

NAVAL POSTGRADUATE SCHOOL

Monterey, California



THESIS

**ANALYSIS OF HOW THE WORK BREAKDOWN
STRUCTURE CAN FACILITATE ACQUISITION REFORM
INITIATIVES**

by

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December 1999

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Program Managers (PMs) need insight into the high-risk and high-cost elements of their programs to effectively manage them. The Department of Defense (DoD) has adopted several acquisition reform initiatives in order to become a smarter, more efficient, and more responsive buyer of goods and services that meet our warfighter's needs. DoD 5000.2-R Regulation requires PMs to tailor a work breakdown structure (WBS) for each program using the guidance in Military-Handbook-881 (MIL-HDBK-881), "DoD Handbook - Work Breakdown Structure." This research concludes that a WBS structured in accordance with MIL-HDB-881 can significantly impede implementation of DoD acquisition reform initiatives. It does not adequately identify the key products and processes essential for program success. An alternate method of constructing a WBS was developed which better identifies and differentiates key products and processes. This research concludes that the alternate WBS has the potential to significantly facilitate implementation of recent DoD acquisition reform initiatives, as well as the potential to provide PMs greater visibility and early identification of cost, schedule, performance, and risk issues using an Earned Value Management System (EVSM).

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FACILITATE ACQUISITION REFORM INITIATIVES**

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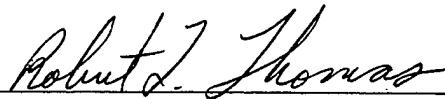
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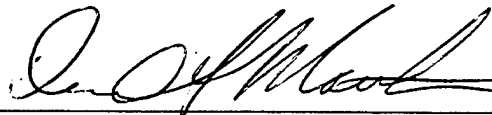
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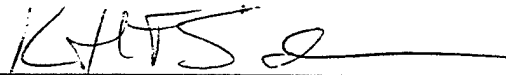
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ABSTRACT

Program Managers (PMs) need insight into the high-risk and high-cost elements of their programs to effectively manage them. The Department of Defense (DoD) has adopted several acquisition reform initiatives in order to become a smarter, more efficient, and more responsive buyer of goods and services that meet our warfighter's needs. DoD Regulation 5000.2-R requires PMs to tailor a work breakdown structure (WBS) for each program using the guidance in Military-Handbook-881 (MIL-HDBK-881), "DoD Handbook - Work Breakdown Structure." This research concludes that a WBS structured in accordance with MIL-HDB-881 can significantly impede implementation of DoD acquisition reform initiatives. It does not adequately identify the key products and processes essential for program success. An alternate method of constructing a WBS was developed which better identifies and differentiates key products and processes. This research concludes that the alternate WBS has the potential to significantly facilitate implementation of recent DoD acquisition reform initiatives, as well as the potential to provide PMs greater visibility and early identification of cost, schedule, performance, and risk issues using an Earned Value Management System (EVSM).

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I. INTRODUCTION

A. PURPOSE

During the past decade, defense acquisition reform has been very intense. The Department of Defense (DoD) has adopted several acquisition reform initiatives in order to be a smarter, more efficient, and more responsive buyer of goods and services that meet our warfighters' needs. The effectiveness of those acquisition reform initiatives may be dependent on the program and contract work breakdown structure (WBS). DoD Regulation 5000.2-R, "Mandatory Procedures for Major Defense Acquisition Programs (MDAPS) and Major Automated Information System (MAIS) Acquisition Programs," requires program managers (PMs) to tailor a program WBS for each program using the guidance in Military-Handbook-881 (DoD, January 98). MIL-HDBK-881, "DoD Handbook - Work Breakdown Structure," presents guidelines for preparing, understanding, and presenting a WBS. The purpose of this thesis research is to analyze how MIL-HDBK-881 can facilitate or impede acquisition reform initiatives. Additionally, this research will consider acquisition reform initiatives that may be affected by the WBS, the uses of the WBS, how to develop a WBS, and an alternative method to

structure the WBS to more effectively facilitate or implement acquisition reform initiatives.

B. BACKGROUND

A WBS provides a consistent and visible framework for defense materiel items and contracts within a program. The WBS provides the basis for communication throughout the acquisition process. It is the common link, which unifies the planning, scheduling, cost estimating, budgeting, contracting, configuration management, and performance reporting disciplines (DoD, January 1998). The WBS is a product-oriented family tree composed of hardware, software, services, data, and facilities. The family tree results from systems engineering efforts during the acquisition of a defense materiel item. The challenge in developing a WBS is to balance the program definition aspects of the WBS against its data-generating aspects.

MIL-HDBK-881, dated 2 January 1998, is a conversion of Military-Standard-881 (MIL-STD-881), "Work Breakdown Structures for Defense Materiel Items," with no substantive changes in WBS definition (DoD, January 1998). During the past decade, there have been several acquisition reform initiatives to streamline the DoD acquisition management process. Some of these acquisition reform initiatives are implemented through or affected by the WBS, which further

increases the challenge to balance the program definition aspects of the WBS. As a DoD civilian with fifteen years of DoD acquisition experience in US Army Program Management and Research, Development, and Engineering offices, the researcher has developed poorly-written WBSs and as a result suffered the consequences of attempting to manage with meaningless data. This first-hand experience of attempting to balance the program definition aspects of the WBS with its data-generating aspects, in addition to acquisition reform initiatives, prompted further exploration.

Many of the assertions and conclusions in this thesis are based on experiences and discussions with Government and contractor personnel during my career. Mr. Lawrence Nee and Mr. Richard Ess of the US Army Project Manager for Mines, Countermine, and Demolitions have provided me with invaluable insight to managing programs from a DoD perspective. Mr. Jim Bob Bryant and Mr. Kent Jacobson of then Tracor Aerospace have provided me with invaluable insight to managing programs from a contractor's perspective. I have attempted to implement many acquisition reform initiatives and have been frustrated by not being able to effectively implement them. I have managed and participated in an Integrated Product and Process Development (IPPD) environment participating in Integrated

Product Teams (IPTs). I have participated in an Alpha Contracting process. Many of the assertions and conclusions in this thesis are a result of discussions during IPT meetings and the Alpha Contracting process.

Part of the assertions and conclusions in this thesis are a result of the various acquisition and management courses taken while attending the US Naval Postgraduate School (NPS). I will be graduating soon and re-entering the acquisition workforce, charged with managing and executing US Army acquisition programs. My personal objective for this thesis was to integrate the lessons learned from the various NPS courses as well as to integrate them with my acquisition experience.

C. RESEARCH QUESTIONS

1. Primary Question

To what extent does MIL-HDBK-881 facilitate or impede execution of acquisition reform initiatives?

2. Subsidiary Questions

- a. *What acquisition reform initiatives does the WBS affect?***
- b. *What are the possible uses of the WBS?***
- c. *What does the project manager need to consider when structuring a WBS?***

- d. *Is there an alternative method(s) to structure the WBS that will allow better execution or implementation of acquisition reform initiatives?*

D. METHODOLOGY

My research began with a literature review of DoD regulations, directives, handbooks, web-sites, magazine articles, CD-ROM systems, and other library information. A thorough review of MIL-HDBK-881 and other DoD publications was conducted. The WBSs along with the definitions presented in MIL-HDBK-881's Appendices were analyzed to determine if WBSs developed in accordance with guidance contained in MIL-HDBK-881 facilitated or impeded acquisition reform initiatives. Based on these findings, an alternative method to structure the program WBS was developed. Finally, the alternative program WBS was analyzed to determine if the new WBS facilitated or impeded acquisition reform initiatives.

E. ORGANIZATION OF STUDY

This thesis is divided into five chapters. The next chapter provides background information and discussion of acquisition reform initiatives implemented through or affected by the WBS. Chapter III provides background information and discussion of MIL-HDBK-881. This chapter discusses the possible uses the WBS. It also discusses the

preparation of the program WBS and contract WBS, along with challenges a project manager must consider during the development of the WBS. This includes methods to incorporate or effectively implement acquisition reform initiatives.

Chapter IV analyzes a program WBS developed in accordance with the guidance contained in MIL-HDBK-881, to determine to what extent MIL-HDBK-881 facilitates or impedes execution of acquisition reform initiatives. Chapter IV also determines an alternative method to structure the program WBS that will allow better execution or implementation of the acquisition reform initiatives. It then analyzes the new program WBS to determine to what extent MIL-HDBK-881 facilitates or impedes execution of acquisition reform initiatives. Chapter V concludes the thesis study by summarizing the findings, answering the research questions, and presents both recommendations for DoD project managers and areas for future research.

F. BENEFITS OF THE STUDY

The initial benefit of this study is that DoD project managers and students of DoD acquisition will be able to better understand the WBS and how it can benefit them during cost, schedule, and performance risk management. The second benefit is to identify methods to structure the WBS that

will allow DoD project managers to more effectively execute acquisition reform initiatives and ultimately save the taxpayer money. Finally, this study will provide beneficial comments such as recommendations, additions, or deletions and any pertinent data, which may be of use in improving MIL-HDBK-881.

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II. ACQUISITION REFORM INITIATIVES

A. INTRODUCTION

Defense spending has decreased in real terms since 1985, causing DoD to rethink how it does business. Acquisition reform is a basic restructuring of the way the DoD does business. The goal of acquisition reform is to do the job better, faster, and cheaper. The focus has been to reduce the cost of the acquisition process by reengineering, consolidation, increased competition, and elimination of activities that are not cost-effective or necessary, i.e., value added. The DoD has been adopting modern business practices to achieve world-class standards of performance; streamlining organizations to reduce redundancy and maximize synergy; applying market mechanisms to improve quality, reduce costs, and respond to customer needs; and reducing excess support structures to free resources and focus on core competencies (Cohen, 1997). We must provide the warfighter what is needed, when it is needed, and at the best available price, while keeping the public trust in the acquisition process by exercising good judgment and adhering to the highest standards of honesty and professionalism (Department of the Army (DA), 1999).

The private sector has been changing their way of doing business to operate more efficiently in order to be competitive in a global marketplace. Secretary of Defense William S. Cohen wrote:

For too long, DoD has labored under support systems and business practices that are at least a generation out of step with modern corporate America. DoD support systems and practices that were once state-of-the-art are now antiquated compared with the systems and practices in place in the corporate world. Other systems grew up in their own defense-unique culture and never did correspond with the best business practices of the private sector. This cannot and will not continue. (Cohen, 1997).

The Defense Reform Initiative (DRI) addresses the DoD corporate vision of igniting a revolution in business affairs within DoD that will bring to the Department, management techniques and business practices that have restored American corporations to leadership in the marketplace (Cohen, 1997). The DoD has been eliminating barriers that will allow the use of good business judgment. They have been providing tools to the workforce, to implement smarter ways of doing business. The DoD has been adopting many of these successful commercial practices.

There is not a consolidated list of all the acquisition reform initiatives. The DoD Regulation 5000.1 and DoD Regulation 5000.2-R have been modified to incorporate many of the acquisition reform initiatives. The WBS does not

affect all of the acquisition reform initiatives. This chapter provides background information and discussion of acquisition reform initiatives implemented through or affected by the WBS.

B. ACQUISITION REFORM INITIATIVES

1. Streamline Acquisition/Adoption of Commercial Practices

Vice President Al Gore stated, "Government should emulate the best in business, learn from them, and adopt their best business practices." He also stated, "Information technology is changing everything from the way we buy equipment to the way we fight" (Kozaryn, 1998). The main focus of streamlined acquisition and adoption of commercial practices has been to reduce cycle-time (i.e., shortening development and fielding cycles for new technology) and change from oversight to insight. This will help to reduce overhead and life-cycle costs. Reducing cycle-time will allow advance technology to be fielded before it is outdated. We can no longer afford to develop systems for ten to fifteen years or longer. We must field technology while it is still advanced and provides our military the technological advantage over our enemies. One commercial practice is incremental product improvements with short cycle-times and continued research and development

efforts on technological advancements which can be inserted rapidly when proven (Gansler, 1998). The use of Advanced Concept Technology Demonstrations (ACTDs) and the Army's Fast Track Acquisition Program are other techniques to shorten cycle-times and make incremental product improvements.

With oversight management, PMs and Milestone Decision Authorities (MDAs) did not have the necessary information to understand program status to make informed decisions in a timely manner. This wasted valuable resources, i.e., time and money, by not making timely decisions. DoD cannot afford to rework or fix mistakes that could have been eliminated through early and continuous insight to resolve major issues. It is easier to change paper early in the acquisition process than changing hardware later in the acquisition process. More knowledge shared between PMs, the Users, Government personnel, and contractors during the acquisition process will help to reduce assumptions and decrease the amount of rework, saving DoD money. It is markedly cheaper to do the right thing the first time. DoD Regulation 5000.1 encourages PMs to continually search for innovative practices that reduce cycle-time, reduce cost, and encourage teamwork. Teamwork will be discussed in the next section. In addition, DoD Regulation 5000.1 requires

continuous focus on implementing major improvements necessary to streamline the acquisition process, reduce infrastructure, and enhance customer service through process reengineering and technological breakthrough. Techniques to reduce oversight include eliminating all but the most essential data requirements, obtaining access to the contractor's own management data, the use of commercial-off-the-shelf (COTS) hardware and software, and the use of contractor logistics support.

DoD Regulation 5000.1 states, "In all cases, no more than two levels of review shall exist between a PM and the MDA." DoD has streamlined the acquisition management structure to clearly define the lines of responsibility, authority, and accountability. This has minimized reporting requirements to only the necessary information for decision authorities to understand program status and make informed decisions in a timely manner. The MDA may tailor the acquisition process, including program documentation, acquisition phases, the timing and scope of decision reviews, and decision levels (DoD, March 1998). Tailored approaches to oversight and review are based on a program's size, risk, and complexity. PMs need insight to actively manage the program's cost, schedule, performance, and risks. They can no longer afford to be risk-averse and must

actively work with the Users and contractors to conduct tradeoffs between cost, schedule, performance, and risk. Risk management encompasses identification, mitigation, and continuous tracking, and control procedures that feed back through the program assessment process to decision authorities (DoD, 1999).

On 24 November 1997, the US Army Aviation and Missile Command's Acquisition Center for Missile Logistics Procurement Directorate received the Hammer Award for efforts to streamline operations and cut costs. Vice President Al Gore asserted in a videotaped statement, "You cut lead time by 45 percent, which translates to a cost cut to taxpayers of 500 million dollars" (Valine, 1998). DoD is adopting business practices to streamline business and improve efficiency. This is especially prevalent with procurement practices. Adoption of commercial practices enables suppliers to efficiently conduct business with the Government in a manner similar to that used with their private-sector customers. This includes the use of information technology and electronic commerce, use of common processes, use of simplified acquisition procedures and credit cards, use of Single Process Initiatives (SPI) (discussed later), simplified acquisition oversight procedures, best-value acquisition, oral presentations,

paperless procurement, multi-year contracting, and Government-industry partnerships. Past performance is used as a prime indicator of the risk of non-performance. Allowing the contractor to be responsible for configuration management reduces the amount of oversight and allows the contractor to more quickly modify their design. Another practice of reducing oversight is the choice of contract type, incentives, or warranties, to transfer or share risk with the contractor.

2. Integrated Product and Process Development (IPPD)/Integrated Product Team (IPT)

In May of 1995, Secretary of Defense William Perry directed the use of IPPD concepts and the use of IPTs in DoD acquisition (Perry, 1995). The use of IPPD and IPTs were later incorporated into DoD Regulation 5000.1 and DoD Regulation 5000.2-R. IPPD is a management technique that simultaneously integrates all acquisition activities through the use of multidisciplinary teams (i.e., IPTs) starting with requirements definition through production, fielding/deployment, and operational support to optimize the design, manufacturing, and supportability processes (Perry, 1995). The IPPD approach is driven by the customer's need. The use of IPPD offers the potential to provide better products in less time and cost. IPTs enable both insight into major issues early and making the right decision at the

right time. The IPT concept was intended to replace the sequential acquisition process characterized by "throwing it over the wall." This sequential process required frequent reviews and normally resulted in substantial modifications or rejection of the product. The sequential review and approval process takes considerably longer time than an IPT approach that simultaneously takes advantage of all members' expertise and produces an acceptable product the first time. (Office of the Under Secretary of Defense for Acquisition and Technology (USD(A&T)), 1995).

IPTs function in a spirit of teamwork with participants empowered and authorized, to the maximum extent possible, to make commitments for the organization or the functional area they represent. IPTs are composed of empowered representatives (stakeholders) from all of the functional areas working together to build successful and balanced programs, identifying and resolving issues, and making sound and timely decisions. IPTs enable decision-makers to make the right decisions at the right time. IPTs are composed of personnel from program management, engineering, manufacturing, test and evaluation, logistics, safety, financial management, contracting including contract administration, contractors, suppliers and the most important, the customer (Perry, 1995).

IPTs are divided into three layers, an Overarching IPT (OIPT), Working IPTs (WIPTs), and Program IPTs. Figure 2.1 shows the IPT structure. The OIPT and the WIPTs, facilitate building more successful and affordable programs, resolve problems, and gain early insight for program insight. DoD Regulation 5000.2-R requires an OIPT and at least one WIPT. WIPTs focus on a particular topic such as cost/performance, test, or contracting. An Integrating IPT (IIPT), which is a WIPT, coordinates WIPT efforts and cover all topics not otherwise assigned to another IPT. The IIPT supports the development of strategies for acquisition and contracts, cost estimates, evaluation of alternatives, logistics management, cost-performance tradeoffs, etc. Participation in IPTs is the primary way for any organization to participate in a program. Mandatory guidance relating to these types of IPTs can be found in DoD Regulation 5000.2-R (Office of the USD(A&T), 1995).

Program IPTs are established to manage program execution. They perform the program tasks. The integration of contractors with the Government occurs primarily at this level. IPTs are usually formed around the key products and processes associated with the program. The WBS is based on the key products and processes in a product-oriented tree structure. The program IPTs are usually structured using

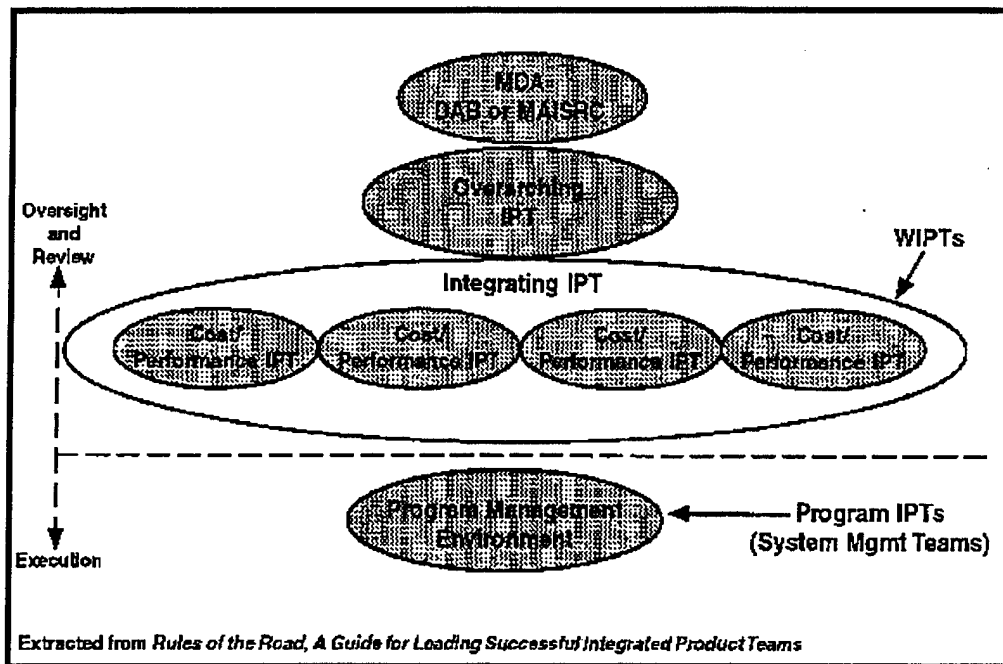


Figure 2.1. IPT Structure (Extracted from Defense Systems Management College (DSMC), Systems Engineering Fundamentals)

the WBS and designed to provide the maximum vertical and horizontal communication during the development process as shown in Figure 2.2 (DSMC, October 1999).

There are different levels of Program IPTs. Level one is normally a program management IPT and a system IPT. The next level is either product or process IPTs. Additional levels may exist based on subsystems, components, or sub-processes. It is critical that these IPTs be a cohesive product/process team that functions efficiently and effectively. Each IPT has a mission to develop and deliver a product and its associated processes. At the program level, IPTs are responsible for a product or process, authority over the resources and personnel, an agreed

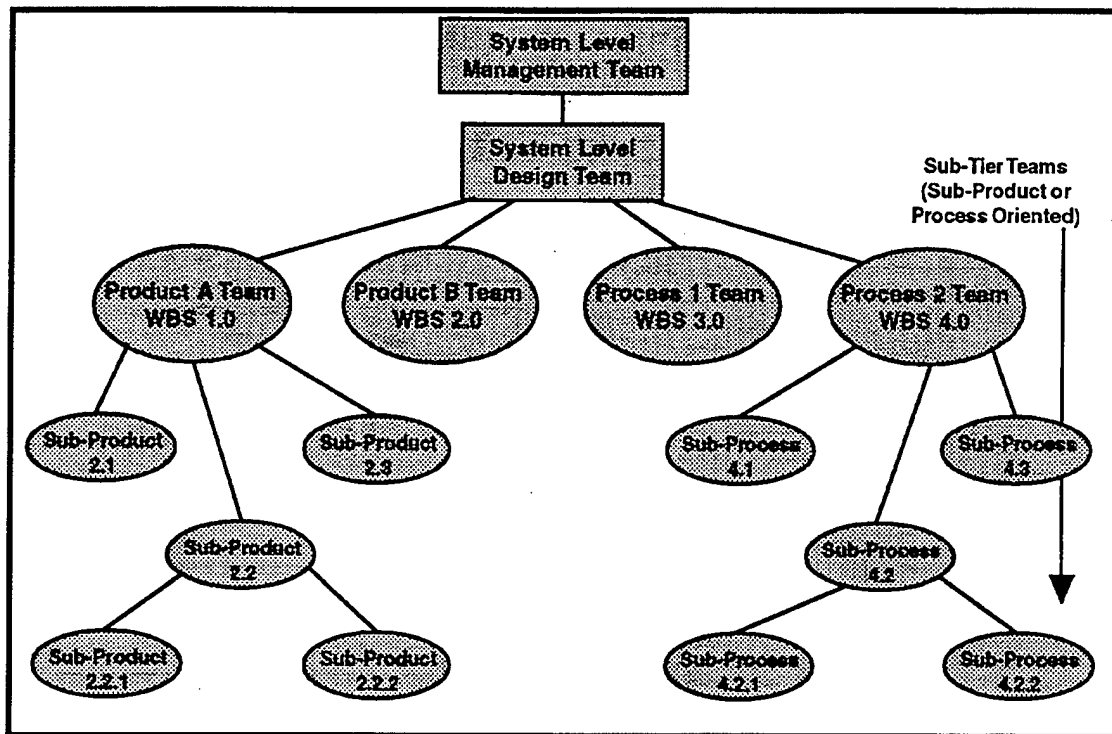


Figure 2.2. IPT Structure based on the WBS (Extracted from DSMC, Systems Engineering Fundamentals)

schedule for delivery of the defined product, an agreed level of risk to deliver the defined product, and an agreed upon set of measurable metrics (Office of the USD(A&T), 1998). Each program IPT functions as a small program with the IPT leader serving as the PM. They are given a budget, schedule, performance requirements, and levels of risk. An IPT Charter documents the above. The IPT Charter is essential and must be agreed upon by management and team members (Office of the USD(A&T), 1998). The IPT Charter should clearly describe the mission and goal supplemented with a project timeline; team members and their authority and accountability; and the resources they control and team

deliverables. If a program deviation or a breach occurs to the agreed to thresholds, they are raised to the next higher-level program IPT to be resolved.

The activities relative to a system's acquisition change and evolve over its life-cycle. The roles of various IPTs and IPT members evolve as well. When the team is dealing with an area that requires a specific expertise, the role of the member with that expertise will predominate; however, other team members' input should be integrated into the overall life-cycle design of the product. Some teams may assemble to address a specific problem and then become inactive or even disband after accomplishing their tasks (Office of the USD(A&T), 1998).

The DoD Guide to IPPD lists the following ten interrelated tenets inherent in IPPD:

1. Customer Focus
2. Concurrent development of products and processes
3. Early and continuous life-cycle planning
4. Maximize flexibility for optimization and use of contractor approaches
5. Encourage robust design and improved process capability
6. Event-driven scheduling
7. Multidisciplinary teamwork
8. Empowerment
9. Seamless Management Tools
10. Proactive identification and management of risk

The Rules of the Road, A Guide for Leading Successful Integrated Product Teams lists the following ground rules for implementing IPTs:

- Open discussions with no secrets.
- Qualified, empowered team members.
- Consistent, success-oriented, proactive participation.
- Continuous, "up-the-line" communications.
- Reasoned disagreement.
- Issues raised and resolved early.

The two most important characteristics of IPTs are cooperation and empowerment. IPTs must have full and open discussions with no secrets, working toward common goals. All members must be able to speak for their superiors and not be overturned later. IPTs with Government and contractor members must have a relationship of partnership and mutual trust versus an adversarial relationship (DoD, 1995).

A successful IPT works together pulling each member's knowledge, skills, and attitudes through the spirit of cooperation. DoD IPPD HDBK lists the following principles that must exist for team unity.

- All team members must be stakeholders in the mission of the group.
- All team members must be empowered and capable in their functional discipline.
- All members must feel free to make suggestions.
- Members must trust one another, especially when sensitive issues surface.
- The team must desire consensus and remain focused on team goals.
- All members must actively seek win-win solutions to problems.

All IPT members are equal and have a vote on all issues. The goal is to obtain team consensus on all issues. There can be disagreement on how to approach a particular issue, but that disagreement must be reasoned disagreement based on an alternative plan of action rather than unyielding opposition (Perry, 1995). Team members must be willing to live with the solutions, even though the solution is not their first choice.

3. Cost As An Independent Variable (CAIV)

With today's lower defense budgets, acquisition managers are faced with fiscal constraints in an environment of interests competing for limited resources. Cost and schedule pressures along with changes in requirements, technology, laws, and policies require acquisition managers to constantly tradeoff between these competing interests. We cannot afford all that we would like to do, so we must decide what is not going to be accomplished. PMs conduct cost, schedule, and performance risk management on a daily basis. Cost as an independent variable (CAIV) is a management technique emphasizing the cost or unit price as a constant. Once the system performance and objective cost are decided (on the basis of cost-performance tradeoffs), the acquisition process makes cost more of a constraint, and less of a variable, while obtaining the needed military

capability of the system (Defense Acquisition Deskbook (DAD), CAIV Working Group Report, 1999). DoD Regulation 5000.1 states that cost must be viewed as an independent variable. It further states that acquisition managers shall establish aggressive but realistic cost objectives for all programs and follow through by trading off performance and schedule, beginning early in the program (when the majority of costs are determined), to achieve a balanced set of goals, based on guidance from the MDA. DoD Regulation 5000.2-R states that cost objectives shall also be set to balance mission needs with projected out-year resources. PMs must actively manage risks to obtain those cost, schedule, and performance objectives.

CAIV enables PMs to refine the requirement, consider cost early, and make tradeoffs between performance and cost to obtain an affordable, mission-effective system in the end. In, the past, meeting the threat dictated an emphasis on performance and created a culture in which cost and schedule were adjusted to achieve the desired outcome. CAIV forces IPTs to determine cost drivers early and to address them promptly. New programs that employ CAIV from the beginning have the potential to generate from thirty to fifty-percent savings in total life-cycle costs, and ten to

twenty-percent savings for existing programs in later acquisition stages (Hoeper and Kern, 1999).

CAIV requires the user to be an active and strong participant in the acquisition process since CAIV enables PMs to refine the requirements. The user must be active in the IPTs throughout the program, during the establishment and adjustment of program goals, particularly in the cost-performance tradeoff process. These tradeoffs have the potential to empower the user to make choices that provide the best performance-for-the-money for each system, thereby helping to ensure maximum benefit from all systems across the force within the resources available. CAIV may require larger investments early in the program in order to realize long-term savings in production and operation and support costs (DAD, CAIV Working Group Report, 1999).

CAIV requires the user to state system requirements in a few broad, top-level performance terms. These performance requirements are stated as threshold values, the minimum level required by the user, and objective values, representing a relevant improvement over the threshold. It also requires the user to establish a few Key Performance Parameters (KPP). The KPPs are those requirements that may not be traded off (Higgins, 1999). Failure to meet a KPP threshold will cause the MDA to reevaluate the concept or

system and to reassess the program. Those broad requirements facilitate CAIV by allowing the requirement to be satisfied in many different designs or approaches. This allows the PM and contractor to focus on the real warfighting requirements in the most affordable methods. CAIV actually increases the probability of fully meeting the requirements. This is true because with ample trade space available to the designer, intelligent trades can be affected quickly and efficiently to trade lower-level requirements to meet the top-level KPPs and meet or reduce costs (Higgins, 1999). Lower cost designs are typically both simpler and therefore easier to manufacture, and more reliable because the designers find themselves forced to invest more heavily in the intellectual challenges of developing creative designs to meet the cost criteria (Higgins, 1997).

4. Total Ownership Costs

DoD Regulation 5000.1 requires acquisition programs be managed to optimize total system performance and minimize the cost of ownership. What are "total ownership costs?" Total ownership costs are the total life-cycle cost (LCC). LCC is the total cost to the Government of a program over its full life of developing, producing, deploying, supporting, and disposing of a system. LCC is all costs

that would not occur if the program did not exist. Total ownership costs are all the costs associated with a system known as "cradle to grave." The Defense Systems Management College (DSMC) describes a successful system acquisition program as one that places a capable and supportable system in the hands of a user when and where it is needed, and does so within the bounds of affordability (DSMC, 1996). DoD Regulation 5000.2-R defines affordability as the degree to which the LCC of an acquisition program is in consonance with the long-range investment and force structure plans of the DoD or individual DoD Components. Affordability procedures establish the basis for fostering greater program stability through the assessment of program affordability and the determination of affordability constraints. LCC estimates (LCCE) form the basis for budget requests to Congress, therefore acquisition managers are faced with fiscal constraints that are based on the LCCE.

DoD Regulation 5000.2-R states that the best time to reduce LCC is early in the acquisition process. Cost reductions are accomplished through cost/performance tradeoff analyses. In the past, acquisition managers would make cost/performance tradeoffs early in the acquisition process based on their current budget and because performance was the independent variable (performance was

the most important variable) (Higgins, 1997). They would not consider the long-term impacts to production, deployment, operational, support, and disposal costs of a system. They were focused on their current cost, schedule, and performance issues, which were mainly based on their current fiscal constraints. Additionally, those costs were not their concern. Their performance rating was not affected by future costs of operating and sustaining the weapon system that they were developing. They could "throw it over the wall" to the operational and sustainment commands, who had to accept the weapon system and budget accordingly. Defense budgets are shrinking or remaining constant, which has forced DoD to require acquisition managers to responsible for optimizing a weapon system's total ownership costs using CAIV and IPTs.

5. Performance Specification

A 1991 study conducted by the Center for Strategic International Studies (CSIS) concluded that military specifications resulted in higher prices for DoD purchases than for purchase of commercial alternatives that could satisfy the same requirements (DSMC, 1997). In the past, the use of performance specifications required a waiver. On 29 June 1994, then Secretary of Defense William Perry reversed this policy by directing the use of performance

specifications, along with requiring a waiver from the MDA for the use of military specifications and military standards. DoD Regulation 5000.1 now states that in solicitations and contracts, standard management approaches or manufacturing processes are not required. It further states that performance specifications will be used in purchasing new systems, major modifications, and commercial and nondevelopmental items.

DoD's focus is now on performance, rather than detailed designs, to better concentrate on satisfying the warfighters' needs. The use of performance-based specifications allows maximum trade space without compromising the KPPs (DoD, 1998). The performance specification states what is required, not how to accomplish it. This allows IPTs to develop innovative approaches to satisfy the warfighters' needs while satisfying CAIV and total ownership costs objectives. The use of performance specifications allows the implementation of dual-use technologies that will help share the cost, thereby lowering the cost of military systems. Dual-use technologies are technologies that can be used for both military and commercial applications.

6. Earned Value Management System

The traditional "cost/schedule management" has been reengineered as "earned value management" (EVM), integrating cost, schedule, and performance aspects of acquisition programs. The cost/schedule management was reengineered to provide insight into the contractor's efforts and processes and to have acquisition managers take ownership of the program baseline. The purpose of an earned value management system (EVMS) is to identify cost and schedule variances in real time, to allow management of cost and schedule risk. These three variables, cost, schedule, and performance, are interrelated, thus planned and unplanned changes to any one variable will usually affect one or both of the other variables. The EVMS measures work accomplishment versus technical accomplishment. Acquisition managers, both Government and contractor, are evaluated according to cost, schedule, and performance. They need to understand the relationship between these variables so that they can manage the variables to reduce the potential for and severity of unplanned changes or program risk. Effective management control systems are essential for managing program risk. The management control systems must be valid, timely, and auditable to properly relate cost, schedule, and performance (DA, 1999).

Earned value (EV) is a method for measuring program performance. It compares the amount of work that was planned known as the Budgeted Cost of Worked Performed (BCWP), with what was actually accomplished known as Actual Cost of Worked Performed (ACWP), to determine if cost and schedule performance is as planned. A program baseline is established early in the program or contract and variances to this baseline are reported. Variance analysis is conducted, which provides IPTs with the information they need to make informed management decisions. The IPTs need to establish cost and schedule reporting requirements to identify what can and will be effectively used to manage the program. Too much information will increase the cost of maintaining and reporting of the EVMS, as well as reducing the effectiveness of the EVMS.

7. Integrated Management Plan (IMP) and Integrated Management Schedule (IMS)

DoD Regulation 5000.1 states that DoD will use a rigorous, event-oriented management process that emphasizes effective acquisition planning, improved and continuous communications with users, and prudent risk management by both the Government and industry. This means that the acquisition process is based on significant events and not arbitrary calendar dates. The Integrated Management Plan or Integrated Master Plan (IMP) is an event-driven plan that

documents the significant accomplishments necessary to complete the tasks defined in the statement of objectives (SOO) or the statement of work (SOW) and ties these accomplishments to a key program event. Each significant event has exit criteria to facilitate the assessment of successful completion. The IMP is oriented by product using the WBS numbering system and contains no calendar information (DA, 1999).

The Integrated Management Schedule (IMS) or Integrated Master Schedule (IMS) is a detailed, time-dependent, task-oriented schedule of the effort required, to accomplish the program and its relationship to the events, accomplishments, and exit criteria identified in the IMP. The IMS is traceable to the IMP and WBS, and contains the predecessors and successors tasks and their dependencies. The IMP and IMS provide the Government insight into how the contractor will perform work (DA, 1999).

8. Alpha Contracting

Alpha Contracting is an innovative use of IPTs in the pre-award phase of sole-source, negotiated contracts. Alpha Contracting is a technique that uses a team approach to prepare, evaluate, and award proposals in substantially less time than the traditional approach. Alpha Contracting is a concurrent versus a serial process that shortens procurement

cycle-time and significantly reduces proposal preparation costs. The goal of Alpha Contracting is to acquire quality products for the warfighter in an expedited and efficient manner at a fair and reasonable price. The Alpha Contracting IPTs consist of the user, acquisition managers, and contracting officers from both the Government and contractor to include principal subcontractors, the Defense Contract Audit Agency, the Defense Contract Management Command (DCMC), and various support organizations. During Alpha Contracting, the contract and cost and technical detail are jointly developed to replace the solicitation and proposal with a "model contract." The IPTs adjusts the model contract to lower cost and risk. This process allows the Government to have greater program insight to contract cost, schedule, performance, and risk. Additionally, this allows the contractor to fully understand what is required, eliminating non-value added requirements (DAD, *Army Acquisition Reform; Tools and Techniques Guidebook*, March 1999).

9. Single Process Initiative (SPI)

In the past, DoD contractors have been inhibited from making major changes in many of their processes because military and standard specifications dictated how-to requirements. The Single Process Initiative (SPI) is an

expansion of Secretary of Defense Perry's directive to eliminate military and standard specifications and to the use performance specifications. The goal of SPI is to eliminate the multiple processes imposed by various existing DoD contracts into a single common commercial process, thereby saving money, obtaining a better system or product, and fostering a more competitive industry (Kaminski, 1996). SPI provides opportunities for contractors to reengineer and standardize processes on a facility-wide basis when it makes good business sense. This not only includes technical processes, but also business processes. SPI facilitates contractors to take ownership of their processes and encourages them to baseline and improve their processes by applying best practices.

C. SUMMARY

Acquisition reform is about saving the taxpayer money, reinventing Government, strengthening our military, and improving the economy. At the core of acquisition reform is reducing cycle-times and the use of insight versus oversight. DoD, the Administration, and Congress have been removing requirements that are uniquely imposed on defense contractors. This has allowed contractors to compete successfully in today's global marketplace, ensure DoD has access to the latest technology, and assist DoD in reducing

its acquisition costs. The way DoD procures systems is continuing to evolve as DoD attempts to provide the warfighter the best product, at the best dollar value, in the timeliest manner. There have been many acquisition reform successes and failures, but DoD is searching for new ways to more effectively implement and accelerate acquisition reform initiatives. How one prepares the WBS, may be one of those techniques.

III. OVERVIEW OF MIL-HDBK-881 "DEPARTMENT OF DEFENSE (DOD) HANDBOOK - WORK BREAKDOWN STRUCTURE (WBS)"

A. INTRODUCTION

DoD Regulation 5000.2-R requires a program WBS be established that provides a framework for program and technical planning, cost estimating, resource allocations, performance measurements, and status reporting, using the guidance in MIL-HDBK-881. It further requires that the WBS and associated WBS dictionary define the total system to be developed or produced; display the total system as a product-oriented family tree composed of hardware, software, services, data, and facilities; and relate the elements of work to each other and to the end product. It also requires that MIL-HDBK-881 be cited in solicitations and contracts "for guidance only" in extending the program WBS to develop the complete contract WBS (DoD, March 1998). This chapter reviews MIL-HDBK-881.

B. ISSUANCE

MIL-STD-881 was converted to MIL-HDBK-881 as a result of the performance specification acquisition reform initiative. There were no substantive changes in WBS definition (DoD, January 1998). MIL-HDBK-881 offers uniformity in definition and consistency of approach for

developing the top three levels of the WBS. MIL-HDBK-881 is for guidance only and cannot be cited as requirement. It was issued on 2 January 1998.

C. PURPOSE

MIL-HDBK-881 provides instructions on how to prepare, understand, and construct a program WBS in the context of planning and monitoring of DoD materiel programs. It provides guidance for developing and implementing a contract WBS. It discusses the role of the WBS in contract negotiation and award and in post-contract performance. It's appendices present generic definitions of WBSs for several DoD system categories. The primary purpose of MIL-HDBK-881 is to provide a consistent application of the WBS across DoD. MIL-HDBK-881 can be applied during any acquisition phase (Concept Exploration, Program Definition and Risk Reduction (PDRR), Engineering and Manufacturing Development (EMD), or production).

D. WBS DEFINITION

1. General

The WBS is a tool used to organize acquisition development activities based on system and product decompositions. The WBS is a tool that allows PMs to break large tasks into smaller, understandable tasks. MIL-HDBK-881 states the WBS will be developed and maintained based on

the systems engineering efforts throughout its life-cycle.

MIL-HDBK-881 defines the WBS as follows:

- A product-oriented family tree composed of hardware, software, services, data, and facilities. The family tree results from systems engineering efforts during the acquisition of a defense materiel item.
- A WBS displays and defines the product, or products, to be developed and/or produced. It relates the elements of work to be accomplished to each other and to the end product.
- A WBS can be expressed down to any level of interest. However the top three levels are as far as any program or contract need go unless the items identified are high-cost or high-risk. Then, and only then, is it important to take the work breakdown structure to a lower level of definition.

MIL-HDBK-881 states several times that the WBS must be product-oriented, not an organization structure. It should represent identifiable work products whether they be equipment, data, or related service products.

MIL-HDBK-881 appendices present definitions of WBSs for seven generic DoD system categories, which can be used as a starting point to construct a WBS for a specified program. The WBS for each of the seven categories is included in Appendix A through G of this document. MIL-HDBK-881 defines the following system categories:

- **aircraft system** -- applies to fixed or movable wing, rotary wing, or compound wing manned/unmanned air vehicles designed for powered or unpowered (glider) guided flight (Appendix A)

- **electronic/automated software system** -- applies to electronic, automated, or software system capability (Appendix B)
- **missile system** -- applies to a weapon in an operational environment which produces a destructive effect on selected targets (Appendix C)
- **ordnance system** -- applies to all munitions (nuclear, biological, chemical, psychological, and pyrotechnic) and the means of launching or firing them (Appendix D)
- **ship system** -- applies to naval weapons, or performing other naval tasks at sea (Appendix E)
- **space system** -- applies to developing, delivering, and maintaining mission payloads in specific orbit placement, operation, and recovery of manned and unmanned space systems (Appendix F)
- **surface vehicle system** -- applies to navigation over the surface (Appendix G)

2. Elements

It is difficult to find a definition of an element. An element of the WBS should represent identifiable work products whether they be equipment, data, or related service products. MIL-HDBK-881 states that each element of the WBS provides logical summary points for assessing technical accomplishments and for measuring the cost and schedule performance accomplished in attaining the specified technical objectives. The WBS has an end product part and an enabling product part (DSMC, October 1999). The end product part is what is delivered to the warfighter and is based on the physical structure developed from the

requirements or the product development. Figure 3.1 presents an example of a program WBS product part. The enabling product part is the products and services

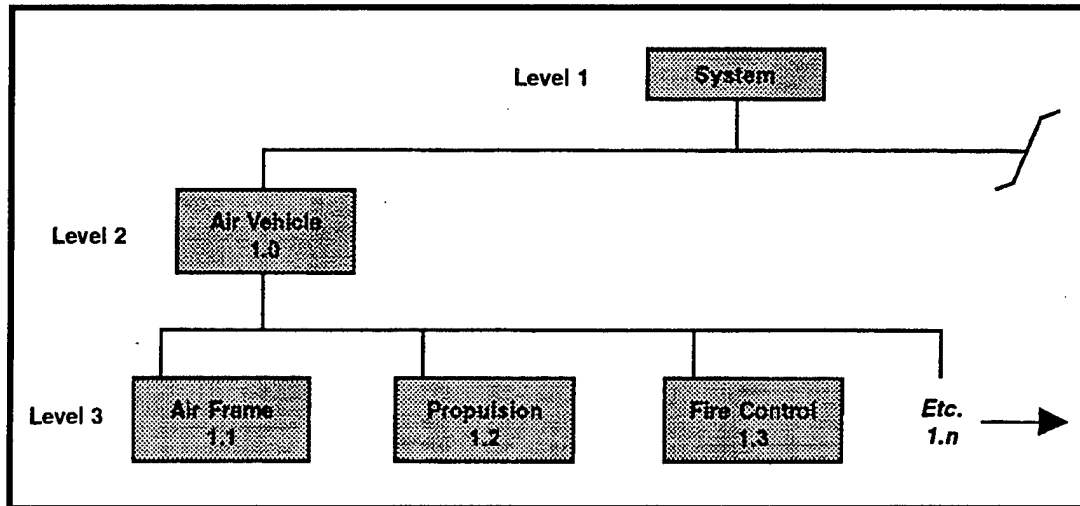


Figure 3.1. Program WBS - The Product Part (Extracted from DSMC, Systems Engineering Fundamentals)

required develop, produce, and support the end product. Figure 3.2 presents an example of a complete program WBS as defined in Appendix A for an aircraft system (DSMC, October 1999).

MIL-HDBK-881 lists these common elements that are pertinent to all seven DoD system categories. They are:

- integration, assembly, test, and checkout efforts
- systems engineering and program management
- training
- data
- system test and evaluation
- peculiar support equipment
- common support equipment
- operational and site activation
- industrial facilities
- initial spares and repair parts

Appendix H further defines these common elements.

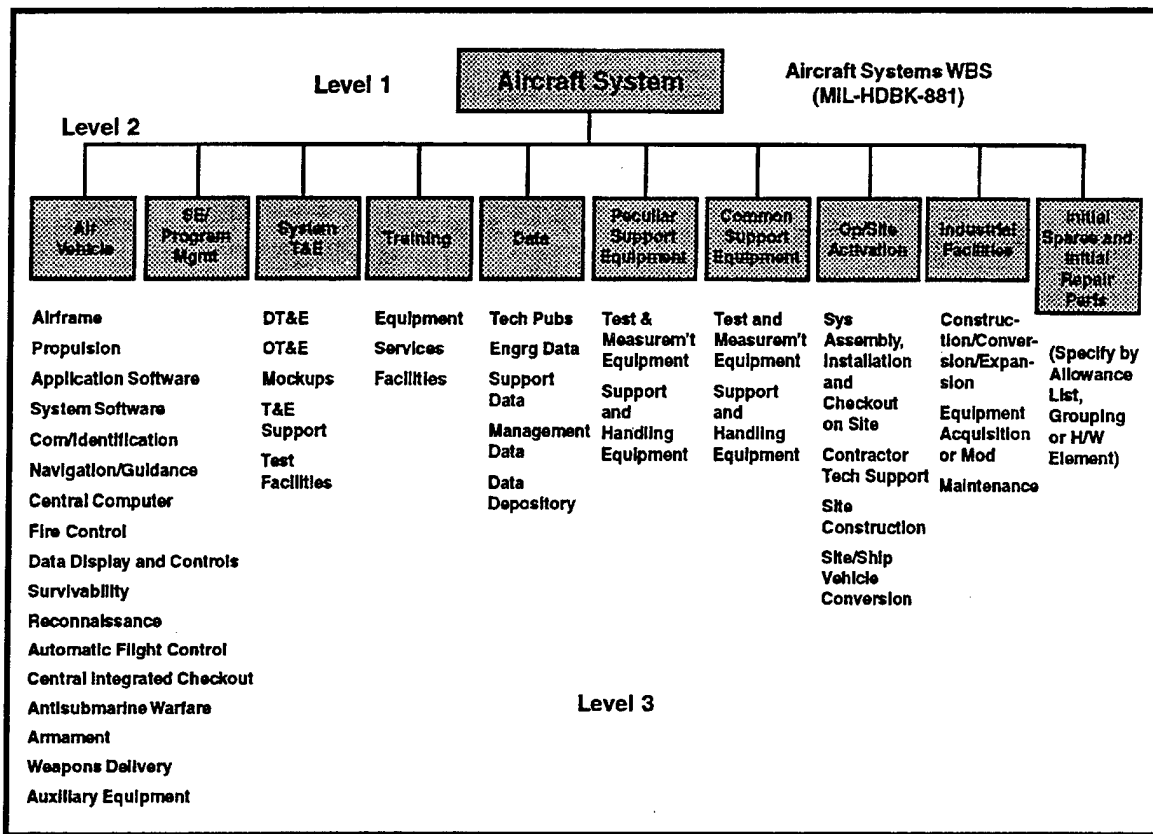


Figure 3.2. Complete Program WBS for an Aircraft System (Extracted from DSMC, Systems Engineering Fundamentals)

3. Level Identification

The WBS is divided into levels of hierarchy as can be seen in Figure 3.1 and Figure 3.2. MIL-HDBK-881 defines the top three levels as:

- Level 1 is the **entire defense materiel item**; for example, an electronic system. An "electronic system" might be a command and control system, a radar system, a communications system, an information system, a sensor system, a navigation or guidance system, or an electronic warfare system. Level 1 is usually directly identified as a program or a sub-element of a program.
- Level 2 elements are the **major elements** of the defense materiel item; for example, a fire control system or an automatic flight control system. These prime mission

products include all hardware and software elements, aggregations of system level services (like system test and evaluation, or systems engineering and program management), and data.

- Level 3 elements are **elements subordinate** to level 2 major elements. For example, a radar data processor, a signal processor, an antenna, a type of service (like development test and evaluation, contractor technical support, or training services), or a type of data (like technical publications) would be typical level 3 elements for an electronic system. Lower levels follow the same process.

E. PRPGRAM WBS AND CONTRACT WBS

MIL-HDBK-881 describes two types of WBSs, the program WBS and the contract WBS. The PM is responsible for preparing and maintaining the program WBS. It describes the program WBS as the structure that encompasses an entire program and provides a framework for specifying the objectives of the program. The program WBS consists of at least the three top levels as can be seen in Figure 3.2, and is used to develop and extend the contract WBS. The contract WBS includes all the elements of the program WBS that are the responsibility of the contractor. The contract WBS is used to organize and identify contractor tasks. Figure 3.3 presents only the product part of the contract WBS. A complete contract WBS would include the enabling products. The Fire Control element is at level 3 of the program WBS, but it is at level 1 of the contract WBS since that is the product the Government is procuring. The

contract WBS includes the applicable program WBS elements extended to the agreed contract reporting level and any discretionary extensions to lower levels based on high-cost or high-risk. The contract WBS forms the structure for the contractor's management control system.

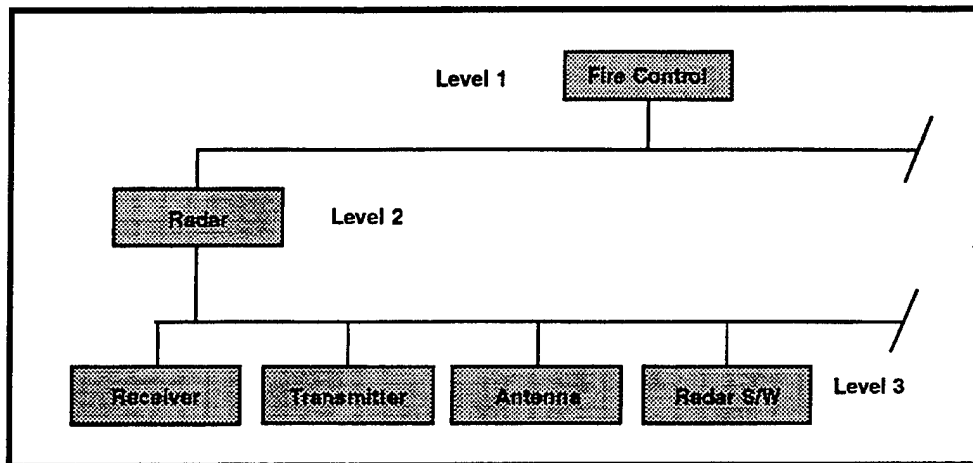


Figure 3.3. Contract WBS (Extracted from DSMC, Systems Engineering Fundamentals)

Work is documented as resources are allocated and expended through the program WBS and contract WBS. MIL-HDBK-881 states that technical, schedule, and cost data are generated for reporting purposes. The WBS summarizes the data for successive levels of management and provides the appropriate information on the projected, actual, and current status of the elements for which they are responsible. This allows the PM, in cooperation with the contractor, to monitor program status so that they can identify and implement changes necessary to assure desired performance.

F. DEVELOPING A WBS

MIL-HDBK-881 breaks this into two chapters, one for the program WBS and one for the contract WBS. The generic WBSs defined in Appendices A through G provide the basis for the program or contract WBSs. The WBS may use more than one of the categories or elements defined in the Appendices. MIL-HDBK-881 allows this "as long as the integrity of the level of placement is maintained."

1. Developing the Program WBS

MIL-HDBK-881 states that the program WBS should be developed early in the conceptual stages of the program. It evolves through iterative analysis of the program objective, functional design criteria, program scope, technical performance requirements, proposed methods of performance, and other technical documentation. The program WBS elements are selected based on the appropriate product parts of the system being developed along with the appropriate enabling product parts. These elements can consist of other elements from generic categories. The systems engineering efforts aid in defining the description of the system and its related levels throughout the life-cycle. The WBS will become more defined during each successive acquisition phase along with defining lower levels of the WBS reflecting the way business is planned and managed. MIL-HDBK-881 states

that the levels of the WBS are directly linked with the detailed configuration of the system. The program WBS can be both the program and contract WBS based on how it relates to the Government activity. For example, if a contract were awarded for the development of a complete system, then it would be both a program and contract WBS.

MIL-HDBK-881 states that for each WBS element, the detailed technical objectives are defined and specified work tasks are assigned along with the resources, materials, and processes required to attain the objectives. The linkage between the specification, the WBS, the SOW, and the master and detailed schedules provides specific insights into the relationship between cost, schedule, and performance. This relationship allows all items to be tracked to the same WBS element. The levels of the program WBS should be related to these requirements and conform to its product-oriented family tree.

2. Developing the Contract WBS

The PM selects WBS elements from the program WBS that apply to the contract. This becomes the initial contract WBS. It along with the initial contract WBS dictionary (discussed later) is included in the Request for Proposal (RFP). MIL-HDBK-881 states that the RFP should instruct potential contractors to extend the selected contract WBS

elements to define the complete contract scope. MIL-HDBK-881 reiterates that the contract line items, configuration items, contract work statement tasks, contract specifications, and contractor responses will be relatable to the WBS to enhance its effectiveness in satisfying the objectives of the particular acquisition. Combining the program WBS with the contract WBS(s) will form a complete WBS of the program for use throughout the acquisition phase.

The contract WBS provides the framework for the management control system. Contractors submit their extended contract WBS with their proposal. The contractor's expanded WBS must address all contract WBS elements in the RFP. MIL-HDBK-881 states that their proposed contract WBS should be based on the WBS in the RFP, although contractors may suggest changes needed to meet an essential requirement of the RFP or to enhance the effectiveness of the contract WBS in satisfying program objectives. It also states that contractors are expected to extend the contract WBS to the appropriate level - the level that satisfies the critical visibility requirements and does not overburden the management control system. MIL-HDBK-881 states that contractors should include lower breakdown levels where they identify risk associated with technical issues or resources,

and identify control plans whether or not the items are reported back to the Government.

MIL-HDBK-881 states that WBS revisions may result due to further elements selected for the contract will become the basis for contractor extension during the contracted effort as both parties become more knowledgeable about the effort. MIL-HDBK-881 states the following note:

Normally, once work is underway after contract award, changes to the work breakdown structure should not be made unless major rescoping of the program occurs.

MIL-HDBK-881 states that the WBS should not influence or in any way affect the contractor's program organization. A contractor can be organized in any way, by function, process, or IPT, and effectively use a valid, product-oriented WBS. This is because at some level in an organization, as well as the WBS, a cost account is managed. The WBS is visible regardless of the contractor's organization.

3. WBS Dictionary

The PM develops a WBS dictionary while developing the program WBS. MIL-HDBK-881 states the requirement for providing the WBS dictionary is placed in the Contract Data Requirements List (CDRL). The contractor while developing the contract WBS expands the WBS dictionary. The WBS dictionary lists and defines the WBS elements. The WBS

dictionary defines a common language that should be clearly understood by all stakeholders. It should eliminate any possible confusion. MIL-HDBK-881 states that the initial WBS dictionary should be based on the generic definitions in the handbook and made program-specific to define the products being acquired. The WBS dictionary describes each WBS element and the resources and the processes required to produce it. The WBS dictionary should be routinely revised throughout the program's life to incorporate changes to the program. Figure 3.4 is an example of a level 2 WBS element dictionary entry.

Index Item No. 2		WBS Level 2		CONTRACT NUMBER F33657-72-C-0923	
WBS Element A10100		WBS Title Air Vehicle		Contract Line Item: 0001, 0001AA, 0001AB, 0001AC, 0001AD 0001AE, 0001AF, 0001AG, 0001AH	
Date	Revision No.	Revision Auth	Approved Chg		
Specification No. 689E078780028		Specification Title: Prime Item Development Specification for AGM 86A Air Vehicle/ Airframe			
Element Task Description				Cost Description	
Technical Content: The Air Vehicle element task description refers to the effort required to develop, fabricate, integrate and test the airframe segment, portions of the Navigation/Guidance element, and Airborne Development Test Equipment and Airborne Operational Test Equipment and to the integration assembly and check-out of these complete elements, together with the Engine Segment, to produce the complete Air Vehicle. The lower-level elements included and summarized in the Air Vehicle element are: Airframe Segment (A11100), Navigation/Guidance Segment (A32100), Airborne Development Test Equipment (A61100), and Airborne Operational Test Equipment (A61200)				MPC/PMC A10100 Work Order/Work Auth See lower level WBS Elements Cost Content – System Contractor The cost to be accumulated against this element includes a summarization of all costs required to plan, develop, fabricate, assemble, integrate and perform development testing, analysis and reporting for the air vehicle. It also includes all costs associated with the required efforts in integrating, assembling and checking our GFP required to create this element. Applicable SOW Paragraph 3.6.2	

Figure 3.4. WBS Dictionary Level 2 Entry (Extracted from the DSMC, Systems Engineering Fundamentals)

4. Avoiding Pitfalls in Constructing a WBS

MIL-HDBK-881 states that a sound WBS clearly describes what the PM wants to acquire. It has a logical structure and is tailored to a particular materiel item. The WBS may tie the SOW, contract line item number (CLIN) structure, and the system description documents together. The WBS addresses the products required, not the functions or costs associated with those products. MIL-HDBK-881 lists the following elements that are to be excluded from the WBS:

- **Do not include elements which are not products.** A signal processor, for example, is clearly a product, as are mock-ups and Computer Software Configuration Items (CSCIs). On the other hand, things like design engineering, requirements analysis, test engineering, aluminum stock, and direct costs, are not products. Design engineering, test engineering, and requirements analysis are all engineering functional efforts; aluminum is a material resource; and direct cost is an accounting classification. Thus none of these elements are appropriate WBS elements.
- **Program phases** (e.g., design, development, production, and types of funds, or research, development, test and evaluation) are inappropriate **as elements in a WBS.**
- **Rework, retesting and refurbishing are not separate elements in a WBS.** They should be treated as part of the appropriate WBS element affected.
- **Non-recurring and recurring classifications are not WBS elements.** The reporting requirements of the Contractor Cost Data Reporting (CCDR) will segregate each element into its recurring and non-recurring parts.
- **Cost saving efforts such as total quality management initiatives, could cost, and warranty are not part of the WBS.** These efforts should be included in the cost of the item they affect, not captured separately.

- **Do not use the structure of the program office or the contractor's organization as the basis of a WBS.**
- **Do not treat costs for meetings, travel, computer support, etc. as separate WBS elements.** They are to be included with the WBS elements with which they are associated.
- **Use actual system names and nomenclature. Generic terms are inappropriate in a WBS.** The WBS elements should clearly indicate the character of the product to avoid semantic confusion. For example, if the Level 1 system is Fire Control, then the Level 2 item (prime mission product) is Fire Control Radar.
- **Treat tooling as a functional cost, not a WBS element.** Tooling (e.g., special test equipment, and factory support equipment like assembly tools, dies, jigs, fixtures, master forms, and handling equipment) should be included in the cost of the equipment being produced. If the tooling cannot be assigned to an identified subsystem or component, it should be included in the cost of integration, assembly, test, and checkout.
- **Include software costs in the cost of the equipment.** For example, when a software development facility is created to support the development of software, the effort associated with this element is considered part of the CSCI it supports or, if more than one CSCI is involved, the software effort should be included under integration, assembly, test, and checkout. Software developed to reside on specific equipment must be identified as a subset of that equipment.

MIL-HDBK-881 does not identify level 3 elements for the systems engineering and program management WBS elements. It also cautions that too much detail may limit the flexibility of the PM and the contractor. MIL-HDBK-881 states that system test and evaluation always separately identifies those tests performed in the development test and

evaluation, i.e., development test and evaluation, and those tests performed by the operational user, i.e., operational test and evaluation.

MIL-HDBK-881 states that it is incorrect to summarize all software on a program or contract in a WBS. By separating software from the hardware they support, performance measurement and management control over each product is difficult to maintain. The true cost of each product is not readily available for decisions concerning that product. MIL-HDBK-881 states that rather than separately summarizing software, it is important to identify software with the hardware it supports.

5. Integrated Cost, Schedule, and Technical Performance Management

The prime use of the WBS is design and the tracking of work. MIL-HDBK-881 states that planning work by WBS elements serves as the basis for estimating and scheduling resource requirements known as work packages. A work package is prepared for each element at its lowest level in the WBS. The work package is a complete description for each task. It includes the what, how, when, by whom, and the budget for each task (Forsberg, Mooz, and Cotterman, 1996). Cost accounts are created when the WBS element is matrixed against those organizations in the company responsible for the tasks as shown in Figure 3.5. The

organization structure depicted in Figure 3.5 could be an IPT organization as well. The WBS divides the product into

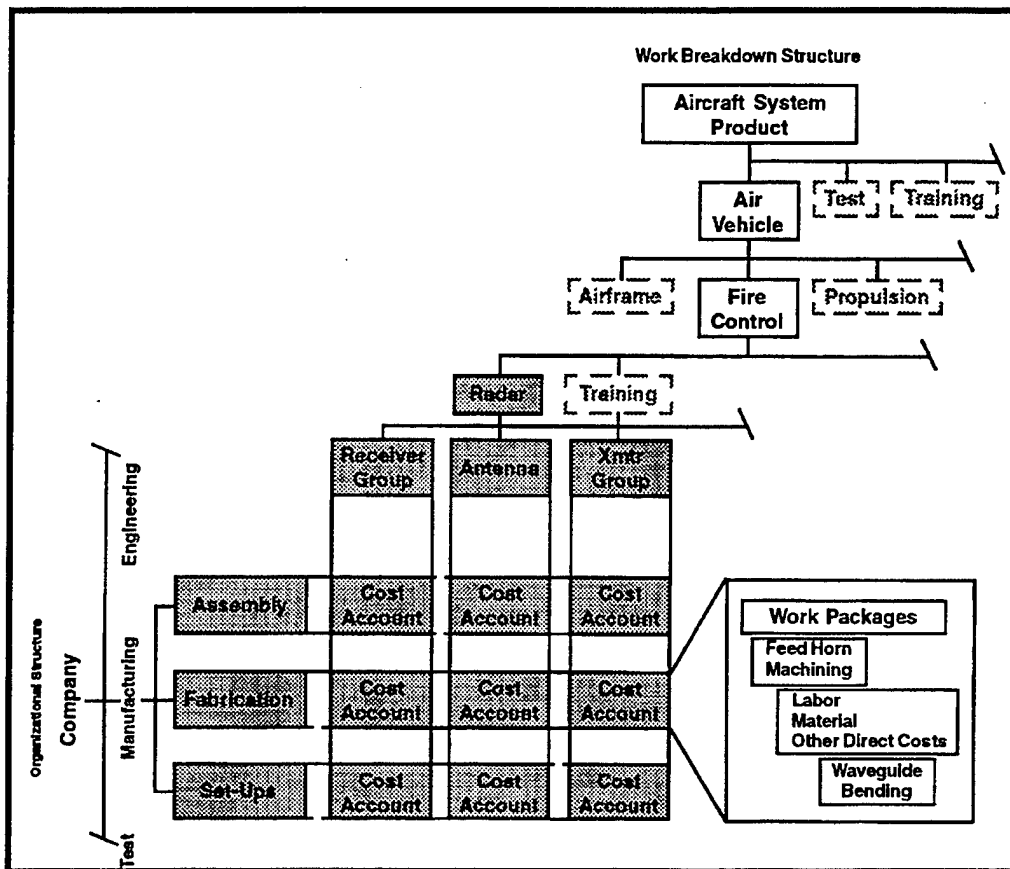


Figure 3.5. WBS Control Matrix (Extracted from DSMC, Systems Engineering Fundamentals)

smaller increments so that management can ensure that all required products are identified in terms of cost, schedule, and performance goals. MIL-HDBK-881 states that virtually all aspects of the contractor's management control system: technical definition, budgets, estimates, schedules, work assignments, accounting, progress assessment, problem identification, and corrective actions, come together at the cost account level. Assigning performance budgets to work

segments and identifying responsible units, produces a time-phased plan against which actual performance can be measured. An IMP and IMS can now be created. As discussed in Chapter II, the IMP is the specific tool used to track and measure successful task completion and is event-based.

G. SUMMARY

DoD Regulation 5000.2 R requires a program WBS be established using the guidance in MIL-HDBK-881. MIL-STD-881 was converted to MIL-HDBK-881 as a result of the performance specification acquisition reform initiative. MIL-HDBK-881 provides instructions on how to prepare, understand, and construct both a program WBS and a contract WBS. MIL-HDBK-881 provides seven generic DoD system categories. The WBS format in MIL-HDBK-881 is to be used as a starting point for constructing and tailoring a WBS. The WBS is a tool used to organize and coordinate work to be completed on a program. The Government PM prepares the program WBS and the initial contract WBS. The contractor develops lower levels of the contract WBS based on the work required by the contract. Work packages and cost accounts are established along with an IMP and IMS, which become the baseline against which performance is measured.

IV. ANALYSIS OF THE WORK BREAKDOWN STRUCTURE (WBS)

A. INTRODUCTION

The previous chapters presented information on acquisition reform initiatives and MIL-HDBK-881's guidance concerning how to construct a WBS. This chapter analyzes how a WBS that is constructed in accordance with MIL-HDBK-881 facilitates or impedes the acquisition reform initiatives presented in Chapter II. Many of the assertions and conclusions in this thesis are based on experiences and discussions with Government and contractor personnel during my career. This analysis is also based on poorly-written WBSs prepared by the researcher who as a result, suffered the consequences of attempting to manage with meaningless data. Before conducting this analysis, a general discussion concerning the various perspectives of WBS stakeholders, the systems engineering process (SEP), and considerations when preparing the WBS is presented. Then based on this analysis, an alternative WBS is developed and analyzed.

B. GENERAL

The major stakeholders in constructing the WBS are the Government PM, Government systems engineer, contractor PM, and the contractor systems engineer. How a WBS is constructed depends on each of their perspectives. As

stated in Chapter I, the challenge in developing a WBS is to balance the program definition aspects against its data-generating aspects. The PMs tend to focus more on the data-generating aspects of the WBS, whereas the systems engineers focus more on the program definition aspects of the WBS. The Government and contractor PMs require the WBS be constructed so that it provides insight to cost, schedule, performance, and risk. They require this data to effectively manage the program. The Government PM is trying to ensure that the Government is obtaining the best value for their dollar spent. Additionally, the Government PM is attempting to ensure the program will be completed on budget and on schedule and provide the desired performance required by the warfighter. In contrast, the contractor PM is attempting to ensure they have insight so that the company obtains a profit, as well as ensuring the program will be completed below budget and ahead of schedule and provide the desired performance required by the warfighter. The Government and contractor systems engineers require the WBS be constructed so that they can clearly define the products and tasks to be accomplished, and execute the program. Their approaches are rarely the same since there are many possible solutions and approaches to satisfy a requirement.

In today's acquisition environment, one uses an IPT to construct a WBS. Additionally, the WBS may be negotiated during the solicitation process to ensure that both Government and contractor perspectives are being satisfied. Throughout the rest of this analysis, I will attempt to balance the various perspectives.

C. SYSTEMS ENGINEERING PROCESS OVERVIEW

The systems engineering process (SEP) supports acquisition decision-making. It is the basic means for planning and assessing system development. Systems Engineering (SE) is an approach that encompasses the entire technical effort to develop, manufacture, verify, deploy, operate, support, dispose of, and train warfighters on the system products and processes. SE is the balancing of people, products, and process solutions that satisfy customer (warfighter) needs. SE attempts to answer the question, "How do you create a product that a customer needs, will be able to use, at the price they are willing to pay, and ensure that no safety hazards exist?" SE involves the discovery, understanding, focus, invention, action, feedback, and feed-forward (sharing) of knowledge. SE poses questions early and continuously in the acquisition process to prevent disasters, increased costs, schedule slippage, and decreased performance. The DSMC's Systems Engineering

Fundamentals states that SE is an interdisciplinary engineering management process to evolve and verify an integrated, life-cycle-balanced set of system solutions that satisfy customer needs (DSMC, October 1999).

SE defines what is to be accomplished. SE does not define how to do what is to be done. Determining how to do what is to be done is a design engineering responsibility. SE develops a description of system parameters. These system parameters are documented in baseline specifications. SE is responsible for conducting tradeoffs to develop the system parameters. The SEP progressively decomposes or allocates the system requirements to the lowest level of detail (Forsberg, Mooz, and Cotterman, 1996).

DoD Regulation 5000.2-R requires PMs to ensure that a SEP is used to translate operational needs and/or requirements into a system solution that includes the design, manufacturing, test and evaluation, and support processes and products. The SEP establishes the proper balance between performance, risk, cost, and schedule, employing a top-down iterative process of requirements analysis, functional analysis and allocation, design synthesis and verification, and system analysis and control, as shown in Figure 4.1. Appendix I is extracted from Chapter 3 of DSMC's Systems Engineering Fundamentals. It explains the SEP depicted by Figure 4.1.

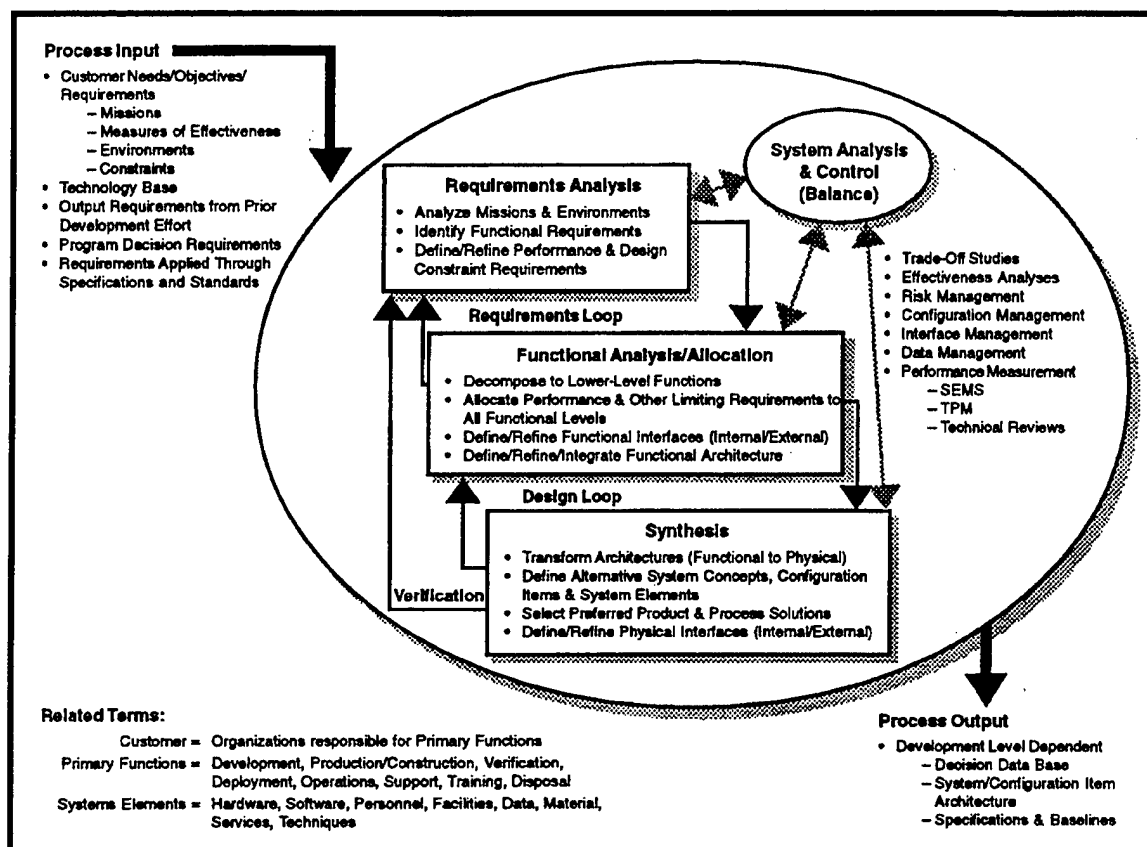


Figure 4.1. The Systems Engineering Process (Extracted from DSMC, Systems Engineering Fundamentals)

DoD Regulation 5000.2-R requires the following SE activities depicted in Figure 4.1 to be performed:

1. **Requirements Analysis.** Throughout the acquisition process the program office shall work with the user to establish and refine operational and design requirements that result in the proper balance between performance and cost within affordability constraints. Requirements analysis shall be conducted iteratively with functional analysis/allocation to develop and refine system level functional and performance requirements, external interfaces and provide traceability among user requirements and design requirements.
2. **Functional Analysis/Allocation.** Functional analysis/allocation shall be performed iteratively to define successively lower level functional and performance requirements, including functional interfaces and architecture. Functional and

performance requirements shall be traceable to higher level requirements. System requirements shall be allocated and defined in sufficient detail to provide design and verification criteria to support the integrated system design.

3. Design Synthesis and Verification. Design synthesis and verification activities shall translate functional and performance requirements into design solutions to include: alternative people, product and process concepts and solutions, and internal and external interfaces. These design solutions shall be in sufficient detail to verify requirements have been met. The verification of the design shall include a cost-effective combination of design analysis, design modeling and simulation, and demonstration and testing. The verification process shall address the design tools, products, and processes.
4. System Analysis and Control. System analysis and control activities shall be established to serve as a basis for evaluating and selecting alternatives, measuring progress, and documenting design decisions. This shall include:
 - The conduct of trade-off studies among requirements (operational, functional, and performance), design alternatives and their related manufacturing, testing and support processes, program schedule, and life-cycle cost at the appropriate level of detail to support decision-making and lead to a proper balance between performance and cost.
 - The establishment of a risk management process to be applied throughout the design process. The risk management effort shall address the identification and evaluation of potential sources of technical risks based on the technology being used and its related design, manufacturing capabilities, potential industry sources, test and support processes, risk mitigation efforts, and risk assessment and analysis. Technology transition planning and criteria shall be established as part of the overall risk management effort.
 - A configuration management process to control the system products, processes, and related documentation. The configuration management effort

includes identifying, documenting, and verifying the functional and physical characteristics of an item; recording the configuration of an item; and controlling changes to an item and its documentation. It shall provide a complete audit trail of decisions and design modifications.

- An integrated data management system to capture and control the technical baseline (configuration documentation, technical data, and technical manuals); provide data correlation and traceability among requirements, designs, decisions, rationale, and other related program planning, and reporting, support configuration procedures, and serve as a ready reference for the systems engineering effort. PMS shall use existing information systems and data formats rather than DoD-unique systems and formats, provided they can readily meet the program's information requirements and do not pose compatibility issues with operational DoD information systems and data.
- The establishment of performance metrics to provide measures of how well the technical development and design are evolving relative to what was planned and relative to meeting system requirements in terms of performance, risk mitigation, producibility, cost, and schedule. Performance metrics must be traceable to performance parameters identified by the operational user.
- The establishment of interface controls to ensure all internal and external interface requirement changes are properly recorded and communicated to all affected configuration items.
- A structured review process to demonstrate and confirm completion of required accomplishments and their exit criteria as defined in program planning. Reviews necessary to demonstrate, confirm, and coordinate progress shall be incorporated into overall program planning.

In today's acquisition environment, IPTs conduct the SEP. During each of the SEP activities (Requirements

Analysis, Functional Analysis/Allocation, and Synthesis), IPTs will conduct System Analysis and Control activities to obtain knowledge from which to base a decision. During System Analysis and Control, IPTs attempt to solve unknowns. This is an iterative process, along with the requirements loop, design loop, and verification loop, each occurring several times during an acquisition phase. IPTs attempt to reduce this process cycle-time each time it is repeated. No decisions are made during System Analysis and Control activities. IPTs make decisions only during Requirements Analysis, Functional Analysis/Allocation, and Synthesis activities.

During System Analysis and Control, IPTs use modeling, simulation, experimentation, and tests to obtain the necessary knowledge to make a decision. Depending on the acquisition phase, thirty-percent, fifty-percent, seventy-percent, ninety-percent, or full-scale systems will be used. Also, these systems may be referred to as prototype, preliminary, detailed, low-rate production, or production systems. Sub-scale models/systems usually cost less, require less time to fabricate, and have lower risk. To reduce risk from test to test, developers attempt to modify as few components as possible. This process allows them to quickly determine the cause of a failure, if it occurs.

This process also allows for reduction of the design, fabricate, test, analyze, and fix cycle-time.

The SEP depicted in Figure 4.1 is conducted throughout the DoD acquisition phases as shown in Figure 4.2. The SEP produces configuration baselines as depicted in Figure 4.2. The functional baseline is the initial configuration baseline, which becomes the System Specification. As alternative solutions are developed and more knowledge is gained during SEP activities, the functional requirements are allocated down forming the allocated baselines, which become the Preliminary Design Specifications. Again as alternative solutions are demonstrated and more knowledge is gained during later SEP activities, the allocated baselines become product baselines, which become detailed item, process, and material specifications (DSMC, October 1999).

At the end on each SEP cycle, a technical review is conducted to ensure the phase objectives have been achieved. DoD is attempting to reduce this SEP cycle-time to reduce costs and field equipment rapidly. These technical reviews are: Alternative Systems Review (ASR), Systems Requirements Review (SRR), System Functional Review (SFR), Preliminary Design Review (PDR), Critical Design Review (CDR), Functional Configuration Audit (FCA)/System Verification Review (SVR), Physical Configuration Audit (PCA), Test

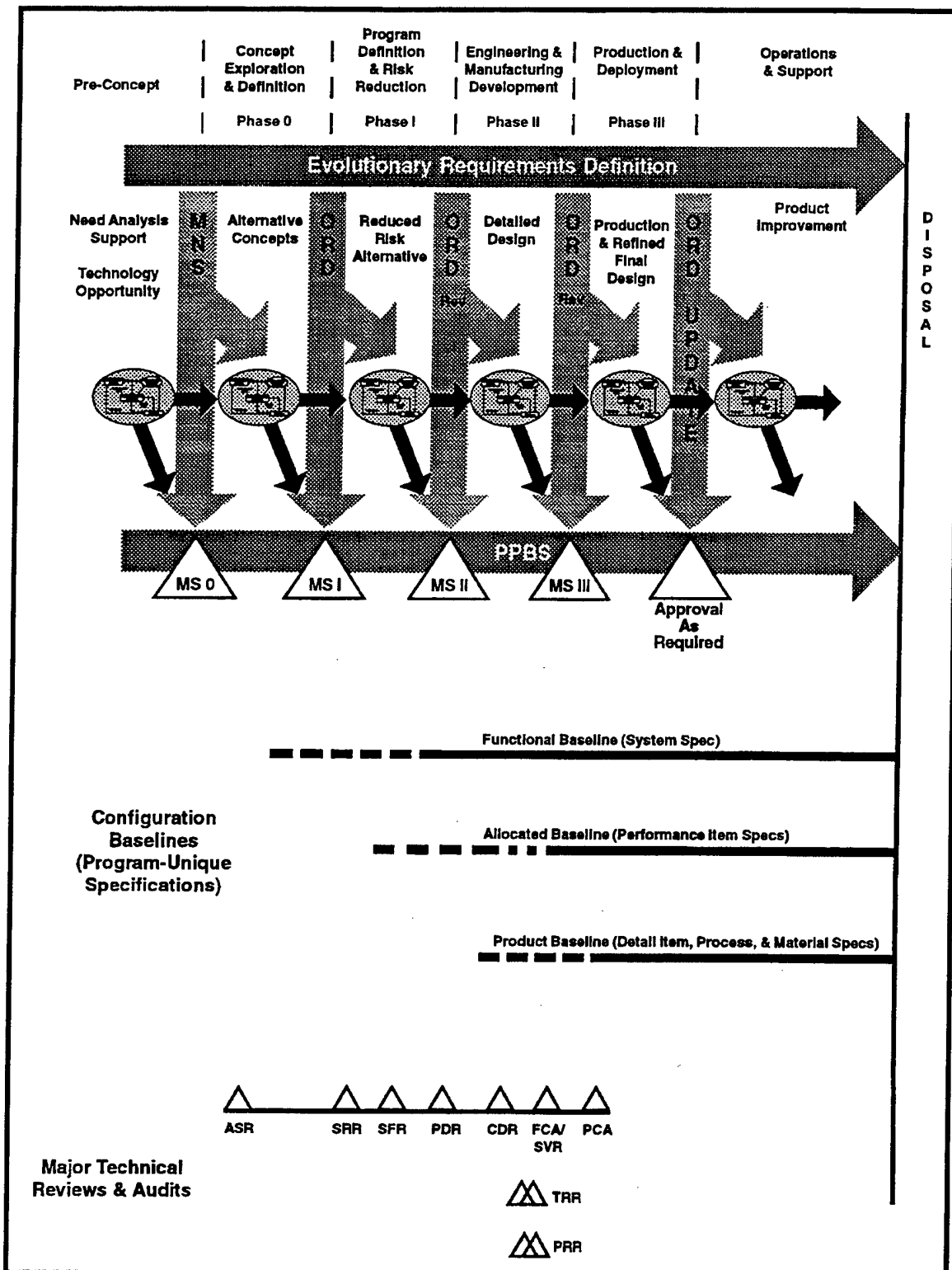


Figure 4.2. Systems Engineering and the Acquisition Life-cycle (Extracted from DSMC Systems Engineering Fundamentals)

Readiness Review (TRR), and Production Readiness Review (PRR). These technical reviews are depicted in Figure 4.2 (DSMC, October 1999). These technical reviews should be event-driven, not calendar-driven. Normally, a test, examination, or demonstration is conducted during the verification loop. This event signals that adequate knowledge is known, the solution satisfies or has the potential to satisfy the requirements (depending on the acquisition phase), and that the program is ready to proceed through the next phase and repeat the SEP.

SE is about doing the right thing right the first time (Forsberg, Mooz, and Cotterman, 1996). IPTs are essential during the SEP to accomplish this. For example, changing paper early in the acquisition process is easier than changing hardware later in the acquisition process. Similarly, modifying a sub-scale system is easier than changing a full-scale system. The DSMC's Systems Engineering Fundamentals states that the SEP management is a critical support process for DoD acquisition. If the SEP management is successful, then the program will likely be successful. If the SEP management effort fails, then the program acquisition effort will also fail.

D. CONSIDERATIONS WHEN STRUCTURING A WBS

The WBS provides a consistent and visible framework for defense materiel items, as well as the basis for communication throughout the acquisition process. The WBS unifies the planning, scheduling, cost estimating, budgeting, contracting, configuration management, and performance reporting disciplines. The WBS will take a large, complex, unmanageable program and break it into small, easily-understandable and manageable modules. These smaller modules are then linked to define a complete program.

DoD acquisition officials and PMs want to have successful programs. They require tools that will allow them to provide the warfighter with an affordable, supportable, and operationally-effective and suitable system when it is needed. They want to know what they are doing, how are they going to do it, and when they are planning to do it. They want to ensure proper planning of all required tasks to successfully meet the objectives of the acquisition phase. They want to know that best practices are being logically employed to make their program successful. Additionally, they want to know what are the high-risk and high-cost areas that will require their attention. The WBS is the framework to allow PMs to quickly determine what they

are doing, how are they going to do it, and when they are planning to do it.

The WBS is used to develop schedules and cost estimates. When cost and schedule estimates are developed early in the life of a program, there is uncertainty or risk, usually high-risk, associated with the estimates. One tends to lose sight that the cost and schedule estimates are the IPT's best point estimate chosen from a range of possible outcomes. IPTs are used to attempt to quantify the degree of uncertainty. A Monte Carlo Simulation tool is also useful when attempting to quantify and add structure to cost estimating. A Monte Carlo Simulation is a system that uses random numbers to measure the effects of uncertainty in a spreadsheet model (Decisioneering, Inc., 1996). With a Monte Carlo Simulation tool like Crystal Ball, an IPT can describe a range of possible values for each uncertainty. The simulation produces a forecasted range of all possible outcomes along with the likelihood of achieving each outcome. This type of model moves beyond what-if analysis by providing a statistical picture of the range of possibilities inherent in the assumptions (Decisioneering, Inc., 1996). Any IPT member can view the assumptions for each spreadsheet entry. These assumptions can be modified by the IPT as they progress through the acquisition phase.

As more knowledge is gained, the IPT can refine their assumptions. This should be accomplished before each technical review depicted in Figure 4.2. The use of a Monte Carlo Simulation tool should result in more accurate and realistic estimates, along with a method to quantify and add structure to risk management.

E. BASELINE WBS

To conduct this analysis to determine the effectiveness of a WBS constructed in accordance with MIL-HDBK-881 in implementing acquisition reform initiatives, a baseline WBS is required. In Chapter III, I have used a WBS for an aircraft system presented in MIL-HDBK-881's Appendix A. This analysis will continue to use the aircraft WBS shown in Figure 4.3 as the baseline WBS.

F. ANALYSIS OF BASELINE WBS EFFECTIVENESS IN IMPLEMENTING ACQUISITION REFORM INITIATIVES

1. Streamline Acquisition/Adoption of Commercial Practices

DoD Regulation 5000.2-R requires PMs to use MIL-HDBK-881 to construct WBSs, even though PMs cannot require contractors to use MIL-HDBK-881. MIL-HDBK-881 presents guidelines, not requirements, for preparing WBSs. MIL-HDBK-881's appendices provide a WBS for seven DoD system categories. The baseline aircraft system WBS along with

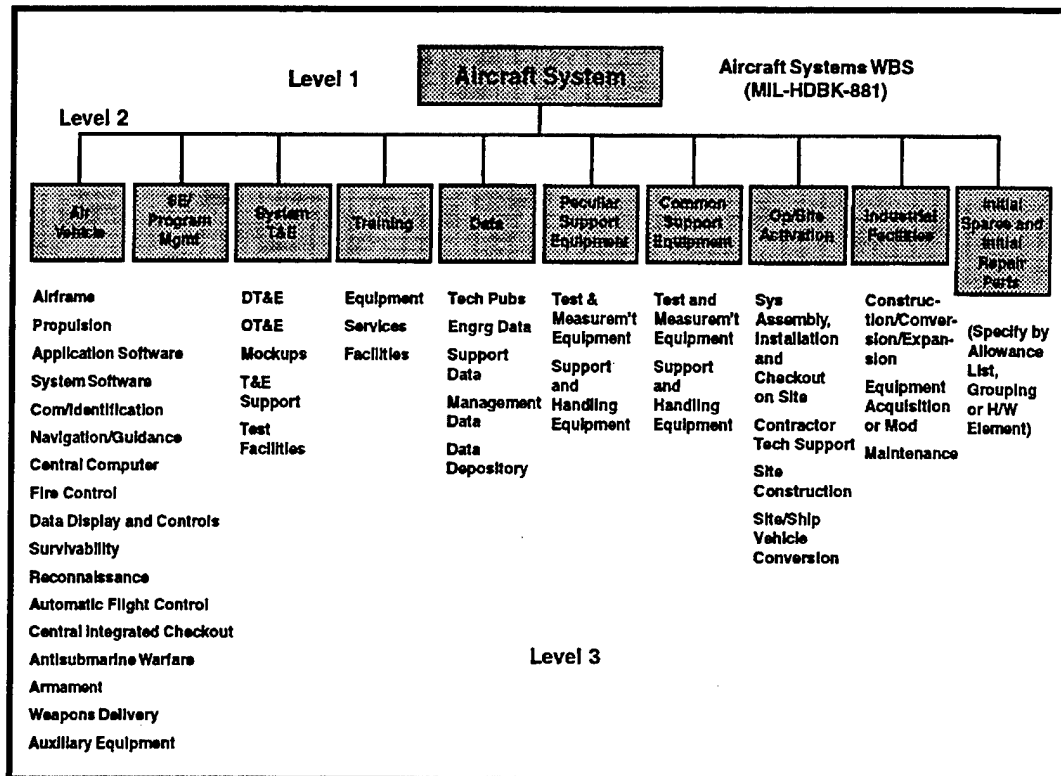


Figure 4.3. Baseline WBS (Extracted from DSMC, Systems Engineering Fundamentals)

MIL-HDBK-881 allows implementation of streamlined acquisition and adoption of commercial practices. It is very difficult to determine the effectiveness of the implementation. Does this baseline WBS allow insight versus oversight and help reduce cycle-time?

A WBS has an end product part and an enabling product part (DSMC, October 1999). The end product part of the baseline WBS is on the left side or the vertical part of the WBS in Figure 4.3. The enabling product part is the horizontal part of the WBS in Figure 4.3. So, the end product part has one level 2 element and several level 3 elements, whereas the enabling product part has several

level 2 elements and a few level 3 elements. Where is the greater risk, the end product part or the enabling product part? The enabling product parts are, or should be, allocated to the end product parts during the SEP. This assertion is based on experience and the following example. To illustrate, level 2 WBS element, Data, is divided down into Technical Publications, Engineering Data, Management Data, Support Data, and Data Depository elements. Each of the end product parts at level 3 will contain each of these elements. The Airframe will have Technical Publications, Engineering Data, Management Data, Support Data, and Data Depository, as well as Propulsion. Technical Publications (TPs) are not a difficult task and could be considered a work package. However, if the TPs are not available when needed, a program will suffer. So a PM needs to ensure that TPs are scheduled and then empower the IPT members to ensure the task is completed. If the allocation of the enabling product parts to the end product parts occurs, then there is no need for the enabling product part of the WBS to exist at level 2. They would exist only at level 4, or lower, for each of the end product parts. Thus all risk should be allocated to the end product parts.

Contractors report down to level 3 unless otherwise directed by the contract. The baseline WBS has only one

level 2 end product element and several level 3 end product elements. The PM will not have adequate insight into these higher risk end product elements. If DoD's objective is to increase insight, especially into those high-risk and high-cost elements, then the end product elements should be at level 2 of the WBS, not level 3. This will require contractors to report data at a higher level and in more detail, which will allow PMs to have greater insight (visibility) and lead to early identification of problem areas.

MIL-HDBK-881 encourages lower level reporting where high technical risk or high-cost exists. This is contrary to normal business practice. If a PM were concerned with a specific issue, he would elevate it to a higher level, requiring it to be reported frequently and in more detail. Additionally, one tends to focus on levels 2 or 3 of the contract WBS unless there is a variance at those levels. This assertion again is based on my experience and discussions with Government and contractor acquisition managers. There are so many numbers, that you attempt to reduce them in order to try and understand them. This higher level summarization may mask lower level element variances. For example, Figure 3.5 decomposes the baseline WBS to level 5. The Receiver Group element is at level 5

and may contain software, which is normally high-risk in a program. The contractor reports data to level 5. If one is reviewing the higher WBS levels (2 and 3), a variance may not exist because the level 3 elements, Airframe or Propulsion, or level 5 elements, Antenna or Xmtr Group, may have a positive variance. This positive variance may offset the negative variance of the Radar or Receiver Group elements. Therefore, the PM would not have early insight to the software problem. Thus the PM would not be able to execute corrective actions to prevent negative cost or schedule impacts. At the higher level WBS, the PM would have early insight and be able to implement corrective actions to mitigate negative program impacts.

The next part of the question, does the baseline WBS help to reduce cycle-time, is more difficult to address. During the SEP, tradeoffs are performed by IPTs. The end product IPTs will conduct tradeoffs that will impact the enabling product part and vice versa. With the enabling product part being separate from the end product part, the potential exists for no communication or miscommunication to occur. Additionally, the potential for the tradeoff decision to negatively impact the enabling product part or vice versa also exists. If either of the above occurs, then the cycle-time is not shortened because the tradeoff process

will have to be repeated or the program will experience a higher cost. Both results are unacceptable. Thus there is a potential of not reducing cycle-time when utilizing the baseline WBS.

Based upon the definitions in Appendix H of MIL-HDBK-881 (Appendix H of this document), how IPTs are established and function, and my experience of working in an IPPD environment, I assert that the SE/Program Management element of the enabling product part should be separated into two level 2 elements, one entitled Program Management and the other entitled Systems Engineering Integration. Appendix H contains several sub-element descriptions into which the PM should have insight. The baseline WBS would have these sub-elements at level 4 or lower. Again, the PM would not have adequate insight into the contractor's activities to identify problem areas early enough to prevent cost and schedule impacts. Level 1 IPTs are normally a program management IPT and a system IPT (DSMC, October 1999 and Office of the USD(A&T), 1998). Based on my experience, the PM IPT establishes and maintains the top-level program plan and acts as program integrator of the lower level IPTs, with the authority to reallocate cost and schedule requirements between IPTs. Based on my experience, the Systems Engineering Integration Product Team (SEIPT) is responsible

for integration, allocation, and verification of technical requirements. Additionally, based on my experience and how IPTs operate, the Program Management element should have a sub-element entitled Business Management. Based on my experience, PMs are extremely busy and thus cannot attend each lower-level IPT meeting in order to be able to stay abreast of all the detailed activities. This Business Management sub-element encompasses the planning and management of all business areas of the program including: contracts, subcontracts, program control, finance, capital equipment, scheduling, data management, Government property, and purchasing and pricing (Tracor, 1998). A member from both the SEIPT and Business Management IPT are also members of the lower-level IPTs. These members serve as the "eyes and ears" of the entire SEIPT and Business Management IPT. They keep the various plans and documents updated to provide consistent and consolidated documents and plans to the lower-level IPTs, the PM IPT, and the Government. This allows the PM to have a clearer picture of the contractor's activities and facilitate adoption of commercial practices.

As stated earlier, the Systems Engineering sub-element should be titled Systems Engineering and Integration. Systems Engineering is mainly focused on integrating the subsystems or components. MIL-HDBK-881 states that WBS

elements should clearly indicate the character of the product to avoid semantic confusion, therefore the recommended name change to Systems Engineering Integration. This name better reflects and emphasizes the tasks to be completed. The level 3 elements under this level 2 element should reflect the work that is actually being planned or accomplished in the SEP. Those elements would be requirements management, technical management, support engineering integration, Integrated Logistics Support (ILS), reliability and maintainability, Human System Integration (HSI), manufacturing, and requirements verification. Based on my experience and lessons learned from NPS courses, Manufacturing would have two level 4 elements entitled: producibility program and quality assurance. ILS will be discussed later. These elements provide a clear picture of the work to be accomplished for the system being developed. This element and its sub-elements could also be part of each end product part.

2. Integrated Product and Process Development (IPPD)/Integrated Product Team (IPT)

In today's acquisition environment, IPTs are used to focus on products and processes. IPTs are formed using the WBS as depicted in Figure 2.2 (DSMC, October 1999). The end product part of the baseline WBS allows implementation of IPTs, as well as the enabling part of the baseline WBS. How

effectively are the IPTs structured by the baseline WBS and does this IPT structure allow the IPPD process to be effectively implemented? Another way to ask this question is, does this baseline WBS allow functional stovepipes? The enabling product part does allow the potential for test and evaluation, HIS, and ILS stovepipes. The enabling product part consists of these three functional areas. If the enabling product parts are not allocated to the end product parts, then a complete multi-disciplinary team may not exist. Additionally, if an IPT is not allocated all life-cycle requirements, then the IPT is conducting tradeoffs that will impact other IPTs. As discussed above in Paragraph 1, the potential exists for repeating the tradeoff process.

For the end product IPTs to effectively function as a small program and use IPPD techniques, the enabling product part needs to be allocated to the end product or vice versa. For example, the enabling product part, Common Support Equipment, is broken down into Test and Measurement Equipment and Support and Handling Equipment. The end product part, Propulsion, may require both Common Support Equipment elements. During the SEP, tradeoffs are conducted by the Propulsion IPT that will affect the Common Support Equipment IPT or vice versa. The discrepancies will need to

be resolved by the SEIPT, which may require the tradeoff analysis to be repeated by both IPTs. (Based on my experience, if an allocated requirement is breached by any lower level IPT, it is raised to the SEIPT to be resolved.) Thus, this baseline WBS does not effectively implement IPPD and IPTs.

Before continuing, the baseline WBS end product parts require analysis. Do those elements breach any of the guidelines in MIL-HDBK-881 and are they actually products? In Chapter III under "Avoiding Pitfalls in Constructing a WBS," MIL-HDBK-881 states, "Include software costs in the cost of the equipment." The Baseline WBS lists two elements entitled Application Software and System Software that are in direct violation of MIL-HDBK-881. Also, many of these elements are requirements that should be allocated to true end products. Those true end products are Airframe, Propulsion, and what I will refer to as the Mission Equipment Package (MEP). This was determined based on conversations with US Marine Corps Major Eric Chase and US Army Captain Jason Galindo, both helicopter pilots attending NPS. As stated earlier, these end products should be at level 2 of the WBS since they are high-cost and probably high-risk. The MEP could have a sub-product entitled Cockpit. If the Cockpit were a high-risk or high-cost sub-

component, I would raise it to level 2 for the reasons indicated above.

3. Cost As An Independent Variable (CAIV)

The baseline WBS allows implementation of CAIV. How effectively does the baseline WBS implement CAIV? It depends on how well one can establish a cost for each element. As discussed above, the potential exists for the end product parts to affect the enabling product parts. Thus cost could be affected. An effective manager may be able to eliminate any affects, but it will require continuous monitoring. Based on my actual experience in implementing CAIV, it was next to impossible to accomplish utilizing the baseline WBS. If a test failed and had to be repeated, but was not planned, then what else was not going to be accomplished in order to fund this additional effort? What risks are the various elements absorbing? How does this track to the program objectives and exit criteria? The costs were spread across several elements and controlled by several IPTs. The coordination required to resolve this issue was very complex, requiring several man-hours of effort, which eventually resulted in the WBS and EVMS not being used to manage the program.

To resolve this issue, the PM IPT looked at the program objectives for the PDRR acquisition phase and the exit

criteria established by the MDA to enter the EMD acquisition phase. Those objectives were then allocated to the SEIPT, along with the questions, "What needs to be done, how is it going to be done, and when will it be done?" The SEIPT then allocated these objectives to the appropriate level 2 Product IPTs. The Product IPTs, along with active involvement of the SEIPT, determined the phases or smaller projects required to meet the objectives. The IPTs divided the remaining work into Flight Test 2 through Flight Test 6. Each Flight Test was a small program. The PM IPT was able to track all resources required to accomplish the objectives of each Flight Test. The SEIPT was able to allocate all requirements to each Product IPT for each Flight Test. This process assisted in being better able to identify and monitor the high-risk areas, along with improved implementation of CAIV.

4. Total Ownership Costs

DoD Regulation 5000.1 requires programs be managed to optimize total system performance and minimize the cost of ownership. Does the baseline WBS allow this? No, because the end product parts are not allocated to the enabling product parts and most of the end product parts are not end products. The end product IPTs are performing tradeoffs during the SEP, but they are not responsible for total cost

of ownership. The end product IPTs are conducting tradeoffs that will affect test and evaluation, training, data, peculiar and common support equipment, operational/site activation, industrial facilities, and initial spare and repair parts, all of which are not allocated to them. The outcome of these tradeoffs could increase or decrease unit cost of the end product, but decrease or increase the cost of training.

This baseline WBS does not effectively integrate logistics. MIL-HDBK-881 states that the acquisition logistics element should be accommodated as indicated in the upper levels of the WBS. This technique creates the potential for a logistics stovepipe and does not allow effective tradeoffs. ILS needs to be an element of the SEIPT and further allocated to each end product. The logistics engineer/manager must be actively involved during all acquisition phases in both the SEIPT and each end product IPT in order to influence the design to reduce operating and maintaining costs. This will also allow the potential for design influence to reduce cost of training, data, peculiar and common support equipment, operational/site activation, industrial facilities, and initial spare and repair parts. As with the discussion on TPs, these elements or work packages are not difficult to

accomplish. The concern is, if they are not accomplished on time, it will adversely impact the program. PMs need to ensure the sub-elements or work packages are planned and then empower the IPTs to accomplish them.

Based on my experience, PMs need to ensure that IPTs are using total ownership costs or life-cycle cost in their tradeoffs. There are many different cost terms and it is easy to become confused and use the wrong cost. Other cost terms include: development cost, flyaway cost, weapon system cost, procurement cost, program acquisition cost, and operating and support costs (DSMC, July 1999). A contractor may have a tendency to use current acquisition costs for that phase of development, because they control that cost data.

5. Performance Specification

The baseline WBS allows the use of performance specifications, but for which WBS elements do you prepare a performance specification? For example, how do you write a performance specification for Survivability? A Survivability performance requirement for the Airframe Performance Specification is relatively easier to prepare and verify than to prepare and verify a performance specification for survivability. Based on my experience, the potential exists for this process of preparing

performance specifications to be very complex, along with having the potential for a requirement to not being allocated, or of being allocated to the wrong end product. The enabling product parts must be allocated to the end product parts to effectively document the performance specifications for each end product part. Also, the end product parts should be products, not requirements.

6. Earned Value Management System (EVMS)

The baseline WBS allows implementation of the EVMS, although it does not allow adequate insight into the high-risk areas of the end product parts. The EVMS requires contractors to report down to level 3 of the contract WBS unless an element has high technical risk or high-cost. In this case, the contractor reports down to the lower levels. Also, if a variance exists, then the contractor must report to the lowest level to explain the variance and to identify the corrective action. As discussed earlier, the end product parts are higher risk than the enabling product parts and a variance may not exist at the baseline level 3 elements because positive variances may cancel negative variances at level 4. The probability of a variance occurring with the enabling product parts is very low. Thus, the EVMS is not allowing adequate insight into potential high-risk areas.

The WBS is the framework for the EVMS to allow PMs to quickly determine what they are doing, how are they going to do it, and when they are planning to do it. The baseline WBS does not effectively provide the framework to allow PMs to quickly determine what they are doing, how are they going to do it, and when they are planning to do it. As stated earlier, the WBS should reflect the key products and processes that are of high-risk and high-cost. The EVMS should reflect IPPD and SEP activities. Is the contractor or the IPTs applying the SEP and best practices to develop the end products? It will be difficult to assess since the low-cost, low-risk, high-cost, and high-risk elements are all entangled. The EVMS must provide PMs with the right information and at the right time. The EVMS must highlight potential problem areas that allow the PM to implement corrective actions to prevent negative program impacts.

MIL-HDBK-881 does not allow low-risk elements to be placed at a lower WBS level. MIL-HDBK-881 cautions that the integrity of the level of placement be maintained and not to overburden the contractor's management control system. Based on my experience, the baseline WBS is having the contractor report EVMS data that is of no use to the contractor or the Government.

7. Integrated Management Plan (IMP) and Integrated Management Schedule (IMS)

The baseline WBS allows implementation of the IMP and IMS. The baseline WBS allows the contractor to develop an event-oriented plan that can be translated into a detailed, time-dependent, task-oriented schedule. How effectively does the baseline WBS allow implementation? The WBS is the framework to allow PMs to quickly determine what they are doing, how are they going to do it, and when they are planning to do it. The baseline WBS contains level 2 elements that are low-cost and low-risk. They should be allocated to the end products. The baseline WBS end products are not all end products. They are requirements that should be allocated to the high-cost and high-risk end products. The baseline WBS does not effectively provide the framework to allow PMs to quickly determine what they are doing, how are they going to do it, and when are they planning to do it. An effective IMP must document the significant accomplishments to be completed that lead to a key program event. This is difficult to accomplish with the Baseline WBS since low-cost, low-risk, high-cost, and high-risk elements are all intertwined. If the IMP is not effective, then the IMS will most likely not be effective.

Therefore, an IMP and IMS developed from the baseline WBS does not effectively implement an IMP and IMS.

8. Alpha Contracting

Alpha Contracting allows the baseline WBS to be developed. Alpha Contracting would allow the Government and contractor to address the concerns raised in the above paragraphs. Based on my experience, this may result in the baseline WBS not being constructed in accordance with MIL-HDBK-881. The Government and contractor would jointly develop the baseline WBS based on their joint interpretation of risks and costs.

9. Single Process Initiative (SPI)

The SPI may not allow the baseline WBS to be developed. If a contractor has an approved procedure for developing a WBS that is not based on MIL-HDBK-881, then the baseline WBS would not be developed. Their procedure may result in a better or a worse baseline WBS. The WBS may need to be negotiated during the solicitation process to ensure that the Government will be obtaining useful data with which to manage and track the contractor's progress.

G. DEVELOPMENT OF AN ALTERNATIVE WBS

An alternative WBS has been developed by the researcher based upon: the above analysis, the information presented in this thesis, my experience especially from actively

participating in Alpha Contracting for award of an EMD program and the conversion of the PDRR program, and a diagram depicted by Blanchard (1998) in his book entitled *"Logistics Engineering and Management."* The diagram depicted a sample WBS which divided the program into two projects entitled "Preliminary System Design Phase" and "Detailed Design and Development Phase." These are phases of an EMD program going through the SEP. This diagram divided the program into smaller, more manageable phases or projects, versus baseline elements. The alternative WBS is based on a program in the EMD acquisition phase. The basic concept used to develop the alternate method was to focus on the key products and processes that need to be accomplished to allow the objectives of an acquisition phase to be successfully completed. Then projects were identified for each key product and process that needed to be accomplished to allow the objectives of the product or process to be successfully completed for an EMD program. The alternative WBS is shown in Table 4.1.

Level 1 of the WBS remained unchanged. Level 2 and level 3 of the WBS have changed significantly. End product parts and enabling product parts are not as easily visible with this alternate WBS design; although, the titles of the elements allows one to quickly distinguish between them. This alternate design is focused on major end products and

Level 1	Level 2	Level 3
Aircraft System	Systems Engineering & Integration	Requirements Management Technical Management Support Engineering Integration Integrated Logistics Support Reliability & Maintainability Human Systems Integration Manufacturing Producibility Program Quality Assurance Requirements Verification
	Program Management	Program Management Business Management
	Airframe	Airframe Preliminary Design Airframe Detailed Design Airframe Requirements Verification Airframe Manufacturing Process Development
	Propulsion	Propulsion Preliminary Design Propulsion Detailed Design Propulsion Requirement Verification Propulsion Manufacturing Process Development
	Mission Equipment Package (MEP)	MEP Preliminary Design MEP Detailed Design MEP Requirements Verification MEP Manufacturing Process Development
	Cockpit	Cockpit Preliminary Design Cockpit Detailed Design Cockpit Requirements Verification Cockpit Manufacturing Process Development
	Hardware Production	Airframe Production Propulsion Production MEP Production Cockpit Production

Table 4.1. Alternate WBS (Source: Created by author)

processes that are key to the success of an EMD program. Then projects were identified for each key product and process that need to be accomplished to allow the objectives of the product or process to be successfully completed for an EMD program. One might use a title of Low Rate Initial Production (LRIP) Hardware instead of Hardware Production. An alternate WBS designed for the PDRR acquisition phase may

not have Hardware Production as an element, since one does not normally build a significant amount of production-like systems for system-level requirements verification (testing). In PDRR, you may not have a Component Preliminary Design and Detailed Design element. Instead, you may have a Component Thirty-Percent Mockup, Seventy-Percent Mockup, Ninety-Percent Mockup, and Prototype Design elements. The concept is to divide the program into smaller programs for each design phase or product that is being planned during the acquisition phase.

Based on experience, Air Vehicle is not an element in this alternate WBS. An Air Vehicle is composed of an Airframe, Propulsion, and MEP which includes Cockpit. The Air Vehicle requirements are allocated to those elements or products. This allocation is accomplished within the Systems Engineering and Integration level 2 element. Thus, the Systems Engineering and Integration element is the Air Vehicle, but Systems Engineering and Integration more clearly depicts the work to be accomplished.

The level 3 elements of Systems Engineering and Integration would also be level 4 elements for each Component level 3 elements. For example, the Airframe Preliminary Design would contain all the level 3 elements of Systems Engineering and Integration except the Manufacturing

element which may change to be entitled Fabrication. Some of the level 3 elements of Systems Engineering and Integration may not be included in the Component Manufacturing Process Development or their titles may change to better indicate the work to be accomplished.

H. ANALYSIS OF THE ALTERNATE WBS EFFECTIVENESS IN IMPLEMENTING ACQUISITION REFORM INITIATIVES

1. Streamline Acquisition/Adoption of Commercial Practices

The alternate aircraft system WBS allows implementation of streamlined acquisition and the adoption of commercial practices. As with the baseline WBS, it is very difficult to determine the effectiveness of the implementation. Does this alternate WBS allow insight versus oversight and help reduce cycle-time?

The total number of level 2 and level 3 elements are significantly reduced from fifty-one elements with the baseline WBS to thirty-seven elements with the alternate WBS. This is a twenty-seven percent reduction. This results in less data being submitted by the contractor. Therefore, one could make the case that since the contractor is presenting less data, there is less insight to the program. One should not be concerned with how much data are being submitted. They should be concerned with the quality and usefulness of the data being submitted. The level 2 and

level 3 elements clearly depict the key products and processes that need to be accomplished to allow the objectives of an EMD program to be successfully completed. Risk can be quantified and easily understood for all the elements in the alternate WBS. All level 2 and 3 elements are usually moderate to high-risk at the start of an EMD program. Thus, the number of elements decreased from the baseline WBS, but the number of elements with higher risk and higher cost significantly increased. This alternate WBS will allow the PM to have greater insight into the program and lead to early identification of problem areas. The PM will be able to implement corrective actions to mitigate negative program impacts.

The next part of the question, does the alternate WBS help to reduce cycle-time, is easier to address with the alternate WBS. Each product and process should be allocated all requirements during the SEP. A tradeoff conducted by the Airframe IPT will not impact another component IPT unless a requirement is breached. Based on experience, if this is the case, the breach or issue is raised back to the SEIPT where it is resolved. As with the baseline WBS, the potential exists for no communication or miscommunication, but this potential has been significantly reduced. Thus,

the alternate WBS has the potential of reducing cycle-time, especially when compared to the baseline WBS.

2. Integrated Product and Process Development (IPPD)/Integrated Product Team (IPT)

The alternate WBS is focused on the key product and processes that need to be accomplished to allow the objectives of an EMD program to be successfully completed. IPTs are used to focus on products and processes. Thus, the alternate WBS allows implementation of IPTs. How effectively are the IPTs structured within the alternate WBS and does this IPT structure allow the IPPD process to be effectively implemented? As with the baseline WBS analysis, another way to ask this question is, does this alternate WBS allow functional stovepipes? The alternate WBS significantly reduces the potential for the existence of functional stovepipes. For example, ILS and HSI are no longer divided into several level 2 elements. They are a part of the System Engineering and Integration element, as well as level 4 elements for each product element. Therefore, the SEIPT and each product IPT are held accountable (ownership) for satisfying ILS and HIS requirements. Each IPT member has a say in the IPPD process (Office of the USD(A&T), 1998). Therefore, the probability of a functional stovepipe existing is reduced.

The alternate WBS is focused on key products and processes which require a multi-disciplinary team to develop solutions. Also, each of the elements at level 2 can function as a miniature project and use IPPD techniques. Thus, this alternate WBS does allow for the potential to effectively implement IPPD and IPTs.

3. Cost As An Independent Variable (CAIV)

The alternate WBS allows for implementation of CAIV. How effectively does the alternate WBS implement CAIV? The alternate WBS is focused on the key products and processes that need to be accomplished to allow the objectives of an EMD program to be successfully completed. One can easily establish a cost for each element of the alternate WBS. All tradeoffs that affect cost are allocated to the product element or product IPT. The probability of any tradeoff or decision impacting another product element or IPT has been significantly reduced. Based on experience, if a breach occurs, then the IPT raises it to the SEIPT to resolve. Therefore, the alternate WBS significantly increases the effectiveness of CAIV implementation.

4. Total Ownership Costs

Does the alternate WBS allow programs be managed to optimize total system performance and minimize the cost of ownership? The alternate WBS is focused on the key products

and processes that need to be accomplished to allow the objectives of an EMD program to be successfully completed. Each product and process should be allocated all requirements during the SEP, which includes all costs associated to it. The costs include the life-cycle cost or total ownership cost. The alternate WBS allows the requirements and costs to be clearly identified and allocated to an element. Therefore, the alternate WBS allows total ownership costs to be effectively allocated and used to optimize total system performance and minimize the cost of ownership.

5. Performance Specification

The alternate WBS allows the use of performance specifications. The alternate WBS is focused on the key products and processes that need to be accomplished to allow the objectives of an EMD program to be successfully completed. All requirements are allocated during the SEP to each of the level 2 product and process elements. Based on experience, the SEIPT maintains the interface control documents for the integration of products and processes. If the level 2 product and process element breaches their allocated requirements, then the issue is raised to the SEIPT to resolve. Based on my experience, any level 3 element breaches are resolved at the respective level 2

element. If this level 3 element breach creates a level 2 element breach, then it is raised to the SEIPT to resolve. Thus, this allows performance specifications to be written to the elements in the alternate WBS.

6. Earned Value Management System (EVMS)

The alternate WBS allows implementation of the EVMS and it allows adequate insight into the high-risk and high-cost areas. The alternate WBS allows PMs to quickly determine what they are doing, how are they going to do it, and when they are planning to do it. The alternate WBS allows an EVMS to reflect IPPD and SEP activities. Is the contractor or are the IPTs applying the SEP and best practices to develop the end products? An EVMS based on the alternate WBS will provide PMs with this data. The alternate WBS significantly improves the use of the EVMS over that of the baseline WBS.

The program estimates (cost, schedule, performance, and risk) are developed at the beginning of an acquisition phase. These estimates are based on some amount of knowledge and have some degree of uncertainty. As work is accomplished during the acquisition phase, more knowledge is being gained that decreases or increases the amount of uncertainty in the estimates. An EVMS based on the alternate WBS will result in some elements (projects) being

closed before the end of the program, similarly to work packages. For example, the Airframe Preliminary Design element will be closed after the PDR is conducted. A PDR is usually conducted after a significant event, which is normally some form of a verification (test). At PDR and other key events, IPTs should re-evaluate their program estimates. Usually, a significant amount of knowledge is gained during a phase. This either reduces or increases the risk of the next phase, i.e., the Airframe Detailed Design. If a Monte Carlo Simulation Tool were used, IPTs will be able to review their assumptions and easily modify them to reflect the current program. These results should be reflected in the EVMS. This process will improve the effectiveness of the EVMS.

7. Integrated Management Plan (IMP) and Integrated Management Schedule (IMS)

The alternate WBS allows implementation of the IMP and IMS. The alternate WBS allows the contractor to develop an event-oriented plan that can be translated into a detailed, time-dependent, task-oriented schedule. How effectively does the alternate WBS allow implementation? Based on my experience, the alternate WBS allows PMs to quickly determine what they are doing, how are they going to do it, and when they are planning to do it. Based on my experience, an IMP based on the alternate WBS will be able

to easily document the significant accomplishments that lead to a key program event, i.e., a verification event (test). Therefore, an IMP and IMS developed from the alternate WBS does effectively implement an IMP and IMS.

8. Alpha Contracting

Alpha Contracting allows the alternate WBS to be developed. Alpha Contracting allows the Government and contractor to jointly develop the alternate WBS based upon their joint interpretation of risks and costs, although, there is a potential for this alternate WBS to not be constructed in accordance with paragraph G of this chapter.

9. Single Process Initiative (SPI)

The SPI may not allow the alternate WBS to be developed. If a contractor has an approved procedure for developing a WBS that is a different concept than the alternate WBS concept, then the alternate WBS would not be developed. Their procedure may result in a better or worse WBS. Again, the WBS may need to be negotiated during the solicitation process to ensure the Government and the contractor will be obtaining useful data with which to manage and track the contractor's progress.

10. Other Impacts Resulting From the Alternate WBS

The alternate WBS may result in some negative impacts. It will be more difficult to determine the cost of initial

spares and repair parts, common and peculiar support equipment, training, data, industrial facilities, and operational site activation. These elements of the baseline WBS are used to support the DoD resource allocation process in order to obtain the necessary funding to accomplish fielding and operation and support. The information required for these elements is allocated and maintained at the lower level elements with the alternate WBS. Financial personnel will have to search through the data or have the IPTs report it to them. There may be other negative impacts which requires further analysis. This is beyond the scope of this research.

I. SUMMARY

The WBS provides a consistent and visible framework for communicating cost, schedule, performance, and risk management for development of defense materiel items. The WBS takes large, complex, unmanageable programs and breaks them into small, easily-understandable, and manageable modules. PMs need to know what they are doing, how are they going to do it, and when they are planning to do it. PMs need insight into high-risk and high-cost elements of the WBS in order to have successful programs. How a WBS is constructed depends on the perspective of the individual IPT members. IPTs use the SEP to progressively decompose or

allocate system requirements to lower level products and processes.

A baseline WBS was constructed in accordance with MIL-HDBK-881. The analysis concluded that this baseline WBS significantly impedes DoD implementation of acquisition reform initiatives. PMs and IPTs do not have insight into the high-risk and high-cost elements. It is difficult to determine what we are doing, how are we going to do it, and when are we planning to do it. It does not adequately identify and differentiate the key products and processes essential for program success.

An alternate WBS was constructed based on the analysis of the baseline WBS. The basic concept used to develop the alternate method was to focus on the key products and processes that need to be accomplished to allow the objectives of an acquisition phase to be successfully completed. Then projects were identified for each key product and process that needed to be accomplished to allow the objectives of the product or process to be successfully completed for an EMD program. This alternate WBS has the potential to significantly facilitate implementation of DoD acquisition reform initiatives, although further analysis is required to determine all of the impacts.

V. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

Many of the assertions and conclusions in this thesis are based on experiences and discussions with Government and contractor personnel during my career. I have attempted to implement many acquisition reform initiatives and have been frustrated by not being able to effectively execute them. Many of the assertions and conclusions in this thesis are a result of discussions during IPT meetings and an Alpha Contracting process. Additionally, part of the assertions and conclusions in this thesis are a result of the various acquisition and management courses taken while attending NPS.

1. Primary Question

To what extent does MIL-HDBK-881 facilitate or impede execution of acquisition reform initiatives?

MIL-HDBK-881 significantly impedes implementation of acquisition reform initiatives. A WBS prepared in accordance with MIL-HDBK-881 does not allow PMs and IPTs to have insight into many of the high-risk and high-cost elements. It is difficult to determine what is being planned, how it is going to be accomplished, and when it will be completed. The WBS does not adequately identify and

differentiate the key products and processes essential for program success.

2. Subsidiary Questions

a) *What acquisition reform initiatives does the WBS affect?*

The WBS affects the following acquisition reform initiatives:

- Streamlined Acquisition/Adoption of Commercial Practices (reduce cycle-time and insight versus oversight management)
- Integrated Product and Process Development (IPPD)/Integrated Product Team (IPT)
- Cost As AN Independent Variable (CAIV)
- Total Ownership Costs
- Performance Specification
- Earned Value Management System (EVMS)
- Integrated Management Plan (IMP) and Integrated Management Schedule (IMS)
- Alpha Contracting
- Single Process Initiative

b) *What are the possible uses of the WBS?*

The WBS provides the basis for communication throughout the acquisition process. The WBS is used for program and technical planning, scheduling, resource allocations, cost estimating, budgeting, contracting, configuration management, and performance reporting (EVMS).

c) *What does the project manager need to consider when structuring a WBS?*

DoD acquisition officials and PMs want to have successful programs. They require tools that will allow

them to provide the warfighter with an affordable, supportable, and operationally-effective and suitable system at the time when it is needed. They want to know what they are doing, how are they going to do it, and when they are planning to do it. They want to ensure proper planning of all tasks required to successfully meet the objectives of the acquisition phase. They want to know that best practices are being logically employed to make their program successful. Additionally, they want to know what are the high-risk and high-cost areas that will require their attention. The WBS is the framework to allow PMs to quickly determine what they are doing, how are they going to do it, and when they are planning to do it.

d) *Is there an alternative method(s) to structure the WBS that will allow better execution or implementation of acquisition reform initiatives?*

Yes, there is an alternate method to structure the WBS that could significantly facilitate DoD acquisition reform initiatives and increase the effectiveness of the EVMS. The basic concept used to develop the alternate method was to focus on the key products and processes that need to be accomplished to allow the objectives of an acquisition phase to be successfully completed. Then projects were identified for each key product and process

that needs to be accomplished to allow the objectives of the product or process to be successfully completed.

B. RECOMMENDATIONS

1. Further Study and Analysis of Alternate WBS Format

This thesis identified an alternate WBS format. This alternate WBS has the potential to significantly facilitate implementation of acquisition reform initiatives and significantly improve the EVMS. This is only a start. It requires further study and analysis to determine its potential as well as any negative affects. Both Government and contractor PMs should be surveyed for their feedback on this new method. Data from a prior or existing program could be reformatted into the alternate WBS format and determine if it is more effective than the actual WBS at identifying high-cost and high-risk elements, and early identification of potential problems.

2. Revise MIL-HDBK-881

MIL-HDBK-881 contradicts itself and I found it difficult to follow. It has excellent definitions of various elements, but some are confusing. It should be revised by using an IPPD environment. Personnel from all stakeholders should be on an IPT, for example: acquisition managers, systems engineers, financial managers, comptrollers, contracting personnel, auditors, etc. The IPT

should consist of both Government and contractor personnel. Each of their perspectives is essential to determining the best technique to construct a WBS that satisfies all of their disparate objectives.

C. RECOMMENDATIONS FOR FURTHER STUDY

1. Survey Acquisition Community

Both the Government and contractor acquisition communities should be polled to determine their opinions of this alternate WBS technique. They should be surveyed to determine if they have implementation problems with executing acquisition reform initiatives as well as the effectiveness of their EVMS. Additionally, they should be questioned on any potential negative impacts this alternate technique may create.

2. Convert Prior Program Data

Data from a prior or existing program should be reformatted into the alternate WBS format and determine if it is more effective than the actual WBS at identifying high-cost and high-risk elements, and early identification of potential problems.

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APPENDIX A. AIRCRAFT SYSTEMS -- WORK BREAKDOWN STRUCTURE LEVELS

(Extracted from MIL-HDBK-881)

A.1. SCOPE

This appendix provides the aircraft system work breakdown structure. Definitions for the aircraft air vehicle are provided in this appendix. Definitions for WBS elements common to all defense materiel items are given in Appendix H: Work Breakdown Structure Definitions, Common Elements.

A.2. WORK BREAKDOWN STRUCTURE LEVELS

Table A.1. depicts the Aircraft Systems WBS levels.

A.3. DEFINITIONS

A.3.1. Aircraft System

The complex of equipment (hardware/software), data, services, and facilities required to develop and produce air vehicles.

Includes:

- those employing fixed, movable, rotary, or compound wing
- those manned/unmanned air vehicles designed for powered or unpowered (glider) guided flight

Level 1	Level 2	Level 3
Aircraft System	Air Vehicle (AV)	Airframe Propulsion AV Applications Software AV System Software Communications/Identification Navigation/Guidance Central Computer Fire Control Data Display and Controls Survivability Reconnaissance Automatic Flight Control Central Integrated Checkout Antisubmarine Warfare Weapons Delivery Auxiliary Equipment Armament
	Systems Engineering/Program Management	
	System Test and Evaluation	Development Test and Evaluation Operational Test and Evaluation Mock-ups Test and Evaluation Support Test Facilities
	Training	Equipment Services Facilities
	Data	Technical Publications Engineering Data Management Data Support Data Data Depository
	Peculiar Support Equipment	Test and Measurement Equipment Support and Handling Equipment
	Common Support Equipment	Test and Measurement Equipment Support and Handling Equipment
	Operational/Site Activation	System Assembly, Installation and Checkout on Site Contractor Technical Support Site Construction Site/Ship/Vehicle Conversion
	Industrial Facilities	Construction/Conversion/Expansion Equipment Acquisition or Modernization Maintenance (Industrial Facilities)
	Initial Spares and Repair Parts	

Table A.1. Aircraft Systems WBS (Extracted from MIL-STD-881)

A.3.2. Air Vehicle

The complete flying aircraft.

Includes:

- airframe, propulsion, and all other installed equipment
- design, development, and production of complete units -- prototype and operationally configured units which satisfy the requirements of their applicable specifications, regardless of end use
- Sub-elements to the air vehicle (A.3.2.1 -- A.3.2.17)

A.3.2.1. Airframe

The assembled structural and aerodynamic components of the air vehicle that support subsystems essential to designated mission requirements.

Includes, for example:

- basic structure -- wing, empennage, fuselage, and associated manual flight control system
- rotary wing pylons, air induction system, thrust reversers, thrust vector devices, starters, exhausts, fuel management, inlet control system
- alighting gear -- tires, tubes, wheels, brakes, hydraulics, etc.
- secondary power, furnishings -- crew, cargo, passenger, troop, etc.
- instruments -- flight, navigation, engine, etc.
- environmental control, life support and personal equipment, racks, mounts, intersystem cables and distribution boxes, etc., which are inherent to, and nonseparable from, the assembled structure
- dynamic systems -- transmissions, gear boxes, propellers, if not furnished as an integral part of the propulsion unit

- rotor group and other equipment homogeneous to the airframe

In addition to the airframe structure and subsystems, this element includes:

Integration, assembly, test, and checkout:

Includes:

- all efforts as identified in Appendix H: Work Breakdown Structure Definitions, Common Elements, to provide the integration, assembly, test, and checkout of all elements into the airframe to form the air vehicle as a whole
- all administrative and technical engineering labor to perform integration of level 3 air vehicle and airframe elements; development of engineering layouts; determination of overall design characteristics, and determination of requirements of design review
 - overall air vehicle design and producibility engineering
 - detailed production design; acoustic and noise analysis
 - loads analysis; stress analysis on interfacing airframe elements and all subsystems
 - design maintenance effort and development of functional test procedures
 - coordination of engineering master drawings and consultation with test and manufacturing groups
 - tooling planning, design, and fabrication of basic and rate tools and functional test equipments, as well as the maintenance of such equipment
 - production scheduling and expediting

- joining or installation of structures such as racks, mounts, etc.
- installation of seats, wiring ducting, engines, and miscellaneous equipment and painting
- set up, conduct, and review of testing assembled components or subsystems prior to installation
- all effort associated with the installation, integration, test, and checkout of the avionic systems into the air vehicle including:
 - design of installation plans
 - quality assurance planning and control including material inspection
 - installation
 - recurring verification tests
 - integration with nonavionics airframe subsystems
- ground checkout prior to flight test; production acceptance testing and service review; quality assurance activities and the cost of raw materials, purchased parts, and purchased equipment associated with integration and assembly

Nonrecurring avionics system integration which is associated with the individual avionics equipment boxes and avionics software in a functioning system.

Includes:

- the labor required to analyze, design, and develop avionics suite interfaces and establish interface compatibility with non-avionics support equipment systems, aircraft systems, and mission planning systems

- drawing preparation and establishment of avionics interface equipment requirements and specifications
- technical liaison and coordination with the military service, subcontractors, associated contractors, and test groups

Excludes:

- development, testing, and integration of software (which should be included in air vehicle applications and system software)
- avionics system testing (included in System Test and Evaluation) and aircraft systems engineering efforts (included in Systems Engineering/Program Management).
- all effort directly associated with the remaining level 3 WBS elements

A.3.2.2. Propulsion

That portion of the air vehicle that pertains to installed equipment (propulsion unit and other propulsion) to provide power/thrust to propel the aircraft through all phases of powered flight.

Includes, for example:

- the engine as a propulsion unit within itself (e.g., reciprocating, turbo with or without afterburner, or other type propulsion) suitable for integration with the airframe
- thrust reversers, thrust vector devices, transmissions, gear boxes, and engine control units, if furnished as integral to the propulsion unit
- other propulsion equipment required in addition to the engine but not furnished as an integral part of the engine, such as booster units

- the design, development, production, and assembly efforts to provide the propulsion unit as an entity

Excludes:

- all effort directly associated with the elements and the integration, assembly, test, and checkout of these elements into the air vehicle
- all ancillary equipments that are not an integral part of the engine required to provide an operational primary power source -- air inlets, instruments, controls, etc.

A.3.2.3. Air Vehicle Applications Software

Includes, for example:

- all the software that is specifically produced for the functional use of a computer system or multiplex data base in the air vehicle
- all effort required to design, develop, integrate, and checkout the air vehicle applications Computer Software Configuration Items (CSCIs)

Excludes:

- the non-software portion of air vehicle firmware development and production (ref. ANSI/IEEE Std 610.12)
- software that is an integral part of any specific subsystem and software that is related to other WBS level 2 elements

Note 1: If lower level information can be collected, use the structure and definitions in Appendix B, Electronic/Automated Software Systems.

A.3.2.4. Air Vehicle System Software

That software designed for a specific computer system or family of computer systems to facilitate the

operation and maintenance of the computer system and associated programs for the air vehicle.

Includes, for example:

- operating systems -- software that controls the execution of programs
- compilers -- computer programs used to translate higher order language programs into relocatable or absolute machine code equivalents
- utilities -- computer programs or routines designed to perform the general support function required by other application software, by the operating system, or by system users (ref. ANSI/IEEE Std 610.12)
- all effort required to design, develop, integrate, and checkout the air vehicle system software including all software developed to support any air vehicle applications software development
- air vehicle system software required to facilitate development, integration, and maintenance of any air vehicle software build and CSCI

Excludes:

- all software that is an integral part of any specific subsystem specification or specifically designed and developed for system test and evaluation
- software that is an integral part of any specific subsystem, and software that is related to other WBS level 2 elements

Note 1: If lower level information can be collected, use the structure and definitions in Appendix B, Electronic/Automated Software Systems.

A.3.2.5. Communications/Identification

That equipment (hardware/software) installed in the air vehicle for communications and identification purposes.

Includes, for example:

- intercoms, radio system(s), identification equipment (IFF), data links, and control boxes associated with the specific equipment
- integral communication, navigation, and identification package (if used)

Note 2: All effort directly associated with the remaining level 3 WBS elements and the integration, assembly, test, and checkout of these elements into the air vehicle is excluded. This item contains embedded software -- software defined in the item specification and provided by the supplier.

A.3.2.6. Navigation/Guidance

That equipment (hardware/software) installed in the air vehicle to perform the navigational guidance function.

Includes:

- radar, radio, or other essential navigation equipment, radar altimeter, direction finding set, doppler compass, computer, and other equipment homogeneous to the navigation/guidance function

Note 1: If lower level information can be collected, use the structure and definitions in Appendix B, Electronic/Automated Software Systems.

Note 2: All effort directly associated with the remaining level 3 WBS elements and the integration, assembly, test, and checkout of

these elements into the air vehicle is excluded. This item contains embedded software -- software defined in the item specification and provided by the supplier.

A.3.2.7. Central Computer

The master data processing unit(s) responsible for coordinating and directing the major avionic mission systems.

Note 1: If lower level information can be collected, use the structure and definitions in Appendix B, Electronic/Automated Software Systems.

Note 2: All effort directly associated with the remaining level 3 WBS elements and the integration, assembly, test, and checkout of these elements into the air vehicle is excluded. This item contains embedded software -- software defined in the item specification and provided by the supplier.

A.3.2.8. Fire Control

That equipment (hardware/software) installed in the air vehicle which provides the intelligence necessary for weapons delivery such as bombing, launching, and firing.

Includes, for example:

- radars and other sensors including radomes
- apertures/antennas, if integral to the fire control system, necessary for search, target identification, rendezvous and/or tracking
- self-contained navigation and air data systems
- dedicated displays, scopes, or sights
- bombing computer and control and safety devices

Note 1: If lower level information can be collected, use the structure and definitions in Appendix B, Electronic/Automated Software Systems.

Note 2: All effort directly associated with the remaining level 3 WBS elements and the integration, assembly, test, and checkout of these elements into the air vehicle is excluded. This item contains embedded software -- software defined in the item specification and provided by the supplier.

A.3.2.9. Data Display and Controls

The equipment (hardware/software) which visually presents processed data by specially designed electronic devices through interconnection (on-or off-line) with computer or component equipment and the associated equipment needed to control the presentation of the data necessary flight and tactical information to the crew for efficient management of the aircraft during all segments of the mission profile under day and night all-weather conditions.

Includes, for example:

- multi-function displays, control display units, display processors, and on-board mission planning systems

Excludes:

- indicators and instruments not controlled by keyboard via the multiplex data bus and panels and consoles which are included under the airframe

Note 1: If lower level information can be collected, use the structure and definitions in Appendix B, Electronic/Automated Software Systems.

Note 2: All effort directly associated with the remaining level 3 WBS elements and the integration, assembly, test, and checkout of these elements into the air vehicle is excluded. This item contains embedded software -- software defined in the item specification and provided by the supplier.

A.3.2.10. Survivability

Those equipments (hardware/software) installed in, or attached to, the air vehicle which assist in penetration for mission accomplishment.

Includes, for example:

- ferret and search receivers, warning devices and other electronic devices, electronic countermeasures, jamming transmitters, chaff, infrared jammers, terrain-following radar, and other devices typical of this mission function

Note 1: If lower level information can be collected, use the structure and definitions in Appendix B, Electronic/Automated Software Systems.

Note 2: All effort directly associated with the remaining level 3 WBS elements and the integration, assembly, test, and checkout of these elements into the air vehicle is excluded. This item contains embedded software -- software defined in the item specification and provided by the supplier.

A.3.2.11. Reconnaissance

Those equipments (hardware/software) installed in, or attached to, the air vehicle necessary to the reconnaissance mission.

Includes, for example:

- photographic, electronic, infrared, and other sensors
- search receivers
- recorders
- warning devices
- magazines
- data link

Excludes:

- gun cameras

Note 1: If lower level information can be collected, use the structure and definitions in Appendix B, Electronic/Automated Software Systems.

Note 2: All effort directly associated with the remaining level 3 WBS elements and the integration, assembly, test, and checkout of these elements into the air vehicle is excluded. This item contains embedded software -- software defined in the item specification and provided by the supplier.

A.3.2.12. Automatic Flight Control

Those electronic devices and sensors, which, in combination with the flight controls subsystem (under airframe), enable the crew to control the flight path of the aircraft and provide lift, drag, trim, or conversion effects.

Includes, for example:

- flight control computers, software, signal processors, and data transmitting elements that are devoted to processing data for either primary or automatic flight control functions
- electronic devices required for signal processing, data formatting, and interfacing between the flight control elements; the data buses, optical links, and

other elements devoted to transmitting flight control data

- flight control sensors such as pressure transducers, rate gyros, accelerometers, and motion sensors

Excludes:

- devices -- linkages, control surfaces, and actuating devices -- covered under the airframe WBS element
- avionics devices and sensors -- central computers, navigation computers, avionics data buses and navigation sensors -- which are included under other avionics WBS elements

Note 1: If lower level information can be collected, use the structure and definitions in Appendix B, Electronic/Automated Software Systems.

Note 2: All effort directly associated with the remaining level 3 WBS elements and the integration, assembly, test, and checkout of these elements into the air vehicle is excluded. This item contains embedded software -- software defined in the item specification and provided by the supplier.

A.3.2.13. Central Integrated Checkout

That equipment (hardware/software) installed in the air vehicle for malfunction detection and reporting.

Note 1: If lower level information can be collected, use the structure and definitions in Appendix B, Electronic/Automated Software Systems.

Note 2: All effort directly associated with the remaining level 3 WBS elements and the integration, assembly, test, and checkout of these elements into the air vehicle is excluded. This item contains embedded software -- software defined in the item specification and provided by the supplier.

A.3.2.14. Antisubmarine Warfare

That equipment (hardware/software) installed in the air vehicle peculiar to the antisubmarine warfare mission.

Includes, for example:

- sensors, computers, displays, etc.

Note 1: If lower level information can be collected, use the structure and definitions in Appendix B, Electronic/Automated Software Systems.

Note 2: All effort directly associated with the remaining level 3 WBS elements and the integration, assembly, test, and checkout of these elements into the air vehicle is excluded. This item contains embedded software -- software defined in the item specification and provided by the supplier.

A.3.2.15. Armament

That equipment (hardware/software) installed in the air vehicle to provide the firepower functions.

Includes, for example:

- guns, high energy weapons, mounts, turrets, weapon direction equipment, ammunition feed and ejection mechanisms, and gun cameras

Note 1: If lower level information can be collected, use the structure and definitions in Appendix B, Electronic/Automated Software Systems.

Note 2: All effort directly associated with the remaining level 3 WBS elements and the integration, assembly, test, and checkout of these elements into the air vehicle is excluded. This item contains embedded software -- software

defined in the item specification and provided by the supplier.

A.3.2.16. Weapons Delivery

That equipment (hardware/software) installed in the air vehicle to provide the weapons delivery capability.

Includes, for example:

- launchers, pods, bomb racks, pylons, integral release mechanisms, and other mechanical or electro-mechanical equipments specifically oriented to the weapons delivery function

Excludes:

- bombing/navigation system (included in the fire control element)

Note 1: If lower level information can be collected, use the structure and definitions in Appendix B, Electronic/Automated Software Systems.

Note 2: All effort directly associated with the remaining level 3 WBS elements and the integration, assembly, test, and checkout of these elements into the air vehicle is excluded. This item contains embedded software -- software defined in the item specification and provided by the supplier.

A.3.2.17. Auxiliary Equipment

Auxiliary airframe, electronics, and/or armament/weapons delivery equipment not allocable to individual element equipments, or which provides the ancillary functions to the applicable mission equipments.

Includes, for example:

- auxiliary airframe equipment such as external fuel tanks, pods, and rotodomes
- multi-use equipment like antennas, control boxes, power supplies, environmental control, racks, and mountings, not homogeneous to the prescribed WBS elements

Note 1: If lower level information can be collected, use the structure and definitions in Appendix B, Electronic/Automated Software Systems.

Note 2: All effort directly associated with the remaining level 3 WBS elements and the integration, assembly, test, and checkout of these elements into the air vehicle is excluded. This item contains embedded software -- software defined in the item specification and provided by the supplier.

Note 3: Auxiliary armament/weapons delivery equipment includes flares and ejection mechanisms, ejector cartridges, and other items peculiar to the mission function that are not identifiable to the armament or weapons delivery elements set forth in A.4.2.15 and A.4.2.16 of this appendix.

A.3.3. Common Elements

WBS Levels 2 and 3. Definitions for common WBS elements applicable to the aircraft as well as all other defense materiel items are in Appendix H: Work Breakdown Structure Definitions, Common Elements.

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**APPENDIX B. ELECTRONIC/AUTOMATED SOFTWARE SYSTEMS -- WORK
BREAKDOWN STRUCTURE LEVELS**

(Extracted from MIL-HDBK-881)

Level 1	Level 2	Level 3
Electronic/ Automated Software System	Prime Mission Product (PMP)	Subsystem 1..n (Specify Names) PMP Applications Software PMP System Software Integration, Assembly, Test and Checkout
	Platform Integration	
	Systems Engineering/Program Management	
	System Test and Evaluation	Development Test and Evaluation Operational Test and Evaluation Mock-ups Test and Evaluation Support Test Facilities
	Training	Equipment Services Facilities
	Data	Technical Publications Engineering Data Management Data Support Data Data Depository
	Peculiar Support Equipment	Test and Measurement Equipment Support and Handling Equipment
	Common Support Equipment	Test and Measurement Equipment Support and Handling Equipment
	Operational/Site Activation	System Assembly, Installation and Checkout on Site Contractor Technical Support Site Construction Site/Ship/Vehicle Conversion
	Industrial Facilities	Construction/Conversion/Expansion Equipment Acquisition or Modernization Maintenance (Industrial Facilities)
	Initial Spares and Repair Parts	

Table B.1. Electronic/Automated Software Systems WBS (Extracted from MIL-STD-881)

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APPENDIX C. MISSILE SYSTEM -- WORK BREAKDOWN STRUCTURE LEVELS

(Extracted from MIL-HDBK-881)

Level 1	Level 2	Level 3
Missile System	Air Vehicle	Propulsion (Stages I..n,] Payload Airframe Reentry System Post Boost System Guidance and Control Ordnance Initiation Set Airborne Test Equipment Airborne Training Equipment Auxiliary Equipment Integration, Assembly, Test and Checkout
	Command and Launch	Surveillance, Identification and Tracking Sensors Launch and Guidance Control Communications Command and Launch Applications Software Command and Launch System Software Launcher Equipment Auxiliary Equipment
	Systems Engineering/ Program Management	
	System Test and Evaluation	Development Test and Evaluation Operational Test and Evaluation Mock-ups Test and Evaluation Support Test Facilities
	Training	Equipment Services Facilities
	Data	Technical Publications Engineering Data Management Data Support Data Data Depository
	Peculiar Support Equipment	Test and Measurement Equipment Support and Handling Equipment
	Common Support Equipment	Test and Measurement Equipment Support and Handling Equipment
	Operational/Site Activation	System Assembly, Installation and Checkout on Site Contractor Technical Support Site Construction Site/Ship/Vehicle Conversion
	Industrial Facilities	Construction/Conversion/Expansion Equipment Acquisition or Modernization Maintenance (Industrial Facilities)
	Initial Spares and Repair Parts	

Table C.1. Missile System WBS (Extracted from MIL-STD-881)

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**APPENDIX D. ORDNANCE SYSTEM -- WORK BREAKDOWN STRUCTURE
LEVELS**

(Extracted from MIL-HDBK-881)

Level 1	Level 2	Level 3
Ordnance System	Complete Round	Structure Payload Guidance and Control Fuze Safety/Arm Propulsion Integration, Assembly, Test and Checkout
	Launch System	Launcher Carriage Fire Control Ready Magazine Adapter Kits Integration, Assembly, Test and Checkout
	Systems Engineering/ Program Management	
	System Test and Evaluation	Development Test and Evaluation Operational Test and Evaluation Mock-ups Test and Evaluation Support Test Facilities
	Training	Equipment Services Facilities
	Data	Technical Publications Engineering Data Management Data Support Data Data Depository
	Peculiar Support Equipment	Test and Measurement Equipment Support and Handling Equipment
	Common Support Equipment	Test and Measurement Equipment Support and Handling Equipment
	Operational/Site Activation	System Assembly, Installation and Checkout on Site Contractor Technical Support Site Construction Site/Ship/Vehicle Conversion
	Industrial Facilities	Construction/Conversion/Expansion Equipment Acquisition or Modernization Maintenance (Industrial Facilities)
	Initial Spares and Repair Parts	

Table D.1. Ordnance System WBS (Extracted from MIL-STD-881)

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APPENDIX E. SHIP SYSTEMS -- WORK BREAKDOWN STRUCTURE LEVEL

(Extracted from MIL-HDBK-881)

Level 1	Level 2	Level 3
Ship System	Ship	Hull Structure Propulsion Plant Electric Plant Command and Surveillance Auxiliary Systems Outfit and Furnishings Armament Integration/Engineering Ship Assembly and Support Services
	Systems Engineering/ Program Management	
	System Test and Evaluation	Development Test and Evaluation Operational Test and Evaluation Mock-ups Test and Evaluation Support Test Facilities
	Training	Equipment Services Facilities
	Data	Technical Publications Engineering Data Management Data Support Data Data Depository
	Peculiar Support Equipment	Test and Measurement Equipment Support and Handling Equipment
	Common Support Equipment	Test and Measurement Equipment Support and Handling Equipment
	Operational/Site Activation	System Assembly, Installation and Checkout on Site Contractor Technical Support Site Construction Site/Ship/Vehicle Conversion
	Industrial Facilities	Construction/Conversion/Expansion Equipment Acquisition or Modernization Maintenance (Industrial Facilities)
	Initial Spares and Repair Parts	

Table E.1. Ship Systems WBS (Extracted from MIL-STD-881)

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APPENDIX F. SPACE SYSTEMS -- WORK BREAKDOWN STRUCTURE LEVEL

(Extracted from MIL-HDBK-881)

Level 1	Level 2	Level 3
Space System	Launch Vehicle	Propulsion (Single Stage Only) Stage I Stage II..n (As Required) Strap-On Units (As Required) Shroud (Payload Fairing) Guidance and Control Integration, Assembly, Test and Checkout
	Orbital Transfer Vehicle	Propulsion (Single Stage Only) Stage I Stage II..n (As Required) Strap-On Units (As Required) Guidance and Control Integration, Assembly, Test and Checkout
	Space Vehicle	Spacecraft Payload I..n (As Required) Reentry Vehicle Orbit Injector/Dispenser Integration, Assembly, Test and Checkout
	Ground Command, Control, Communications and Mission Equipment	Sensor I..n (As Required) Telemetry, Tracking and Control External Communications Data Processing Equipment Launch Equipment Auxiliary Equipment
	Flight Support Operations and Services	Mate/Checkout/Launch Mission Control Tracking and C ³ Recovery Operations and Services Launch Site Maintenance/Refurbishment
	Storage	Planning and Preparation Storage Transfer and Transportation
	Systems Engineering/Program Management	
	System Test and Evaluation	Development Test and Evaluation Operational Test and Evaluation Mock-ups Test and Evaluation Support Test Facilities
	Training	Equipment Services Facilities
	Data	Technical Publications Engineering Data Management Data Support Data Data Depository
	Peculiar Support Equipment	Test and Measurement Equipment Support and Handling Equipment

	Common Support Equipment	Test and Measurement Equipment Support and Handling Equipment
	Operational/Site Activation	System Assembly, Installation and Checkout on Site Contractor Technical Support Site Construction Site/Ship/Vehicle Conversion
	Industrial Facilities	Construction/Conversion/Expansion Equipment Acquisition or Modernization Maintenance (Industrial Facilities)
	Initial Spares and Repair Parts	

Table E.1. Space Systems WBS (Extracted from MIL-STD-881)

**APPENDIX G. SURFACE VEHICLE SYSTEMS -- WORK BREAKDOWN
STRUCTURE LEVEL**

(Extracted from MIL-HDBK-881)

Level 1	Level 2	Level 3
Surface Vehicle System	Primary Vehicle	Hull/Frame Suspension/Steering Power Package/Drive Train Auxiliary Automotive Turret Assembly Fire Control Armament Body/Cab Automatic Loading Automatic/Remote Piloting Nuclear, Biological, Chemical Special Equipment Navigation Communications Integration, Assembly, Test and
	Secondary Vehicle	(Same as Primary Vehicle)
	Systems Engineering/ Program Management	
	System Test and Evaluation	Development Test and Evaluation Operational Test and Evaluation Mock-ups Test and Evaluation Support Test Facilities
	Training	Equipment Services Facilities
	Data	Technical Publications Engineering Data Management Data Support Data Data Depository
	Peculiar Support Equipment	Test and Measurement Equipment Support and Handling Equipment
	Common Support Equipment	Test and Measurement Equipment Support and Handling Equipment
	Operational/Site Activation	System Assembly, Installation and Checkout on Site Contractor Technical Support Site Construction Site/Ship/Vehicle Conversion
	Industrial Facilities	Construction/Conversion/Expansion Equipment Acquisition or Modernization Maintenance (Industrial Facilities)
	Initial Spares and Repair Parts	

Table G.1. Surface Vehicle Systems WBS (Extracted from MIL-STD-881)

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APPENDIX H. COMMON ELEMENTS -- WORK BREAKDOWN STRUCTURE AND DEFINITIONS

(Extracted from MIL-HDBK-881)

H.1. SCOPE

This appendix provides the WBS elements common to all types of systems. Definitions for the common WBS elements are provided in this appendix.

H.2. DEFINITIONS

H.2.1. Integration, Assembly, Test, and Checkout

In those instances in which an integration, assembly, test, and checkout element is used (Appendices A through G), this element includes all effort of technical and functional activities associated with the design, development, and production of mating surfaces, structures, equipment, parts, materials, and software required to assemble the level 3 equipment (hardware/software) elements into a level 2 mission equipment (hardware/software) as a whole and not directly part of any other individual level 3 element.

Includes:

- the development of engineering layouts, determination of overall design characteristics, and determination of requirements of design review
- the set up, conduct, and review of testing assembled components or subsystems prior to installation
- the detailed production design, producibility engineering planning (PEP), and manufacturing process capability, including the process design

development and demonstration effort to achieve compatibility with engineering requirements and the ability to produce economically and consistent quality

- inspection activities related to receiving, factory and vendor liaison
- design maintenance effort
- quality planning and control
- tooling (initial production facilities, factory support equipment) including planning, design, and fabrication
- administrative engineering
- the joining or mating and final assembly of level 3 equipment elements to form a complete prime mission equipment when the effort is performed at the manufacturing facility
- integration of software (including loading and verification of firmware)
- conduct of production acceptance testing

Excludes:

- all systems engineering/program management and system test and evaluation which are associated with the overall system

Note: *When an integration, assembly, test, and checkout element is utilized at lower levels of the contract WBS, it will be summarized into the next higher level equipment (hardware/software) WBS element and should never be summarized directly into a level 3 integration, assembly, test, and checkout element.*

H.2.2. Systems Engineering/Program Management

The systems engineering and technical control as well as the business management of particular systems and

programs. Systems engineering/program management elements to be reported and their levels will be specified by the requiring activity.

Includes:

- the overall planning, directing, and controlling of the definition, development, and production of a system or program including supportability and acquisition logistics, e.g., maintenance support, facilities, personnel, training, testing, and activation of a system

Excludes:

- systems engineering/program management effort that can be associated specifically with the equipment (hardware/software) element

H.2.2.1. Systems Engineering

The technical and management efforts of directing and controlling a totally integrated engineering effort of a system or program.

Includes but not limited to:

- effort to define the system and the integrated planning and control of the technical program efforts of design engineering, specialty engineering, production engineering, and integrated test planning
- effort to transform an operational need or statement of deficiency into a description of system requirements and a preferred system configuration
- technical planning and control effort for planning, monitoring, measuring, evaluating, directing, and replanning the management of the technical program

- (all programs, where applicable) value engineering, configuration management, human factors, maintainability, reliability, survivability/vulnerability, system safety, environmental protection, standardization, system analysis, logistic support analysis, etc.
- (for ships) the extended Ship WBS (ESWBS), Configuration Management (811), Human Factors (892), Standardization (893), Value Engineering (894), and Reliability and Maintainability (895) elements

Excludes:

- actual design engineering and the production engineering directly related to the WBS element with which it is associated

Examples of systems engineering efforts are:

- 1) System definition, overall system design, design integrity analysis, system optimization, system/cost effectiveness analysis, and intra-system and inter-system compatibility assurance, etc.; the integration and balancing of reliability, maintainability, producibility, safety, human health, environmental protection, and survivability; security requirements, configuration management and configuration control; quality assurance program, value engineering, preparation of equipment and component performance specifications, design of test and demonstration plans; determination of software development or software test facility/environment requirements.
- 2) Preparation of the Systems Engineering Management Plan (SEMP), specification tree, program risk analysis, system planning, decision control process, technical performance measurement, technical reviews, subcontractor and vendor reviews, work authorization, and technical documentation control.
- 3) Reliability engineering -- the engineering process and series of tasks required to examine the probability of a device or system performing its mission adequately for the period of time

intended under the operating conditions expected to be encountered.

- 4) Maintainability engineering -- the engineering process and series of tasks required to measure the ability of an item or system to be retained in or restored to a specified condition of readiness, skill levels, etc., using prescribed procedures and resources at specific levels of maintenance and repair.
- 5) Human factors engineering -- the engineering process and the series of tasks required to define, as a comprehensive technical and engineering effort, the integration of doctrine, manpower, and personnel integration, materiel development, operational effectiveness, human characteristics, skill capabilities, training, manning implication, and other related elements into a comprehensive effort.
- 6) Supportability analyses -- an integral part of the systems engineering process beginning at program initiation and continuing throughout program development. Supportability analyses form the basis for related design requirements included in the system specification and for subsequent decisions concerning how to most cost effectively support the system over its entire life-cycle. Programs allow contractors the maximum flexibility in proposing the most appropriate supportability analyses.

H.2.2.2. Program Management

The business and administrative planning, organizing, directing, coordinating, controlling, and approval actions designated to accomplish overall program objectives which are not associated with specific hardware elements and are not included in systems engineering.

Includes for example:

- cost, schedule, performance measurement management, warranty administration, contract management, data management, vendor liaison, subcontract management, etc.
- support element management, defined as the logistics tasks management effort and technical control, and the business management of the support elements. The logistics management function encompasses the support evaluation and supportability assurance required to produce an affordable and supportable defense materiel system
- planning and management of all the functions of logistics. Examples are:
 - maintenance support planning and support facilities planning; other support requirements determination; support equipment; supply support; packaging, handling, storage, and transportation; provisioning requirements determination and planning; training system requirements determination; computer resource determination; organizational, intermediate, and depot maintenance determination management; and data management
- (for ships) the Extended Ship WBS (ESWBS), Project Management (897); Data Management (896); and Supply Support (853) elements.

H.2.3. System Test and Evaluation

The use of prototype, production, or specifically fabricated hardware/software to obtain or validate engineering data on the performance of the system during the development phase (normally funded from RDT&E) of the program.

Includes:

- detailed planning, conduct, support, data reduction and reports (excluding the Contract Data

Requirements List data) from such testing, and all hardware/software items which are consumed or planned to be consumed in the conduct of such testing

- all effort associated with the design and production of models, specimens, fixtures, and instrumentation in support of the system level test program

Note: *Test articles which are complete units (i.e., functionally configured as required by specifications) are excluded from this WBS element.*

Excludes:

- all formal and informal testing up through the subsystem level which can be associated with the hardware/software element
- acceptance testing

Note: *These excluded efforts are to be included with the appropriate hardware or software elements.*

H.2.3.1. Development Test and Evaluation

This effort is planned, conducted and monitored by the developing agency of the DoD component. It includes test and evaluation conducted to:

- demonstrate that the engineering design and development process is complete.
- demonstrate that the design risks have been minimized.
- demonstrate that the system will meet specifications.
- estimate the system's military utility when introduced.

- determine whether the engineering design is supportable (practical, maintainable, safe, etc.) for operational use.
- provide test data with which to examine and evaluate trade-offs against specification requirements, life-cycle cost, and schedule.
- perform the logistics testing efforts to evaluate the achievement of supportability goals, the adequacy of the support package for the system, (e.g., deliverable maintenance tools, test equipment, technical publications, maintenance instructions, and personnel skills and training requirements, etc.).

Includes, for example:

- all contractor in-house effort
- (all programs, where applicable) models, tests and associated simulations such as wind tunnel, static, drop, and fatigue; integration ground tests; test bed aircraft and associated support; qualification test and evaluation, development flight test, test instrumentation, environmental tests, ballistics, radiological, range and accuracy demonstrations, test facility operations, test equipment (including its support equipment), chase and calibrated pacer aircraft and support thereto, and logistics testing
- (for aircraft) avionics integration test composed of the following:
 - test bench/laboratory, including design, acquisition, and installation of basic computers and test equipments which will provide an ability to simulate in the laboratory the operational environment of the avionics system/subsystem
 - air vehicle equipment, consisting of the avionics and/or other air vehicle subsystem modules which are required by the bench/lab or flying test bed in order to provide a compatible airframe avionics system/subsystem for evaluation purposes

- flying test bed, including requirements analysis, design of modifications, lease or purchase of test bed aircraft, modification of aircraft, installation of avionics equipment and instrumentation, and checkout of an existing aircraft used essentially as a flying avionics laboratory
- avionics test program, consisting of the effort required to develop test plans/procedures, conduct tests, and analyze hardware and software test results to verify the avionics equipments' operational capability and compatibility as an integrated air vehicle subsystem
- software, referring to the effort required to design, code, de-bug, and document software programs necessary to direct the avionics integration test
- (for engines) engine military qualification tests and engine preliminary flight rating tests
- (for ships) model basin, hydrostatic, fatigue, shock, special sea tests and trials, etc., including the Extended Ship WBS (ESWBS), Trials Agenda Preparation, Data Collection & Analysis (842); Dock and Sea Trials (9823); and Hull Vibration Survey (9825) elements

H.2.3.2. Operational Test and Evaluation

The test and evaluation conducted by agencies other than the developing command to assess the prospective system's military utility, operational effectiveness, operational suitability, logistics supportability (including compatibility, inter-operability, reliability, maintainability, logistic requirements, etc.), cost of ownership, and need for any modifications.

Includes, for example:

- Initial operational test and evaluation conducted during the development of a weapon system
- such tests as system demonstration, flight tests, sea trials, mobility demonstrations, on-orbit tests, spin demonstration, stability tests, qualification operational test and evaluation, etc., and support thereto, required to prove the operational capability of the deliverable system
- contractor support (e.g., technical assistance, maintenance, labor, material, etc.) consumed during this phase of testing
- logistics testing efforts to evaluate the achievement of supportability goals and the adequacy of the support for the system (e.g., deliverable maintenance tools, test equipment, technical publications, maintenance instructions, personnel skills and training requirements, and software support facility/environment elements)

H.2.3.3. Mock-Ups

The design engineering and production of system or subsystem mock-ups which have special contractual or engineering significance, or which are not required solely for the conduct of one of the above elements of testing.

H.2.3.4. Test and Evaluation Support

The support elements necessary to operate and maintain, during test and evaluation, systems and subsystems which are not consumed during the testing phase and are not allocated to a specific phase of testing.

Includes, for example:

- repairable spares, repair of repairable, repair parts, warehousing and distribution of spares and repair parts, test and support equipment, test bed vehicles, drones, surveillance aircraft, tracking vessels, contractor technical support, etc.

Excludes:

- operational and maintenance personnel, consumables, special fixtures, special instrumentation, etc., which are utilized and/or consumed in a single element of testing and which should be included under that element of testing

H.2.3.5. Test Facilities

The special test facilities required for performance of the various developmental tests necessary to prove the design and reliability of the system or subsystem.

Includes, for example:

- test tank test fixtures, propulsion test fixtures, white rooms, test chambers, etc.

Excludes:

- brick and mortar-type facilities identified as industrial facilities

H.2.4. Training

Deliverable training services, devices, accessories, aids, equipment, and parts used to facilitate instruction through which personnel will learn to operate and maintain the system with maximum efficiency.

Includes:

- all effort associated with the design, development, and production of deliverable training equipment as well as the execution of training services

Excludes:

- overall planning, management, and task analysis function inherent in the WBS element Systems Engineering/Program Management

H.2.4.1. Equipment

Distinctive deliverable end items of training equipment, assigned by either a contractor or military service, required to meet specific training objectives.

Includes, for example:

- operational trainers, maintenance trainers, and other items such as cutaways, mock-ups, and models

H.2.4.2. Services

Deliverable services, accessories, and aids necessary to accomplish the objectives of training.

Includes:

- training course materials; contractor-conducted training (in-plant and service training); and the materials and curriculum required to design, execute, and produce a contractor developed training program
- materiel, courses, and associated documentation (primarily the computer software, courses and training aids)

Excludes:

- deliverable training data associated with the WBS element Support Data

H.2.4.3. Facilities

The special construction necessary to accomplish training objectives.

Includes, for example:

- modification or rehabilitation of existing facilities used to accomplish training objectives

Excludes:

- installed equipment used to acquaint the trainee with the system or establish trainee proficiency
- the brick and mortar-type facilities identified as industrial facilities

H.2.5. Data

The deliverable data required to be listed on a Contract Data Requirements List, DD Form 1423.

Includes:

- only such effort that can be reduced or avoided if the data item is eliminated
- (government-peculiar data) acquiring, writing, assembling, reproducing, packaging and shipping the data
- transforming into government format, reproducing and shipping data identical to that used by the contractor but in a different format

H.2.5.1. Technical Publications

Technical data, providing instructions for installation, operation, maintenance, training, and support, formatted into a technical manual. Data may be presented in any form (regardless of the form or method of recording). Technical orders that meet the criteria of this definition may also be classified as technical manuals.

Includes, for example:

- operation and maintenance instructions, parts lists or parts breakdown, and related technical information or procedures exclusive of administrative procedures
- data item descriptions set forth in categories selected from the Acquisition Management Systems and Data Requirements Control List (DoD Regulation 5010.12-L)
- (for ships) Extended Ship WBS (ESWBS), Technical Manuals and Other Data (856) element

H.2.5.2. Engineering Data

Recorded scientific or technical information (regardless of the form or method of recording) including computer software documentation. Engineering data defines and documents an engineering design or product configuration (sufficient to allow duplication of the original items) and is used to support production, engineering and logistics activities.

Includes, for example:

- all final plans, procedures, reports, and documentation pertaining to systems, subsystems, computer and computer resource programs, component engineering, operational testing, human factors, reliability, availability, and maintainability, and other engineering analysis, etc.
- Technical data package (reprocurement package) which includes all engineering drawings, associated lists, process descriptions, and other documents defining physical geometry, material composition, and performance procedures
- (for ships) Extended Ship WBS (ESWBS), Design Support, Ship's Selected Records (8302); Design Support, Services, Reproduction (8303); and Engineering Drawings and Specifications (855) elements

Excludes:

- computer software or financial, administrative, cost or pricing, or management data or other information incidental to contract administration

H.2.5.3. Management Data

The data items necessary for configuration management, cost, schedule, contractual data management, program management, etc., required by the government in accordance with functional categories selected from the DODISS and DoD Regulation 5010.12-L.

Includes, for example:

- contractor cost reports, cost performance reports, contract funds status reports, schedules, milestones, networks, integrated support plans, etc.
- (for ships) Extended Ship WBS (ESWBS), Contract Data Requirements (988) element

H.2.5.4. Support Data

The data items designed to document support planning in accordance with functional categories selected from DoD Regulation 5010.12-L.

Includes, for example:

- supply; general maintenance plans and reports; training data; transportation, handling, storage, and packaging information; facilities data; data to support the provisioning process and all other support data; and software supportability planning and software support transition planning documents.

H.2.5.5. Data Depository

The facility designated to act as custodian to maintain a master engineering specification and establish a drawing depository service for government approved documents that are the property of the U.S. Government. As custodian for the government, the depository, authorized by approved change orders, maintains these master documents at the latest approved revision level. This facility is a distinct entity.

Includes, for example:

- all drafting and clerical effort necessary to maintain documents

Excludes:

- all similar effort for facility's specification and drawing control system, in support of its engineering and production activities.

Note: *When documentation is called for on a given item of data retained in the depository, the charges (if charged as direct) will be to the appropriate data element.*

H.2.6. Peculiar Support Equipment

The design, development, and production of those deliverable items and associated software required to support and maintain the system or portions of the system while the system is not directly engaged in the performance of its mission, and which are not common support equipment (See H.3.7 below).

Includes:

- vehicles, equipment, tools, etc., used to fuel, service, transport, hoist, repair, overhaul, assemble, disassemble, test, inspect, or otherwise maintain mission equipment
- any production of duplicate or modified factory test or tooling equipment delivered to the government for use in maintaining the system. (Factory test and tooling equipment initially used by the contractor in the production process but subsequently delivered to the government will be included as cost of the item produced.)
- any additional equipment or software required to maintain or modify the software portions of the system

Excludes:

- overall planning, management and task analysis functions inherent in the WBS element, Systems Engineering/Program Management
- common support equipment, presently in the DoD inventory or commercially available, bought by the using command, not by the acquiring command

H.2.6.1. Test and Measurement Equipment

The peculiar or unique testing and measurement equipment which allows an operator or maintenance function to evaluate operational conditions of a system or equipment by performing specific diagnostics, screening or quality assurance effort at an organizational, intermediate, or depot level of equipment support.

Includes, for example:

- test measurement and diagnostic equipment, precision measuring equipment, automatic test equipment, manual test equipment, automatic test systems, test program sets, appropriate interconnect devices, automated load modules, taps, and related software, firmware and support hardware (power supply equipment, etc.) used at all levels of maintenance
- packages which enable line or shop replaceable units, printed circuit boards, or similar items to be diagnosed using automatic test equipment

H.2.6.2. Support and Handling Equipment

The deliverable tools and handling equipment used for support of the mission system.

Includes, for example:

- ground support equipment, vehicular support equipment, powered support equipment, nonpowered support equipment, munitions material handling equipment, materiel handling equipment, and software support equipment (hardware and software)

H.2.7. Common Support Equipment

The items required to support and maintain the system or portions of the system while not directly engaged in the

performance of its mission, and which are presently in the DoD inventory for support of other systems.

Includes:

- acquisition of additional quantities of this equipment needed to support the item
- all efforts required to assure the availability of this equipment to support the item

H.2.7.1. Test and Measurement Equipment

The common testing and measurement equipment which allows an operator or maintenance function to evaluate operational conditions of a system or equipment by performing specific diagnostics, screening or quality assurance effort at an organizational, intermediate, or depot level of equipment support.

Includes, for example:

- test measurement and diagnostic equipment, precision measuring equipment, automatic test equipment, manual test equipment, automatic test systems, test program sets, appropriate interconnect devices, automated load modules, taps, and related software, firmware and support hardware (power supply equipment, etc.) used at all levels of maintenance
- packages which enable line or shop replaceable units, printed circuit boards, or similar items to be diagnosed using automatic test equipment

H.2.7.2. Support and Handling Equipment

The deliverable tools and handling equipment used for support of the mission system.

Includes, for example:

- ground support equipment, vehicular support equipment, powered support equipment, nonpowered support equipment, munitions material handling equipment, materiel handling equipment, and software support equipment (hardware/software)

H.2.8. Operational/Site Activation

The real estate, construction, conversion, utilities, and equipment to provide all facilities required to house, service, and launch prime mission equipment at the organizational and intermediate level.

Includes:

- conversion of site, ship, or vehicle
- system assembly, checkout, and installation (of mission and support equipment) into site facility or ship to achieve operational status
- contractor support in relation to operational/site activation

H.2.8.1. System Assembly, Installation, and Checkout on Site

The materials and services involved in the assembly of mission equipment at the site.

Includes, for example:

- installation of mission and support equipment in the operations or support facilities and complete system checkout or shakedown to ensure operational status. (Where appropriate, specify by site, ship or vehicle.)

H.2.8.2. Contractor Technical Support

The materials and services provided by the contractor related to activation.

Includes, for example:

- repair of repairable, standby services, final turnover, etc.

H.2.8.3. Site Construction

Real estate, site planning and preparation, construction, and other special-purpose facilities necessary to achieve system operational status.

Includes, for example:

- construction of utilities, roads, and interconnecting cabling

H.2.8.4. Site/Ship/Vehicle Conversion

The materials and services required to convert existing sites, ships, or vehicles to accommodate the mission equipment and selected support equipment directly related to the specific system.

Includes, for example:

- operations, support, and other special purpose (e.g., launch) facilities conversion necessary to achieve system operational status. (Where appropriate, specify by site, ship or vehicle.)

H.2.9. Industrial Facilities

The construction, conversion, or expansion of industrial facilities for production, inventory, and

contractor depot maintenance required when that service is for the specific system.

Includes:

- equipment acquisition or modernization, where applicable
- maintenance of these facilities or equipment
- industrial facilities for hazardous waste management to satisfy environmental standards

H.2.9.1. Construction/Conversion/Expansion

The real estate and preparation of system peculiar industrial facilities for production, inventory, depot maintenance, and other related activities.

H.2.9.2. Equipment Acquisition or Modernization

The production equipment acquisition, modernization, or transferal of equipment for the particular system. (Pertains to government owned and leased equipment under facilities contract.)

H.2.9.3. Maintenance (Industrial Facilities)

The maintenance, preservation, and repair of industrial facilities and equipment.

H.2.10. Initial Spares and Repair Parts

The deliverable spare components, assemblies and subassemblies used for initial replacement purposes in the materiel system equipment end item.

Includes:

- repairable spares and repair parts required as initial stockage to support and maintain newly fielded systems or subsystems during the initial phase of service, including pipeline and war reserve quantities, at all levels of maintenance and support

Excludes:

- development test spares and spares provided specifically for use during installation, assembly, and checkout on site. Lower level WBS elements should be by subsystem.

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APPENDIX I. SYSTEMS ENGINEERING PROCESS OVERVIEW

(Extracted from DSMC, Systems Engineering Fundamentals)

I.1. THE PROCESS

The Systems Engineering Process (SEP) is a comprehensive, iterative and recursive problem solving process, applied sequentially top-down by integrated teams. It transforms needs and requirements into a set of system product and process descriptions, generate information for decision-makers, and provides input for the next level of development. The process is applied sequentially, one level at a time, adding additional detail and definition with each level of development. As shown by Figure I-1, the process includes inputs and out-puts, requirements analysis, functional analysis and allocation, requirements loop, synthesis, design loop, verification, and system analysis and control.

I.2. SE PROCESS INPUTS

Inputs consist primarily of the customer's needs, objectives, requirements and project constraints. Inputs can include, but are not restricted to, missions, measures of effectiveness, environments, available technology base, output requirements from prior application of the systems

engineering process, program decision requirements, and requirements based on "corporate knowledge."

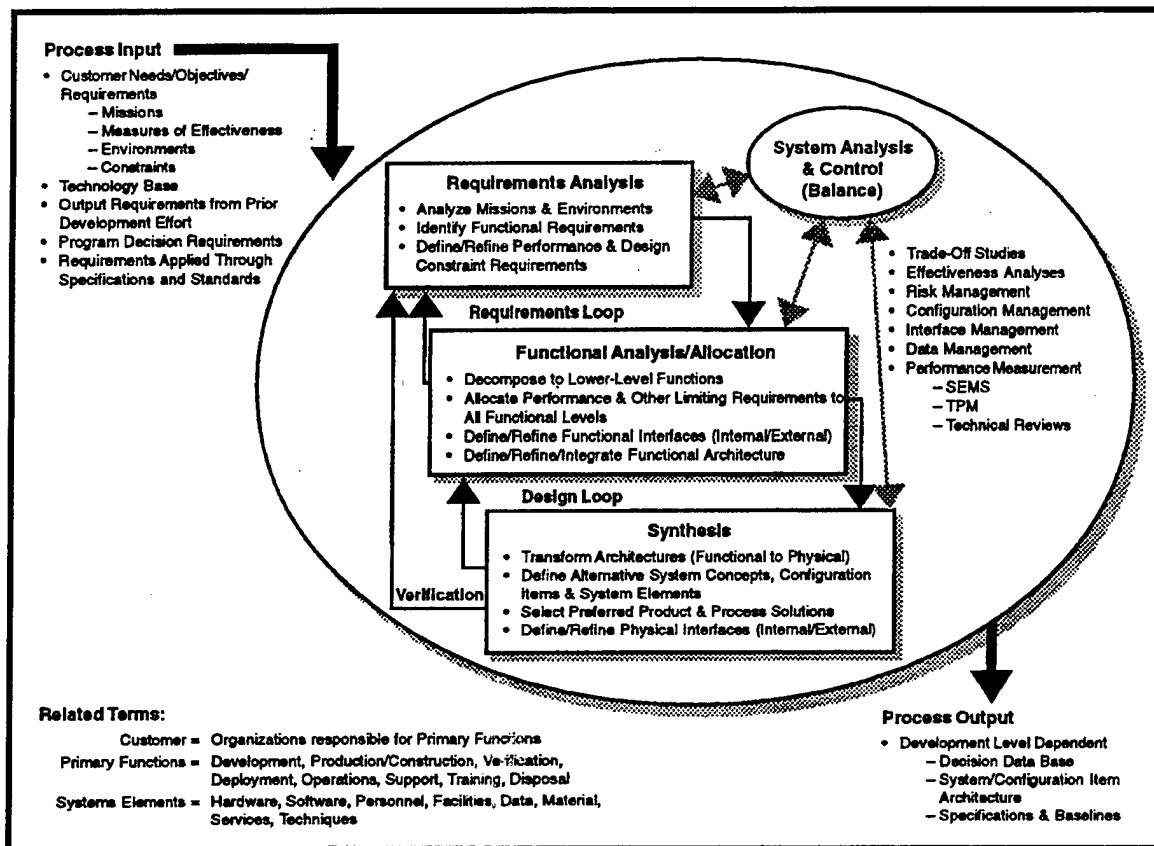


Figure I.1. The Systems Engineering Process

I.3. REQUIREMENTS ANALYSIS

The first step of the Systems Engineering Process is to analyze the process inputs. Requirements analysis is used to develop functional and performance requirements; that is, customer requirements are translated into a set of requirements that define what the system must do and how well it must perform. The systems engineer must ensure that the requirements are understandable, unambiguous, comprehensive, complete, and concise. Requirements analysis

must clarify and define functional requirements and design constraints. Functional requirements define quantity (how many), quality (how good), coverage (how far), time lines (when and how long), and availability (how often.) Design constraints define those factors that limit design flexibility, such as environmental conditions or limits, defense against internal or external threats, contract, customer or regulatory standards.

I.4. FUNCTIONAL ANALYSIS/ALLOCATION

Functions are analyzed by decomposing higher-level functions identified through requirements analysis into lower-level functions. The performance requirements associated with the higher level are allocated to lower functions. The result is a description of the product or item in terms of what it does logically and in terms of the performance required. This description is often called the functional architecture of the product or item. Functional analysis and allocation allows for a better understanding of what the system has to do, in what ways it can do it, and to some extent, the priorities and conflicts associated with lower-level functions. It provides information essential to optimizing physical solutions. Key tools in functional analysis and allocation are Functional Flow Block Diagrams, Time Line Analysis, and the Requirements Allocation Sheet.

I.5. REQUIREMENTS LOOP

Performance of the functional analysis and allocation results in a better understanding of the requirements and should prompt reconsideration of the requirements analysis. Each function identified should be traceable back to a requirement. This iterative process of revisiting requirements analysis as a result of functional analysis and allocation is referred to as the requirements loop.

I.6. DESIGN SYNTHESIS

Design synthesis is the process of defining the product or item in terms of the physical and software elements which together make up and define the item. The result is often referred to as the physical architecture. Each part must meet at least one functional requirement, and any part may support many functions. The physical architecture is the basic structure for generating the specifications and baselines.

I.7. DESIGN LOOP

Similar to the requirements loop described above, the design loop is the process of revisiting the functional architecture to verify that the physical design synthesized can perform the required functions at required levels of performance. The design loop permits reconsideration of how

the system will perform its mission, and this helps optimize the synthesized design.

I.8. VERIFICATION

For each application of the system engineering process, the solution will be compared to the requirements. This part of the process is called the verification loop, or more commonly, Verification. Each requirement at each level of development must be verifiable. Baseline documentation developed during the systems engineering process must establish the method of verification for each requirement. Appropriate methods of verification include examination, demonstration, analysis (including modeling and simulation), and testing. Formal test and evaluation (both developmental and operational) are important contributors to the verification of systems.

I.9. SYSTEMS ANALYSIS AND CONTROL

Systems Analysis and Control include technical management activities required to measure progress, evaluate and select alternatives, and document data and decisions. These activities apply to all steps of the SE process. System analysis activities include trade-off studies, effectiveness analyses, and design analyses. They evaluate alternative approaches to satisfy technical requirements and

program objectives, and provide a rigorous quantitative basis for selecting performance, functional, and design requirements. Tools used to provide input to analysis activities include modeling, simulation, experimentation, and test. Control activities include risk management, configuration management, data management, and performance-based progress measurement including event based scheduling, Technical Performance Measurement (TPM), and technical reviews. The purpose of Systems Analysis and Control is to ensure that:

- Solution alternative decisions are made only after evaluating the impact on system effectiveness, life-cycle resources, risk, and customer requirements;
- Technical decisions and specification requirements are based on systems engineering outputs;
- Traceability from systems engineering process inputs to outputs is maintained;
- Schedules for development and delivery are mutually supportive;
- Required technical disciplines are integrated into the systems engineering effort;
- Impacts of customer requirements on resulting functional and performance requirements are examined for validity, consistency, desirability, and attainability; and;
- Product and process design requirements are directly traceable to the functional and performance requirements they were designed to fulfill, and vice versa.

I.10. SE PROCESS OUTPUT

Process output is dependent on the level of development. It will include the decision database, the system or configuration item architecture, and the baselines, including specifications, appropriate to the phase of development. In general, it is any data that describes or controls the product configuration or the processes necessary to develop that product.

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