issue is the outdated governing and reference documents which still limit the contractual implementation of a program.

1.1 Problem Statement

As things currently stand today, it is difficult to achieve the full benefits of utilizing Agile software development on a DoD funded project while also adhering to the contractual obligations levied by the DoD governing documents as they are presently written.

1.2 Thesis Statement

The Work Breakdown Structure (WBS) options currently available in the DoD Standard MIL-STD-881C are in conflict with utilizing Agile techniques and the supporting AgileEVM tool.

1.3 Project Relevance

Major DoD contractors are having to reevaluate their traditional methods of doing business in an effort to adapt to reduced budgets for new contracts and increased oversight and scrutiny of existing contracts caused by the economic downturn and the effect of sequestration resulting from the lack of an approved budget from the U.S. Congress and the presidential administration.

One of the changes already starting to appear in this environment is the attempt to use Agile development methods to respond more quickly to customer engineering change requests or to address potential future program issues with the end goal of reducing the overall cost of new development. The merits of this approach and the relative successes or failures are yet to be seen, but the challenges encountered in merging Agile practices with the required use of earned value management as outlined in the GEIA Standard for Earned Value Management Systems ANSI/EIA-748-B, the NDIA PMSC ANSI/EIA-748-A Standard for Earned Value Management Systems Intent Guide, the DFAR, the FAR, and the DoD MIL-STD-881C must be resolved in order to claim success.

In addition to the economic and political pressures, Racheva & Daneva (2008) note that "Recent studies indicate an increased attention by the software engineering research community in the application of metrics in an agile context." This indicates a continued interest in developing Agile based metrics even if the results of the fiscal year 2013 budget debate and sequestration alters the current economic pressure and political influence.

1.4 Project Scope

The perceived restrictions of using EVM and Agile software development methodology are in the details of meeting contractual requirements specified in the various governing documents. Specifically, the perceived restrictions stem from how to reconcile planning a project under EVM while still maintaining the flexibility of adapting the next iteration based on the current state of the product backlog. Using the groundwork established by Sulaiman (2007a, 2007b), Sulaiman, Barton, and Blackburn (n.d.), and Sulaiman and Smits (2007) and the findings from the reports published by the U.S. GAO (2012), Northern, Mayfield, Benito, & Casagni (2010), and the SEI (2010), this paper will discuss the need for a new WBS that is tailored for the nuances of Agile software development.

1.5 Project Limitations

The scope of this research paper was restricted by the author's limited accessibility to acquire and freely manage a DoD contract. The author has access via her employer to work on DoD contracts, but the corporation was not inclined to allow the author to have free-reign with regard to experimenting with the implementation of Agile development on a DoD awarded contract. The author also did not have the resources to support independently competing for any of the DoD contracts that were up for bid over the last few years.

1.6 Definition of Terms

1.6.1 An Introduction to EVM

EVM is a method used to track how successfully a program or project performs against its cost and schedule plans (Fleming & Koppelman, 1998). The details of EVM are outlined within the GEIA published ANSI-EIA-748 standard and are comprised of 32 concepts which lay out the structure of the method. "Most of the information and experience with earned value is centered on large programs with systems and organizations in place explicitly to support project management and earned value" (Alleman, Henderson, & Seggelke, 2003).

The project management value from EVM is derived from the structure that requires:

- Creating a plan that is "fully defined at the outset" with a "bottom-up plan" created to capture the low level details (Fleming & Koppelman, 1998).
- Implementing a WBS that outlines the entirety of the scope of work for the project (Fleming & Koppelman, 1998).
- "Continuously manage the project's remaining work" (Fleming & Koppelman, 1998)
- Constantly managing all project baseline changes (Fleming & Koppelman, 1998).

"Anything less, and management must commit to a job by authorizing a 'blank check' for the project." (Fleming & Koppelman, 1998).

EVM involves a number of facets and the details of many of these components are beyond the scope of this study. The following paragraphs will provide a basic overview of the EVM concepts that are directly related to AgileEVM implementation as discussed in this study. These concepts involve the details of tracking work progress against the original baseline and against the actual cost incurred at a specific point in time. EVM uses values in monetary terms, or dollars in the U.S., to allow a comparison between schedule and cost to be completed.

EVM utilizes three pieces of information; the initial project plan, the actual costs accrued, and the percent complete progress (earned value) of each task. These three data points are measured at a specific point in time and compared to produce two values used to indicate program health, the Cost Performance Index (CPI) and the Schedule Performance Index (SPI) (Alleman, Henderson, & Seggelke, 2003; Humphreys, 2002). CPI is equal to the Budgeted Cost of Work Performed (BCWP) divided by the Actual Cost of Work Performed (ACWP) (Alleman, Henderson, & Seggelke, 2003; Humphreys, 2002). ACWP represents the dollar amount a project has spent up to a specific point in time; its actual costs for the work that has been completed (Humphreys, 2002). The BCWP is a dollar representation of the project's progress that has been completed up to the same specific point in time as the ACWP (Humphreys, 2002). BCWP is the sum of the earned value for all tasks that have been started (Humphreys, 2002). SPI is equal to the BCWP divided by the Budgeted Cost of Work Scheduled (BCWS) (Alleman, Henderson, & Seggelke, 2003; Humphreys, 2002). BCWS is the sum of the assigned value for all tasks that were scheduled to be performed up to the same specific point in time being used to measure the ACWP and BCWP (Humphreys, 2002). A CPI of equal to or greater than one indicates a project is running at or below the expected costs for the work being performed and a CPI of less than one indicates a project that is over running expected costs for the work being performed (Humphreys, 2002). An SPI with a result equal to or greater than one indicates the project is performing at or ahead of the original schedule, while an SPI result less than one means the project is behind the baseline schedule (Humphreys, 2002).

Three additional acronyms that are frequently encountered when discussing EVM metrics are ETC (Estimate to Complete), EAC (Estimate at Complete), and BAC (Budget at Complete). The ETC is the current outlook for the remaining work on the project (Humphreys, 2002). It

takes into account the "current reality" as it impacts the project's performance and costs for the future work. EAC is the total of the ACWP added to the ETC and is the current estimate for how much it will cost and how much time will be needed to complete the entire project (Humphreys, 2002). BAC is the baseline projection for the project (Humphreys, 2002). At the start of the project, it is equivalent to the initial baseline but can diverge from the initial baseline as project replans occur (Humphreys, 2002). The Defense Acquisition University (DAU) routinely publishes the EVM Gold Card, which provides an EVM graph (Figure 1 below) showing the relationships of ACWP, BCWS, BCWP, EAC, ETC, BAC, the schedule variance and the cost variance.

The Program Management Institute's (PMI) *Guide to the Project management Body of Knowledge (PMBOK) (*2008) defines the WBS as

A deliverable-oriented hierarchical decomposition of the work to be executed by the project team to accomplish the project objectives and create the required deliverables, with each descending level of the WBS representing an increasingly detailed definition of the project work. The WBS organizes and defines the total scope of the project, and represents the work specified in the current approved project scope statement.

A project's WBS is used as the framework for the BAC and the project schedule. As such, it defines smaller sections of work which then have a dollar value and timeframe assigned to each task listed. The value for each task is intended to be equivalent to the baseline estimate for the cost that will be incurred to accomplish the task and the timeframe is used to build the complete project schedule (Humphreys, 2002). For DoD contracts, MIL-STD-881C provides WBS guidelines. The currently available WBSs from MIL-STD-881C are included in Appendix B.

Figure 1: Defense Acquisition University EVM Gold Card

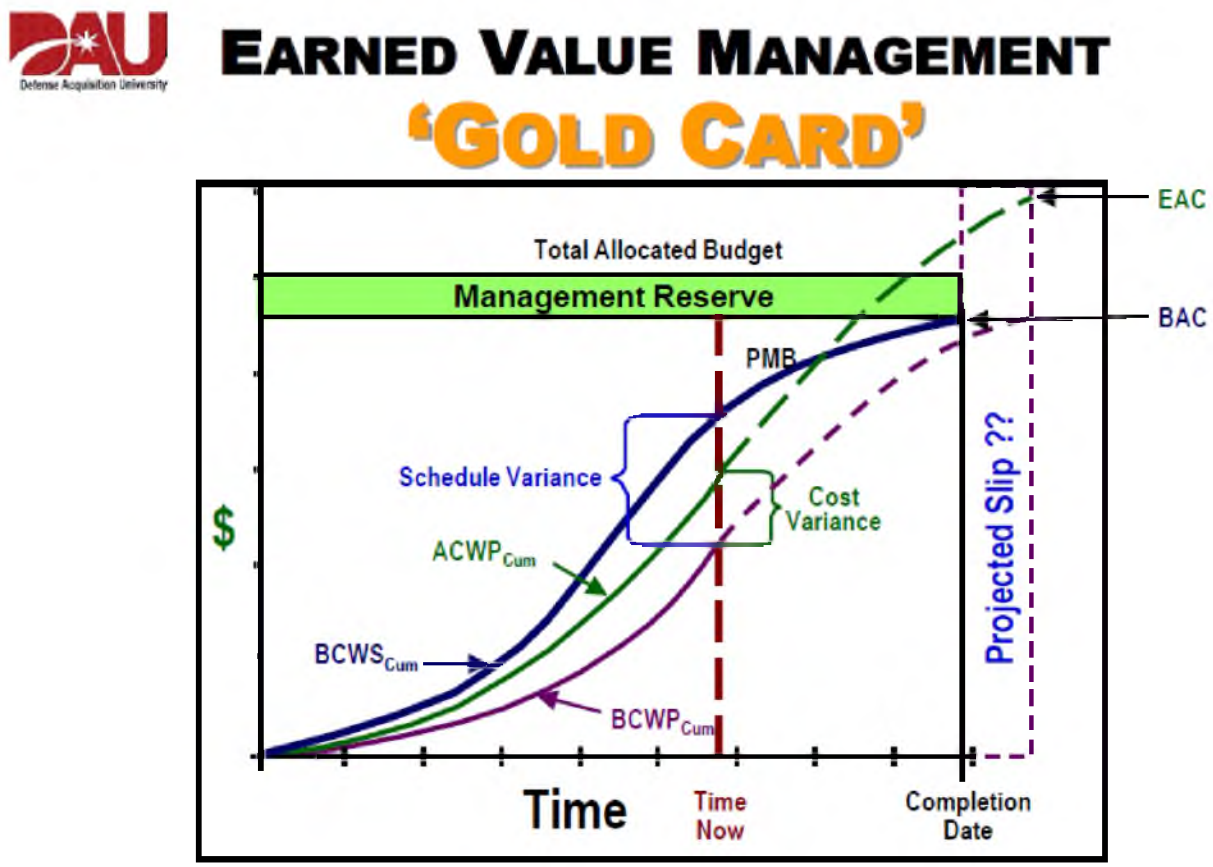

Figure 1. Graphical representation of a project's baseline plan compared to the current cost and schedule performance using traditional EVM. Published by the Defense Acquisition University, 2012.

It's important to note the value of EVM is only as good as the inputs to the original baseline, the care taken to claim performance, and the avoidance of management interference to modify the performance being reported, (Alleman, Henderson, & Seggelke, 2003). Another potential challenge when using EVM is "The Earned Value Management process is generally good for tracking whether the project is meeting its original plan. However, it becomes difficult to administer if the project's plan changes rapidly." (Boehm, 2003). These potential problems need to be kept in mind when utilizing EVM metrics to track program performance.

1.6.2 Government Documents

As mentioned earlier in this paper, there are a handful of documents which software development organizations are contractually obligated to adhere to during the execution of a DoD project. This section will discuss each of the applicable documents.

The GEIA Standard for EVMS ANSI/EIA-748-B is the definitive authority for EVM. This document outlines the seven principles of an EVMS at a high level and briefly discusses the 32 guidelines for setting up and implementing an EVMS on a program or project. The intent of the standard is not to provide the final solution for all EVM related questions, only to supply a framework for an organization to work within.

In addition to the EVM standard published by GEIA, the NDIA has published the ANSI/EIA-748-A Standard for Earned Value Management Systems Intent Guide; a supporting document which provides direction and clarification regarding how to implement EVM within U.S. Government funded projects and programs. The NDIA document is meant to be used to supplement the GEIA document and provides additional detail for each of the 32 guidelines.

The FAR is the authoritative document created to support the Federal Acquisition Regulation System (FARS) which was "established for the codification and publication of uniform policies and procedures for acquisition by all executive agencies" (FAR 1.101). Furthermore, FAR section 1.102a states that "The vision for the Federal Acquisition System is to deliver on a timely basis the best value product or service to the customer, while maintaining the public's trust and fulfilling public policy objectives."

Adherence to both the system and the document are cited as a contractual obligation for any DoD program. The FAR provides a definition of an EVMS and in Subpart 34.0 details the related policies and procedures to be implemented on the applicable contracts. The crux of this

document can be found in section 34.005-2 paragraph b.6 which states "The contracting officer shall send the final solicitation of all prospective offerors. It shall – require the use of an Earned Value Management System that complies with the guidelines of ANSI/EIA Standard-748 (current version at time of solicitation)."

The DFAR and the Procedures, Guidance and Information (PGI) are the DoD supplements to the FAR and provides a listing of DoD specific contractual obligations above and beyond those stipulated in the FAR. Subpart 234.2 specifically addresses the requirements related to implementing an EVMS for a DoD awarded contract and the associated DCMA oversight responsibility.

The DoD Standard: Work Breakdown Structures (WBS) for Defense Material Items (MIL-STD-881C) is the Military Standard (MIL-STD) for EVM. MIL-STDs have been created per the direction of the Defense Standardization Program (DSP) to provide "A document that establishes uniform engineering or technical criteria, methods, processes, and practices (MIL-STD-962D)" on a specific topic. MIL-STD-881C "presents direction for preparing, understanding, and presenting a WBS. It provides the framework for DoD Program Managers to define their program's WBS and also to defense contractors in their application and extension of the contract's WBS" (MIL-STD-881C).

1.6.3 The Basics of Agile Software Development

All software development methods contain the same basic components: requirements development, design, coding, integration, testing, and final product delivery. The differences lay in how each of these components are completed. Agile development methodologies are driven by the Manifesto for Agile Software Development, Figure 2. As Poole (2006) noted, "the common theme [of Agile] is taking a traditional development process with a single deliverable at the end

and splitting it into a series of small iterations, each of which is a microcosm of the full process and each producing working software." An important difference with Agile software development is the level of customer involvement and responsibility to the project. Recheva and Daneva (2008) note the customer's control over the final project result due to their control over requirements prioritization for each iteration and Rawsthorne (2004) points out the "validation and feedback" which supports incremental development that can adapt to "changing priorities, requirements, and other realities of development."

Figure 2: Manifesto for Agile Software Development

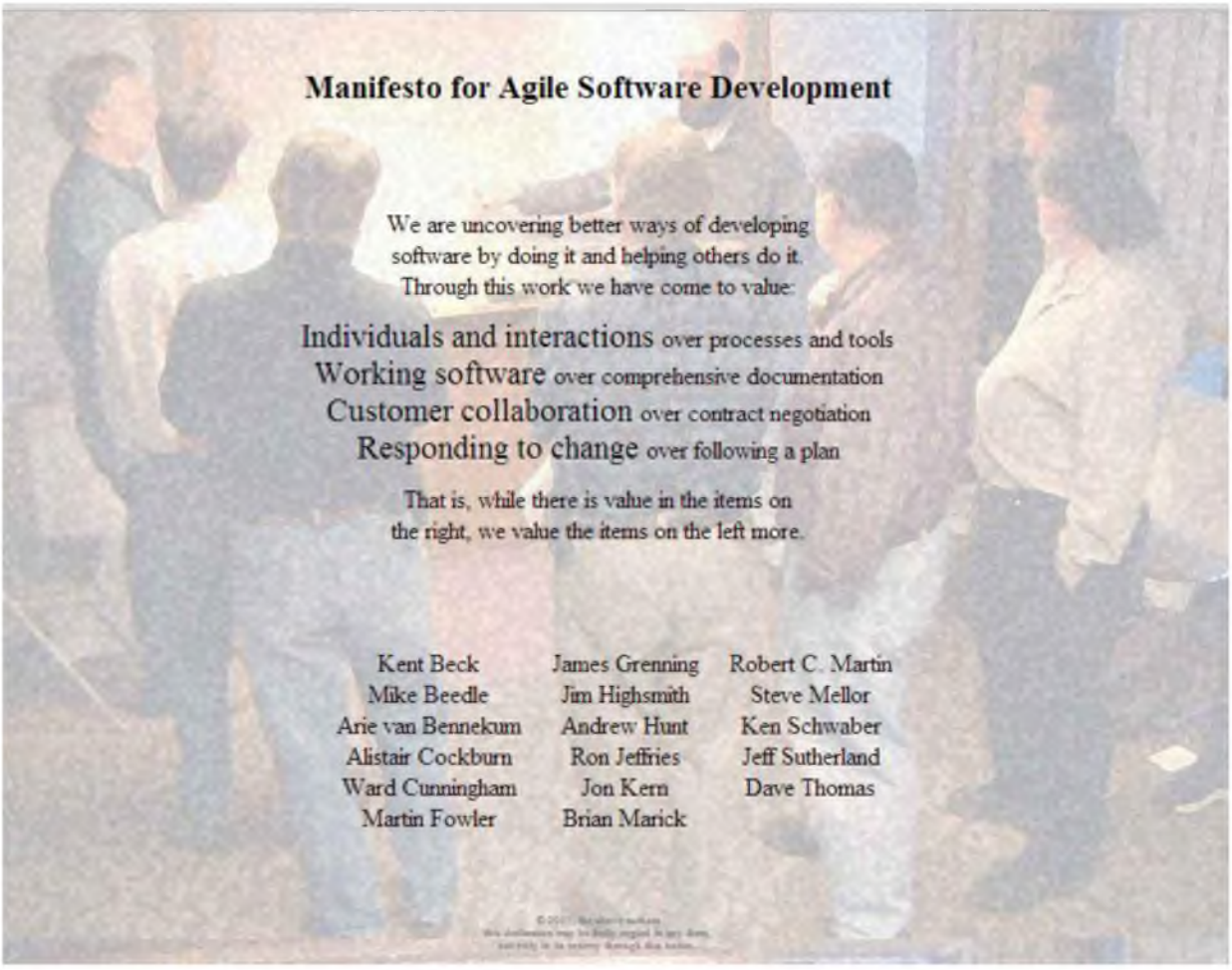

Figure 2. Agile methodologies share a basic set of values, defined above. This manifesto was developed by a group of the leading Agile software subject matter experts.

Agile development makes use of stories, tasks, and sprints or iterations to define the actual work being accomplished. As Rawsthorne (2004), describes, "A story is the fundamental unit of work…they need only have three things: a description, usually in business terms, a size, for rough estimation purposes, a short description of how the story will be validated." Stories are then further decomposed into tasks; these are the smaller units of work that are actually assigned to an individual developer. Tasks are defined by "a description of the work to be performed, in either technical or business terms; an estimate of how much time the work will take; an owner, who may or may not be pre-assigned; exit criteria and verification method" (Rawsthorne, 2004). Sections of stories that are combined together create a sprint or iteration. Ideally, a sprint is 30 days long (Highsmith, 2002). The short duration of the sprint is intentionally designed to re-enforce the team's short-term deliverable focus which enables "the emergence of new requirements as the system is delivered in small increments – iterations" (Alleman, 2003).

While the sprint is focused on the work currently under development, Agile methodologies makes use of a work backlog to manage the stories that have yet to be assigned to a sprint (Rawsthorne, 2004). Each story in the backlog is assigned a value or weight to represent the work involved to complete the story. The story value/weight can be in terms of almost anything, so long as the team has the ability for comparison. Cohn (2005), Highsmith (2002), and Schwaber (2004), provide a number of examples: gummy bears, t-shirt sizes, story points, or small-medium-large rankings. The weights are used to calculate the amount of work that can be assigned to an individual sprint/iteration. The initial number of story points (or gummy bears or T-shirt sizes) assigned to an iteration is originally derived from previous project experience or could be a random guess (Schwaber, 2004). Once the development starts and a couple of sprints

are complete, the team can calculate their actual velocity and adjust the number of story points to be assigned to each sprint (Highsmith, 2002).

The backlog is not a fixed set of stories, but can continuously evolve based on customer priorities and the deliverables from prior sprints (Schwaber, 2004). The customer is then able to make mid-point adjustments to the project via modification to the backlog and to understand early the cost and schedule impact of adding or removing stories from the backlog.

1.6.4 The Establishment of AgileEVM

AgileEVM is a product of work completed by Tamara Sulaiman and Thomas Blackburn during their effort to address the perceived conflict of using EVM techniques and metrics on Scrum projects (Sulaiman, 2007a). Sulaiman (2007a) encountered shock from other ScrumMasters as well as a frustrating lack of supporting documentation for this approach. Their research eventually resulted in utilizing modified calculations which allowed them to implement the project management and tracking tools available from EVM on a project utilizing the flexibility of Scrum software development. While Sulaiman and Blackburn focused on Scrum, they believe AgileEVM to be flexible enough for use with any Agile methodology (Sulaiman, Barton, & Blackburn, n.d.). As Sulaiman (2007b) notes, "These key metrics are the same measurements in AgileEVM as in traditional EVM. Only the method for obtaining the measurements has been adapted."

To successfully apply AgileEVM in place of traditional EVM, Sulaiman and Blackburn created an AgileEVM worksheet using "five initial parameters, and four recurring inputs for easy calculation." (Sulaiman, 2007a). The five initial parameters are: BAC, iteration length, planned iterations, planned release story points (PRSP), and the project start date (Sulaiman, 2007a). The four recurring inputs are: the current iteration number, the number of story points completed, the

number of story point that have been added or removed from the release, and the actual cost (AC) which is the same as ACWP (Sulaiman, 2007a). As with traditional EVM, an initial baseline must be established to allow AgileEVM to provide the same progress and project health reporting capabilities (Sulaiman, 2007a). As part of establishing the initial baseline, Sulaiman and Smits (2007) note that care must be taken when determining the iteration boundaries to be used for AgileEVM calculations and that the appropriate cumulative values are assigned to each iteration. This means when assigning story points to stories and selecting stories for each iteration, the team needs to be careful to correctly weight each story and to evenly distribute (as much as possible) the stories across iterations.

Within AgileEVM, BAC and ACWP (called AC in AgileEVM) remain the same as traditional EVM (Sulaiman, 2007b, & Sulaiman, Barton, & Blackburn, n.d.). However, a couple of new measurements are added; PRSP which are the story points planned for a specific release, expected percent complete (EPC) calculated by dividing the current sprint number by the total number of planned sprints, and the actual percent complete (APC) which is the sum of story points completed divided by the sum of total planned story points (Sulaiman, 2007b, & Sulaiman, Barton, & Blackburn, n.d.). From these numbers, the planned value (PV), earned value (EV), CPI and SPI are calculated. The PV is the product of BAC multiplied by the EPC and is similar to BCWS in traditional EVM (Sulaiman, 2007b, & Sulaiman, Barton, & Blackburn, n.d.). The EV is the product of BAC multiplied by the APC and is similar to BCWP in traditional EVM (Sulaiman, 2007b, & Sulaiman, Barton, & Blackburn, n.d.). For CPI, AgileEVM uses EV divided by AC and for SPI the calculation is EV divided by PV (Sulaiman, 2007b, & Sulaiman, Barton, & Blackburn, n.d.). Figure 3 provides an AgileEVM equivalent of

the DAU Gold Card graph. This figure shows the relationship of AgileEVM measurements: AC, PV, EV, EAC, BAC, the schedule variance and the cost variance.

Figure 3: AgileEVM based graph

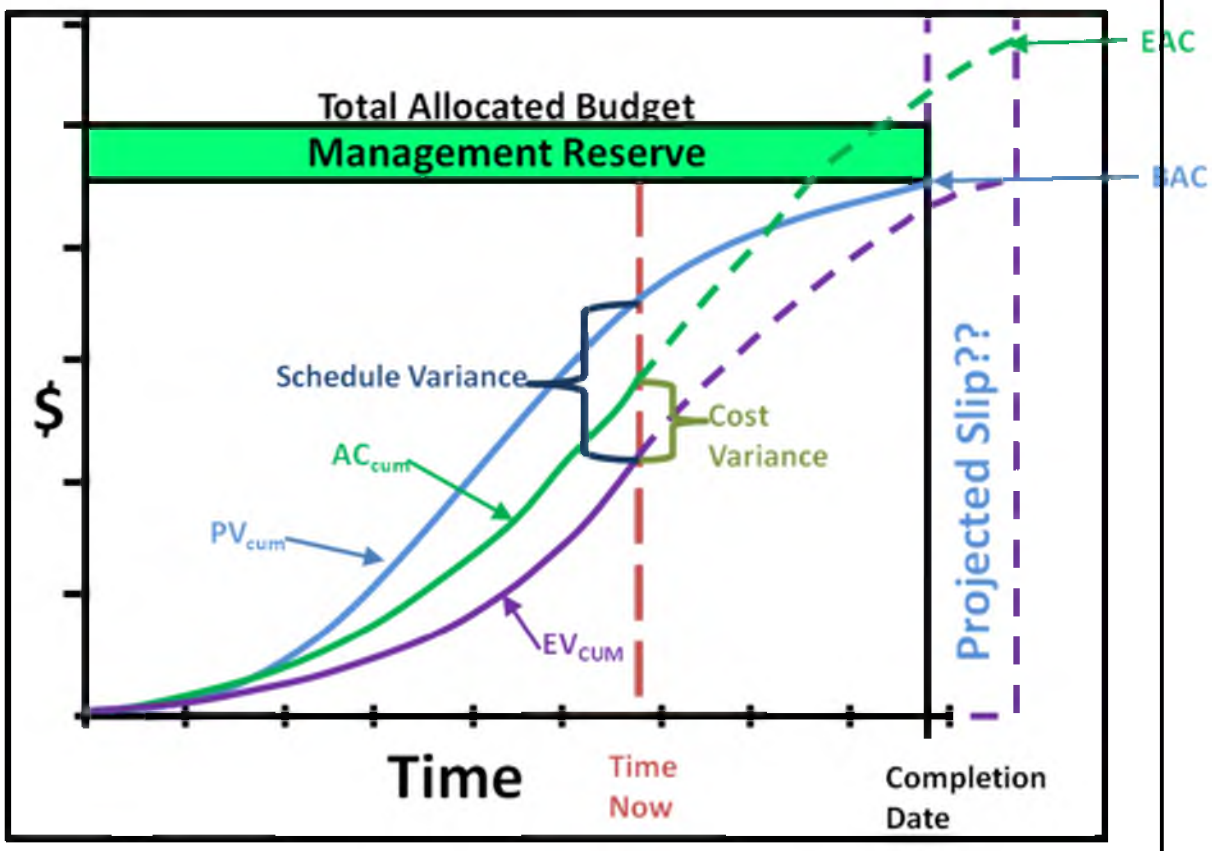

Figure 3. Graphical representation of a project's baseline plan compared to the current cost and schedule performance using AgileEVM.

1.7 Summary

The abundance of documentation on both EVM and Agile methodologies indicate the success and wide acceptance both practices have across the software industry. EVM has been a very popular tool for managing DoD contracts and will continue to be one of the mandated obligations to aid contractual oversight for future programs and projects. All forms of Agile software development have a proven track record for successfully delivering software projects within budget and schedule constraints. The documentation and real-world studies completed by

Sulaiman and Blackburn have proven that AgileEVM can address the conflicts frequently raised when considering applying EVM principles to projects using Agile methodologies.

Chapter 2 – Review of Literature and Research

A review of the literature for EVM and Agile within the context of a DoD contract uncovered a variety of opinions and real-world scenarios on the challenges encountered during the actual implementation of an Agile type of development within the structured EVM required in the DoD acquisition environment. This chapter categorizes the discussion into three main sections; a) the heavy-weight oversight inherent on these type of contracts, b) the outdated WBSs provided and the lack of a software focused WBS within the governing documents, and c) the inability of the current processes and contractual obligations to accommodate iterative development and rapidly changing schedules inherent with Agile methodologies. These three distinct challenges are tightly coupled with one another and the difficulties encountered in one area tend to fuel difficulties in the other two categories.

2.1 Heavy-weight oversight

Progressively, over the many years that DoD acquisitions have been occurring, the government has instituted "extensive and well-documented engineering and development lifecycles" which provide a series of formal milestones tightly aligned with traditional waterfall and spiral type development (Knausenberger & Shah, 2012). The process has been formalized to the point that extensive documentation and rigid milestone reviews are now completely integrated with contractually binding requirements and adherence is compulsory for a project to be considered successfully completed (Alleman, Henderson & Seggelke, 2003, Knausenberger & Shah, 2012 and SEI 2010). This process relies heavily on EVM criteria aligned with and supporting the formal milestones found in the rigid, sequential waterfall based lifecycle.

As documented by Northern, et al. (2010), "Traditional software development approaches have been considered 'heavyweight' processes defined by up-front planning and formal

documentation, and functional teams that develop the product in a linear phase approach (requirements, design, etc.)." The original EVM criteria which the DoD acquisition process is based on was developed for application on "complex major system acquisitions" (Fleming & Koppelman, 2006). Northern, et al. (2010) support Fleming & Koppelman explaining that the origination of these heavyweight processes was derived from the development experiences for large weapons systems of the 1960's and 1970's which were designed and built in a very different fashion than a modern day IT system. The SEI report (2010) noted, as paraphrased from Boehm & Turner (2004), "Traditional Waterfall provides significant oversight and insight into the implementation details of the program; this method is very structured so that it provides predictability, stability, and high assurance." This process relies on document heavy milestone checkpoints during which the DoD program office reviews and evaluates the inception-to-date (ITD) progress of the project and may provide re-direction to the project team. As the SEI report (2010) points out, "The essence of the traditional structure is created to allow for close oversight and insight into the working of a program. The structure requires immense amounts of documentation, which is evaluated at key milestones throughout the program." Figure 4, taken from MIL-STD-881C (2011) shows the Defense Acquisition Management Framework which is the expected development process including some of the required milestone reviews (e.g. Preliminary Design Review (PDR) and Critical Design Review (CDR)).

The SEI report (2010) also notes the use of periodic oversight reviews tied to a regular business rhythm which require the creation and delivery of additional documentation outside of the milestone reviews. These periodic reviews can include EVM budget and schedule status and in combination with the milestone reviews are used to "provide the government with a high level of 'comfort' that the program is progressing the way it should" (SEI, 2010).

Figure 4: Defense Acquisition Management Framework

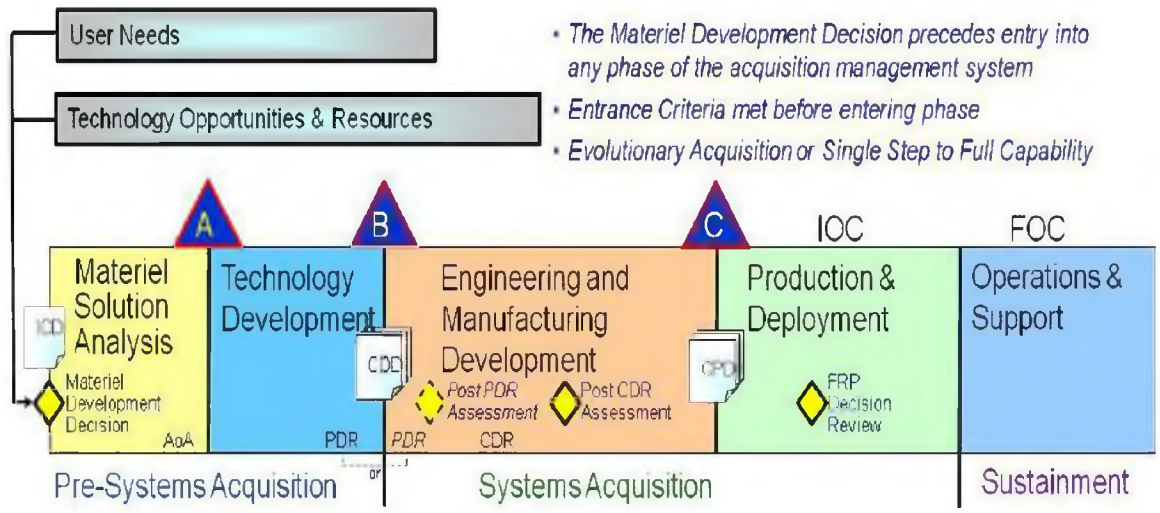

Figure 4. A typical DoD acquisition lifecycle showing the high level phases of the acquisiton process and including some of the major review milestones.

The U.S. GAO report (2012) has also documented the difficulties uncovered when "federal oversight bodies want status reports at waterfall-based milestones rather than timely statements regarding the current state of the project" and when resources such as the Office of Management and Budget's (OMB) IT Dashboard require monthly metrics reporting regardless of the lifecycle state of the project or the development methodology being used. In addition, attempts to negotiate modifications to the standard contractual obligations for oversight documentation and reviews were found to be an "ineffective practice" and "difficult to implement" (U.S. GAO, 2012).

The documentation requirements referenced above are identified independently for each acquisition activity and referred to as Contract Document Requirements Lists (CDRLs) (MIL-HDBK-254D). These documents are defined by, and their delivery schedule set according to, one or more DD Form 1423s issued with the program contract (MIL-HDBK-254D). Each CDRL is

required to be delivered in a very specific format as defined by the accompanying DD Form 1664 (MIL-HDBK-254D) or as outlined in MIL-STD-963B. Examples of these forms are located in Appendix C.

However, this well documented and formalized approach is proving to be the downfall when implementing Agile. In their report, the SEI (2010) noted "Agile methodology does not accommodate large capstone events such as Critical Design Review (CDR), which is usually a major, multi-day event with many smaller technical meetings leading up to it." This report also found problems with the typical monthly EVM CDRLs, specifically the report questioned the Integrated Master Schedule (IMS). A traditional IMS requires a lower level of task detail and gradation for all tasks included in the project. Similar comments were found in the U.S. GAO report (2012), "…federal contracts that require onerous, waterfall-based artifacts to constantly evaluate contractor performance are not needed in an Agile approach..." The U.S. GAO also noted difficulties implementing Agile because "…contracting officers require cumbersome traditional structured tasks and performance checks." The overall community is supportive of the idea of implementing Agile methodologies and interested in using these options, but as the recent investigations by Northern, et al. (2010), the SEI (2010), and the U.S. GAO (2012) discovered, issues still need to be resolved regarding the level of oversight and documentation that has traditionally been required versus what the process should be when using Agile methodologies.

2.2 Dated WBS/WBS not focused on software development

MIL-STD-881 was originally published back in 1968 (MIL-STD-881A) it "establishes criteria governing the preparation and employment of work breakdown structures for use during the acquisition of designated defense materiel items" (MIL-STD-881). Since then, the standard has been updated a handful of times over 45 years (MIL-STD 881A in 1975, MIL-STD-881B in

1993, MIL-HDBK-881A in 2005 and MIL-STD-881C in 2011), but a review of the available WBS outlines provided in the current standard's appendices shows the document continues to focus on the same "complex major systems" (Fleming & Koppelman, 2006) or megalithic type contracts similar to those the initial 1968 document first addressed. These appendices are replicated in Appendix B of this paper, and they provide outlines for Aircraft Systems, Electronic Systems, Missile Systems, Ordnance Systems, Sea Systems, Space Systems, Surface Vehicle Systems, Unmanned Air Vehicle (UAV) Systems, Unmanned Maritime Systems, Launch Vehicle Systems, and Automated Information Systems (AIS) (MIL-STD-881C). In each of these outlines, software is only a subset of the WBS with no consideration provided for the unique, intangible nature of software development compared with the rest of the traditionally manufactured system the software is being integrated with. Northern, et al. (2010) states a number of reasons why software should not and cannot be treated in the same manner as traditional manufacturing acquisitions:

- "IT system development can be fraught with uncertainty and ambiguity making it difficult to accurately define the end state up front" (Northern, et al., 2010).
- "The product is intangible or abstract, which makes it difficult for users to define what they want up front" (Northern, et al., 2010).
- "…complicated even more by stakeholders with differing objectives and perceptions of the problem space and what they think the system should do…" (Northern, et al., 2010).
- "…software development has a high level of technical complexity due to numerous internal and external interrelationships in the code and interfaces, which can result in unforeseen issues." (Northern, et al., 2010).

- "…planning and design is completed when the least information is known." (Northern, et al., 2010).

2.3 Inability to accommodate iterative development and quick changes to schedules

MIL-STD-881C does not eliminate the option of utilizing Agile methodologies, and in fact, it does make some references to using iterative development within the document, but the overall structure does not support a transition to Agile. This is a topic that has been discussed in published literature many times over the last 10 years. Alleman, Henderson & Seggelke (2003) comment on the "linear development process" that is the standard for government acquisitions. A few years later, McMahon (2006) touched on this topic again "…the traditional approach to scheduling is to build a large detailed schedule early in the project. The problem with this is that it can become difficult to maintain when changes on the project happen quickly." Northern, et al. (2010), revisit this topic when they discuss the traditional process a DoD project follows. Their report not only talks about the rigid structure but they also mention this structure is "based on the assumption that an end state is known" which is not always a guarantee and is likely to change over the course of the project's life (Northern, et al., 2010). Lastly, the U.S. GAO lent internal U.S. Government credence to this position when they pointed out in their report, "Contracts requiring waterfall-based artifacts and milestone reviews may not support the frequent changes and product demonstrations in iterations and may inhibit adoption" of Agile methodologies (U.S. GAO, 2012).

Even the time honored use of EVM has received its share of critiques. These tend to be focused not on whether EVM and Agile can exist together on the same project, but on the premise that EVM ignores customer value in any of its calculations. An oversight that could be easily remedied by the high customer involvement required with the iterative nature of Agile

development methodologies. Boehm (2003) not only stated that " 'Earned value' systems track project cost and schedule, not stakeholder or business value;" but went on to explain that a project could be viewed as "tremendously successful" based on traditional SPI and CPI but in reality be "an absolute disaster in terms of actual organizational value earned" because it didn't meet the evolving needs of the end user, didn't adapt to the changing marketplace, or that it wasn't the most effective use of the current funds. Boehm & Huang (2003) recommend a stakeholder feedback loop be incorporated in EVM to remedy this oversight and enhance EVM's usefulness.

During their investigation, the U.S. GAO (2012), noted a number of issues tied to the difficulties encountered when government agencies attempted to adapt to iterative schedules and quickly changing priorities. These issues included:

- The traditional software development best practices and documented guidance for the agencies under review tended to replicate sequential, waterfall methods. One particular comment was "it was challenging to develop policy and procedure guidance for iterative projects because they were new, and the agency strategy aligned with the waterfall approach" (U.S. GAO, 2012).
- The overall acquisition practices have not proven to be flexible enough to adapt to iterative changes and the adjustments required to the staffing plans (U.S. GAO, 2012).
- "Compliance reviews were difficult to execute within an iteration time frame." Reviews required for adherence to legal or agency policy requirements were difficult to complete within the iteration time frame and could be delayed for

months waiting in line because the reviewers themselves were working to more of a waterfall type schedule (U.S. GAO, 2012).

- "Traditional status tracking does not align with Agile," no guidance has been developed for applying EVM oversight on an iterative, Agile style implementation. Methods used within Agile, such as estimating and tracking story points, does not easily align with more traditional EVM estimating and status tracking methods using hours (U.S. GAO, 2012).
- The process of incorporating changes between iterations was perceived as signs of problematic changes to the project instead of being seen as a normal part of the iterative process (U.S. GAO, 2012).

2.4 Summary

The DoD acquisition process has not kept pace with the changes in the types of acquisitions that have evolved over the past 45 years. Reviewing the available literature shows a strong opinion trend within the last 10 years indicating that change within the acquisition process and the actual project implementation for DoD awarded contracts needs to happen and that Agile is a serious contender for this change. However, the literature clearly details a number of issues impeding the adoption and successful implementation of Agile methodologies on these types of contracts. This conflict begs the question, 'How can this environment facilitate the initial change and support the continued adoption and embracement of this change once initiated?'

Chapter 3 – Methodology

3.1 Overview

This paper documents the scientific method approach to review the hypothesis posed in the scope section. This section will discuss the applicability of the selected research methodology for this paper and explain the rationale behind the methodology selection.

3.2 Choice of Methodology

The scientific method utilizes observation and reasoning to define a problem, develop a hypothesis to solve that problem, then gather and analyze data to compare to the hypothesis (Leedy & Ormrod, 2005). This method requires the researcher to utilize "both deductive and inductive reasoning" (Leedy & Ormrod, 2005) by way of empirical analysis to review evidence gathered "through one or more of the five senses" (Irwin, 2003). The resulting analysis will then be compared to the initial hypothesis to determine if the evidence supports the hypothesis, thereby solving the original problem; or to confirm if the evidence contradicts the hypothesis and leaves the problem unresolved.

Irwin (2003) outlines a six step approach for the scientific method. The initial step is to create the theory, "in essence defining the nature of our research question or policy problem" (Irwin, 2003). The second step is to take the initial theory and define a hypothesis or set of hypotheses that are "concrete, measurable and testable" (Irwin, 2003) with clearly defined "independent and dependent variables"(Irwin, 2003). Step three of the scientific method defines the supporting data for evaluating the independent and dependent variables and outlines the procedure that will be used to collect this data while adhering to the need for the data to be relatively error-free, bias-free, able to be extrapolated out to generalized statements, suitable for the hypothesis and for the collection procedure to be practicable (Irwin, 2003). Once the research

plan has been developed, the fourth step is to implement the plan and collect the data. After the required amount of data has been gathered, the researcher then proceeds to step five and begins the data analysis. It is during this point that the researcher questions the validity of the data and determines if the data is "compelling and persuasive" (Irwin, 2003). The culmination of step five then leads to step six, the comparison of the data to the initial hypothesis/hypotheses and the researcher's interpretation of the evidence (Irwin, 2003).

For this paper, the author started off with an interest in how EVM supported the use of Agile development methodologies on DoD contracts. At this point, the author created a hypothesis about the changes that would need to happen to better allow Agile and EVM to be used together on a DoD contract. The author gathered a variety of peer reviewed articles, publications from subject matter experts as recognized by the Agile and EVM industries, and collected the most recently published versions of applicable DoD contract governing documents. These documents were reviewed and the author critically compared the documentation to the hypothesis. Over a period of months, the author continued to refine the focus of the hypothesis and this research paper based on the available literature. Eventually, the hypothesis was solidified to its current state and this research paper was completed.

3.3 Summary

As summarized by Irwin (2003), "When we speak of the scientific method, we are merely speaking of the goal of identifying important questions, theorizing answers to those questions, and then seeking confirmation of our theories through logical reasoning and objective observation." This research paper is the culmination of starting with a number of questions regarding successfully implementing Agile software development with EVM oversight as required on DoD contracted projects. These questions were then used to focus a literature review

on Agile software development, EVM practices, contractually obligated requirements for DoD projects and programs and the available information about AgileEVM. The facts and theories uncovered during the literature review were subsequently used to develop a theory for the future changes needed to support the utilization of both Agile and AgileEVM within the DoD contracting environment.

Chapter 4 –Results

4.1 Overview

As discussed earlier in this paper, Agile development implementation within the structure established by MIL-STD-881C and all its accompanying forms, processes, and best practices is fraught with challenges. This section will discuss how the introduction of a new WBS structure for MIL-STD-881C will mitigate the issues discussed in Chapter 2.

4.2 Heavy-weight oversight

This challenge has its basis in the DoD acquisition and project management culture. As examined in Chapter 2, the milestone reviews and the supporting documentation that are an integral part of the heavy-weight oversight have been defined by decades upon decades of practice on very large, major weapon-system acquisitions. The military today has a very different focus than they did during the height of the cold war years in the 1960s, 1970s, and the early 1980s. Along with this change in focus, DoD acquisitions are also dealing with very different technological factors. The adaptation of the oversight processes haven't kept pace with the changes in the practical world.

An iterative based WBS that is specifically designed with software development in mind and structured to accommodate the special needs of iterative software development would be a catalyst to facilitate the major changes needed to support the new direction to the acquisition and contract implementation processes outlined in section 804 of Public Law 111-84. As previously mentioned, the WBS is the foundation for the entire project. A new WBS would provide the framework for a fresh start allowing new oversight processes to be built and best practices developed to describe the appropriate review cycles for iterative based software development and the proper level of supporting documentation that should be required to present project status and

continue to provide the level of confidence and comfort the DoD program managements offices, DCMA, and DCAA are familiar with receiving.

4.3 Dated WBS/WBS not focused on software development

The MIL-STD 881 was originally published in 1968 when DoD contracts were very large, manufacture driven programs that only had a portion of software development which was almost exclusively waterfall based. According to the Defense Science Board (2000), software functionality within a weapon system has increased by up to 60% from 1970 to 2000. Developing a WBS which is software centric and specifically structured for iterative development would benefit the DoD software development community by providing the community with the foundation to start building processes and best practices that align with the nuances of software development and address the challenges outlined by Northern, et al. (2010).

A new software focused WBS would document the basic structure for software development projects and provide both the contractors implementing the project and the government oversight agencies with a set of common expectations. This would also support the DoD acquisition process need for standardization across programs and allow acquisition agents to continue to compare success rates across programs as they are traditionally used to.

4.4 Inability to accommodate iterative development and quick changes to schedules

The prevalence of sequential waterfall based processes within the DoD acquisition environment has meant that software projects were forced to assume the end result was known in advance and would not change as technology or the war-fighters' environment changed. As the pace of change of the environmental factors increases, the need to be able to quickly adjust project plans also increases. The currently available WBS alternatives and the rigid structure of

the current waterfall-based EVM implementation simply don't support the use of iterative development or a rapidly changing real-world environment.

An iterative based software focused WBS would reinforce the use of iteration based milestone reviews instead of the traditional waterfall based reviews and would enhance the customer feedback necessary to support Agile development methodologies. The iterative nature of Agile would require more frequent government representative involvement as more reviews of smaller sections of code and deliverable functionality would be required.

4.5 Summary

The creation and publication of a software focused WBS able to accommodate iterative development and utilize AgileEVM would be the initial step to a larger community wide change towards accepting and implementing Agile methodologies on DoD awarded contracts. By resolving the challenges of the historically based oversight, the traditional manufacturing focused legacy attitudes, and the inflexibility of the current processes, the new WBS would set the stage for broader community acceptance of Agile software development and help to fulfill the mandate of section 804 of Public Law 111-84 and the desires of many authors in the DoD community to better utilize Agile methodologies on DoD acquisitions.

Chapter 5 – Conclusions

5.1 Conclusions

The balance of the recent literature reviewing the use of Agile within a DoD context strongly supports migrating to Agile methodologies to improve customer satisfaction and increase software project success rates. However, the most recent studies completed show serious challenges to mainstream adoption and successful utilization of Agile methodologies within the DoD contracting environment. The various governing documents (e.g. the GEIA Standard for Earned Value Management Systems ANSI/EIA-748-B, the NDIA PMSC ANSI/EIA-748-A Standard for Earned Value Management Systems Intent Guide, the DFAR, the FAR, the DoD MIL-STD-881C, etc) do not specifically preclude utilizing Agile methodologies, but the inertia of processes built up over the last four to five decades certainly make the prospect of implementing Agile methodologies difficult. In addition, the currently available WBS options provided by MIL-STD-881C lack the structure to support attempts at adopting Agile development.

A project's WBS is the starting point for developing the project's cost and schedule plan, and it is the foundation for all other project management activities. The currently available WBS options provided in MIL-STD-881C do not sufficiently support the implementation of Agile software development methodologies. These WBSs are outdated and focused on major systems acquisitions emphasizing traditional manufacturing based projects utilizing waterfall or spiral based development methods requiring major phase based milestone reviews and formal documentation deliveries. The increased role of software within weapons system programs and the nuances of software development compared to manufacturing development are not represented within the currently approved WBS alternatives.

Developing a software focused WBS capable of incorporating iterative development and applying the precepts of AgileEVM would provide DoD acquisition officers and contractors with the introductory tools to encourage the initial adoption of Agile techniques and subsequently the continued implementation of Agile within the DoD contracting environment needed to start developing the industry best practices to support agency wide acceptance.

5.2 Summary of Contributions

In contrast to the discussions and recommendations found in the published literature, this paper proposes the governing documents which control and provide structure for DoD acquisitions should be updated. In particular, this paper discusses the impact that adding a new software focused WBS to the DoD Standard: Work Breakdown Structures (WBS) for Defense Material Items (MIL-STD-881C) that is also able to accommodate iterative development would have on the acquisition process.

5.3 Lessons Learned

During the process of investigating this topic and preparing this paper, the author learned valuable lessons about researching and developing a document of this type. Some of these lessons are more personal in nature, but others would be applicable to other researchers or to other types of "ground-up" projects.

5.3.1 Trials and Tribulations

As mentioned at the start of this paper, this topic is related to the author's profession. At first this seemed an ideal situation as the author had real-world experience with the topic and had numerous colleagues to discuss ideas with. However, in the midst of attempting to write this paper, the author discovered this was not as ideal is initially thought. There were a number of statements and fixes the author wished to include as part of this paper but was unable to do so

because of a lack of publicly available supporting literature. The additional material was not incorrect, however much of it could be considered "tribal knowledge" which was widely accepted by individuals working within the industry but not adequately documented.

Another challenge the author encountered was a lack of recent documentation opposing the use of Agile methodologies within the DoD acquisition environment. The concern of this challenge was the lack of a balanced or contrary view to this topic. While this challenge did not appear to hinder the discussion surrounding using Agile and EVM within a DoD environment, it did cause a potential for bias in accepting that Agile methodologies "should" work on these types of projects.

5.3.2 Pleasant Surprises

A situation that initially appeared to be negative actually turned out to be a positive occurrence and greatly aided the end result of this paper. The author, for a variety of reasons, took a hiatus from working on this paper. The interruption in work flow on this paper happened at a fortuitous time as three important reviews of using Agile within DoD/U.S. Government contracts were completed during the break. All three of these reports provided invaluable support to the arguments in this paper.

5.3.3 Future Actions

The logical next step from this paper would be the development of a new software focused WBS for MIL-STD-881C able to accommodate iterative development. The establishment of this new WBS would be best served with inputs from a cross section of industry representatives specializing in EVM and Agile. Once the WBS is defined, it would then need to be tested out on a sampling of projects to fine-tune the WBS structure.

5.4 Recommendations and Future Research

A number of possible leads exist that other researchers may wish to consider for future investigation and research. Future work could examine if other alternate WBS structures need to be developed or if different types of Agile methodologies would be better served with alternate WBS structures. Other governing documents or military standards involved in the software development/project management process may need an overhaul. There is also the possibility that a completely new set of documents solely focused on software development should be created. A critique of the current commercial Agile best practices and their applicability to the DoD acquisition process would also be beneficial, since the DoD environment does not have its own set of best practices documented for use on DoD contracts. Lastly, an investigation into the cultural changes within the DoD acquisition environment required to support Agile software development methodologies would be beneficial to the industry.

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Appendix A

AC – Actual Cost (AgileEVM)

ACWP – Actual Cost of Work Performed

AgileEVM – Agile Earned Value Management

AIS – Automated Information System

ANSI -American National Standards Institute

APC – Actual Percent Complete

BAC – Budget at Complete

BCWP – Budgeted Cost of Work Performed

BCWS – Budgeted Cost of Work Scheduled

CDR – Critical Design Review

CDRL – Contract Document Requirements List

CMM – Capability Maturity Model

CPI – Cost Performance Index

DAU – Defense Acquisition University

DCAA – Defense Contract Auditing Agency

DCMA – Defense Contract Management Agency

DFAR – Defense Federal Acquisition Regulation

DID – Data Item Description

DoD – Department of Defense

DSP – Defense Standardization Program

EAC – Estimate at Complete

EIA – Electronic Industries Alliance

EPC – Expected Percent Complete

ETC – Estimate to Complete

EV – Earned Value

EVM – Earned Value Management

EVMS – Earned Value Management Systems

FAR – Federal Acquisition Regulation

FARS – Federal Acquisition Regulation System

GAO – Government Accountability Office

GEIA – Government Electronics and Information Technology Association

IMS – Integrated Master Schedule

IT – Information Technology

ITD – Inception-to-Date

MIL-STD – Military Standard

NDIA – National Defense Industrial Association

OMB – Office of Management and Budget

PDR – Preliminary Design Review

PGI – Procedures, Guidance and Information

PMBOK – Guide to the Project Management Body of Knowledge

PMI – Program Management Institute

PMSC – Program Management Systems Committee (PMSC)

PRSP – Planned Release Story Points

PV – Planned Value

SEI – Systems Engineering Institute

SPI – Schedule Performance Index

UAV – Unmanned Air Vehicle

U.S. – United States

WBS – Work Breakdown Structure

Appendix B

MIL-STD-881C WBS alternatives – the following WBS outlines are the currently available WBS options found in MIL-STD-881C for use on DoD awarded acquisitions.

WBS Structure for Aircraft Systems

WBS #	Level 1	Level 2	Level 3	Level 4
1.0	Aircraft System			
1.1		Air Vehicle		
1.1.1			Airframe	
1.1.1.1				Airframe Integration, Assembly, Test and Checkout
1.1.1.2				Fuselage
1.1.1.3				Wing
1.1.1.4				Empennage
1.1.1.5				Nacelle
1.1.1.6				Other Airframe Components 1..n (Specify)
1.1.2			Propulsion	
1.1.3			Vehicle Subsystems	
1.1.3.1				Vehicle Subsystem Integration, Assembly, Test, and Checkout
1.1.3.2				Flight Control Subsystem
1.1.3.3				Auxiliary Power Subsystem
1.1.3.4				Hydraulic Subsystem
1.1.3.5				Electrical Subsystem
1.1.3.6				Crew Station Subsystem
1.1.3.7				Environmental Control Subsystem
1.1.3.8				Fuel Subsystem
1.1.3.9				Landing Gear
1.1.3.10				Rotor Group
1.1.3.11				Drive Group
1.1.3.12				Vehicle Subsystem Software
1.1.3.13				Other Subsystems 1…n (Specify)
1.1.4			Avionics	
1.1.4.1				Avionics Integration, Assembly, Test, and Checkout
1.1.4.2				Communication/Identification
1.1.4.3				Navigation/Guidance
1.1.4.4				Mission Computer/Processing
1.1.4.5				Fire Control
1.1.4.6				Data Display and Controls
1.1.4.7				Survivability
1.1.4.8				Reconnaissance
1.1.4.9				Automatic Flight Control
1.1.4.10				Health Monitoring System
1.1.4.11				Stores Management
1.1.4.12				Avionics Software Release 1…n
1.1.4.13				Other Avionics Subsystems 1…n (Specify)
1.1.5			Armament/Weapons Delivery	
1.1.6			Auxiliary Equipment	
1.1.7			Furnishings and Equipment	
1.1.8			Air Vehicle Software Release 1…n	
1.1.9			Air Vehicle Integration, Assembly, Test, and Checkout	
1.2		System Engineering		
1.3		Program Management		
1.4		System Test and Evaluation		
1.4.1			Development Test and Evaluation	
1.4.2			Operational Test and Evaluation	
1.4.3			Mock-ups / System Integration Labs (SILs)	
1.4.4			Test and Evaluation Support	
1.4.5			Test Facilities	
1.5		Training		
1.5.1			Equipment	
1.5.2			Services	
1.5.3			Facilities	
1.6		Data		
1.6.1			Technical Publications	
1.6.2			Engineering Data	
1.6.3			Management Data	

1.6.4 Support Data
1.6.5 Data Depository
1.7 Peculiar Support Equipment
1.7.1 Test and Measurement Equipment
1.7.2 Support and Handling Equipment
1.8 Common Support Equipment
1.8.1 Test and Measurement Equipment
1.8.2 Support and Handling Equipment
1.9 Operational/Site Activation
1.9.1 System Assembly, Installation and Checkout on Site
1.9.2 Contractor Technical Support
1.9.3 Site Construction
1.9.4 Site/Ship/Vehicle Conversion
1.9.5 Sustainment/Interim Contractor Support
1.10 Industrial Facilities
1.10.1 Construction/Conversion/Expansion
1.10.2 Equipment Acquisition or Modernization
1.10.3 Maintenance (Industrial Facilities)
1.11 Initial Spares and Repair Parts

WBS Structure for Electronic Systems

WBS # Level 1 Level 2 Level 3 Level 4
1.0 Electronic System
1.1 Prime Mission Product (PMP) 1...n (Specify)
1.1.1 PMP Subsystem 1...n (Specify)
1.1.1.1 PMP Subsystem Hardware 1...n
1.1.1.2 PMP Subsystem Software Release 1...n
1.1.1.3 Subsystem Integration, Assembly, Test and Checkout
1.1.2 PMP Software Release 1...n (Specify)
1.1.2.1 Software Product Engineering
1.1.2.2 Computer Software Configuration Item (CSCI) 1...n
1.1.2.3 Subsystem Integration, Assembly, Test and Checkout
1.1.3 PMP Integration, Assembly, Test and Checkout
1.2 Platform Integration, Assembly, Test and Checkout
1.3 System Engineering
1.4 Program Management
1.5 System Test and Evaluation
1.5.1 Development Test and Evaluation
1.5.2 Operational Test and Evaluation
1.5.3 Mock-ups / System Integration Labs (SILs)
1.5.4 Test and Evaluation Support
1.5.5 Test Facilities
1.6 Training
1.6.1 Equipment
1.6.2 Services
1.6.3 Facilities
1.7 Data
1.7.1 Technical Publications
1.7.2 Engineering Data
1.7.3 Management Data
1.7.4 Support Data
1.7.5 Data Depository
1.8 Peculiar Support Equipment
1.8.1 Test and Measurement Equipment
1.8.2 Support and Handling Equipment
1.9 Common Support Equipment
1.9.1 Test and Measurement Equipment
1.9.2 Support and Handling Equipment
1.10 Operational/Site Activation
1.10.1 System Assembly, Installation and Checkout on Site
1.10.2 Contractor Technical Support
1.10.3 Site Construction
1.10.4 Site/Ship/Vehicle Conversion
1.10.5 Sustainment/Interim Contractor Support
1.11 Industrial Facilities
1.11.1 Construction/Conversion/Expansion
1.11.2 Equipment Acquisition or Modernization
1.11.3 Maintenance (Industrial Facilities)
1.12 Initial Spares and Repair Parts

WBS Structure for Missile Systems

WBS #	Level 1	Level 2	Level 3	Level 4
1.0	Missile System			
1.1		Air Vehicle		
1.1.1			Airframe	
1.1.1.1				Airframe Integration, Assembly, Test and Checkout
1.1.1.2				Primary Structure
1.1.1.3				Secondary Structure
1.1.1.4				Aero-Structures
1.1.1.5				Other Airframe Components 1…n (Specify)
1.1.2			Propulsion Subsystem (1…n) Specify	
1.1.2.1				Propulsion Integration, Assembly, Test and Checkout
1.1.2.2				Motor/Engine (Specify)
1.1.2.3				Thrust Vector Actuation
1.1.2.4				Attitude Control System
1.1.2.5				Fuel/Oxidizer Liquid Management
1.1.2.6				Arm/Fire Device
1.1.2.7				Flight Termination/Mission Termination
1.1.2.8				Propulsion Software Release 1…n
1.1.2.9				Other Propulsion Subsystems 1…n (Specify)
1.1.3			Power and Distribution	
1.1.3.1				Power and Distribution Integration, Assembly, Test and Checkout
1.1.3.2				Primary Power
1.1.3.3				Power Conditioning Electronics
1.1.3.4				Distribution Harness
1.1.3.5				Power and Distribution Software Release 1…n
1.1.3.6				Other Power and Distribution Subsystems 1…n (Specify)
1.1.4			Guidance	
1.1.4.1				Guidance Integration, Assembly, Test and Checkout
1.1.4.2				Dome Assembly
1.1.4.3				Seeker Assemblies
1.1.4.4				Guidance Software Release 1…n
1.1.4.5				Other Guidance Subsystems 1…n (Specify)
1.1.5			Navigation	
1.1.5.1				Navigation Integration, Assembly, Test and Checkout
1.1.5.2				Sensor Assemblies
1.1.5.3				Navigation Software Release 1…n (Specify)
1.1.5.4				Other Navigation Subsystems 1…n (Specify)
1.1.6			Controls	
1.1.6.1				Controls Integration, Assembly, Test and Checkout
1.1.6.2				Primary Structure
1.1.6.3				Fin/Canard Deployment System
1.1.6.4				Actuators
1.1.6.5				Control Power
1.1.6.6				Controls Software Release 1…n
1.1.6.7				Other Control Subsystems 1…n (Specify)
1.1.7			Communications	
1.1.7.1				Communications Integration, Assembly, Test and Checkout
1.1.7.2				Antenna Assembly
1.1.7.3				Communications Software Release 1…n
1.1.7.4				Other Communications Subsystems 1…n (Specify)
1.1.8			Payload	
1.1.8.1				Payload Integration, Assembly, Test and Checkout
1.1.8.2				Target Detection Mechanism
1.1.8.3				Target Detection Device
1.1.8.4				Fuze
1.1.8.5				Payload Software Release 1…n
1.1.8.6				Other Payload Subsystems 1…n (Specify)
1.1.9			Reentry System	
1.1.10			Post Boost System	
1.1.11			Ordnance Initiation Set	
1.1.12			On Board Test Equipment	
1.1.13			On Board Training Equipment	
1.1.14			Auxiliary Equipment	
1.1.15			Air Vehicle Software Release 1…n	
1.1.16			Air Vehicle Integration, Assembly, Test and Checkout	
1.2		Encasement Device		
1.2.1			Encasement Device Integration, Assembly, Test and Checkout	

1.2.2			Encasement Device Structure	
1.2.3			Encasement Device Software Release 1…n	
1.2.4			Other Encasement Device Subsystems 1…n (Specify)	
1.3		Command and Launch		
1.3.1			Command and Launch Integration, Assembly, Test and Checkout	
1.3.2			Surveillance, Identification and Tracking Sensors	
1.3.3			Launch and Guidance Control	
1.3.4			Communications	
1.3.5			Launcher Equipment	
1.3.6			Auxiliary Equipment	
1.3.7			Booster Adapter	
1.3.8			Command and Launch Software Release 1…n	
1.3.9			Other Command and Launch 1…n (Specify)	
1.4		Missile System Software Release 1…n		
1.5		Missile System Integration, Assembly, Test and Checkout		
1.6		System Engineering		
1.7		Program Management		
1.8		System Test and Evaluation		
1.8.1			Development Test and Evaluation	
1.8.2			Operational Test and Evaluation	
1.8.3			Mock-ups / System Integration Labs (SILs)	
1.8.4			Test and Evaluation Support	
1.8.5			Test Facilities	
1.9		Training		
1.9.1			Equipment	
1.9.2			Services	
1.9.3			Facilities	
1.10		Data		
1.10.1			Technical Publications	
1.10.2			Engineering Data	
1.10.3			Management Data	
1.10.4			Support Data	
1.10.5			Data Depository	
1.11		Peculiar Support Equipment		
1.11.1			Test and Measurement Equipment	
1.11.2			Support and Handling Equipment	
1.12		Common Support Equipment		
1.12.1			Test and Measurement Equipment	
1.12.2			Support and Handling Equipment	
1.13		Operational/Site Activation		
1.13.1			System Assembly, Installation and Checkout on Site	
1.13.2			Contractor Technical Support	
1.13.3			Site Construction	
1.13.4			Site/Ship/Vehicle Conversion	
1.13.5			Sustainment/Interim Contractor Support	
1.14		Industrial Facilities		
1.14.1			Construction/Conversion/Expansion	
1.14.2			Equipment Acquisition or Modernization	
1.14.3			Maintenance (Industrial Facilities)	
1.15		Initial Spares and Repair Parts		

WBS Structure for Ordnance Systems

WBS #	Level 1	Level 2	Level 3	Level 4
1.0	Ordnance System			
1.1		Munition		
1.1.1			Airframe	
1.1.1.1				Airframe Integration, Assembly, Test and Checkout
1.1.1.2				Primary Structure
1.1.1.3				Secondary Structure
1.1.1.4				Aero-Structures
1.1.1.5				Other Airframe Components 1…n (Specify)
1.1.2			Propulsion	
1.1.2.1				Propulsion Integration, Assembly, Test and Checkout
1.1.2.2				Motor/Engine
1.1.2.3				Fuel Management
1.1.2.4				Arm/Fire Device
1.1.2.5				Propulsion Software Release 1…n
1.1.2.6				Other Propulsion Subsystems 1…n (Specify)
1.1.3			Power and Distribution	

1.1.3.1 Power and Distribution Integration, Assembly, Test and Checkout
1.1.3.2 Primary Power
1.1.3.3 Power Conditioning Electronics
1.1.3.4 Distribution Harnesses
1.1.3.5 Power and Distribution Software Release 1…n
1.1.3.6 Other Power and Distribution Subsystems 1…n
1.1.4 Guidance
1.1.4.1 Guidance Integration, Assembly, Test and Checkout
1.1.4.2 Dome Assembly
1.1.4.3 Seeker Assemblies
1.1.4.4 Guidance Software Release 1…n
1.1.4.5 Other Guidance Subsystems 1…n (Specify)
1.1.5 Navigation
1.1.5.1 Navigation, Integration, Assembly, Test and Checkout
1.1.5.2 Sensor Assemblies
1.1.5.3 Navigation Software Release 1…n
1.1.5.4 Other Navigation Subsystems 1…n (Specify)
1.1.6 Controls
1.1.6.1 Controls Integration, Assembly, Test and Checkout
1.1.6.2 Primary Structure
1.1.6.3 Fin/Canard Deployment System
1.1.6.4 Actuators
1.1.6.5 Control Power
1.1.6.6 Controls Software Release 1…n
1.1.6.7 Other Controls Subsystems 1…n (Specify)
1.1.7 Communications
1.1.7.1 Communications Integration, Assembly, Test and Checkout
1.1.7.2 Antenna Assembly
1.1.7.3 Communications Software Release 1…n
1.1.7.4 Other Communications Subsystems 1…n (Specify)
1.1.8 Payload
1.1.8.1 Payload Integration, Assembly, Test and Checkout
1.1.8.2 Target Defeat Mechanism
1.1.8.3 Target Detection Device
1.1.8.4 Fuze
1.1.8.5 Payload Software Release 1…n
1.1.8.6 Other Payload Subsystems 1…n (Specify)
1.1.9 On Board Test Equipment
1.1.10 On Board Training Equipment
1.1.11 Auxiliary Equipment
1.1.12 Munition Software Release 1…n
1.1.13 Munition Integration, Assembly, Test and Checkout
1.2 Encasement Device
1.2.1 Encasement Device Integration, Assembly, Test and Checkout
1.2.2 Encasement Device Structure
1.2.3 Encasement Device Software Release 1…n
1.2.4 Other Encasement Device Subsystems 1…n (Specify)
1.3 Launch System
1.3.1 Launch System Integration, Assembly, Test and Checkout
1.3.2 Launcher
1.3.3 Carriage
1.3.4 Fire Control
1.3.5 Ready Magazine
1.3.6 Adapter Kits
1.3.7 Launch System Software Release 1…n
1.3.8 Other Launch System 1…n
1.4 Ordnance System Software Release 1…n
1.5 Ordnance System Integration, Assembly, Test and Checkout
1.6 System Engineering
1.7 Program Management
1.8 System Test and Evaluation
1.8.1 Development Test and Evaluation
1.8.2 Operational Test and Evaluation
1.8.3 Mock-ups / System Integration Labs (SILs)
1.8.4 Test and Evaluation Support
1.8.5 Test Facilities
1.9 Training
1.9.1 Equipment
1.9.2 Services
1.9.3 Facilities

1.10		Data	
1.10.1			Technical Publications
1.10.2			Engineering Data
1.10.3			Management Data
1.10.4			Support Data
1.10.5			Data Depository
1.11		Peculiar Support Equipment	
1.11.1			Test and Measurement Equipment
1.11.2			Support and Handling Equipment
1.12		Common Support Equipment	
1.12.1			Test and Measurement Equipment
1.12.2			Support and Handling Equipment
1.13		Operational/Site Activation	
1.13.1			System Assembly, Installation and Checkout on Site
1.13.2			Contractor Technical Support
1.13.3			Site Construction
1.13.4			Site/Ship/Vehicle Conversion
1.13.5			Sustainment/Interim Contractor Support
1.14		Industrial Facilities	
1.14.1			Construction/Conversion/Expansion
1.14.2			Equipment Acquisition or Modernization
1.14.3			Maintenance (Industrial Facilities)
1.15		Initial Spares and Repair Parts	

WBS Structure for Sea Systems

WBS #	Level 1	Level 2	Level 3
1.0	Sea System		
1.1		Ship	
1.1.1			Hull Structure
1.1.2			Propulsion Plant
1.1.3			Electric Plant
1.1.4			Command, Communications and Surveillance
1.1.5			Auxiliary Systems
1.1.6			Outfit and Furnishings
1.1.7			Armament
1.1.8			Total Ship Integration/Engineering
1.1.9			Ship Assembly and Support Services
1.2		System Engineering	
1.3		Program Management	
1.4		System Test and Evaluation	
1.4.1			Development Test and Evaluation
1.4.2			Operational Test and Evaluation
1.4.3			Mock-ups / System Integration Labs (SILs)
1.4.4			Test and Evaluation Support
1.4.5			Test Facilities
1.5		Training	
1.5.1			Equipment
1.5.2			Services
1.5.3			Facilities
1.6		Data	
1.6.1			Technical Publications
1.6.2			Engineering Data
1.6.3			Management Data
1.6.4			Support Data
1.6.5			Data Depository
1.7		Peculiar Support Equipment	
1.7.1			Test and Measurement Equipment
1.7.2			Support and Handling Equipment
1.8		Common Support Equipment	
1.8.1			Test and Measurement Equipment
1.8.2			Support and Handling Equipment
1.9		Operational/Site Activation	
1.9.1			System Assembly, Installation and Checkout on Site
1.9.2			Contractor Technical Support
1.9.3			Site Construction
1.9.4			Site/Ship/Vehicle Conversion
1.9.5			Sustainment/Interim Contractor Support
1.10		Industrial Facilities	
1.10.1			Construction/Conversion/Expansion

1.10.2 Equipment Acquisition or Modernization
1.10.3 Maintenance (Industrial Facilities)
1.11 Initial Spares and Repair Parts

WBS Structure for Space Systems

WBS # Level 1 Level 2 Level 3 Level 4 Level 5
1.0 Space System
1.1 SEIT/PM and Support Equipment (1…s) 1
1.1.1 Systems Engineering
1.1.2 Assembly, Integration and Test
1.1.3 Program Management
1.1.4 Support Equipment
1.2 Space Vehicle 1..n (Specify)2
1.2.1 SEIT/PM and Support Equipment
1.2.1.1 Systems Engineering
1.2.1.2 Assembly, Integration and Test
1.2.1.3 Program Management
1.2.1.4 Support Equipment
1.2.2 Bus
1.2.2.1 SEIT/PM and Support Equipment
1.2.2.1.1 Systems Engineering
1.2.2.1.2 Assembly, Integration and Test
1.2.2.1.3 Program Management
1.2.2.1.4 Support Equipment
1.2.2.2 Structures and Mechanisms (SMS)
1.2.2.2.1 SEPM
1.2.2.2.2 Assembly, Integration and Test
1.2.2.2.3 Support Equipment
1.2.2.2.4 Structures
1.2.2.2.5 Mechanisms and Pyrotechnics
1.2.2.2.6 SMS Other
1.2.2.3 Thermal Control (TCS)
1.2.2.3.1 SEPM
1.2.2.3.2 Assembly, Integration and Test
1.2.2.3.3 Support Equipment
1.2.2.3.4 Cryogenic Devices
1.2.2.3.5 Liquid Loops
1.2.2.3.6 Electric Coolers
1.2.2.3.7 Heaters, Thermisters and Thermostats
1.2.2.3.8 Passive Devices
1.2.2.3.9 TCS Other
1.2.2.4 Electrical Power (EPS)
1.2.2.4.1 SEPM
1.2.2.4.2 Assembly, Integration and Test
1.2.2.4.3 Support Equipment
1.2.2.4.4 Solar Array
1.2.2.4.5 Solar Array Positioner
1.2.2.4.6 Radioisotope Thermionic Generator
1.2.2.4.7 Other Power Sources
1.2.2.4.8 Power Control, Switching and Distribution Electronics
1.2.2.4.9 Power Conditioning, Conversion and Regulation
1.2.2.4.10 Power Dissipation Devices
1.2.2.4.11 Rechargeable Batteries
1.2.2.4.12 Charge Control Electronics
1.2.2.4.13 Harnesses and Cables
1.2.2.4.14 EPS Other
1.2.2.5 Attitude Control (ACS)
1.2.2.5.1 SEPM
1.2.2.5.2 Assembly, Integration and Test
1.2.2.5.3 Support Equipment
1.2.2.5.4 Star Tracker/Sensors 1…n (Specify)
1.2.2.5.5 Earth (Horizon) Sensors 1…n (Specify)
1.2.2.5.6 Sun Sensors 1…n (Specify)
1.2.2.5.7 Magnetometers
1.2.2.5.8 Global Positioning System (GPS) Receiver
1.2.2.5.9 Inertial Reference Unit-IRU / Inertial Measurement Unit-IMU 1…n (Specify)
1.2.2.5.10 Rate Gyros 1…n (Specify)
1.2.2.5.11 Accelerometers 1…n (Specify)
1.2.2.5.12 Bearing and Power Transfer Assy (BAPTA)

1.2.2.5.13 Attitude Control Wheels 1…n (Specify)
1.2.2.5.14 Magnetic Control Devices
1.2.2.5.15 Spin Control Devices
1.2.2.5.16 Control Electronics 1…n (Specify)
1.2.2.5.17 ACS Other
1.2.2.6 Propulsion 1..n (Specify)
1.2.2.6.1 SEPM
1.2.2.6.2 Assembly, Integration and Test
1.2.2.6.3 Support Equipment
1.2.2.6.4 Tanks 1…n (Specify)
1.2.2.6.5 Plumbing
1.2.2.6.6 Thrusters 1…n (Specify)
1.2.2.6.7 Solid Rocket Motors
1.2.2.6.8 Liquid Propellant and Pressurant
1.2.2.6.9 Power Electronics
1.2.2.6.10 Propulsion Other
1.2.2.7 Telemetry, Tracking, and Command (TTandC)
1.2.2.7.1 SEPM
1.2.2.7.2 Assembly, Integration and Test
1.2.2.7.3 Support Equipment
1.2.2.7.4 Antennas
1.2.2.7.5 Passive Signal Flow Control
1.2.2.7.6 Transmitter/Receiver/Transceiver/Transponder 1..n (Specify)
1.2.2.7.7 Modulators/Demodulators/Modems
1.2.2.7.8 Amplifiers
1.2.2.7.9 Frequency Upconverter/Downconverter
1.2.2.7.10 Computers and Processors 1…n (Specify)
1.2.2.7.11 Command/Telemetry Units 1…n (Specify)
1.2.2.7.12 Command Sensors 1…n (Specify)
1.2.2.7.13 Frequency and Timing
1.2.2.7.14 Signal Conditioners
1.2.2.7.15 Communications Security 1…n (Specify)
1.2.2.7.16 Data Storage, Handling and Interface 1…n (Specify)
1.2.2.7.17 TTandC Other
1.2.2.8 Bus Flight Software
1.2.2.8.1 SEPM
1.2.2.8.2 Assembly, Integration and Test
1.2.2.8.3 Support Equipment
1.2.2.8.4 CSCI 1…n (Specify)
1.2.3 SEIT/PM and Support Equipment (If applicable for integration of Multiple Payloads)
1.2.3.1 Systems Engineering
1.2.3.2 Assembly, Integration and Test
1.2.3.3 Program Management
1.2.3.4 Support Equipment
1.2.4 Payload 1...n (Specify)
1.2.4.1 SEIT/PM and Support Equipment
1.2.4.1.1 Systems Engineering
1.2.4.1.2 Assembly, Integration and Test
1.2.4.1.3 Program Management
1.2.4.1.4 Support Equipment
1.2.4.2 Structures and Mechanisms
1.2.4.2.1 SEPM
1.2.4.2.2 Assembly, Integration and Test
1.2.4.2.3 Support Equipment
1.2.4.2.4 Structures
1.2.4.2.5 Mechanisms and Pyrotechnics
1.2.4.2.6 Structures and Mechanisms Other
1.2.4.3 Thermal Control
1.2.4.3.1 SEPM
1.2.4.3.2 Assembly, Integration and Test
1.2.4.3.3 Support Equipment
1.2.4.3.4 Cryogenic Devices
1.2.4.3.5 Liquid Loops
1.2.4.3.6 Electric Coolers
1.2.4.3.7 Electric Heaters, Thermisters and Thermostats
1.2.4.3.8 Passive Devices
1.2.4.3.9 Sun Shields
1.2.4.3.10 Thermal Control Other
1.2.4.4 Electrical Power
1.2.4.4.1 SEPM

1.2.4.4.2 Assembly, Integration and Test
1.2.4.4.3 Support Equipment
1.2.4.4.4 Power Sources
1.2.4.4.5 Power Control Switching and Distribution Electronics
1.2.4.4.6 Power Conditioning, Conversion and Regulation
1.2.4.4.7 Harnesses and Cables
1.2.4.4.8 Electrical Power Other
1.2.4.5 Pointing, Command, and Control Interface
1.2.4.5.1 SEPM
1.2.4.5.2 Assembly, Integration and Test
1.2.4.5.3 Support Equipment
1.2.4.5.4 Computers and Processors 1…n (Specify)
1.2.4.5.5 Command/Telemetry Units 1…n (Specify)
1.2.4.5.6 Control Electronics 1...n (Specify)
1.2.4.5.7 Pointing Sensors 1…n (Specify)
1.2.4.5.8 Payload Positioners1...n (Specify)
1.2.4.5.9 Security, Encryption and Decryption Devices1...n (Specify)
1.2.4.5.10 Data Storage, Handling and Interface 1…n (Specify)
1.2.4.5.11 Multifunctional Digital Electronic Boxes 1…n (Specify)
1.2.4.5.12 Pointing, Command, and Control Interface Other
1.2.4.6 Payload Antenna1..n (Specify)
1.2.4.6.1 SEPM
1.2.4.6.2 Assembly, Integration and Test
1.2.4.6.3 Support Equipment
1.2.4.6.4 Structures and Mechanisms
1.2.4.6.5 Antenna Positioners
1.2.4.6.6 Reflector/Horn1…n (Specify)
1.2.4.6.7 Feed1…n (Specify)
1.2.4.6.8 Waveguide/Coax/Cabling
1.2.4.6.9 Transmit/Receive Modules
1.2.4.6.10 Antenna Other
1.2.4.7 Payload Signal Electronics
1.2.4.7.1 SEPM
1.2.4.7.2 Assembly, Integration and Test
1.2.4.7.3 Support Equipment
1.2.4.7.4 Passive Signal Flow Control
1.2.4.7.5 Transmitter/Receiver/Transceiver/Transponder 1…n (Specify)
1.2.4.7.6 Modulators/Demodulators/Modems 1…n (Specify)
1.2.4.7.7 Multiplexers/Demultiplexers 1…n (Specify)
1.2.4.7.8 Amplifiers 1…n (Specify)
1.2.4.7.9 Frequency Upconverters/Downconverters 1…n (Specify)
1.2.4.7.10 Frequency and Timing 1…n (Specify)
1.2.4.7.11 Signal Conditioners 1…n (Specify)
1.2.4.7.12 Multifunctional Signal Electronic Boxes 1…n (Specify)
1.2.4.7.13 Signal Electronics Other
1.2.4.8 Optical Assembly
1.2.4.8.1 SEPM
1.2.4.8.2 Assembly, Integration and Test
1.2.4.8.3 Support Equipment
1.2.4.8.4 Structure/Outerbarrel/Cover
1.2.4.8.5 Mirrors and Optics 1…n (Specify)
1.2.4.8.6 Aft Optics Assembly
1.2.4.8.7 Alignment and Calibration 1…n (Specify)
1.2.4.8.8 Optical Assembly Other
1.2.4.9 Sensor
1.2.4.9.1 SEPM
1.2.4.9.2 Assembly, Integration and Test
1.2.4.9.3 Support Equipment
1.2.4.9.4 Enclosure 1..n (Specify)
1.2.4.9.5 Focal Plane Array 1…n (Specify)
1.2.4.9.6 Sensor Positioners 1…n (Specify)
1.2.4.9.7 Sensor Electronics 1…n (Specify)
1.2.4.9.8 Alignment and Calibration 1…n (Specify)
1.2.4.9.9 Magnetometer (1…n (Specify))
1.2.4.9.10 Spectrometer 1…n (Specify)
1.2.4.9.11 Radiometer 1…n (Specify)
1.2.4.9.12 Camera 1…n (Specify)
1.2.4.9.13 Sounder 1…n (Specify)
1.2.4.9.14 Other Sensor Types 1…n (Specify)
1.2.4.9.15 Mission Sensor Other

1.2.4.10 Payload Flight Software
1.2.4.10.1 SEPM
1.2.4.10.2 Assembly, Integration and Test
1.2.4.10.3 Support Equipment
1.2.4.10.4 CSCI 1…n (Specify)
1.2.4.11 Payload Other
1.2.5 Booster Adapter
1.2.6 Space Vehicle Storage
1.2.7 Launch Systems Integration (LSI)
1.2.8 Launch Operations
1.2.9 Mission Operations Support
1.2.10 Space Vehicle Other
1.3 Ground Operations and Processing Center 1…n (Specify) 2
1.3.1 SEIT/PM and Support Equipment
1.3.1.1 Systems Engineering
1.3.1.2 Assembly, Integration and Test
1.3.1.3 Program Management
1.3.1.4 Support Equipment
1.3.2 Function (1…F) 3
1.3.2.1 SEIT/PM and Support Equipment
1.3.2.1.1 Systems Engineering
1.3.2.1.2 Assembly, Integration and Test
1.3.2.1.3 Program Management
1.3.2.1.4 Support Equipment
1.3.2.2 COTS Hardware
1.3.2.2.1 SEPM
1.3.2.2.2 Assembly, Integration and Test
1.3.2.2.3 Support Equipment
1.3.2.2.4 Workstations 1…n (Specify)
1.3.2.2.5 Servers 1…n (Specify)
1.3.2.2.6 Storage and Archive 1…n (Specify)
1.3.2.2.7 network Equipment
1.3.2.2.8 Interface Equipment
1.3.2.2.9 Security Encryption/Decryption 1…n (Specify)
1.3.2.2.10 Data Processing 1…n (Specify)
1.3.2.2.11 COTS Hardware Other
1.3.2.2.12 Pre-Ops Maintenance 1…n (Specify)
1.3.2.3 Custom Hardware
1.3.2.3.1 SEPM
1.3.2.3.2 Assembly, Integration and Test
1.3.2.3.3 Support Equipment
1.3.2.3.4 Custom Hardware Configured Item 1…n (Specify)
1.3.2.3.5 Pre-Ops Maintenance 1…n (Specify)
1.3.2.4 GOPC Software
1.3.2.4.1 SEPM
1.3.2.4.2 Assembly, Integration and Test
1.3.2.4.3 Support Equipment
1.3.2.4.4 CSCI 1..n (Specify)
1.3.2.4.5 Pre-Ops Maintenance 1…n (Specify)
1.3.2.5 Pre-Operations Mission Support
1.4 Ground Terminal/Gateway (GT) 1…n (Specify) 2
1.4.1 SEIT/PM and Support Equipment
1.4.1.1 Systems Engineering
1.4.1.2 Assembly, Integration and Test
1.4.1.3 Program Management
1.4.1.4 Support Equipment
1.4.2 Antenna 1..n (Specify)
1.4.2.1 SEPM
1.4.2.2 Assembly, Integration and Test
1.4.2.3 Support Equipment
1.4.2.4 Pedestal
1.4.2.5 Radome
1.4.2.6 Other Structure and Mechanisms
1.4.2.7 Aperture
1.4.2.8 Feed 1...n (Specify)
1.4.2.9 Waveguide/Coax/Cabling
1.4.2.10 Antenna Other
1.4.3 Optical Communication Assembly 1...n (Specify)
1.4.3.1 SEPM
1.4.3.2 Assembly, Integration and Test

1.4.3.3 Support Equipment
1.4.3.4 Structure/Outerbarrel/Cover
1.4.3.5 Mirror/Optics 1..n (Specify)
1.4.3.6 Aft Optics and Bench
1.4.3.7 Alignment Sensors/Calibration
1.4.3.8 Optical Assembly Other
1.4.4 RF Electronics (Band 1…n (Specify))
1.4.4.1 SEPM
1.4.4.2 Assembly, Integration and Test
1.4.4.3 Support Equipment
1.4.4.4 Passive Signal Flow Control
1.4.4.5 Transmitter/Receiver/Transceiver/Transponder 1…n (Specify)
1.4.4.6 Modulators/Demodulators/Modems 1…n (Specify)
1.4.4.7 Multiplexers/Demultiplexers 1…n (Specify)
1.4.4.8 Power Amplifiers 1…n (Specify)
1.4.4.9 Frequency Upconverters/Downconverters 1…n (Specify)
1.4.4.10 Signal Conditioners 1…n (Specify)
1.4.4.11 Signal Electronic Boxes 1…n (Specify)
1.4.4.12 Focal Plane Array 1…n (Specify)
1.4.4.13 RF Electronics Other
1.4.5 Timing
1.4.5.1 SEPM
1.4.5.2 Assembly, Integration and Test
1.4.5.3 Support Equipment
1.4.5.4 Receiver
1.4.5.5 Antenna 1...n (Specify)
1.4.5.6 Frequency and Timing Generators
1.4.5.7 Amplifier and Distribution 1…n (Specify)
1.4.5.8 Timing Other
1.4.6 Baseband-network
1.4.6.1 SEPM
1.4.6.2 Assembly, Integration and Test
1.4.6.3 Support Equipment
1.4.6.4 Switches/Hubs and Routers
1.4.6.5 network Interface and Other Hardware
1.4.6.6 Modems
1.4.6.7 Security/Encryption and Decryption Devices 1...n (Specify)
1.4.6.8 Baseband-network Electronic Boxes 1…n (Specify)
1.4.6.9 Baseband-network Other
1.4.7 Monitor and Control Hardware
1.4.7.1 SEPM
1.4.7.2 Assembly, Integration and Test
1.4.7.3 Support Equipment
1.4.7.4 Workstations 1…n (Specify)
1.4.7.5 Servers 1…n (Specify)
1.4.7.6 Hardware Configured Item 1…n (Specify)
1.4.8 GT Software
1.4.8.1 SEPM
1.4.8.2 Assembly, Integration and Test
1.4.8.3 Support Equipment
1.4.8.4 CSCI 1…n (Specify)
1.4.9 Pre-Operations Maintenance 1…n (Specify)
1.4.10 Pre-Operations Mission Support
1.5 External network (T-COMM)
1.5.1 SEIT/PM and Support Equipment
1.5.1.1 Systems Engineering
1.5.1.2 Assembly, Integration and Test
1.5.1.3 Program Management
1.5.1.4 Support Equipment
1.5.2 Leased Circuits
1.5.2.1 Leased Circuit 1…n (Specify)
1.5.3 Purchased Circuits
1.5.3.1 Purchased Circuit 1…n (Specify)
1.5.3.2 Pre-Ops Maintenance 1…n (Specify)
1.6 User Equipment
1.6.1 SEIT/PM and Support Equipment
1.6.1.1 Systems Engineering
1.6.1.2 Assembly, Integration and Test
1.6.1.3 Program Management
1.6.1.4 Support Equipment

1.6.2 Equipment 1..n (Specify)
1.6.2.1 SEPM
1.6.2.2 Assembly, Integration and Test
1.6.2.3 Support Equipment
1.6.2.4 Hardware Configured Item 1...n (Specify)
1.6.2.5 CSCI 1…n (Specify)
1.6.3 Pre-Ops Maintenance 1…n (Specify)
1.7 Facilities 1..n (Specify)
1.7.1 SEIT/PM and Support Equipment
1.7.1.1 Systems Engineering
1.7.1.2 Assembly, Integration and Test
1.7.1.3 Program Management
1.7.1.4 Support Equipment
1.7.2 Site Preparation
1.7.2.1 SEPM
1.7.2.2 Assembly, Integration and Test
1.7.2.3 Support Equipment
1.7.2.4 Graded Land
1.7.2.5 Roads
1.7.2.6 Pads
1.7.2.7 Retaining Walls / Fencing
1.7.2.8 Utilities
1.7.2.9 Site Preparation Other
1.7.3 Landscape
1.7.4 Buildings 1…n (Specify)
1.7.4.1 SEPM
1.7.4.2 Assembly, Integration and Test
1.7.4.3 Support Equipment
1.7.4.4 Foundation and Sub Structure
1.7.4.5 Superstructure and Finishing
1.7.4.6 Buildings Other
1.7.5 Equipment and Building Fit Out 1...n (Specify)
1.7.5.1 SEPM
1.7.5.2 Assembly, Integration and Test
1.7.5.3 Support Equipment
1.7.5.4 HVAC
1.7.5.5 Power Conditioning/UPS
1.7.5.6 network Wiring/Cable Trays
1.7.5.7 Generators
1.7.5.8 Computer Flooring
1.7.5.9 Appliances
1.7.5.10 Furniture
1.7.5.11 Equipment and Building Fit Out Other
1.7.6 Pre-Operations Maintenance 1…n (Specify)
1.8 Vehicles and Shelters
1.8.1 SEIT/PM and Support Equipment
1.8.1.1 Systems Engineering
1.8.1.2 Assembly, Integration and Test
1.8.1.3 Program Management
1.8.1.4 Support Equipment
1.8.2 Vehicles
1.8.2.1 Vehicle 1…n (Specify)
1.8.3 Shelters
1.8.3.1 Shelter 1...n (Specify)
1.8.4 Pre-Operations Maintenance 1…n (Specify)
1.9 Insurance
1.9.1 SEPM
1.9.2 Insurance Policy
1.9.3 Insurance Settlements
1.10 Task Orders
1.10.1 Task Order 1...n (Specify)
1.11 Orbital Transfer Vehicle (OTV)
1.12 Launch Vehicle 1...n (Specify)

WBS Structure for Surface Vehicle Systems

WBS # Level 1 Level 2 Level 3
1.0 Surface Vehicle System
1.1 Primary Vehicle
1.1.1 Primary Vehicle Integration, Assembly, Test and Checkout

1.1.2			Hull/Frame/Body/Cab
1.1.3			System Survivability
1.1.4			Turret Assembly
1.1.5			Suspension/Steering
1.1.6			Vehicle Electronics
1.1.7			Power Package/Drive Train
1.1.8			Auxiliary Automotive
1.1.9			Fire Control
1.1.10			Armament
1.1.11			Automatic Ammunition Handling
1.1.12			Navigation and Remote Piloting
1.1.13			Special Equipment
1.1.14			Communications
1.1.15			Primary Vehicle Software Release 1…n
1.1.16			Other Vehicle Subsystems 1…n (Specify)
1.2		Remote Control System (UGV specific)	
1.2.1			Remote Control System Integration, Assembly, Test and Checkout
1.2.2			Ground Control Systems
1.2.3			Command and Control Subsystem
1.2.4			Remote Control System Software Release 1…n
1.2.5			Other Remote Control System 1…n (Specify)
1.3		Secondary Vehicle	
1.4		System Engineering	
1.5		Program Management	
1.6		System Test and Evaluation	
1.6.1			Development Test and Evaluation
1.6.2			Operational Test and Evaluation
1.6.3			Mock-ups / System Integration Labs (SILs)
1.6.4			Test and Evaluation Support
1.6.5			Test Facilities
1.7		Training	
1.7.1			Equipment
1.7.2			Services
1.7.3			Facilities
1.8		Data	
1.8.1			Technical Publications
1.8.2			Engineering Data
1.8.3			Management Data
1.8.4			Support Data
1.8.5			Data Depository
1.9		Peculiar Support Equipment	
1.9.1			Test and Measurement Equipment
1.9.2			Support and Handling Equipment
1.10		Common Support Equipment	
1.10.1			Test and Measurement Equipment
1.10.2			Support and Handling Equipment
1.11		Operational/Site Activation	
1.11.1			System Assembly, Installation and Checkout on Site
1.11.2			Contractor Technical Support
1.11.3			Site Construction
1.11.4			Site/Ship/Vehicle Conversion
1.11.5			Sustainment/Interim Contractor Support
1.12		Industrial Facilities	
1.12.1			Construction/Conversion/Expansion
1.12.2			Equipment Acquisition or Modernization
1.12.3			Maintenance (Industrial Facilities)
1.13		Initial Spares and Repair Parts	

WBS Structure for UAV Systems

WBS #	Level 1	Level 2	Level 3	Level 4
1.0	UAV System			
1.1		Air Vehicle		
1.1.1			Airframe	
1.1.1.1				Airframe Integration, Assembly, Test and Checkout
1.1.1.2				Fuselage
1.1.1.3				Wing
1.1.1.4				Empennage
1.1.1.5				Nacelle
1.1.1.6				Other Airframe Components 1…n (Specify)

1.1.2 Propulsion
1.1.3 Vehicle Subsystems
1.1.3.1 Vehicle Subsystems Integration, Assembly, Test and Checkout
1.1.3.2 Flight Control Subsystem
1.1.3.3 Auxiliary Power Subsystem
1.1.3.4 Hydraulic Subsystem
1.1.3.5 Electrical Subsystem
1.1.3.6 Environmental Control Subsystem
1.1.3.7 Fuel Subsystem
1.1.3.8 Landing Gear
1.1.3.9 Rotor Group
1.1.3.10 Drive System
1.1.3.11 Vehicle Subsystems Software Release 1…n
1.1.3.12 Other Vehicle Subsystems 1…n (Specify)
1.1.4 Avionics
1.1.4.1 Avionics Integration, Assembly, Test and Checkout
1.1.4.2 Communication/Identification
1.1.4.3 Navigation/Guidance
1.1.4.4 Automatic Flight Control
1.1.4.5 Health Monitoring System
1.1.4.6 Stores Management
1.1.4.7 Mission Computer/Processing
1.1.4.8 Fire Control
1.1.4.9 Avionics Software Release 1…n
1.1.4.10 Other Avionics Subsystems 1…n (Specify)
1.1.5 Auxiliary Equipment
1.1.6 Air Vehicle Software Release 1…n
1.1.7 Air Vehicle Integration, Assembly, Test and Checkout
1.2 Payload
1.2.1 Payload Integration, Assembly, Test and Checkout
1.2.2 Survivability Payload 1...n (Specify)
1.2.3 Reconnaissance Payload 1...n(Specify)
1.2.4 Electronic Warfare Payload 1...n (Specify)
1.2.5 Armament/Weapons Delivery Payload 1..N (Specify)
1.2.6 Payload Software Release 1…n
1.2.7 Other Payload 1…n (Specify)
1.3 Ground/Host Segment
1.3.1 Ground Segment Integration, Assembly, Test and Checkout
1.3.2 Ground Control Systems
1.3.3 Command and Control Subsystem
1.3.4 Launch and Recovery Equipment
1.3.5 Transport Vehicles
1.3.6 Ground Segment Software Release 1…n
1.3.7 Other Ground/Host Segment 1…n (Specify)
1.4 UAV Software Release 1…n
1.5 UAV System Integration, Assembly, Test and Checkout
1.6 System Engineering
1.7 Program Management
1.8 System Test and Evaluation
1.8.1 Development Test and Evaluation
1.8.2 Operational Test and Evaluation
1.8.3 Mock-ups/System Integration Labs (SILs)
1.8.4 Test and Evaluation Support
1.8.5 Test Facilities
1.9 Training
1.9.1 Equipment
1.9.2 Services
1.9.3 Facilities
1.10 Data
1.10.1 Technical Publications
1.10.2 Engineering Data
1.10.3 Management Data
1.10.4 Support Data
1.10.5 Data Depository
1.11 Peculiar Support Equipment
1.11.1 Test and Measurement Equipment
1.11.2 Support and Handling Equipment
1.12 Common Support Equipment
1.12.1 Test and Measurement Equipment
1.12.2 Support and Handling Equipment

1.13		Operational/Site Activation		
1.13.1			System Assembly, Installation and Checkout on Site	
1.13.2			Contractor Technical Support	
1.13.3			Site Construction	
1.13.4			Site/Ship/Vehicle Conversion	
1.13.5			Sustainment/Interim Contractor Support	
1.14		Industrial Facilities		
1.14.1			Construction/Conversion/Expansion	
1.14.2			Equipment Acquisition or Modernization	
1.14.3			Maintenance (Industrial Facilities)	
1.15		Initial Spares and Repair Parts		

WBS Structure for Unmanned Maritime Systems

WBS #	Level 1	Level 2	Level 3	Level 4
1.0	Unmanned Maritime System			
1.1		Maritime Vehicle		
1.1.1			Hull and Structure	
1.1.2			Propulsion	
1.1.3			Energy Storage / Conversion	
1.1.4			Electrical Power	
1.1.5			Vehicle Command and Control	
1.1.5.1				Vehicle Command and Control Integration, Assembly, Test and Checkout
1.1.5.2				Mission Control
1.1.5.3				Navigation
1.1.5.4				Guidance and Control
1.1.5.5				Health Status Monitoring
1.1.5.6				Rendezvous, Homing and Docking Systems
1.1.5.7				Fire Control
1.1.5.8				Vehicle Command and Control Software Release 1…n
1.1.5.9				Other Vehicle Command and Control 1…n (Specify)
1.1.6			Surveillance	
1.1.7			Communications/Identification	
1.1.8			Ship Control Systems	
1.1.8.1				Ship Control System Integration, Assembly, Test and Checkout
1.1.8.2				Steering and Dive Control
1.1.8.3				Hovering and Depth Control
1.1.8.4				Ballast and Trim
1.1.8.5				Maneuvering System
1.1.8.6				Ship Control Systems Software Release 1…n
1.1.8.7				Other Ship Control Systems 1…n (Specify)
1.1.9			Auxiliary Systems	
1.1.9.1				Auxiliary Equipment Integration, Assembly, Test and Checkout
1.1.9.2				Emergency Systems
1.1.9.3				Launch and Recovery System
1.1.9.4				Environmental Control System
1.1.9.5				Anchoring, Mooring and Towing
1.1.9.6				Miscellaneous Fluid Systems
1.1.9.7				Auxiliary Systems Software Release 1…n
1.1.9.8				Other Auxiliary Systems 1…n (Specify)
1.1.10			Vehicle Software Release 1…n	
1.1.11			Vehicle Integration, Assembly, Test and Checkout	
1.2		Payload 1…n		
1.2.1			Payload Integration, Assembly, Test and Checkout	
1.2.2			Survivability Payload 1…n (Specify)	
1.2.3			Intelligence, Surveillance Reconnaissance (ISR) Payload 1...n (Specify)	
1.2.4			Armament/Weapons Delivery Payload 1…n (Specify)	
1.2.5			Mission Payload 1…n (Specify)	
1.2.7			Payload Software Release 1…n	
1.2.8			Other Payload 1…n (Specify)	
1.3		Shipboard Segment		
1.3.1			Shipboard Segment Integration, Assembly, Test and Checkout	
1.3.2			Shipboard UM Command and Control Subsystem	
1.3.2.1				UM Control Console(s)
1.3.2.2				Payload Control Console(s)
1.3.3			Shipboard Communication Subsystem	
1.3.4			Shipboard Power Subsystem	
1.3.5			Launch and Recovery Equipment	
1.3.6			Storage Subsystems	
1.3.7			Vehicle Handling Equipment	

1.3.8 Shipboard (or Shore Based) Auxiliary Equipment
1.3.9 Shipboard Software Release 1…n
1.3.10 Other Shipboard Segment 1…n (Specify)
1.4 Shore Segment (Duplicate any shipboard segment elements as appropriate)
1.5 Transportation Segment/Vehicles
1.6 UM System Software Release 1…n
1.7 UM System Integration, Assembly, Test and Checkout
1.8 System Engineering
1.9 Program Management
1.10 System Test and Evaluation
1.10.1 Development Test and Evaluation
1.10.2 Operational Test and Evaluation
1.10.3 Mock-ups/System Integration Labs (SILs)
1.10.4 Test and Evaluation Support
1.10.5 Test Facilities
1.11 Training
1.11.1 Equipment
1.11.2 Services
1.11.3 Facilities
1.12 Data
1.12.1 Technical Publications
1.12.2 Engineering Data
1.12.3 Management Data
1.12.4 Support Data
1.12.5 Data Depository
1.13 Peculiar Support Equipment
1.13.1 Test and Measurement Equipment
1.13.2 Support and Handling Equipment
1.14 Common Support Equipment
1.14.1 Test and Measurement Equipment
1.14.2 Support and Handling Equipment
1.15 Operational/Site Activation
1.15.1 System Assembly, Installation and Checkout on Site
1.15.2 Contractor Technical Support
1.15.3 Site Construction
1.15.4 Site/Ship/Vehicle Conversion
1.15.5 Sustainment/Interim Contractor Support
1.16 Industrial Facilities
1.16.1 Construction/Conversion/Expansion
1.16.2 Equipment Acquisition or Modernization
1.16.3 Maintenance (Industrial Facilities)
1.17 Initial Spares and Repair Parts

WBS Structure for Launch Vehicle Systems

WBS # Level 1 Level 2 Level 3 Level 4
1.0 Launch Vehicle System
1.1 System Engineering, Integration, Test, Program Management (SEIT/PM)
1.1.1 System Engineering (SE)
1.1.2 Integration and Test
1.1.3 Program Management
1.2 Launch Vehicle
1.2.1 SEIT/PM
1.2.2 Stages 1…n (Specify)
1.2.2.1 SEIT/PM
1.2.2.2 Structures and Mechanisms
1.2.2.3 Propulsions System
1.2.2.4 Reaction Control System
1.2.2.5 Recovery System
1.2.2.6 Environmental Control System
1.2.2.7 Stage Peculiar Avionics
1.2.2.8 Other Systems 1…n (Specify)
1.2.3 Payload Accommodations 1…n (Specify)
1.2.3.1 SEIT/PM
1.2.3.2 Payload Fairing
1.2.3.3 Payload Adapter (Pedestals)
1.2.3.4 Mission Unique Hardware (Launch vehicle) 1…n (Specify)
1.2.4 Avionics
1.2.4.1 SEIT/PM
1.2.4.2 Guidance navigation and Control

1.2.4.3 Power
1.2.4.4 Data Acquisition and Telemetry
1.2.4.5 Range Tracking & Safety (Airborne)
1.2.4.6 Flight Software Release 1…n
1.2.4.7 Other Avionics 1…n (Specify)
1.3 Mission Integration and Analysis 1…f (Specify)
1.3.1 Mission Standard Integration & Analysis
1.3.2 Mission Unique Integration & Analysis 1...n (Specify)
1.4 Launch Operations Site 1...n (Specify)
1.4.1 SEIT/PM
1.4.2 Vehicle Processing and Checkout
1.4.3 Mission Services
1.4.3.1 Mission Unique Hardware (Launch Operations) 1…n (Specify)
1.4.3.2 Space Vehicle Processing
1.4.4 Launch
1.4.5 Flight Operations
1.4.6 Post Launch
1.4.6.1 Recovery Operations and Services
1.4.6.2 Post Launch Refurbishment
1.4.7 Site Maintenance
1.4.8 Base Support
1.4.9 Range Tracking & Safety (Ground)
1.4.9.1 Range Ground System
1.4.9.2 Range Operations
1.5 Launch Site 1…n (Specify)
1.5.1 SEIT/PM
1.5.2 Operational/Site Activation
1.5.3 Peculiar Support Equipment
1.5.4 Ground Command, Control and Communications (GC3)
1.5.4.1 SEIT/PM
1.5.4.2 Command, Control and Communication
1.5.4.3 Other Ground 1…n (Specify)
1.6 System Test and Evaluation
1.6.1 Development Test and Evaluation
1.6.2 Operational Test and Evaluation
1.6.3 Mock-ups/System Integration labs (SILs)
1.6.4 Test and Evaluation Support
1.6.5 Test Facilities
1.7 Training
1.7.1 Equipment
1.7.2 Services
1.7.3 Facilities
1.8 Data
1.8.1 Technical Publications
1.8.2 Engineering Data
1.8.3 Management Data
1.8.4 Support Data
1.8.5 Data Depository
1.9 Peculiar Support Equipment
1.9.1 Test and Measurement Equipment
1.9.2 Support and Handling Equipment
1.10 Common Support Equipment
1.10.1 Test and Measurement Equipment
1.10.2 Support and Handling Equipment
1.11 Industrial Facilities
1.11.1 Construction/Conversion/Expansion
1.11.2 Equipment Acquisition or Modernization
1.11.3 Maintenance (Industrial Facilities)
1.12 Initial Spares and Repair Parts

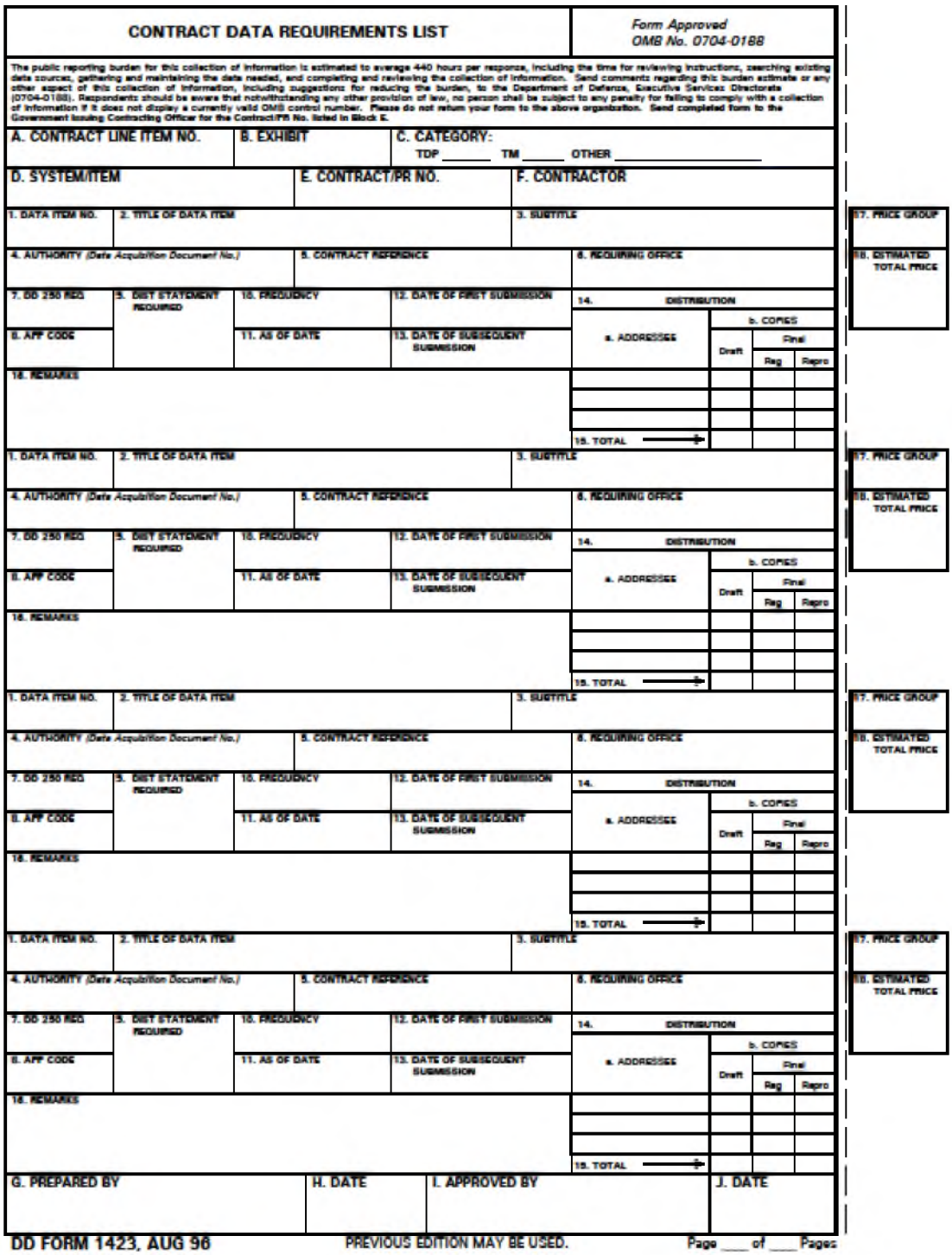
WBS Structure for AIS

WBS # Level 1 Level 2 Level 3 Level 4
1.0 Automated Information System (AIS)
1.1 Automated Information System Prime Mission Product Release/Increment X
1.1.1 Custom Application Software 1…n (Specify)
1.1.1.1 Subsystem Hardware
1.1.1.2 Subsystem Software CSCI 1…n (Specify)
1.1.1.3 Subsystem Software Integration, Assembly, Test and Checkout
1.1.2 Enterprise Service Element 1…n (Specify)

1.1.2.1 Enterprise Service Element Hardware
1.1.2.2 Enterprise Service Element Software CSCI 1...n (Specify)
1.1.2.3 Enterprise Service Element Integration, Assembly, Test and Checkout
1.1.3 Enterprise Information System 1…n (Specify)
1.1.3.1 Business Area Hardware
1.1.3.2 Business Area Software CSCI 1…n (Specify)
1.1.3.3 Business Area Integration, Assembly, Test and Checkout
1.1.4 External System Interface Development 1…n (Specify)
1.1.4.1 External System Interface Hardware
1.1.4.2 External System Interface Software CSCI 1…n (Specify)
1.1.4.3 External System Interface Integration, Assembly, Test and Checkout
1.1.5 AIS Platform Hardware
1.1.6 System Level Integration
1.2 System Engineering
1.3 Program Management
1.4 Change Management
1.5 System Test and Evaluation
1.5.1 Development Test and Evaluation
1.5.2 Operational Test and Evaluation
1.5.3 Mock-ups / System Integration Labs (SILs)
1.5.4 Test and Evaluation Support
1.5.5 Test Facilities
1.6 Training
1.6.1 Equipment
1.6.2 Services
1.6.3 Facilities
1.7 Data
1.7.1 Technical Publications
1.7.2 Engineering Data
1.7.3 Management Data
1.7.4 Support Data
1.7.5 Data Depository
1.8 Peculiar Support Equipment
1.8.1 Test and Measurement Equipment
1.8.2 Support and Handling Equipment
1.9 Common Support Equipment
1.9.1 Test and Measurement Equipment
1.9.2 Support and Handling Equipment
1.10 Operational/Site Activation
1.10.1 Site Type 1
1.10.1.1 Deployment Hardware and Software
1.10.1.2 User Documentation
1.10.1.3 Site Activation
1.10.1.4 User Training
1.10.1.5 Data Migration
1.10.1.6 Management/Engineering Support
1.10.1.7 Interim Logistics Support
1.11 Industrial Facilities
1.11.1 Construction/Conversion/Expansion
1.11.2 Equipment Acquisition or Modernization
1.11.3 Maintenance (Industrial Facilities)
1.12 Initial Spares and Repair Parts

Appendix C

Blank DD Form 1423 – this form defines the data required and the schedule delivery terms for the project under contract.



CONTRACT DATA REQUIREMENTS LIST

Form Approved
OMB No. 0704-0188

The public reporting burden for this collection of information is estimated to average 440 hours per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the burden, to the Department of Defense, Executive Services Directorate (0704-0188). Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. Please do not return your form to the above organization. Send completed form to the Government Issuing Contracting Officer for the Contract/PR No. listed in Block E.

A. CONTRACT LINE ITEM NO. | B. EXHIBIT | C. CATEGORY: TDP _____ TM _____ OTHER _____

D. SYSTEM/ITEM | E. CONTRACT/PR NO. | F. CONTRACTOR

1. DATA ITEM NO. | 2. TITLE OF DATA ITEM | 3. SUBTITLE | 17. PRICE GROUP | 18. ESTIMATED TOTAL PRICE

4. AUTHORITY (Data Acquisition Document No.) | 5. CONTRACT REFERENCE | 6. REQUIRING OFFICE

7. DD 250 REQ | 8. APP CODE | 9. DIST STATEMENT REQUIRED | 10. FREQUENCY | 11. AS OF DATE | 12. DATE OF FIRST SUBMISSION | 13. DATE OF SUBSEQUENT SUBMISSION

14. DISTRIBUTION | a. ADDRESSEE | b. COPIES: Draft; Final: Reg; Repro

16. REMARKS

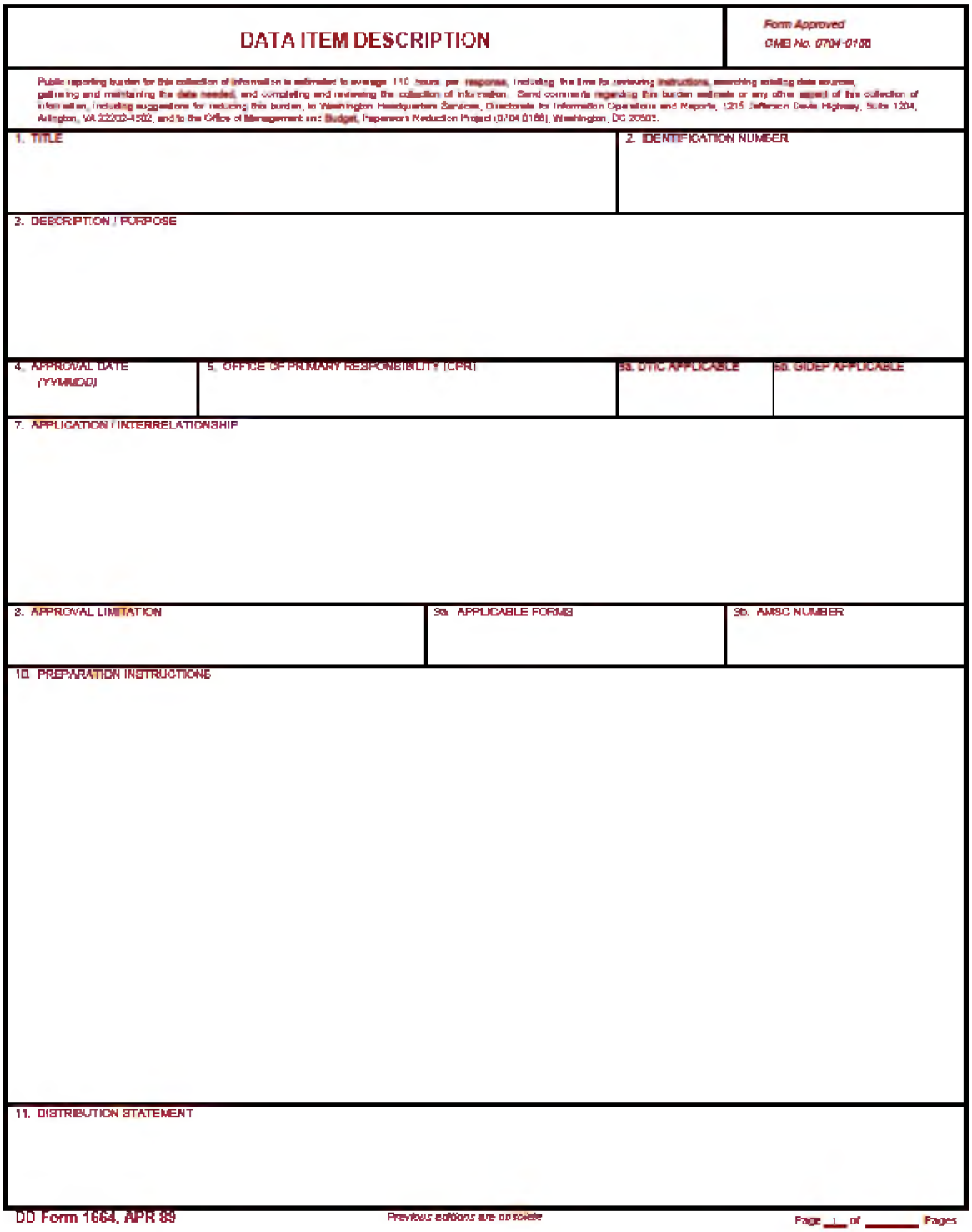
15. TOTAL

(Repeated for additional data items)

G. PREPARED BY | H. DATE | I. APPROVED BY | J. DATE

DD FORM 1423, AUG 96 PREVIOUS EDITION MAY BE USED. Page ___ of ___ Pages

Blank DD Form 1664 – this form defines the required content and format that the data specified in the DD Form 1423 must adhere to.



DATA ITEM DESCRIPTION

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 110 hours per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. TITLE

2. IDENTIFICATION NUMBER

3. DESCRIPTION / PURPOSE

4. APPROVAL DATE (YYMMDD)

5. OFFICE OF PRIMARY RESPONSIBILITY (OPR)

6a. DTIC APPLICABLE

6b. GIDEP APPLICABLE

7. APPLICATION / INTERRELATIONSHIP

8. APPROVAL LIMITATION

9a. APPLICABLE FORMS

9b. AMSC NUMBER

10. PREPARATION INSTRUCTIONS

11. DISTRIBUTION STATEMENT

DD Form 1664, APR 89 Previous editions are obsolete Page 1 of _____ Pages

MIL-STD-963B DID Repetitive Acquisition Sample – this form shows an example of a DID for use on a contract with repetitive acquisitions.

DATA ITEM DESCRIPTION

Title: TECHNICAL MANUAL RESEARCH AND ANALYSIS SOURCE DATA

Number: DI-TMSS-8XXX4
Approval Date: 19930720
AMSC Number: N6946
Limitation:
DTIC Applicable: Yes
GIDEP Applicable: Yes
DTIC Northwestern Regional Office at
Boston, ATTN: DTIC_BRNB
Building1103, 5 Wright Street
Hanscom AFB, MA 01731-3012
GIDEP Operations Center
Naval Warfare Assessment Center
PO Box 8000
Corona, CA 91718-8000
Office of Primary Responsibility: SH
Applicable Forms:
Use/relationship: The Technical Manual Research and Analysis Source Data will be used to obtain essential information from contractors for accomplishing required technical manual changes by Government publications personnel or through contractor technical writing concerns.

a. Information to be acquired through these data will include engineering change records, hardware modification records, engineering judgement records (EJRs), service experience records, and other related data.

b. This DID contains the format, content, and intended use information for the data product resulting from the work task described by 3.2.3.1 of MIL-PRF-XXXXXA, and is applicable to the acquisition of military systems, equipment, and facilities.

Requirements:

1. Reference documents. The applicable issue of the documents cited herein, including their approval dates and dates of any applicable amendments, notices, and revisions, shall be as cited in the current issue of the DODISS at the time of the solicitation.

2. Format. The Research and Analysis Source Data shall be in contractor's format.

3. Content. The Research and Analysis Source Data shall be presented in the style of the technical manual for which the changes are recommended specified in the contract. Pages shall be typewritten and double-spaced. Illustration changes shall be presented in textual descriptive form, marked-up illustrations, or by free-hand sketches that illustrate the required changes.

3.1 Introduction Section. This section shall contain a brief description of the changes, reason for changes, and a recapitulation of the requirements; also a listing of the technical manuals affected and any relevant information pertaining to related changes.

DI-TMSS-8XXX4

3.2 Required Change Section. This section shall contain a separate section for each technical manual for which changes are required. The sections shall be titled "Changes Required in Technical Manual Number _____, Book Dated _____, Changes Dated _____."

a. Each page of each section shall be identified with the applicable technical manual number. An introductory statement in each section shall identify any modifications for technical manuals that are incorporated in accordance with MIL-DTL-2XXX4.

b. The source data shall contain essential information that will enable publications personnel to accomplish all required technical manual changes. When an illustration which is used in more than one technical manual has been changed, the change shall be referenced in the other applicable Required Change Sections.

3.3 Research and Analysis. Engineering change records, modification records, service experience records, and all change information not yet incorporated in the technical manual(s) shall be included from past publication records.

3.4 Text Changes. Each recommended technical manual text change shall be identified by the paragraph number listed in the outstanding issue of the technical manual to be changed. New paragraphs to be added shall be identified by paragraph numbers in accordance with MIL-DTL-2XXX4.

3.5 Illustration Changes. Illustration changes shall be identified by figure numbers in the outstanding issue of the technical manual to be changed. New illustrations to be added shall be identified by new figure numbers in accordance with MIL-DTL-2XXX4. When illustration changes consist of only nomenclature changes, these changes may be identified by a textual description of the change(s) to be made.

3.6 Change Listings. Change listings shall include only part numbers to be added, part numbers to be changed, and part numbers to be deleted, as applicable.

4. End of DI-TMSS-8XXX4

MIL-STD-963B DID One-time Sample – this form shows an example of a DID for use on a contract with a one-time acquisition.

DATA ITEM DESCRIPTION

Title: GENERIC CODING SCHEME REPORT

Number: OT-5XXXX
Approval Date: 19880701
AMSC Number:
Limitation: DLA600-95-C-XXXX
DTIC Applicable:
GIDEP Applicable:
Office of Primary Responsibility: DO
Applicable Forms:
Use/relationship: The report on generic coding scheme for MIL-STD-961 describes the tagging structure (generic tags), the hierarchy or relationship of the tags, basic generic processing instructions, and error checking procedure which will be used for an in-process review of the coding scheme being developed to ensure that the scheme will meet the requirements of the contract.

This DID contains the format, content, and intended use information for the data product resulting from the work task described in the contract SOW. This DID is for one-time use for solicitation DLA600-95-C-XXXX.
Requirements:
1. Reference documents. The applicable issue of the documents cited herein, including their approval dates and dates of any applicable amendments, notices, and revisions, shall be as cited in the current issue of the DODISS at the time of the solicitation.

2. Format. The plan shall be in contractor's format.

3. Content. The report shall contain the following:

3.1. Names of elements developed from analysis of MIL-STD-961 and conforming documents.

3.2. Tag names.

3.3. Relationship or place in document hierarchy of tag; example could be the (DOCTYPE) element name and it is the highest element on the document tree.

3.4. Basic generic processing instructions: for example, the text associated with the (DOCTITLE) element is used to generate the running head on all left hand pages throughout the document.

3.5. Error checking procedures; for example, the (SCOPE) element is required in all specification documents and if it is not found an error is generated.

4. End of OT-5XXXX

Annotated Bibliography

Alleman, G.B. (2003). Project management == herding cats. [Electronic version]. Retrieved November 30, 2012 from http://pmforum.org/viewpoints/2003/0203agilepm.htm

The author discusses the high-level application of earned value performance on Agile software development tasks. The basic tenant of earned value measuring is reviewed and the high-level step-by-step process to plan an earned value tasking schedule is provided from the point of view of an Agile project manager. This paper provided a basic introduction into some of the challenges that can be encountered implementing Agile methodologies with EVM on a government contract.

Alleman, G.B., Henderson, M., & Seggelke, R. (2003). Making agile development work in a government contracting environment. [Electronic version]. Retrieved December 20, 2012, from https://engineering.lmco.com/docs/ieee_xplore/

An example of utilizing Earned Value Management with Agile Development on a government acquisition is reviewed. The discussion includes an explanation of introductory EVM concepts and the challenges involved with U.S. Government acquisitions. The authors explain their approach to solving the challenge of utilizing Extreme Programming within this environment.

Anderson, D.J. (2003). *Agile management for software engineering: Applying the theory of constraints for business results.* Retreived from www.safaribooksonline.com.

This book discusses the business aspects of improving software development projects and the impact utilizing the Theory of Constraints has on the software industry. The author discusses traditional challenges encountered on software development projects and

provides suggestions and case studies to aid project managers with improving their current and future projects.

Beck, K., et. Al. (2001). Manifesto for agile software development. [Electronic version]. Retrieved December 24, 2012, from http://agilemanifesto.org/.

This site provides the list of commonalities across all Agile development methodologies which make up the foundation for the Agile community.

Boehm, B. (2003). Value-based software engineering. [Electronic version]. Retrieved December 24, 2012, from ACM Digital Library http://delivery.acm.org.dml.regis.edu/10.1145/640000/638776/p4-boehm2.pdf?ip=207.93.211.102&acc=ACTIVE%20SERVICE&CFID=161273638&CFTOKEN=92420880&__acm__=1356376921_1cc8f5ed8d44c1d942f8e5d26bbc355d.

An analysis of the changing importance of software development in the overall project success and the importance of shifting from value-neutral decisions to value-based project management. The discussion provides insight into the limitation EVM has with regard to customer prioritization of requirements and the importance of including value-based assessments to the overall project success and the customer's return on their investment.

Boehm, B., & Huang, L. (2003). Value-based software engineering: Reinventing "earned value" monitoring and control. [Electronic version]. Retrieved 28 December 2012 from http://csse.usc.edu/csse/TECHRPTS/2003/usccse2003-512/usccse2003-512.pdf.

The authors discuss the importance of value-based software engineering and how this approach improves a customer's return on investment for the software development project they are funding. They explain the shortcomings traditional EVM systems have

with incorporating evolving stakeholder needs and a rapidly changing technological market and suggest an improved method of incorporating customer value feedback into the overall project management cycle.

Cohn, M. (2005). *Agile estimating and planning.* Retreived from www.safaribooksonline.com.

This book provides guidelines by one of the early Agile Manifesto signatories for laying out the plan on an Agile-based software development project. The author includes his insights from years of experience as well as explaining the need for some of the less well understood practices.

Department of Defense. (1996). *Department of defense handbook for preparation of statement of work (SOW)* (MIL-HDBK-245D). Retrieved February 22, 2013, from http://www.everyspec.com.

This document is published by the U.S. Department of Defense for use on DoD acquisitions as defined within the acquisition's contract. The document provides a complete description of a DOD Statement of Work including the expected format and data to be included in the SOW and the implementation of a SOW.

Department of Defense. (1975). *Department of defense standard practice work breakdown structures for material items* (MIL-STD-881A). Retrieved January 23, 2013, from http://www.everyspec.com.

This document is an older version of MIL-STD-881C published by the U.S. Department of Defense for use on DoD acquisitions as defined within the acquisition's contract. This document explains the nature of a Work Breakdown Structure within a DoD acquisition as of 1975 and provides the guidance in place at that time for the implementation and structure of a WBS on a variety of DoD projects.

Department of Defense. (2011). *Department of defense standard practice work breakdown structures for material items* (MIL-STD-881C). Retrieved December 20, 2012, from http://www.everyspec.com.

This document is published by the U.S. Department of Defense for use on DoD acquisitions as defined within the acquisition's contract. This document explains the nature of a Work Breakdown Structure within a DoD acquisition and provides the guidance in place for the implementation and structure of a WBS on a variety of DoD projects.

Department of Defense. (2003). *Department of defense standard practice defense standards format and content* (MIL-STD-962D). Retrieved December 28, 2012, from http://www.everyspec.com.

This document is published by the U.S. Department of Defense for use on DoD acquisitions as defined within the acquisition's contract. This document provides the requirements for document format and content for standards created as a result of a DoD acquisition activity. Detailed section by section descriptions and examples are provided for the expected contract deliverable document.

Department of Defense. (1997). *Department of defense standard practice data item descriptions (DIDs)* (MIL-STD-963B). Retrieved January 31, 2013, from http://www.everyspec.com.

This document is published by the U.S. Department of Defense for use on DoD acquisitions as defined within the acquisition's contract. This standard provides direction for the format and data to be provided in a Data Item Description (DID) created under the direction of a DoD acquisition. DIDs can be created as a single use document or for

repetitive acquisition. Detailed section by section descriptions and examples are provided for the expected contract deliverable document.

Defense Science Board. (2000). *Report of the defense science board taskforce on: Defense software*. Retrieved February 14, 2013 from http://www.acq.osd.mil/dsb/reports/ADA385923.pdf

This report provides an analysis of the state of change within the DoD software acquisition environment. The task force reviewed the status of both commercial and DoD software development programs looking for differences and ways to improve the DoD programs' performance. The final report provides 6 recommendations for improvement to facilitate increased performance and project satisfaction.

Federal Acquisition Regulation. (n.d). Retrieved December 12, 2012 from https://www.aqusisition.gov/far/html.

This document establishes the rules governing the acquisition process for all U.S. Federal Executive agencies. The standards defined in this document are intended to ensure government issued acquisitions are awarded in a fair manner and that the projects are managed in a way to ensure the products and services rendered meet the expected quality, schedule, and cost constraints. This document covers all topics related to the acquisition process and is the minimum standard for performance.

Fleming, Q.W., & Koppelman, J.M. (1998). Earned value project management, a powerful tool for software projects. [Electronic version]. *STSC Crosstalk, 11*(7), 19-23. Retrieved December 24, 2012, from http://www.crosstalkonline.org/storage/issue-archives/1998/199807/199807-Fleming.pdf.

The authors review the origins of EVM on U.S Government contracts and discuss the value of implementing EVM on current programs. A brief introduction to EV concepts is provided, discussing the basic concepts of measuring planned vs actual cost and schedule milestones. The authors provide a list of 10 steps they recommend as the minimum for implementing EVM and include details for employing each step and conclude that many smaller projects would greatly benefit from the insight that a streamlined version of EVM would provide to their projects.

Flemming, Q.W., & Koppelman, J.M. (2006). Start with "simple" earned value on all your projects. [Electronic version]. *STSC Crosstalk, 19*(6), 16-19. Retrieved December 24, 2012, from http://www.crosstalkonline.org/storage/issue-archives/2006/200606/200606-Fleming.pdf.

This paper provides some background on the development of the current EVM standard and discusses modifications that can be made to the traditional 32 criteria to make EVM more palatable for a wider spectrum of projects. The authors provide their breakdown of the ten "must-haves" that a project should include to institute an effective yet flexible EVM system.

Highsmith, J. (2002). *Agile software development ecosystems.* Retrieved from www.safaribooksonline.com.

The author focuses on three main discussions in this book, providing a description of what Agile is, explaining the types of problems that Agile techniques are best designed to fix, and defining what are Agile Software Development Ecosystems. This book provides an explanation of the various Agile methodologies or ecosystems for use by both project management and the individual software developers.

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

This book provides an in-depth review of EVM and, as part of a class provided by the publisher, walks through step by step how to set up an EVM system for a project. In addition to detailed explanations of all EVM related concepts, the book also provides exercises and scenarios to aid the reader with understanding the importance and usefulness of EVM for managing a project.

Humphrey, W. (2005). Why big software projects fail: The 12 key questions. [Electronic version]. *STSC Crosstalk, 18*(3), 25-29. Retrieved January 5, 2013, from http://www.crosstalkonline.org/storage/issue-archives/2005/200503/200503-Humphrey.pdf.

The author discusses the low success rate on software development projects and reviews the difficulties encountered when managing these types of projects. He highlights 12 specific questions for a management team to ask themselves in an effort to improve the potential for success on their project. In this article, the author also provides suggestions for resolving the issues discussed based on personal experience and observation.

Irwin, L. G. (2003). *The policy analyst's handbook: Rational problem solving in a political world.* Retrieved January 20, 2013 from www.safaribooksonline.com.

The author provides in-depth, step-by-step reviews of problem solving techniques. These techniques start with the initial problem definition and work thru problem development, research, and analysis. As part of this review, the author includes discussion on different methods of research and problem resolution.

Kannenberg, A. & Saiedian, H. (2009). Why software requirements traceability remains a challenge. *STSC Crosstalk, 22*(7), 14-19. Retrieved January 5, 2013, from http://www.crosstalkonline.org/storage/issue-archives/2009/200907/200907-Kannenberg.pdf.

The authors discuss the significant difficulties software development projects have historically had with successfully meeting cost and schedule goals and the role that requirements traceability has played in this challenge. They investigate the importance of requirements traceability to the successful delivery of a software development project, the industry challenges that exist, and the potential corrections and improvements that can be made to both tools and processes.

Knausenberger, E., & Shah, R. (2012). Making agile work for government: A blended approach. [Electronic version]. Retrieved December 24, 2012, from http://agileconnection.communities.techwell.com/article/making-agile-work-government-blended-approach.

The first of a three-part report, the authors discuss the characteristics of traditional waterfall based software development, what they define as "pure" Agile, and a middle of the road approach called blended Agile. The authors encourage increased use of blended Agile techniques to balance the desire for improved program performance and adaptability against the rigid structure of government acquisition processes.

Leedy, P. & Ormrod, J. (2005). *Practical research planning and design.* Upper Saddle River, NJ:Pearson Merrill Prentice Hall.

In this book, the authors explain basic research concepts in support of developing and publishing a research paper. They provide step-by-step instructions from topic inception through planning the research to the final stages of analysis and report preparation. The

book not only explains the different between basic concepts such as information gatherings and reporting versus actual analysis and interpretation of data, but also provides examples of different types of research and the impact these types have on how the data can be analyzed and used to support or contradict a hypothesis.

McMahon, P.E. (2006). Are management basics affected when using agile methods? [Electronic version]. *STSC Crosstalk, 19*(11), 4-8. Retrieved December 24, 2012, from http://www.crosstalkonline.org/storage/issue-archives/2006/200611/200611-McMahon.pdf.

This article provides a comparison of traditional project management activities versus agile project management activities. The author provides a description of his five steps for project management and follows up with comparative examples for completing each step utilizing both traditional project management and agile project management techniques. Each comparison is supported by case studies to re-enforce the techniques. The article also discusses the benefits of implementing a hybrid traditional-agile approach to resolving project management challenges.

National Defense Authorization Act for Fiscal Year 2010, Pub. L. No. 111-84, § 804,123 Stat. 2190 (2009). Retrieved January 28, 2013 from http://www.intelligence.senate.gov/pdfs/military_act_2009.pdf.

This law applies to the DoD appropriations for fiscal year 2010. Section 804 specifically addresses the new acquisition process to be utilized for information technology systems contracts expected to be developed and implemented by the Secretary of Defense. The new process follows the recommendations found in the Defense Science Board Task Force report published in March 2009 which align with Agile focused techniques.

Northern, C., Mayfield, K., Benito, R., & Casagni, M. (2010). Handbook for implementing agile in department of defense information technology acquisition. [Electronic version]. Retrieved January 30, 2013, from http://www.mitre.org/work/tech_papers/2011/11_0401/11_0401.pdf.

The authors reviewed the challenges facing DoD projects and investigated the potential Agile development methodologies has to resolve these challenges. This report includes a description of the benefits provided by Agile techniques and recommendations from other DoD projects that have attempted to implement Agile to improve the projects' ability to deliver the needed functionality within the cost and schedule constraints agreed to in the projects' contracts.

Poole,D. (2006). Breaking the major release habit. [Electronic version]. Retrieved December 20, 2012 from ACM Digital Library.

This article discusses the ability of Agile development techniques to more quickly adapt to a changing market and technological environment than traditional development methods. It also reviews some of the challenges involved with transitioning to Agile, mainly the lack of tool support and the difficulties scaling Agile methodologies to large, distributed teams.

Project Management Institute (PMI). (2008). *A guide to the project management body of knowledge (PMBOK guide)*. Retrieved 20 December, 2012 from www.safaribooksonline.com.

This book is recognized across multiple industries as the "gold" standard for project management processes and practices. It includes an introduction into basic project management concepts, recognized best practices for project managers, and the tools and techniques of the project management standard as defined by the Project Management Institute.

Racheva, Z. & Daneva, M. (2008). Using measurements to support real-option thinking in agile software development. [Electronic version]. Retrieved December 24, 2012, from ACM Digital Library.

The authors investigate the lack of supporting metrics and measurement tools for Agile development projects. They review available measurement techniques for Agile and explain how these current metrics continue to fall short of meeting customer needs. Their solution is to adapt Real Options Analysis for Agile and resolve the gap in customer support.

Rawsthorne, D. (2004). Managing the work in an agile project. [Electronic version]. Retrieved January 2, 2012, from http://www.torak.com/site/files/Managing%20the%20Work%20in%20an%20Agile%20Project.pdf.

The author investigates the conflict that occurs between management and the developers when attempting to come to consensus on the status of progress on Agile software development projects. Traditional work backlog data is helpful for the developers but is not insightful for the project management. The author suggests implementing a functional WBS to aid with mitigating the conflict and provides an example of utilizing a WBS to plan the work and track performance against the funds being used. The author does not suggest implementing a full EVM system, but the basic concepts presented do correlate closely with EVM.

Schwaber, K. (2004). *Agile project management with scrum.* Retrieved February 2, 2013 from www.safaribooksonline.com.

This book is written be one of the Scrum co-creators and takes advantage of his vast experience with the methodology across multiple scenarios. In it, the author provides insights, via a number of case studies, into successfully implementing Scrum from the point of view of the project manager. The case studies depict both thriving and unsuccessful Scrum implementations.

Software Engineering Institute. (2010). *Considerations for using agile in DoD acquisition* (CMU/SEI-2010-TN-002). Retrieved from http://www.sei.cmu.edu/reports/10tn002.pdf.

This report investigates the experiences and literature available regarding using Agile software development methodologies on a DoD contract. Specifically this report looks for any potential challenges posed by DoDD 5000.01 and DoDI 5000.02. The authors provide background on the DoD standards and supply a high level explanation of Agile.

Sulaiman, T. (2007a). AgileEVM – earned value management the agile way. *Agile Journal.* Retrieved December 24, 2012, from http://agileconnection.communities.techwell.com/article/agileevm-earned-value-management-agile-way?page=0%2C2.

The author revisits the discussion of applying a modified version of EVM for use on projects employing agile software development methods. She discusses the industry reluctance to employ AgileEVM and offers potential assistance, in the form of a worksheet, to some of the measurement challenges that arise during the planning and implementation process. The author continues to lobby in support of using AgileEVM as an additional tool to help managers monitor progress towards project completion. She also briefly discusses how AgileEVM was used successfully on 2 Scrum projects.

Sulaiman, T. (2007b). AgileEVM: Measuring cost efficiency across the product lifecycle. Retrieved December 24, 2012, from http://www.infoq.com/articles/agile-evm.

The author discusses an alternative method of calculating traditional EVM CPI and SPI metrics that has been tailored for projects using Scrum software development methodology. She walks through examples using the alternate inputs and displays how AgileEVM can be combined with traditional EVM within the same project while maintaining the ability to provide meaningful data. Sulaiman takes her initial work with Barton and Blackburn and provides additional detail of how AgileEVM was implemented in a real world scenario at InfoTech. This article builds on the initial AgileEVM work, but still lacks discussion on many of the implementation details.

Sulaiman, T., Barton, B., & Blackburn, T. (n.d.). AgileEVM – earned value management in scrum projects. [Electronic version]. Retrieved December 24, 2012, from http://www.solutionsiq.com/Portals/93486/docs/Earned-Value-Analysis-in-Scrum-Projects-WP.pdf.

The authors explain how to adapt traditional EVM measurements to fit environments using Scrum software development. The paper explains the mathematical proof detailing how Scrum EAC (based on mean velocity) equates with traditional EVM EAC and supports the hypothesis that "Release date estimates using EAC calculations provided by EVM correlate to Mean velocity predictions provided by Scrum." The authors also discuss the potential schedule impact or "drag" of using AgileEVM to aid in managing Scrum projects. Based on their limited experience with two projects, Sulaiman, Barton and Blackburn conclude AgileEVM is not an overweight process to be included with other program metrics as a way to monitor program cost and schedule progress. This

paper provides a good foundation for the initial discussion of implementing EVM on projects using Scrum, but the tests were run on smaller projects during a limited timeframe.

Sulaiman, T., & Smits, H. (2007). Measuring integrated progress on agile software development projects. [Electronic version]. *Methods & Tools, 15*(3), 2-9. Retrieved January 26, 2009, from http://www.methodsandtools.com/archive/archive.php?id=61.

As with the other resources Sulaiman has authored or co-authored, this article discusses the origins of AgileEVM and supports the argument for implementing AgileEVM on programs utilizing agile development methodologies. Compared to the other works, there is more focus on the topic from a first line manager point of view and the authors use a simplified example project to aid in explaining the value that can be derived from EVM metrics and how AgileEVM is flexible enough for use on an agile development program.

United States Government Accountability Office. (2012). *Software development: Effective practices and federal challenges in applying agile methods* (GAO-12-681). Retrieved from http://www.gao.gov/assets/600/593091.pdf.

This report reviewed the successes and difficulties encountered implementing Agile methodologies on real-world government projects. The GAO investigated projects across five government agencies: the Department of Commerce, the Department of Defense, the Department of Veterans Affairs, the Internal Revenue Service, and the National Aeronautics and Space Administration. 32 effective practices were documented and recommended for continued use while 14 challenges were recorded that will need further work to resolve.

Glossary

AC – Actual Cost (AgileEVM) – equivalent to ACWP, the sum of the costs charged for the work completed through a specific date.

ACWP – Actual Cost of Work Performed (traditional EVM) – equivalent to AC, the sum of the costs charged for the work completed through a specific date.

APC – Actual Percent Complete (AgileEVM) –the sum of story points completed for the entire project divided by the sum of total planned story points for the entire project.

BAC – Budget at Complete (both traditional EVM and AgileEVM) – the total baseline cost of the project.

BCWP – Budgeted Cost of Work Performed (traditional EVM) – the sum of the performance or earned value being claimed as complete.

BCWS – Budgeted Cost of Work Scheduled (traditional EVM) – the sum of the earned value of the work that was expected to be complete.

CPI – Cost Performance Index (traditional EVM) – a ratio of the BCWP (sum of the performance or earned value claimed) at a specific date divided by the ACWP (sum of the cost incurred) at that same specific date.

CPI – Cost Performance Index (AgileEVM) – a ratio of EV (the product of the total baseline cost of the project multiplied by the APC) divided by AC (the sum of the costs for the work completed).

EAC – Estimate at Complete (both traditional EVM and AgileEVM) – the sum of the actual costs incurred to date (ACWP or AC) and the expected future cost to complete the remaining work (ETC).

EPC – Expected Percent Complete (AgileEVM) – the product of dividing the current sprint number by the total number of planned sprints.

ETC – Estimate to Complete (both traditional EVM and AgileEVM) – the sum of the expected costs to complete the work remaining on the project.

EV – Earned Value (AgileEVM) – similar to BCWP, it is the product of BAC (total budget for the entire project) multiplied by the APC (the ratio of completed story points divided by the total expected story points for the project..

PRSP – Planned Release Story Points (AgileEVM) – the story points planned for a specific release.

PV – Planned Value (AgileEVM) – similar to BCWS, it is the product of BAC (total budget for the entire project) multiplied by the EPC (the ratio of the current sprint number divided by the total number of sprints planned).

SPI – Schedule Performance Index (traditional EVM) – a ratio of the BCWP (sum of the performance or earned value claimed) at a specific date divided by the BCSW (sum of the work expected to be completed) at that same specific date. This calculation is used in traditional EVM.

SPI – Schedule Performance Index (AgileEVM) – a ratio of EV (the product of the total project budget multiplied by the ratio of the completed story points divided by the total planned number of story points for the project) divided by AC (the sum of the actual costs incurred).