Environmental, Safety, and Health (ESH) Cost Analysis Guide

A Guide for Developing, Using, and Supporting Communities

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Prepared for

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Foreword

This Guide has been prepared as an AFMC discretionary document for use by members of the Environmental, Safety, and Health (ESH), Engineering, and Financial Management Communities that need to identify, treat or use ESH costs in system decision making. Ms. Mary Helen Alverio of the Air Force Space and Missile Systems Center (SMC) served as the Government project director. EER Systems prepared the ESH Cost Analysis Guide under contract F04701-95-D-0002, Delivery Order 0021. The EER team of Mr. Gerald B. Kos (Program Manager), Mr. Charlie Purvis, and Mr. James E. Ivie developed the Guide for the Air Force Space and Missile Systems Center with funding and direction from HQ AFMC/DRIE.

The approach taken in developing this handbook was to use the 1996 SMC ESH Management and Cost Handbook as a point of departure. Since the ESH Management and Cost Handbook was published, several excellent guides on ESH management have been published. These documents are referenced and the emphasis of the Guide is now focused on cost estimating methodologies and the identification and treatment of ESH cost data. Responsibility for this document is with the financial management community (AFMC/FMC).

This effort was related to three previous tasks funded by SMC. The first was an initial study (F04701-90-D-0003, Delivery Order 0017) performed in 1994 entitled, Hazardous Material Study: Background Information Collection. That study provided an overview of the various regulations that impact the acquisition of weapon systems, the environmental considerations that are tied to acquisition milestones and phases, the process for implementing a pollution prevention program, and a summary of the cost estimator's roles and responsibilities during those processes. The second task prepared the predecessor handbook, the Environmental Cost Handbook (F04701-95-D-0002, Delivery Order 0001). In the third task, the Environmental, Safety, and Health (ESH) Management and Cost Handbook was developed in response to growing ESH regulations and increased need to have visibility into system ESH costs.

This product could not have been completed without the openness and cheerful support provided by the personnel and organizations listed in Appendix O.

The point of contact for questions, comments and suggestions regarding this Guide should be directed to SMC/FMC Ms. Mary Helen Alverio at 310-363-2822. Faxes may be sent to 310-363-3518. Ms. Alverio may also be reached at her Internet address, mary.alverio@losangeles.af.mil. In the event that Ms. Alverio may not be reached, contact Mr. Gerald Kos at 310-322-2682. His Internet address is kosgb@aol.com.

Preface

In the Pollution Prevention Act of 1990, Congress stated that, *there are significant opportunities for industry to reduce or prevent pollution at the source through **cost-effective changes** in production, operation, and raw materials use. Such changes offer industry substantial savings in reduced raw material, pollution control, and liability costs as well as help protect the environment and reduce risks to worker health and safety.*

In September 1993, the National Performance Review pointed out that most federal decision-makers do not have access to environmental cost and benefit information. The review further concluded that environmental costs are obscured by placing them in overhead categories or group accounts rather than associating them with the category or account responsible for generating the environmental costs. The need for accounting concepts that enable managers to uncover the hidden costs of environmental degradation and regulatory compliance was emphasized throughout the report.

Since the National Performance Review, cost estimating and analysis has become a vital part of the Environmental, Safety, and Health (ESH) decision making process for Department of Defense (DoD) weapon system acquisition. Compliance regulations are imposing challenges to the acquisition of new systems. Critical decisions regarding ESH issues must be made in each phase of the acquisition process. In addition, today's processes and business practices are being carefully examined and alternatives explored to reduce the cost of ownership of current systems. Reductions in the cost of ownership of current systems may be the financial key to affording the development and production of needed new systems. The timeliness, accuracy and consistency of ESH cost data will influence the quality of those decisions.

The requirements to identify and address ESH costs in the life cycle of systems are contained in ESH, Systems Engineering and Financial Management Guidance. This Guide takes that guidance and translates it into procedures, methods, and techniques so that the reader will be able to develop those processes and documents necessary to address ESH costs during the life of a system.

The purpose of the Guide is to provide the cost analyst processes to assure all ESH costs are included in the weapon system Program Cost Estimate (PCE) and trade studies supporting design alternatives. This will help support program decisions that are based upon sound cost data and to prevent ESH related delays in program planning and execution.

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Executive Summary

This Guide seeks to bring together in one document all ESH cost estimating related requirements and processes. Figure 1, on the following page, shows how the ESH Cost Analysis Guide brings together the ESH related requirements in the ESH specialties, Systems Engineering principles, and Financial Management policies and procedures. The right side of the figure shows some applications of the Guide that support sound decision-making processes for the Single Manager (SM).

The Guide has two primary parts: ESH information and ESH Cost Estimating. Part One, ESH Information, consists of two sections. Section one provides an overview of ESH management information that a cost analyst will need for ESH cost estimating efforts. This involves providing the background history and defining ESH Management and ESH Cost. Section two informs the cost analyst of the major ESH activities, by phase, over the life cycle of a weapon system.

Part Two, ESH Cost Estimating, is also broken into two sections. Section one discusses the basic cost estimating concepts that include ESH cost estimating requirements, objectives, and activities. Section two reviews the cost estimating common processes and their application to ESH cost estimating.

The appendices of this document furnish reference material that is very helpful to the cost analyst recently introduced to ESH cost estimating. Appendices A and B provide the cost analyst samples and examples of program cost estimates (PCEs) and trade studies that incorporate ESH costs within the cost estimating common process illustrated in Part Two. PCE examples are provided for a Delta Launch Vehicle, Fighter Aircraft, Global Positioning System (GPS) space vehicle, Radar Program, and Satellite Communications Terminal. Trade study examples are provided for a Hush House Fire Suppression System, Coating Removal Processes for Helicopter Remanufacture, Canopy Replacement for the F-15E, Replacing Cadmium Plating with IVD Aluminum Coating for Corrosion protection, and CFC-114 Refrigerant Replacement Study. Other key information provided in the appendices includes a glossary of ESH terms and definitions, a summary of ESH related laws and regulations and their impact to the single manager, functional support organizations for the cost analyst, an enhanced ESH Work Breakdown Structure (WBS), cost identifying questions by topic and organization/function, potential ESH cost estimating tools, and a discussion about the potential use of Activity-Based Costing (ABC) / Activity-Based Management (ABM) with ESH cost estimating.

Excellent ESH Management material is available in several documents to supplement this Guide. The Electronics Systems Center (ESC) developed Tactical Environmental, Safety and Health Action Guide (TEAG), published in the Fall of 1997 and updated periodically on the Internet, addresses key documents, processes, and activities in the acquisition life cycle. The intended audience is program office personnel. The ESC developed Weapon System Environmental, Safety and Health Evaluation Development Guide for Single Managers, November 1996, defines the process for periodically evaluating the ESH impacts, issues, and concerns of programs to remain compliant with DoD 5000.2-R. The Air Force Space and Missile Systems Center (SMC) prepared an ESH Management and Cost Handbook in September 1996. While some of the references in that Handbook are dated, the responsibilities of developing, using, and supporting communities are unchanged and the descriptions of activities are still valuable. The cost analyst should find these documents helpful to compliment their understanding of ESH issues.

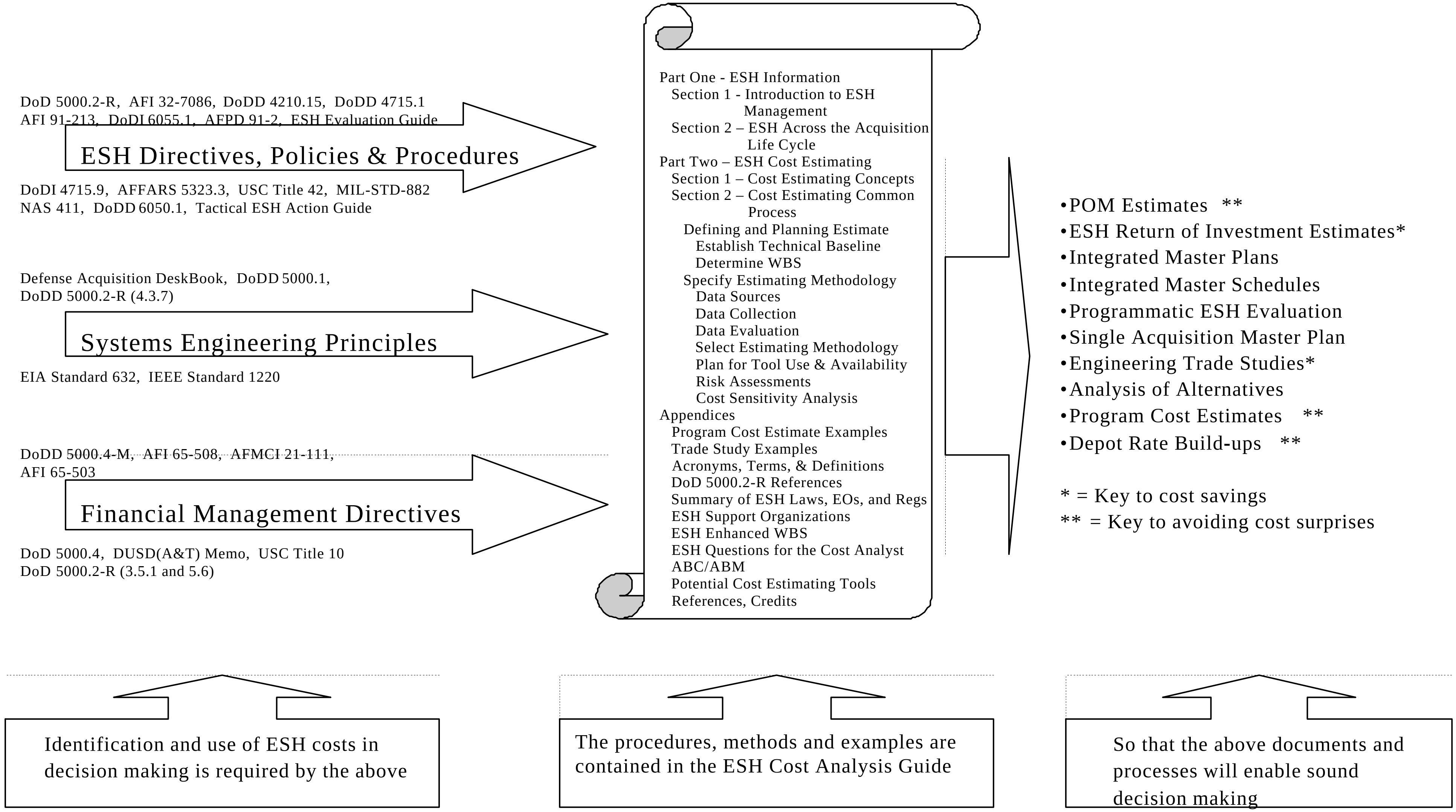

Figure 1, Guide Interfaces

Part One - ESH Information

Section One - Introduction to ESH Management

The need for ESH Management is derived from Department of Defense Regulation 5000.2-R, *Mandatory Procedures for Major Defense Acquisition Programs (MDAPs) and Major Automated Information System (MAIS) Acquisition Programs*, 07 October 1997. Section 4.3.7, Environmental, Safety, and Health, of 5000.2-R states that all programs, regardless of acquisition category, shall comply with the following elements (1) National Environmental Policy Act, (2) Environmental Compliance, (3) System Safety and Health, (4) Hazardous Materials and (5) Pollution Prevention as described in the regulation. In addition, all programs shall also be conducted in accordance with applicable federal, state, interstate, and local environmental laws and regulations, Executive Orders (EOs), treaties, and agreements (see Appendix F for a summary of these laws, regulations, etc.). For the complete reference of Section 4.3.7, see Appendix E of this document.

Introduction to the Terms "ESH Management" and "ESH Cost"

It is important to point out to readers that the transition of terms and definitions from "environmental" to "ESH" is still not complete. Policies and directives three or more years old may use the term "environmental" but current practical application is to associate the more global meaning of ESH with that term. There will be locations in this Guide where the term "environmental" is used and it would appear that "ESH" should be used instead. Where citing or referencing older documents, the term in the cited document, rather than "ESH", will be used. There will also be locations where the term "ESH" is used but the material associated with the term is limited to "environmental". These uses reflect the AFMC intent to expand the subject to ESH. Another acronym that may be used interchangeably with ESH is ESOH where the added letter stands for "Occupational".

ESH Management

ESH Management is defined in this Guide as:

The application of management activities on the collective specialties of Environmental, Safety, and Health with an emphasis on the reduction of the total life cycle costs consistent with DoD and Air Force objectives. Several points are implicit in the definition. One is that the focus is on the collective specialties, not one at the expense of the other. Second, reduction of life cycle costs is total costs, not just those associated with ESH. For example, a reduction in pollution emissions that significantly drives up operating and support costs or reduces readiness is not a sound management decision. Finally, there are goals and objectives within DoD and the Air Force for ESH that must be taken into consideration. For example, the DoD may be willing to accept increased costs in specified areas to become a better neighbor to the civilian community from an ESH perspective. Therefore, while a cost benefit analysis is useful, it may not be the only determining factor.

ESH Management focuses on understanding the requirements, identifying the issues, evaluating alternatives, and managing their implementation.

Environmental Security is at the top of the ESH pyramid as described in DoD Directive 4715.1. Environmental Security is defined in that directive as including environmental, safety, and health activities. The cornerstone policy is for environmental security leadership within DoD activities demonstrated by a series of proactive measures. DoD has stated intent to comply with applicable statutes, executive orders, agreements, regulations and other legal requirements and integrate these factors into the DoD decision-making processes. Environmental, safety, and health values will additionally be integrated into DoD acquisition, procurement, test, maintenance, repair, and disposal processes for systems, equipment, facilities, and land. The 32-, 48-, and 91- series Air Force Policy Directives (AFPD) and Air Force Instructions (AFI) address ESH areas.

DoD Occupational Safety and Health (OSH) Program guidance is provided by DoD Instruction 6055.1. Part of this guidance includes the requirement to implement OSH standards and apply them where appropriate in the acquisition, design, or alteration of new or upgraded systems and equipment. Inspections, correction of conditions, and reporting are the key features of safety programs.

The term ESH embraces environmental, safety, and health. The relationship between environmental, safety, and health is shown in Figure 2. Environmental issues focus on compliance, hazardous materials management, pollution prevention, conservation, and restoration. Safety issues focus on system safety, operational safety, and the elimination of fire and equipment hazards. Health issues focus on the detection and protection from chemical, biological, physical, and radiation hazards. The three ellipses in Figure 2 show where several issues impact all three areas. Eliminating a hazardous material (such as Beryllium from a launch vehicle) prevents chemical hazards, reduces the need for safety equipment, eliminates monitoring and record keeping, reduces specialized training, and eliminates unique storage, treatment, and disposal.

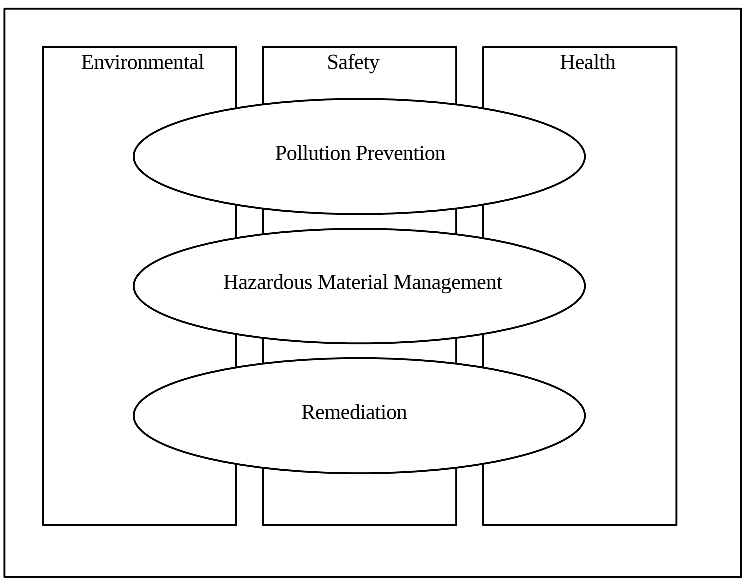

Figure 2, ESH Commonality

There are several ESH management issues that may surface in a weapon system acquisition. Program Managers must be aware of the ESH risks that can result from program actions including test, maintenance, beddown, operation, demilitarization, and disposal. Program Managers need to be sensitive to the program risks that may be posed by changing ESH laws. Within the safety area, the emphasis remains the man-machine and system-to-system interfaces but broader safety issues such as insensitive munitions and the safe deactivation and disposal of munitions are also being addressed. Within the health area, specific personal health risk issues and broad community-right-to know requirements need to be addressed. Whether the ESH risks are environmental, safety, or health, the method described in the System Safety Program Requirements (MIL-STD-882C) for assessing the probability of occurrence against severity is useful in ESH risk management.

The significant ESH issues that need to be addressed should not overwhelm program offices developing weapon systems. Each major facility has a staff of certified and trained ESH specialists ready to assist you. All you need to do is ask. The lists of functional support organizations that may be useful to the cost analyst are shown in Appendix G.

Sound Early Decision Making Is Key To ESH Success

ESH management is like acquisition logistics in that early design influence is often the most effective. The figure below illustrates this point. The greatest ESH influence in a system comes early in the life cycle when designs are fluid. This is why participation by all personnel concerned with ESH issues is so critical early in the program. Changes and corrections initiated later in the life cycle are likely to be more costly than those implemented prior to production and deployment. After hardware designs have been finalized, production begun or even completed, modifications or corrections will require costly redesign, removal, replacement, or retrofit.

A theme being stressed throughout the Department of Defense is that programs can reduce their total life cycle costs and maintain readiness through the application of sound business decisions. The figure below shows that inputs to sound business decisions include customer requirements, ESH skills on the decision team, resources, processes and technology. Bringing all of the factors into play and making sound business decisions can result in improved system performance and reduced overall life cycle cost.

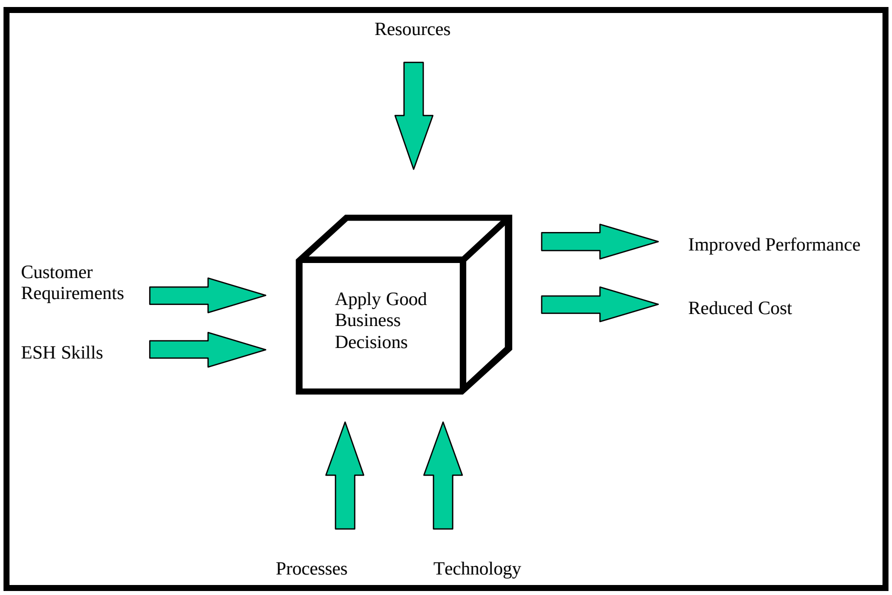

Figure 3, ESH Sound Business Practices

ESH Management: An Integral Part Of Systems Engineering

DoD 5000.2-R requires that Program Managers ensure that a system engineering process 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. More than one major defense contractor’s systems engineering methodology handbook echoes the principal that the design, development, and production of a system requires integration across all engineering and programmatic disciplines. Similarly, DoD 5000.2-R, Section 4.3.7, requires ESH to be integrated into the systems engineering process. There are several reasons why the use of the systems engineering process is preferred. Personnel understand that process as it is used to integrate such specialties as logistics, safety, and security. The systems engineering process translates operational requirements into technical requirements. These technical requirements form the basis of engineering trade studies. Finally, it is simply more efficient than inventing a separate method for integrating this critical subject. For example, at SMC, a series of Critical Process Assessment Tools (CPATs) are available to support project officers and project engineers. CPATs have been prepared for Program Management, Systems Engineering, and ESH. The ESH CPAT was completed in May 1997 and provides an extremely thorough description of the ESH process and includes questions for measuring progress. All CPATs are available in the Defense Acquisition Deskbook.

ESH Cost

ESH Cost focuses on estimating and analyzing cost associated with or driven by ESH issues and then using that information to support sound system and program decisions. ESH costs are normally a minimal part of the initial acquisition costs but can be a significant cost when viewed over the life cycle of a system. Thus, the estimating of ESH life cycle costs during system acquisition is especially critical. While the magnitude of the ESH portion of weapon system life cycle costs (LCCs) for systems such as tactical aircraft should not be a major cost driver of total LCC, other elements/projects such as chemical munitions, may be significant, especially when demilitarization and safe disposal costs are included. The General Accounting Office (GAO) has estimated that the total future cost to complete cleanups at Federal sites is almost $400 billion (GAO/RCED-96-150). The DoD Inspector General (IG) has estimated that more than 80 percent of the hazardous wastes generated by the DoD are industrial wastes associated with the production, operation, and maintenance of DoD weapon systems (SAF/AQ ESH Tutorial, March 1996). Industry experience has shown that the average cost ratio of a Hazardous Material (HAZMAT) to the costs for handling, treating, and disposal of waste is 1:80 (SAF/AQ ESH Tutorial, March 1996).

Sometimes the terms and definitions associated with ESH costs can appear confusing. The Venn diagram on the following page (Figure 4) is useful for explaining ESH costs. Consider the final phase of acquisition. ESH costs may be thought of as a subset of the total costs accrued by a system in that acquisition phase. ESH costs can be sub-divided into Environmental, Safety, and Health categories. Sub-categories within ESH costs include but are not limited to pollution prevention (PP), compliance, and hazardous materials (HAZMATs) management. Let’s look at some examples of costs to see where they would be placed on this diagram:

ESH Cost Sample:

A. Consider base weekly trash service throughout the maintenance area. This is normally an operating and support cost. Since it is not driven by any specific weapon system environmental requirement, it could be excluded from ESH costs.

B. Consider that because several toxic chemicals are used in the maintenance area, an occupational health survey of the maintenance areas is required yearly. The cost of the survey would be an example of a Health cost within ESH. If the use of the chemicals require engineering controls, personal protective equipment, and/or training and medical surveillance of the workers, then these would also be Health costs.

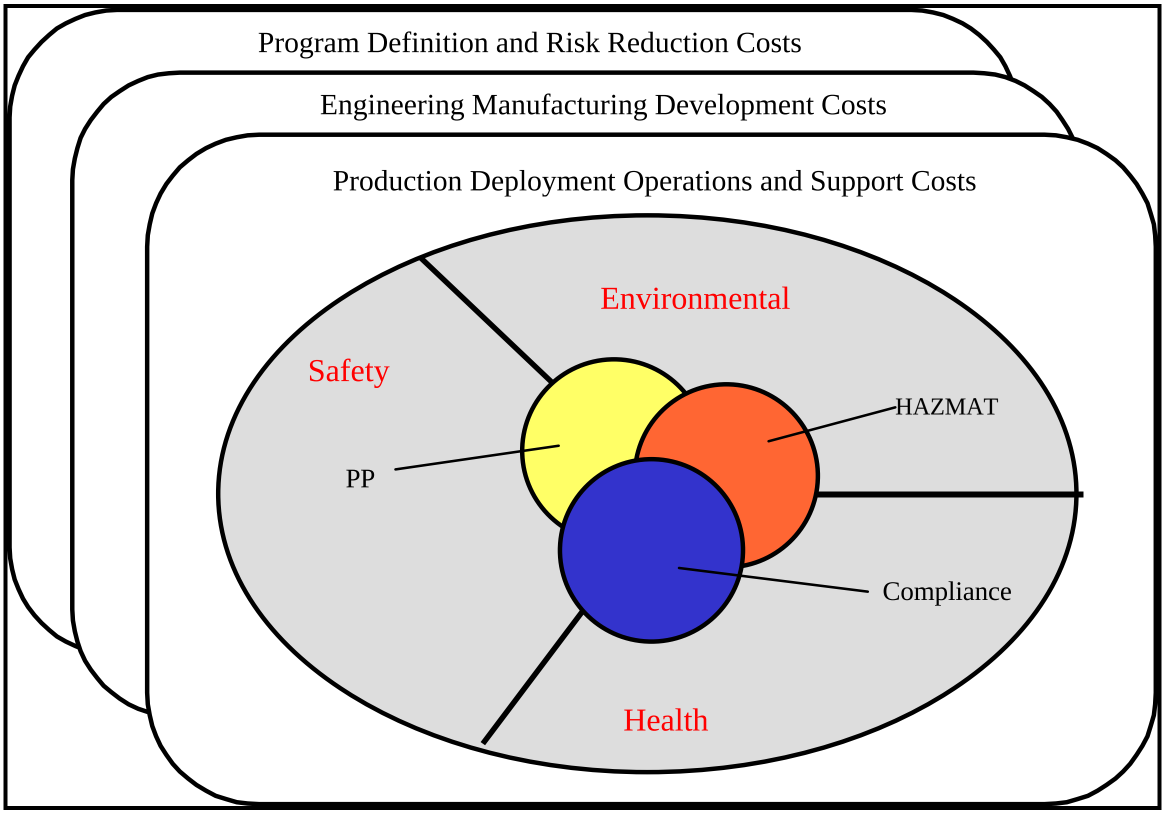

Figure 4, ESH Costs

C. Suppose that as part of the system being deployed, a new base or base facility is required. Construction of the facility requires an Environmental Impact Statement (EIS). The EIS is required by federal regulations and could be considered an environmental compliance cost under the category of ESH costs.

D. Going back to the maintenance area again, consider the lead acid battery maintenance area. Several chemicals require special disposal or recycling costs. The cost to dispose or recycle the acid and lead plates could be considered hazardous material costs under ESH costs.

E. Consider now the need to provide an oil separator for the maintenance area. The oil separator is used to separate oil that gets washed into the drains in the repair areas and wash racks. Since this device prevents pollution, its procurement/purchase cost could be allocated to pollution prevention.

F. Finally, consider a modification that is required on the hydrazine tank farm. This is where hydrazine is stored and hydrazine bottles are checked and refilled. A modification to the facility may require an EIS (compliance cost), hazardous material management cost, and potentially a pollution prevention cost.

The examples above are just a few of many possible views of ESH costs. By forming a concept of ESH costs within the system life cycle and then breaking the cost categories down to lower levels, cost analysts will become more sensitive to detecting the ESH costs.

Affordability of systems is an Air Force leadership concern when assessing programs. It is usually a risk based milestone decision that considers the program cost in comparison to a number of parameters, such as:

- What the service believes is a reasonable cost for the capability anticipated;
- What the service believes the leadership (President, Secretary of Defense, and Congress) will support;
- How the service feels about the level of technical and schedule risks; and
- How the service feels about the level of cost risk associated with the accuracy and completeness of the programs' estimates.

Note that the last parameter is not, "What the cost figure is" as much as it is, "Do we have a reasonable handle on how we came to the cost figure." Each program office needs to present objective, complete, and accurate cost data for the leadership to make informed management decisions. The concept of low bidding (sometimes called "buying-in") based on incomplete or inaccurate cost data (whether intentional or not) has in the past, led to cost overruns, program slippage, program cancellations, and external scrutiny. Organizations like the Office of the Secretary of Defense Program Analysis and Evaluation (OSD/PA&E) and the Cost Analysis Improvement Group (CAIG) were formed to provide independent assessments as input to the affordability issue. As the DoD budget shrinks, sound management decisions become increasingly important. Decision-makers may be tempted to trade-off even more operational performance in favor of lower costs. More than ever the Defense Department leadership is relying on program offices to provide complete life cycle costs. Unforeseen costs cropping up later in the field is no longer solved by going back to the Congressional "money-well". Today, the bills come directly out of the ever-shrinking operating costs. It is this potential impact on operational readiness that is driving the Air Staff to bring the User closer to the acquisition decision making process. The Air Staff believes the real stakeholders must be in the data loop and each program office must properly address significant life cycle costs (i.e., operation, support and disposal).

Industry leaders have determined that to remain viable in an ever-increasing competitive market, they must get a handle on making better corporate decisions with respect to their cost centers and their product-lines. The industry solution includes educating the somewhat autonomous cost center managers to realize they *do* impact the wellness of the overall corporate cost situation and demonstrating corporate resolve by rewarding or penalizing individual cost center managers based on their input to the corporation. Based on comments from industry members on the Defense Science Board Panel on Logistics, industry has not burdened itself with complicated computer cost models but rather has taken a more empirical approach based on audits and experience. Typically the metrics that industry uses are sales recognized, profit, and productivity. Affordability in industry is usually a short term risk analysis to determine if the corporate investments (product research and development (R&D), product prototyping, tooling, and manufacturing costs) will be sufficiently outweighed by the performance of the cost center and its product line. Within the Air Force acquisition community, there is realization that sound accounting practices and good judgment (based on experience) can produce sound cost based decisions. Single Managers are the front line troops in the control of system ESH life cycle costs.

ESH Cost Defined

A precise definition of the term "ESH Cost" is very useful to the cost analyst. The next three pages recap where the AFMC ESH and financial communities are in the development of a precise definition. Background information will be provided for readers that are not familiar with the research performed over the past two years on the subject. Finally, a definition will be offered for financial management community adoption.

Definition History

There are two primary drivers for defining ESH costs. The first is a Congressional mandate, Public Law 103-337, Section 815, Environmental Consequence Analysis of Major Defense Acquisition Programs. It states, "The Secretary of Defense shall issue guidance to apply uniformly throughout the Department of Defense regarding how to analyze, as early in the process as feasible, the life-cycle environmental costs for such Major Defense Acquisition Programs, including the materials to be used, the mode of operations and maintenance, requirements for demilitarization, and methods of disposal, after consideration of all pollution prevention opportunities and in light of all environmental mitigation measures to which the Department expressly commits." The second is Department of Defense Regulation 5000.2-R, Mandatory Procedures for Major Defense Acquistion Programs (MDAPs) and Major Automated information System (MAIS) Acquisition Programs, Section 4.3.7, Environmental, Safety, and Health, which was discussed at the beginning of Part One.

In addition to the two primary drivers, there are also other requirements that impact the estimating of ESH costs. Appendix F provides the cost analyst a brief summary, description, and impact to the program/single manager of the ESH laws, executive orders, DoD requirements, and Air Force requirements they may encounter.

The development of this ESH cost analysis guide is an effort to provide the Air Force costing community with a process for addressing the ESH requirements imposed on them from Congress, DoD, and the Air Force.

Various Interpretations of ESH Cost

The spectrum of definition interpretation is significant. A narrow interpretation of ESH costs are those program delta ESH costs that are driven by specific ESH requirements. Examples are provided below to show this narrow interpretation:

- A federal law requires that an Ozone Depleting Substance (ODS) used for weapon system maintenance be phased out. A study to identify and test an alternative, institute the change in technical orders, and the delta cost of the alternative over the current substance would be ESH costs. This example focuses on *delta program costs*
- A base elects to implement a recycling program that is not required by regulations or directives. There is a cost to implement this program. While the program is an excellent idea, it is not required by directives, therefore this is not an ESH cost. This example focuses on *specific ESH requirements*.
- The manning of a base safety office must be increased due to the addition of a flying unit at the installation (i.e., B-2 at Whiteman AFB). The additional manning in the base safety office is an ESH cost. This example focuses on *delta program costs*.
- In the interest of efficient management of pollution efforts, a command staff organization is established to manage pollution prevention initiative common to more that one weapon system and to develop needed new technologies. This would not be an ESH program cost. This example focuses on *program* cost.

A very broad interpretation of ESH costs would be to allocate all ESH costs within the Air Force to weapon systems. Another broad interpretation would be to trace each ESH activity or cost-causing event to every related cost. Examples are provided below to show these broad interpretations:

- An airman drives a truck in an unsafe manner under the wing of an aircraft. The top of the truck strikes the aircraft. The truck and aircraft are both damaged. The incident is investigated and a safety report prepared. The airman is punished and replaced. Another warning is added to the dash of all flightline vehicles. The airplane and vehicles are repaired. The cost to repair the aircraft and truck, the cost of manpower for the investigation, the Permanent Change of Station (PCS) costs for a replacement technician, and the warning placard are all weapon system program ESH costs. This example shows *tracing the event to every related cost.*

- A hazardous material pharmacy system is implemented on a base. Maintenance personnel must man the pharmacy 24 hours per day. The cost of manning the pharmacy could be included as an ESH cost under the broad interpretation. This example shows *an ESH cost traced to a system.* This can be contrasted with a narrow interpretation that says since the maintenance organization received no additional personnel slots for the pharmacy requirement, there are no ESH costs for a pharmacy system.

Requirements For The ESH Cost Definition

Before trying to refine the ESH cost definition, it is important to remember what problem we are trying to solve. First, why do we need a definition? The concern about ESH costs is that we have not been very successful accurately estimating ESH costs during the operating and support years of our weapon systems. We have underestimated ESH LCC for several reasons, some beyond our control. We have not estimated the growth and expansion of regulations and laws that have caused many of our ESH costs. The banning of Ozone Depleting Substances (ODSs) is an excellent example of our not taking into consideration future events that have impacted ESH costs.

In addition to changing regulations, we have not been very good at identifying and estimating the impact of ESH cost drivers on systems. For example, consider the use of a hazardous material in a maintenance activity. There are potential associated costs with personal protective equipment, training, health monitoring, and administrative activities such as planning and reporting. We are now just starting to realize the total life cycle cost impact from the use of a particular hazardous material with a system.

While we cannot accurately foresee and estimate the ESH costs driven by legislation, we can certainly do better at understanding and estimating the impact of ESH decisions during the design process. That is the foremost concern of ESH cost estimating today.

Secondly, who needs a definition? The definition of ESH costs should consider the use and users of those cost values. There are several participants.

- **Financial Management personnel** need a definition that applies well in the preparation of program cost estimates and trade studies. It should permit the construction of an ESH cost data dictionary.
- **ESH specialists** need a definition that is narrow enough so that it aligns with their area of responsibility. They should be able to read the source material and validate that the item is an ESH cost.
- **The developing community (systems engineers)** needs a definition that is narrow enough for their span of design control. They should be able to construct a trade study within the definition of the ESH costs.

Other Considerations

The traditional method for cost estimating is to define, as required, the items to be estimated and then cost the item(s) using accepted methodologies. ESH cost estimating should not be any different. There are several documents that the cost analyst will use to understand the item to be estimated. Understanding how programs are described in such documents as the Cost Analysis Requirement Description (CARD), Operational Requirements Document (ORD), or System Specification will help the cost analyst understand the ESH cost definition. Risk, as a subject, should be included in the definition. If the consequence of risk is quantifiable, consider the cost. Finally, attrition through ESH related risks needs to be considered in the definition.

ESH Cost Defined For The Cost Analyst

Based upon the discussion above, this Guide will use the following as the definition for ESH Cost:

> ESH costs are subsets of program life cycle costs that have an established relationship with the three systems engineering specialties of environmental management, safety, and occupational health. The costs incurred could be Air Force costs outside of the program's direct costs. These costs are typically considered the cost of infrastructure and as such impacts in these areas either directly or indirectly resulting from the Single Manager's (SMs) decisions are not considered in the decision making process. SMs and cost analysts need to approach life cycle costing from a perspective of Total Ownership Costs. An example includes the impact on the base clinic when a SM selects a plating process that requires shop and field personnel to undergo medical surveillance. The SM cannot make a fully informed decision if these indirect costs are not considered. Other potential examples include the cost of personal protection equipment and associated lost productivity, medical treatment and disability costs associated with exposure to hazardous materials, projected equipment loss and personnel injury costs associated with identified system safety and health hazards, special training to protect First Responders in cases of system accidents, fires, and potential exposures to pyrolysis products. ESH costs for program cost estimates have the same burden for inclusion as other costs. Refer to the guidance for program costs estimates for these rules. ESH costs for trade studies have the same relational requirement to the specialties as in the case of program cost estimates. Once identified, these costs are filtered and only those that are sensitive to the alternatives are included.

ESH Key Acronyms, Terms and Definitions

The reader may not be familiar with some of the ESH related terms. Acronyms are found in Appendix C. The terms and their definitions are located in Appendix D.

Section Two - ESH Across the Acquisition Life Cycle

In Section One, an overview of ESH Management was explored. This section will give a short tutorial on ESH activities during each phase and how the emphasis and information changes. The description by phases will be from the eyes of cost analysts and focus on the work they can expect during that phase. It is important to remember that the activity in a phase almost always includes planning and estimating for subsequent phases (i.e., almost all cost work will be done before disposal begins). Following the description for Demilitarization and Disposal, Table 1 is provided for the cost analyst to illustrate a potential mapping of ESH costs to acquisition phase WBS elements.

Pre-Concept Exploration (Technology Development)

Prior to programs being formed and the concept exploration phase beginning, the Air Force Research Laboratories work on technologies for potential use in new systems. Some of that work is directly related to ESH such as the development of alternatives for hazardous materials and ozone depleting substances. When eventually implemented in weapon systems, these technologies can have an impact on ESH related life cycle costs. The cost analyst should ensure that these ESH-related life cycle contributions are identified. While there may not be a need for a program cost estimate in this pre-concept exploration activity, there will exist a need to support the trade studies that emerge from this work.

Concept Exploration - Phase 0

During the concept exploration phase, competitive, parallel short-term concept studies and analyses are performed to define and evaluate the feasibility of alternative concepts and to provide a basis for assessing the relative merits of these concepts. Environmental, safety, and health (ESH) impacts should be considered during this phase. Activities associated with this phase include:

- Environmental Compliance
- National Environmental Policy Act (NEPA) Compliance (Form 813)
- System Safety and Health Identification and Management
- Hazardous Materials (HAZMATs) Management Program (e.g., identification of potential HAZMATs, trade-off studies on impact of HAZMATs on design alternatives, etc.)
- Pollution Prevention Programs.

The above ESH activities will continue into Phases I and II.

Program Definition and Risk Reduction (PDRR) – Phase I

During PDRR, studies and analyses of the one or more concepts, design approaches, and/or parallel technologies are conducted, and assessments of the advantages and disadvantages of alternative concepts shall be refined. At this point, the ESH activities would include the continuation of the ESH activities from Phase 0 such as NEPA compliance, addressing of system peculiar safety and health issues and potential compliance issues, identification of potential HAZMATs, and pollution prevention results. Also included are the preparation of compliance documentation; systematic and interdisciplinary studies that support the documentation of ESH impacts; application fees and payments made to legally certify operations; and one-time surveys as well as recurring monitoring activities that support compliance documentation.

Engineering Manufacturing Development (EMD) – Phase II

During EMD, activities performed include studies and analyses, design development, evaluation, testing, and redesign for the system component(s) during the system development efforts, including preparation of specifications, engineering drawings, parts list, test planning and scheduling, raw and semi-fabricated material plus purchased parts, engineering test equipment, and preplanned product improvement efforts. Activities also include ensuring the producibility of the developmental materiel system, inspection test and evaluation requirements, and quality control procedures. Low Rate Initial Production (LRIP) occurs while the Engineering and Manufacturing Development phase is still continuing as test results and design fixes or upgrades are incorporated. ESH activities during this phase include the continuation of similar activities from Phase I, such as NEPA compliance which may impact the test program, contractor compliance issues and possible inherited compliance issues at the depot, safety and health issues, identification and elimination of HAZMATs, and pollution prevention. What-if studies should be performed for hazardous materials (HAZMATs) alternatives (e.g., choosing HAZMATs that will be easier to handle, maintain, and dispose and that are cost effective - an example of this is the choice of enamel coating on the system that may cause compliance, cost, and handling/disposal problems for the paint stripping shop at the depot); development of pollution prevention and waste minimization programs as well as their implementation; hands-on control of HAZMATs for all processes throughout each phase (e.g., capital outlay for equipment used to capture and store waste, changes to manufacturing processes and other operations in order to minimize the use and production of HAZMATs, lost productivity due to personal protection equipment, cost of operating a HAZMATs pharmacy system); and fees paid for off-site disposal of waste material.

Production, Fielding/Deployment and Operational Support – Phase III

The ESH cost considerations for manufacturing operations and maintenance activities include continuation of pollution prevention plans to ensure minimal ESH problems downstream, and efforts to address ESH litigation and liabilities. Some of the ESH activities started during Phase II will continue during this Phase (e.g., NEPA, environmental compliance, system safety and health, HAZMATs, pollution prevention and waste minimization programs, hands-on control of HAZMATs for all processes).

Phase III also includes the cost provision for industrial facilities, depot maintenance plant equipment, and layaway of industrial facilities that are system specific; and procurement-funded costs of construction, conversion, or expansion of facilities for production, inventory, or maintenance required to accomplish the program. ESH issues to be addressed here include NEPA compliance for beddown, compliance for air logistics centers (ALCs), safety and health concerns for personnel, HAZMATs tracking/handling/disposal, pollution prevention, air emissions testing, noise compliance plans, etc. Environmental Baseline Surveys (EBSs) also need to be conducted on property being considered for a transaction with the government.

Demilitarization and Disposal

Although Demilitarization and Disposal (D&D) is not considered a formal phase in the life cycle of a system (some consider it an extension of the previous phase), there may be significant ESH activities in this phase. D&D captures the costs associated with disposing of a system or facility at the end of its useful life. Disposal is the process of re-distributing, transferring, donating, selling, or demilitarizating the system. Demilitarization is a subset of disposal and is the act of deactivating or rendering inoperable by destroying the military offensive or defensive advantage inherent in an item. Where applicable, this category includes salvage values as well as costs incurred during the phase-out period. The complete deactivation and demilitarization of a system entails not only the disposal of hazardous wastes but also the proper distribution of inert materials and support as well. Most of the remediation and restoration activities will occur in this phase as facilities are either demolished or turned over to other government agencies for use. The amount of expenses associated with the Base Reallocation and Consolidation (BRAC) effort is a striking example of why planning is needed early in system life.

ESH COST	Phase 0-III WBS	Phase III / D&D WBS
Analysis, environmental impact	System Engineering/Pgm Management (SE/PM)	Sustaining Support, Engineering
Analysis, of ESH alternatives	SE/PM	Sustaining Support, Engineering
Analysis, system safety hazard	SE/PM	Sustaining Support, Engineering
Assessments, ESH	SE/PM	Sustaining Support, Engineering
Contributions to common initiatives	SE/PM	Sustaining Support, Engineering
Disposal services, specialized	Hardware Configuration Item (CI)	D&D, Disposal
Disposal, detoxification	Hardware CI	D&D, Detoxification
Disposal, disassembly	Hardware CI	D&D, De-installation
Emergency response deployment	System Test, DT&E or OT&E	Indirect Support, Installation
Emergency response force development	System Test, DT&E or OT&E	Indirect Support, Installation
Facility construction	Industrial facilities, Test Facilities, or Training Facilities	Indirect Support, Installation
Facility modification	Industrial facilities, Test facilities, or Training facilities	Indirect Support, Installation
Hazardous materials procurement	Hardware CI	Sustaining Support, Recurring Investment
Insurance	SE/PM or against specific CI	Sustaining Support, Other
Labeling	Data, Support Data	Sustaining Support, Engineering
Labor to manage ESH programs	SE/PM	Indirect Support, Personnel and Installation
Legal, claims	SE/PM	Indirect Support, Installation
Legal, penalties and fines	SE/PM	Indirect Support, Installation
Legal, review of plans	SE/PM	Indirect Support, Personnel
Lost duty time	SE/PM	Mission Personnel
Lost productivity due to personnel protection requirements	SE/PM	Mission Personnel
Manifesting	Activity for which transportation required	Unit/Depot Maintenance, Other
Material handling, specialized equipment	Peculiar Support Equipment	Sustaining Support, Support Equipment Replacement

ESH COST	Phase 0-III WBS	Phase III / D&D WBS
Medical examinations	Test and Evaluation Support	Indirect Support, Personnel
Modeling and simulation	SE/PM	Sustaining Support, Sustaining Engineering
Modifications, Pollution Prevention	Hardware CI	Sustaining Support, Modification Kit
Modifications, Safety	Hardware CI	Sustaining Support, Modification Kit
Permits	SE/PM	Indirect Support, Installation Support
Personnel protective equipment	Peculiar Support Equipment	Sustaining Support, Support Equipment Replacement
Pharmacy distribution systems	Initial Spares and Repair Parts	Unit Level Consumption. Other
Plans, Compliance and Safety Program	SE/PM	Sustaining Support, Sustaining Engineering or Contractor Support, Other
Pollution Prevention, Filters	SE/PM, Industrial Facilities, or Hardware CI	Unit Level Support, Other
Pollution Prevention, Incinerators	SE/PM, Industrial Facilities, or Hardware CI	Unit Level Support, Other
Pollution Prevention, Scrubbers	SE/PM, Industrial Facilities, or Hardware CI	Unit Level Support, Other
Preservation, natural/cultural	SE/PM, Industrial Facilities, or Hardware CI	Indirect Support, Installation
Public relations/community image	SE/PM	Indirect Support, Installation
Qualifying vendors/suppliers	Hardware CI	Sustaining Support, Recurring Investment
R&D, alternatives to unacceptable materials	Hardware CI	Sustaining Support, Sustaining Engineering
Record keeping, Safety and Health	SE/PM	Indirect Support, Installation
Record keeping, hazardous material	SE/PM	Indirect Support, Installation
Recycling, collection and separation	Hardware CI	Indirect Support, Installation
Recycling, receipts	Hardware CI	Indirect support, Installation
Release monitoring equipment	Peculiar Support Equipment or Industrial Facilities	Sustaining support, Support Equipment replacement
Release monitoring labor	Hardware CI	Indirect Support, Personnel
Remediation, activities	Hardware CI or System Test	Indirect Support, Installation
Remediation, design	Hardware CI	Sustaining Support, Sustaining Engineering
Reporting	SE/PM	Indirect Support, Installation

ESH COST	Phase 0-III WBS	Phase III / D&D WBS
Restoration investigations, assessments and studies	SE/PM	Sustaining Support, Other or Contractor Support, Other
Risk, cost of not meeting requirements	SE/PM	Sustaining Support, Sustaining Engineering
Risk, of catastrophic events and safety hazards	SE/PM	Sustaining Support, Sustaining Engineering
Sampling	SE/PM	Indirect Support, Installation Support
Storage structures/containers, specialized	Storage, Planning and Preparation	Sustaining Support, Other
Supervision and audits	SE/PM	Indirect Support, Installation Support
Surveys, site	SE/PM	Indirect Support, Installation Support
Surveys, work	SE/PM	Indirect Support, Installation Support
Technical support, contractors	SE/PM	Contractor Support, Other
Training classes	Training, Services	Mission Personnel, Operation and Maintenance as required
Training materials	Training, Materials	Mission Personnel, Operation and Maintenance as required
Transportation, specialized requirements	Storage, Transfer and Transportation or Hardware CI	Sustaining Support, Other
Water treatment, specialized	Hardware CI or System Test	Indirect Support, Installation

Table 1, Potential Mapping of ESH Costs to Acquisition Phase WBS Elements

Other Topics

Commercial Item (CI) and Non-Developmental Item (NDI) Acquisitions

Commercial Items are items customarily used for non-governmental purposes and that have been or will be sold to the general-public. A non-developmental item is any previously developed item of supply used exclusively for governmental purposes by a Federal, State, or local agency/government or foreign government that the United States has a mutual defense cooperation agreement. A non-developmental item also includes any commercial items that require only minor modifications of a type customarily available in the commercial marketplace.

Programs following commercial or non-developmental item acquisition strategies are not relieved from the requirement to address the integration of ESH considerations into the systems engineering process. The systems engineering process for commercial items are typically already completed. The SM must assess how well the supplier integrated ESH considerations into the systems engineering process as part of the market research and analysis. ESH-related questions during this phase are critical to making informed decisions concerning the life cycle impacts of the commercial or non-developmental item. Life cycle cost assessments that include ESH-related costs are important information to the decision-making process. The Air Force has examples where this was done effectively and where it was not done at all.

The Joint Primary Training Aircraft System (JPATS) is the single largest aircraft commercial item program. The SM assessed the impact upon the life cycle of JPATS about the use of Ozone Depleting Substances (ODS). The SM determined that the use of Class I ODS in the JPATS would result in unacceptable Operational and Support (O&S) burdens and prohibited their use. The JPATS Request For Proposal (RFP) included a statement that indicated bidders would not be considered responsive if their proposed designs required any Class I ODS in the design, operation, or maintenance of the system.

The C130J is an unfortunate example of a program that did not assess the life cycle ESH-related impacts of its commercial item on the Air Force. The new engine nacelle fire suppression system uses Halon 1211, a Class I ODS that has been banned from production under the Clean Air Act Amendments. The program's decision to accept this Class I ODS also appears to violate Air Force policy that prohibits new systems from using Class I ODS.

Most commercial and non-developmental items will already have some cost data available from industry and government users of the product. The cost analyst can determine where the item is currently used and gather available life cycle cost data to include the ESH-related contribution. The program office will usually know where the item is currently used.

Summary

Thorough Environmental, Safety, and Health planning throughout the acquisition phases is essential and must be an integral part of the Program Management and Systems Engineering process to complete a successful progam. The Environmental, Safety, and Health plans and procedures cover subjects such as record keeping, metrics submittals, survey submittals, audits, training, and corrective action measures. Environmental and pollution prevention objectives are defined and met by the development of a detailed strategy describing the necessary elements. Elements may include establishing evaluation criteria, performing environmental/safety data analyses, identifying environmental/safety requirements, interpretation of data, and the documentation of environmental and safety results. The resources required for environmental and safety compliance must also be identified. This includes trained personnel, facilities, funds, processes, alternatives, equipment, and regulatory constraints. An integrated schedule is essential to provide for the availability of necessary resources before the commencement of the environmental, health, hazardous materials, pollution prevention, and safety management activities.

The successful performance of the Environmental, Safety, and Health (ESH) process described in this section requires a well organized, knowledgeable and disciplined organization to pre-plan, develop, and apply specific key elements. The SMC ESH Critical Process Assessment Tool (CPAT) lists most of the ESH related activities expected in the acquisition life cycle. A cost analyst may use the CPAT to gain insight into the activities where cost estimating support may be required and where ESH cost data may be collected or reside. This concludes the summary introduction to ESH Management. The reader is encouraged to refer to the documents listed below for more information on ESH Management in AFMC. Additional references are located in the Bibliography that is found in Appendix N.

References:

1. DoD 5000.2-R Mandatory Procedures for Major Defense Programs (MDAPs) and Major Automated Information System (MAIS) Acquisition Programs, Section 4.3.7, 7 October 1997.
2. Tactical Environmental, Safety and Health Action Guide, ESC/BP, September 1997.
3. Weapon System Environmental, Safety and Health Evaluation Development Guide for Single Managers, ESC/BP, November 1996.
4. Environmental, Safety, and Health Critical Process Assessment Tool, SMC/AXZ, 1 May 1997.
5. Environmental, Safety, and Health Management and Cost Handbook, SMC/FMC, 13 September 1996.

Part Two - ESH Cost Estimating

This part of the guide will begin with the cost requirements, introduce the processes, and progress into the details of ESH cost estimating. In an October 1996 report by the Army Industrial Ecology Center and the National Defense Center for Environmental Excellence, the researchers concluded that DoD would benefit from guidelines to identify key environmental costs and efficient methods to obtain them. They also concluded that environmental costs can be gathered and used in supporting pollution prevention decisions. The report pointed out that some costs are more easily gathered than others, a message that will be echoed in Part Two when addressing cost estimating data sources. The challenge for the cost analyst is to accurately estimate costs so that the correct program decisions can be made.

Section One - Cost Estimating Concepts

This section will explain the cost estimating requirements for ESH cost estimating in financial management terms.

In November 1994, the General Accounting Office (GAO) published a report on the status of DoD's efforts at pollution prevention. Cost estimating and cost analysis were cited in that report as follows:

> *DoD has not issued guidance for performing life-cycle costs analyses for comparing the costs of toxic chemicals with less toxic chemicals. As a result, purchasing decisions are not always environmentally sound or cost-effective because they are generally based on the initial price of the material. Life-cycle costs associated with environmental considerations such as the cost to dispose of hazardous waste, are not considered and can total more than the purchase price.*

ESH costing issues within the Department of Defense (DoD), such as restoration and cleanup costs, have increased dramatically over the last few years. The impacts of such costs on Major Defense Acquisition Programs (MDAPs) are now reviewed much more closely than before. Additionally, stronger and more stringent legislative and regulatory requirements have made existing methods for identifying and estimating ESH costs for programs more critical. Costing requirements currently exist in a variety of guides, directives, handbooks, policy directives, and instructions. While there is not one central list of policies and procedures, there are three consistent requirements (early planning, emphasis of LCC, and risk management) that are echoed throughout the guidance. They are expanded upon in the following subsection called ESH cost estimating requirements.

Draft changes to DoD 5000.4-M propose that, where the ESH costs cannot be separately broken out, the cost estimate should present evidence that the ESH costs are adequately accounted for elsewhere in the estimate. The cost analyst should be cautioned that the proposed changes emphasize environmental but not the safety and health aspects. Be sure to include all three.

The final piece of advice regarding ESH costing seeks to quantify the efforts. The guidance was to "*Spend effort on program ESH costing that is consistent with the ratio of ESH costs to total program costs*". ESH costing techniques and methods should not burden the cost estimating effort so much that time and energies are distracted from the goals of hazardous materials reduction and personnel safety. You will note when reading our examples in Appendix A, in no case did we find ESH costs that were higher than 2%. Taken out of context, this would seem to be too low to bother estimating for similar programs; however, every program is unique. The examples are meant to show what we found when investigating the ESH costs in typical Air Force Weapon systems. These may or may not be representative of what you will find on your program. What the italicized sentence is saying is that if in your research into the costs on the program you find that your ESH costs are small, then don't spend too much time delving into them. This is not peculiar to ESH but is what you would do on any WBS element. You do need to look, however, to determine if the ESH costs are minor or not.

ESH Cost Estimating Requirements

The first requirement, early planning for cost estimating, relates to the timing of ESH costing activities. Almost all acquisition management guidance points out that ESH planning should begin as early as possible. For example, Department of Defense Regulation DoD 5000.2-R, references the Programmatic Environmental, Safety, and Health Evaluation for integrating ESH considerations into the acquisition strategy at the earliest possible time. It is well recognized and accepted that the greatest cost benefit occurs when the correct decisions are made early enough in the acquisition life cycle to avoid rework or post fielding modification. Results from the ESH Evaluation may be utilized as early as the Concept Exploration phase to identify the cost, schedule, and performance impacts for alternative systems. Program Cost Estimates (PCEs) that are prepared as early as Milestone I are required to include all relevant ESH costs. This again illustrates the need for early planning and preparation for ESH considerations.

The second requirement echoed is the emphasis of life cycle cost as the measure of merit for examining ESH alternatives. Life Cycle Cost (LCC) analysis is a valuable tool used for both program decision making and budget inputs. It is imperative that program decisions be based upon the program LCC and not solely on the program acquisition cost. Air Force Instruction (AFI) 32-7080, Pollution Prevention Programs, requires Program Managers to reduce the use of hazardous materials and *measure their life cycle costs.* From an ESH perspective, that means including direct and indirect costs that may be associated with the following sample of ESH topics:

> acquisition, ESH laws, ESH regulations, disposal, emission control, engineering and administrative controls, environmental monitoring, exposure assessments and evaluations, final demilitarization and disposal, fines, hazard assessments, hazardous waste management, inspections, labeling, liability, manufacture, medical monitoring, medical surveillance, permits, personal protective equipment, pollution prevention, recycling, regulatory overhead, remedial actions, resource conservation, spills, storage inventory control, supply use, training, and work place safety.

The third requirement is risk management. Risk management is an organized process of identifying potential undesirable program events and then establishing and executing the appropriate risk mitigation actions. ESH risk management is a subset of program risk management with focus on ESH events. The goal of ESH risk management is scientifically sound, cost effective, integrated actions that reduce or prevent risks while taking into account social, cultural, ethical, political, and legal considerations. ESH events include but are not limited to, health risks from exposure to harmful elements, ecosystem damage, injury or death to personnel, and damage to or loss of equipment. The consequences of ESH risk will vary and can include cost impacts, schedule delays, degraded performance, and the loss of public goodwill. There are currently excellent and accepted techniques for ESH risk management (in MIL-STD 882C and in National Aerospace Standard (NAS) 411). In addition to these, there have been several initiatives regarding risk in the past year, each of which may impact the subset of risk called ESH risk management. All of these initiatives have one item in common, they bring more emphasis to the subject of risk management.

In February 1997, the Presidential/Congressional Commission on Risk Assessment and Risk Management issued both volumes of their final report. The key contribution of the effort was to introduce a risk management six step process that can be applied to public health or environmental problems. The six step process includes:

1. Defining the problem and putting it into context;
2. Analyzing the risks associated with the problem in context;
3. Examining options for addressing the risk;
4. Making decisions about which options to implement;

5. Taking action to implement the decisions; and
6. Conducting and evaluating the actions results.

In addition to the six step process, another portion of the report that may provide value to Air Force cost analysts is the section on linking risk and economics. The section, while recognizing the value of economic analysis, cautions about placing too much emphasis on dollar values of the environment that are difficult to quantify in monetary terms.

A second initiative that may impact ESH risk management is the Operational Risk Management (ORM) Program. Covered by AFPD 91-2 and AFI 91-213, ORM uses the same six step process as identified by the Presidential/Congressional Commission laced with military terms. One key theme is the required participation at all levels of command. As with the first initiative, ESH risk management fits well into the ORM program.

The third initiative regarding risk management is focused on the cost consequence of ESH risk. There has been a lot of interest regarding the accounting and disclosure aspects of ESH risk where an organization may have considerable potential liability resulting from ESH claims, fines and penalties. More investors and government organizations are closely reviewing company forms for proper application of Federally Accepted Accounting Principle Five, Accounting for Contingencies. This principle requires a firm to declare a loss contingency when information is available that it is probable that a liability has been incurred, and that the amount of the loss can be reasonably estimated. The Defense Contract Audit Agency (DCAA) Contract Audit Manual contains guidance on the treatment of actual and contingent ESH costs and ties the treatment to applicable Federal Acquisition Regulation (FAR) subsections. The importance of this information to the cost analyst is knowing where to look for the costs and the criteria for inclusion of ESH risk related costs in estimates.

Clearly, there is renewed emphasis upon risk management. Several ESH activities, including the preparation of the ESH Evaluation, are focused on identifying and reducing ESH risk. It appears that the tools and techniques for general risk management are valid for ESH risk. Almost all product centers have policies, procedures, and tools for risk management. Cost analysts should embrace standard risk management procedures for ESH risk (i.e., MIL-STD-882C, ORM, and the six step process) until evidence is presented that these processes are inadequate for ESH cost estimating.

ESH Costing Objectives

Complex activities and efforts can be more efficiently managed if clearly defined goals or objectives are understood by the performing team. The same holds true for cost estimating. This section discusses the objectives of ESH costing and their implications for the cost analyst who must answer the questions posed by the reviewing authorities. This section will address two general objectives that apply to all programs and then specific objectives based upon program content.

General Objectives

There are two general ESH costing objectives based on simple logic. First, all ESH costs must be included in the program estimate. Second, visibility into the identified costs must be provided so that acquisition and supporting decisions can be based on valid ESH costs.

The first objective, including all ESH costs, focuses on avoiding cost omissions. Meeting that objective requires:

- A technical baseline that addresses all ESH cost drivers;
- A Work Breakdown Structure (WBS) that includes all possible ESH costs; and

- Necessary estimating tools and methodologies that generate those costs.

The Technical Baseline (TB) or Cost Analysis Requirements Description (CARD) provides technical definitions from which key ESH cost drivers can start to be identified. For optimal results, the use of ESH experienced personnel in TB/CARD preparation is essential. The ESH Evaluation will provide insight about alternative processes that may be part of the technical baseline. Some of the WBSs developed in the last two years for ESH costing will provide a potential framework to include all possible ESH costs. The final requirement, utilization of necessary estimating tools and methodologies is currently being worked through a variety of DoD, Air Force, Army, and Navy ESH costing initiatives.

The second objective, providing visibility to the ESH costs such that decisions may be based upon them, requires:

- Documentation of Life Cycle Cost (LCC) estimates conducted for trade-off studies of design alternatives;
- A method to transition trade studies, which are delta cost analyses, into program quality LCC estimates;
- Participation from personnel familiar with ESH requirements; and
- Participation and support from prime contractors to provide insight and guidance to cost elements that have embedded ESH costs.

As part of the process and materials trade-off studies conducted during system design, there will be meaningful cost data available for conversion into LCC estimates. It may be advantageous for the cost analyst to standardize the ESH trade studies for a program such that the results will align with the LCC estimate cost elements.

Specific Objectives

Guidance directed to Program Managers as well as the cost analyst's specific objectives of obtaining definitions of what to cost and how much detail to place in the cost estimate will depend upon an accurate assessment of the program and the TB/CARD. The assessment of the program focuses upon answering the following question:

- Are ESH risks and associated life cycle cost contributions significant?

Air Force Materiel Command Pamphlet (AFMCP) 63-101, Risk Management, will be primarily useful for the cost analyst to use in identifying ESH contributions to the PCE because it provides a procedure to implement risk management into the overall program planning and management process. At the systems engineering/trade study level, the methodology contained in MIL-STD-882C provides the cost analyst with insight into ESH life cycle cost drivers.

The TB/CARD is the final driver for determining the specific cost estimating details. All program cost estimates must align with the information in the TB/CARD. If a cost analyst discovers during the assessment that a program has a potential for significant ESH risk or ESH costs, it is then appropriate to forward that information to the owners of the TB/CARD so they can document the potential ESH costs for additional detail in cost estimates. This assures that the TB/CARD accurately reflects the risks of the program and the cost estimates address the system requirements.

Cost Estimating Activities

Program Cost Estimates

Interest in the ESH costs of a program continues to grow. Policies and procedures continue to be refined. The guiding principal is that any PCE must include the total life cycle cost estimate for all costs including ESH related activities, products, and services. Such costs may arise in any or all of the major segments of a program. For example, specific guidance in DoD 5000.4-M, Chapter 1, requires the identification of any hazardous materials that may be encountered or generated during development, manufacture, test, transportation, storage, operation, or disposal. The quantities of each should be estimated over the life of the system.

ESH related risks may be found in the various program analyses. Environmental risks are usually found in the program's environmental compliance effort for NEPA analyses. Safety risks are usually found in the program's system safety program. Health risks are usually found in the Health Hazard Assessments (HHAs). The cost analyst can use these risks to identify the associated ESH life cycle cost contributions.

ESH risk is a sensitive subject to address in the PCE. ESH risk, as defined in the DoD Acquisition Deskbook, refers to whether or not a given technology solution, alternative, or process can be used without generating an intolerable level of hazardous materials, unacceptable environmental damage, or risking personnel safety. Standard guidance for PCEs is that the estimate should not include any dollars for management reserve. In procurements where attrition or loss rates are known, cost estimates include replacement systems. Aircraft attrition and booster failures are examples where historical data provides insight into future performance. In the environmental area, the potential for cost liability during the life of a system, including remediation and fines, may not be as quantifiable as attrition. Safety analysis uses a technique where the likelihood of a mishap is combined with the consequences of a mishap to identify the safety risk. A similar approach could be considered for ESH risk.

Defense Plant Representative Offices (DPRO) are included in program level and selected subordinate level Integrated Product Teams (IPTs) (such as Manufacturing IPT). The DPROs have excellent knowledge of contractor activities that may affect the cost of the system. In addition, the DPROs will have information on potential liabilities at different contractor facilities. For example, a contractor may have significantly higher overhead rates for cleanup actions, which are still in litigation. While the new program did not contribute to the contamination, it may pay for a portion of the cleanup in the form of increased overhead.

Trade Studies

Trade Studies are performed to evaluate a variety of solutions to ESH compliance requirements. The requirement to consider cost, in particular a life cycle cost assessment for evaluating ESH alternatives, is laid out in DoD 5000.2-R and DoD 5000.1. Trade studies are subsets of the consideration of overall life cycle costs. The next few paragraphs will discuss ESH trades and their requirements.

ESH cost trade studies are much like any other comparative analysis. They are an assessment of the economic cost of alternatives designed to assist decision making. They are not different from other trade studies except for the focus on ESH costs. In an ideal cost estimating world, all trade studies would be ESH studies because the cost analyst would be careful to incorporate all sensitive ESH costs.

A review of the cost estimating guidance at DoD, Air Force and Air Force Materiel Command levels revealed that there are not any specific ESH cost trade study requirements. The cost analyst is guided by the general and situational comparative cost analysis guidance. This Guide will supplement that by adding the following suggestions:

- When performing comparative cost analyses, the cost analyst should be diligent to consider the potential ESH costs associated with each alternative. The ESH costs should be identified with a narrative description and estimated where the costs are sensitive to the alternatives and can be quantified. Rationale for the suggestion: ESH is a new element in the life cycle cost estimate, costs are not well identified and the increased emphasis is warranted until the costs are better understood.

- When using cost estimating tools and methods for cost comparisons such as Cost Estimating Relationships (CERs) or factors, the ESH costs included in such tools should be identified where practical. For example, if a factor for Systems Engineering and Program Management is known to include costs for the environmental analysis as well as the system safety analysis, it should be stated in the estimate documentation. The rationale for the suggestion is that ESH cost estimating needs to develop consistent categories and grouping for costs so that comparisons across systems will be possible.

Analysis of Alternatives (AOA)

An analysis of alternatives is prepared and considered at appropriate milestone decision reviews of Acquisition Category (ACAT) I programs beginning with program initiation (usually Milestone I). An AOA takes the place of what was formerly referred to as the Cost and Operational Effectiveness Analysis (COEA). For ACAT IA programs, an analysis of alternatives is prepared for consideration at Milestone 0. These analyses are intended to:

- <u>Aid and document decision making</u> by illuminating the relative advantages and disadvantages of the alternatives being considered. They show the sensitivity of each alternative to possible changes in key assumptions (e.g., threat) or variables (e.g., selected performance capabilities). The analyses aid decision makers in judging whether or not any of the proposed alternatives to an existing system offer sufficient military and/or economic benefit to be worth the cost. There is a clear linkage between the analysis of alternatives, system requirements, and system evaluation measures of effectiveness.

- <u>Foster joint ownership and afford a better understanding of subsequent decisions</u> by early identification and discussion of reasonable alternatives among decision-makers and staffs at all levels. The analysis should be quantitatively based, producing discussion on key assumptions and variables.

The DoD Component (or Principal Staff Assistant (PSA) for ACAT IA programs) responsible for the mission area in which a deficiency or opportunity has been identified prepares the analysis of alternatives. Normally, the DoD Component completes the analysis for ACAT I programs and documents its findings in preparation for a program initiation decision (usually Milestone I). The Milestone Decision Authority (MDA) may direct updates to the analysis for subsequent decision points, if conditions warrant.

Just as the ESH professionals supported the COEA development in the past, similar inputs should be provided to the AOA. Pollution prevention considerations should be part of the assumptions, variables, and constraints, especially for the life cycle cost of each alternative. For example, an alternative for using a launch vehicle might include the use of hydrazine as a fuel. The AOA should address the life cycle cost of using hydrazine.

Any updates to the initial AOA should be sufficiently detailed to determine a preferred alternative and its worth. The update should establish performance minimums and cost ceilings. Life Cycle Cost estimates are required for all design approaches. Cost estimates for AOA should take into account advanced research and development (R&D) and engineering development. Also, gross estimates of investment and disposal costs should be included.

Most of the ESH costing associated with the AOA will focus on computing delta life cycle costs for alternate systems, locations, or processes (which use less hazardous materials). The product center may want to consider supporting the using community in the ESH analysis and life cycle cost estimating portions of the AOA. The advantage of early support will pay off when translating cost trade study results from the AOA to the program cost estimate.

Selected Topics Related to ESH Cost Estimating

As the planning and data collection began for this Guide, research and discussions among the participants of the Guide project examined several initiatives that have direct relationships to ESH cost estimating procedures. It was found that Activity-Based Costing (ABC) / Activity-Based Management (ABM) may be useful for expanding the accounting systems to embrace ESH. Appendix L provides for ABC/ABM a descriptive definition, a discussion of applicability to current ESH cost estimating and analysis, and a recommended position relative to ESH cost estimating.

Section Two - Cost Estimating Common Process

The Electronic Systems Center (ESC) Financial Management community has identified a seven-step process for performing cost estimates. This seven-step process may be used for both program estimates and trade studies. This section will use the seven-step process as the basis for discussing ESH cost estimating. The seven steps are introduced below:

1. **Define and Plan.** Define the purpose, scope and time constraints for the estimate in very specific terms. This includes knowing where the estimate is going, who is going to use it, and what decisions are going to be based on it; reviewing program documentation; establishing a team; and developing a WBS. Remember, you cannot start the estimate without a definition of the program.
2. **Specify Estimating Methodology.** Define precisely how you are going to accomplish your cost estimate. Data collection and evaluation is part of this step (and the most time consuming). This step also includes planning for the risk assessment and cost-sensitivity analyses that are performed after the point estimate is calculated.
3. **Calculate the Cost Estimate.** Take the information from Step 2 and calculate estimate values in base year dollars. Calculate primary costs with risk as well as any excursions such as cost sensitivity analyses.
4. **Time Phase the Estimate.** Ensure it is consistent with the program schedule and budget constraints.
5. **Calculate the estimate in Then Year Dollars.** Translate the Base Year values to inflated dollars.
6. **Document the Estimate.** This is wrap up time. Complete the documentation that was done as the methodology and calculations were performed. Organize the documentation into chapters and write transition paragraphs and sentences.
7. **Complete Final Reviews.** Varies with the type of program. For trade studies this may be a review with the project engineers. For a program cost estimate, it may include reviews at all levels of command up through DoD.

The Seven-Step Process

The next few pages will probe deeper into each of the seven steps introduced above and present any ESH unique aspects about each of the steps. The format for discussion will be to describe each step as it would apply to both a program cost estimate and a trade study and then to add specifics where appropriate about each. In this section and the appendices, there are a number of checklists, tables, and lists of questions that can be used in ESH cost estimating. Where useful, the reader is encouraged to duplicate and use this information.

Step One - Define and Plan the Cost Estimate

Whether you are preparing the ESH portion of a program cost estimate or supporting an engineering organization with a trade study, constraints will exist. You will have a job to do and a deadline for completing the work. There will be an objective granularity and scope for your estimate. You should be able to visualize what the end product (cost estimate) will look like. You should know what resources you will have at your disposal. Through the tasking and some questioning, you should be able to get enough information to build a resource-loaded schedule for the estimate. Two key components of the estimate planning are the technical baseline and the work breakdown structure. In fact, these components are so essential that after some work in defining the approach to each, it is often worthwhile to go back and revisit the estimate schedule.

When defining and planning the program cost estimate, the customer will be the program or single manager. The amount of coordination will be significant and will center on the Cost Integrated Product

Team (CIPT) for those estimates receiving Air Force CAIG or higher review. Inputs to planning a program cost estimate should include whether ESH costs for the system are going to be separately identified or included where appropriate in a normal WBS such as MIL-HDBK-881, Work Breakdown Structures.

The planning steps for a trade study should be the same as for a program cost estimate, just tailored to the customer. The customer for a cost trade study will more likely be the system engineering organization in the program office or single manager organization. The turn around time for the estimate may be very short and you can expect to be pressured for results.

Establish The Technical Baseline To Be Estimated

If the activities, products or services to be estimated are associated with a weapon system or program, a Technical Baseline (TB) or Cost Analysis Requirement Description (CARD) should be available. The TB/CARD is important to the ESH management of a program. This document provides the ESH baseline from a costing perspective, as all program cost estimates are required to be consistent with the TB/CARD. The analyst should find the TB/CARD with the weapon system program office.

Program Cost Estimate

Since the TB/CARD is created for a program level life cycle cost estimate, it may not provide much detail with respect to costing the ESH area. If it does not, the cost analyst will want to review the TB/CARD with the engineers and ESH specialists to assure the ESH topics have been addressed properly and in sufficient detail. Ask the engineers and ESH specialist(s) what factors they believe are the key risks. All key cost drivers should be planned for inclusion in the TB/CARD.

Trade Study

In planning the establishment of a technical baseline for a trade study, the technical baseline assumes less importance. The TB/CARD may not have been prepared, and even if prepared, may not have the level of detail required of the technical baseline for a trade study. In planning the trade study, discuss the alternatives with the appropriate engineers to get a handle on the sensitive factors. Most trades have a benefit in mind (performance, reduced labor, less expensive materials, increased safety, etc.). If you can understand where they are going with these alternatives, it will help you plan to estimate the sensitive values. Ask the engineers and ESH specialists what factors they believe are sensitive to the alternatives. All sensitive factors should be planned for inclusion in the technical baseline.

Determine The Appropriate WBS For The Estimate

ESH cost estimating across the total life cycle of a system may require the use of multiple contract work breakdown structures. Most program office personnel are very familiar with the acquisition work breakdown structures described in MIL-HDBK-881. The MIL-HDBK-881 work breakdown structures are used to estimate the cost of acquiring a system. MIL-HDBK-881 work breakdown structures do not however, provide the granularity needed to define the operating and support costs of a system and ultimately the total LCC of a system. Appendix H provides a sample ESH enhanced MIL-HDBK-881 WBS and dictionary that addresses the full life cycle of an Electronic/Automated Software system. Table 1 located in Part One, Section Two, also provides example ESH costs and a potential cost mapping into cost elements by acquisition phase. The cost analyst may find these useful in the development of a WBS for a new weapon system or modifying an existing WBS. Following are discussions of different WBS considerations for program cost estimates and trade studies.

Program Cost Estimate

For a program cost estimate, the selection and use of a WBS is straightforward. Although MIL-HDBK-881 is now a guidance document, most program estimates continue to reflect a strong influence of the standard.

Trade Study

While there is great latitude in WBS selection for a trade study, the analyst should keep in mind that the primary goal of the trade study is on the ESH contribution to the life cycle cost of the system. Some analysts may plan the trade study around a MIL-HDBK-881 WBS, just listing the WBS items that are expected to be sensitive to the alternatives. They then expand those sensitive items to the level of the expected sensitive data. For example, if an ESH cost trade is being performed on two alternatives and one eliminates all hazardous materials from the system, clearly the Hazardous Material Management Planning which is included in Systems Engineering/Program Management (SE/PM) will be sensitive to the alternatives. SE/PM would be an included WBS item and may have a lower elements level such as handling, treating and disposal costs.

Step Two - Specify Estimating Methodology

Step Two is often the most time and labor consuming of the seven steps in the cost estimating process. This step includes data sources, data collection, and data evaluation, which often are performed in an iterative process because all the data is rarely in the first location the analyst searches. Then, the availability and quality of the data determines the selection of estimating methodologies, tool selection, risk assessments and cost sensitivity analyses. We will take each of the components of Step Two and address them individually. As we did for Step One, we will describe Step Two in general and then explain, where appropriate, any differences between program estimates and trade studies.

<u>Data Sources</u>

In general, data sources can be primary (data obtained from the original source of information) or secondary (data derived from primary). Potential data sources for the cost analyst include the following:

- Contractor's Accounting System: This is a primary source of data and includes contract information, labor hours, dollars and cost of material.
- Contracts, Contractor Proposals, Cost Reports: A secondary source as the data in them has been extracted from the contractor's accounting system. To use these sources, you need to be able to map costs in the WBS items and into recurring vs. nonrecurring categories of cost. One should not use these reports unless you have gone to the contractor's plant/site and examined the mapping of the accounting system data to the cost report.
- Historical Databases: These can be primary or secondary. When using CERs, models or studies, you should note how the database was derived. Did it come from primary or secondary sources? This is where you will determine the validity of the data.
- Functional Specialists: These can be primary or secondary. For example, a Government test agency that conducts their own work in-house and gives actual costs, is a primary source. If the same agency gave a ballpark estimate of how much something cost three years ago, it is secondary.
- Other Organizations/Agencies: These can be primary or secondary. If a medical center at an Air Wing collects their in-house medical examination actual costs, it is a primary source. If the same medical center gave a ballpark estimate of how much something cost three years ago and the Wing has increased or decreased in size, it is secondary.

For ESH technical and cost data, there are many data sources. However, because the topic is relatively new to the costing community and evolving, it may not be the typical places the cost analyst has searched in the past. When trying to select initial data sources, the cost analyst should focus on where the technical risks are found and then filter for those that are ESH related. One of the best places to start is with the weapon system program office. If they do not have the relevant ESH data needed to support your program cost estimate or trade study, they can usually direct you to the proper personnel associated with the weapon system. It may be an ESH specialist, engineer, organization/agency, or contractor. Finally, there are numerous external data sources for ESH technical and cost data. The next few paragraphs will describe a number of the data sources that the cost analyst may find useful.

- Center Cost Libraries. Center cost libraries as well as other Air Force and Services cost libraries may be useful for locating program cost estimates or trade studies with analogous systems ESH estimates and actual costs.

- Visibility and Management of Operating and Support Costs (VAMOSC). VAMOSC is the Air Force's primary information system for reporting historical weapon system O&S costs in standard format. It contains O&S costs and operational statistics (flying hours, inventory) by Mission Design Series (MDS), Major Command (MAJCOM) and Fiscal Year (FY) and is derived from base and depot level financial, personnel, and operational data. ESH costs may be extracted via queries of selected Program Element Codes (PECs), Responsibility Centers/Cost Centers (RC/CCs), and Expense Element Investment Codes (EEICs).

- Standard Base Supply System. Contains the unit costs of national stock numbered items. Information may be obtained through the Base Supply Customer Support Function.

- Phoenix/Command Core. Phoenix is a system used by Bioenvironmental Engineering and Occupational Health organizations to track information related to occupational exposure to chemical, noise, and ergonomic hazards. Phoenix is being replaced by the Command Core System. More detailed information is available at:

  http://wwwsam.brooks.af.mil/commandcore/homepage.html-SSI.

- Schedule of Refunds and Reimbursements (RRI). This is a program used by Civil Engineering organizations to track the cost of facility maintenance and to bill reimbursable organizations.

- Air Logistics Center (ALC) Manifest Databases. The manifest databases are used to track hazardous wastes and provide the respective disposal costs for each ALC.

- G035A. This is a system used by financial organizations or ALC directorates to track direct labor and material costs by organization codes. Indirect costs are reflected in the labor multiplier. The Depot Maintenance Budget and Management Cost System (G035A) provides a series of mechanized reports to measure the cost of operations against the objectives contained in the Operating Cost Based Budget (OCBB). The cost data in the G035A system should agree with those amounts in the organic portion of the Depot Maintenance Business Area (DMBA) general ledger, and those expenses input to the Depot Maintenance Production Cost System (G072A). Procedures pertaining to G035A, examples of output products, reports, and reconciliation with other documents are contained in Air Force Materiel Command Regulation (AFMCR) 170-10.

- Injury Tracking. Many base Safety Offices use the Automated Safety Analysis Program. This program tracks the type and cause of personnel injury. Costs associated with the injuries are not tracked in this system. Contact the base safety office for information.

- Air Force Safety Center (AFSC). The AFSC maintains a database that tracks loss and injury safety-related costs for weapon systems.
- Defense Logistics Agency Defense Reutilization and Marketing Service (DLA/DRMS). The Air Force DRMS database provides disposal cost of hazardous materials by fiscal year. If the cost analyst has identified the hazardous materials and quantity expected for disposal, they may apply the factors given in the database to estimate the total disposal cost for those materials.

Program Cost Estimate

Early in the acquisition life cycle, estimates may rely on prime contractor cost estimates that have been done as part of the proposal process. The cost analyst should be careful in the use of this data, an analogous estimate should be used as a cross check. For example, a follow-on satellite program's Environmental Assessment (EA) was estimated to be $40K. The initial satellite program's EA was $75K. The follow-on EA estimate was valid because it took into consideration an existing database of information from the initial program. The Continuous Acquisition Life Cycle Support (CALS) system implementation may also provide useful ESH cost information in databases that are accessible directly from the program office. The formation of the Cost Integrated Product Team (CIPT) means more cost experts will be available and accessible during the preparation of cost estimates. Take advantage of this exposure to explore data sources through this group.

Trade Studies

One of the key challenges in Trade Studies is keeping the data collection broad enough to consider all impacts of the alternatives. Certain ESH activities may be readily separable and easy to cost, such as a unique waste stream. However many of the ESH alternatives have implications on performance, reliability, and logistics support. Data must be collected on all of these impacted functional areas.

<u>Data Collection</u>

In most cases the ESH cost data exists, it just may not be in the SM's shop. If necessary, the cost analyst may have to visit the data sources. Historical ESH cost data is available at the bases for fielded systems. Fielded systems that might be replaced by the new system or improved by a modification program are excellent sources of ESH cost data. The cost analyst will need to tailor these data to the specific program they are supporting. Baseline data voids will be the exception not the rule; however, the data usually resides outside of the normal cost channels. For newer materials and processes, the data may need to be obtained from other services or industry sources and research reports. The ESH cost data for fielded systems can usually be found at ALCs, contractor logistic centers, base clinics, in safety offices, and at the base Civil Engineering (CE) offices. These offices must react to and mitigate ESH problems with the weapon systems at their bases. The safety database at the Air Force Safety Center is also a good source of loss and injury information. Following are some general discussions talking about cost data availability by discipline.

The environmental category is where hazardous material and waste related costs are incurred but not clearly accounted for. Historically, environmental costs have been hidden in overhead accounts or wrapped into labor rates for environmental related efforts that are performed in the development and production of the system. The cost analyst may find relevant environmental studies in their organizations' cost library or with the weapon system program office they are supporting. A review of the other Service cost libraries may also provide useful data. Finally, contractors/industry are good sources for information on current and newer material hazards.

Safety cost data during acquisition is readily available. During weapon system acquisition there are a number of system safety tasks. These include the development of a system safety plan and system safety analyses. Most of the safety activities and their associated deliverables by prime contractors have been separately priced. The government side of safety is associated with the review of contractor material and generally can be estimated by manpower. The safety plan will identify the high and medium/serious risk. In all likelihood, the high and medium/serious risk issues are the significant cost drivers.

Occupational Health is also generally characterized as having adequate cost data. The Medical function provides support in the area of occupational health and includes physicals and occupational health surveys. The cost of physicals and medical treatment of personnel is contained in base operating support factors. At the depots, it is provided through reimbursements by host medical organizations. Finally, the staff of the occupational health organization can be allocated to the functions supported.

In data collection, asking the right question is often the key to getting the right data. Several agencies have prepared questions or templates to assist in data collection. Listed below are sample questions the cost analyst may find helpful.

- New versus old system
- What existing system is being replaced?
- What are the risks associated with the existing system?
- Are there ESH related cost drivers associated with the risks?
- Are the ESH related cost drivers applicable to the new system?
- Has the program identified mitigation actions for the cost drivers?
- What is the life cycle cost of the mitigation actions versus the life cycle cost if the risk is not mitigated?
- Are there unique ESH related life cycle costs associated with the new system?

Other questions that may assist the cost analyst are listed in Appendices I, J, and K. Appendix I provides ESH cost identifying questions that are arranged in alphabetical order by topic name. This is especially helpful for the cost analyst that is new to the ESH topics. Appendix J provides ESH cost identifying questions that are aimed at organizations and functions. Appendix K provides sample questions for the ESH professional to use evaluating alternative materials and processes. Answers to these questions will help identify ESH cost drivers or sources of cost data useful to the cost analyst. Participants of this document found these questions to be very helpful with the data collection effort for the fighter aircraft example that is included in Appendix A of this document.

Program Cost Estimate

In Step One, (defining and planning the cost estimate) a technical baseline and work breakdown structure appropriate to the acquisition phase were defined. These two items drive the data collection effort. The cost analyst will look for data that will plug directly into the cost elements. If the program cost estimate is being performed early in the acquisition life cycle, the cost data sought may be general in nature. The lack of system definition may lead the analyst to use analogous systems for the estimates. While this is a sound approach, few program offices have separately estimated the ESH costs of their systems and even fewer have done it consistently. A space system such as the Delta launch vehicle, which uses both liquid engines and solid motors, may look to the Titan IV, which uses both types as well. The challenge will be that the chemistry of propellants and quantities of fuel are significantly different.

Another challenge in using analogous cost collection techniques is that the ESH costs may not be defined in the same cost elements. One way to work this problem is to ask questions from the ESC Enhanced WBS to identify the costs and then ask which cost element contains the costs. The following steps may be useful in the questioning.

1. Review the applicable cost work breakdown structures (highlight the cost elements expected to have ESH costs).

2. Read the definition of those cost elements to the functional expert, ask them if they will have similar costs.
3. Ask them where those costs are captured on their program (which cost elements).
4. Where costs are embedded in cost elements with non-ESH costs, ask for an estimate of the percentage of the cost element value attributable to ESH.
5. Ask how the ESH percentage was obtained.

Trade Studies

Questioning for Trade Studies is different than for program cost estimates. Questions must focus on the definition of technical baselines for each alternative and identification of the sensitive differences between alternatives. In some respects the questioning is similar to a program cost estimate where an engineer is asked to describe the new system in relationship to the one it will replace. The big difference is in the level of detail. Listed below are some questions that may be helpful in data collection for trade studies.

1. Why was the trade study initiated? (The purpose, be it compliance, cost, performance, or risk, gives insight to the cost analyst)
2. What are the alternatives being considered? (This frames each technical baseline)
3. For each of the life cycle phases (design, development, test and evaluation, production, operations, and disposal), how do the alternatives differ? (This gives the analyst insight about which phase(s) to focus on)
4. What data sources were used for technical information regarding the alternatives? (The technical information may have cost data associated with it that the engineer is not aware of)
5. Do any of the alternatives have applicability to other programs, systems, or components? (The analyst can check those other programs for any applicable cost research)

<u>Data Evaluation</u>

This portion will discuss the evaluation of technical and cost data. Data evaluation addresses considerations such as the source of the data, how it was collected, the completeness of the data, and other factors. When the evaluation is completed, it then drives the selection of estimating methodology, tool selection, risk assessments, and cost sensitivity analyses. Data evaluation is standard procedure for a cost analyst with methods and procedures contained in standard cost estimating guidance. One of the biggest issues in ESH evaluation is the mixing of commercial and defense data. For example, consider alternatives for solvents. There are a number of commercial databases that list alternatives for solvents that are ODSs. There is reluctance on the part of military systems developers to use these alternatives databases as the analysis and evaluation may not have considered the more extreme environmental conditions of the systems use (i.e., weather, space, or nuclear environments). The cost analysts need to make similarly sure that the cost data reflects the same intended environment.

The completeness of ESH cost data is very important. Complete cost data means that all the sensitive background information is included. As an example, consider the cost of an Environmental Assessment (EA) for a satellite system. Assume that a cost for an EA was cited as $50,000. That number might be useful for an analogous estimate. But if the number reflected the EA for the initial system production rather than simply the follow-on production award to another contractor, the use of this cost could be misapplied. The bottom line is to make sure all the cost background information is available and understood before using a number.

Data completeness in trade studies is equally important. Locality is a good example. A cost for hazardous material use may vary because of the location it is used in. The Southern California Air

Quality Management District (SCAQMD) is one of the nation's most stringent. Complete cost background information will prevent a number from a less stringently regulated area being applied to a more stringent area.

Since there is no distinction between data evaluation in program cost estimates and trade studies, no separate breakout paragraphs are provided.

Selection of Estimating Methodologies

Having chased the data at the data sources and collected the information, the next few paragraphs describe how data evaluation is fed into the selection of estimating methodologies. Some of the estimating methodologies the cost analyst may use are parametric, analogous, engineering build-up, and vendor quotes. Parametric involves the development and utilization of an estimating relationship between historical costs and the program/physical/performance characteristics of the system. An example of a parametric estimate is the amount and cost of hazardous paint remover expressed as a function of the square feet of skin surface on an aircraft.

The analogous cost estimating method is often used early in the program life when sufficient cost data is not available but adequate program and technical definition exists. It is based upon actual costs of similar current or past systems. This method requires detailed engineering assessment to ensure that the best analogy is used. An example of an analogous estimate would be to compare the waste steam costs of paint/depaint operations between the F-16 and the F-15 aircraft. Here, some care would be required as the F-15 has significantly more surface area.

An example of an engineering build-up ESH estimate would be one that identifies all the hazardous materials, safety hazards, and occupation health risks associated with a system and then builds up the ESH costs using detailed labor and material information from the lowest level possible in the WBS.

An example of using a vendor quote for an ESH estimate would be collecting the cost of personal protective equipment (PPE) that will be used for an abrasive stripping depainting operation on aircraft. It is important to have the quantities correct for this method because there are often volume discounts for large orders.

For a comprehensive description of cost estimating methodologies, the cost analyst should use the AFMC Cost Estimating Handbook. Specific cost methodology options and preferences may also be available at the Product Center Cost Divisions or at the Air Logistics Centers.

Program Cost Estimate

Parametric cost methodologies are frequently used in ESH cost estimates. One common example is ESH planning costs. These costs are often included in the Systems Engineering/Program Management cost element. This cost element is estimated as a percent factor of research and development costs. Engineering Build-up is a method used in ESH cost estimating of the O&S phase. An engineering build-up is performed on the depot labor rates with each applicable Responsibility Center/Cost Center (RC/CC) being summed until a rate total is calculated. For example, ESH costs were found to be approximately three percent of the fully burdened hourly depot rate during an analysis of the F-16 program.

Trade Studies

While a trade study may have all types of methodologies, it is most likely that the sensitive elements of cost will be estimated using engineering build-ups. One reason is that the alternatives are by nature, fairly technical. Another reason is that ESH costing is in its infancy and Cost Estimating Relationships (CERs) that define specific alternatives have not yet been developed. There is some potential in the use of analogous estimating methods as other system's leading edge techniques are adopted by weapon systems in development.

Planning For Tool Use And Availability

The type of data collected and estimating methodologies chosen will determine the selection of estimating tools utilized. The majority of ESH estimates will not require any special cost estimating tools. The use of spreadsheet tools (e.g., Excel, Lotus) should provide sufficient capability. However, where the use of a unique tool is required, it is not uncommon for cost estimating tool availability, training, and data transfer/translation to impact the schedule for a cost estimate. When planning, consider any special tools or models that may be required. If they are not available or require training for their use, request support early in the planning period. The lead-time for training could be a matter of weeks or months. If the model or tools will not be available to complete the estimate on time, then revise the estimate schedule or change to alternative estimating approaches or methods.

The compatibility or fit of cost tools to the desired presentation of cost values should also be considered. Certain models may calculate costs that include ESH costs but do not display the ESH costs separately. Others may clearly breakout the ESH costs. Try to match the model to the desired presentation of costs and where that is not possible, plan for translating the model output to the form desired. For example, depot maintenance costs using the Visibility and Management of Operating and Support Costs (VAMOSC) database or the Cost Oriented Resource Estimating (CORE) database will include ESH costs. However, the visibility of ESH cost to functional discipline (i.e., medical surveillance or protective equipment purchase) is not provided without additional queries.

There are numerous past and current ongoing research studies that seek to improve the defense community's ability to estimate ESH costs. Efforts have included surveys of existing techniques and models, modifications to improve the current family of tools, and development of new techniques and tools. Possibly the most noted study to date that has researched available tools and techniques was performed for the Office of the Secretary of Defense (OSD) Program Analysis and Evaluation (PA&E) by the Capstone Corporation. The study, *Evaluation of Environmental Management Cost-Estimating Capabilities for Major Defense Acquisition Programs, 22 March 1994*, revealed that ESH cost tools cover the areas of environmental restoration and corrective measures very well but are lacking in the ESH activities that occur during the acquisition and support phases. The cost tools/methods that have been developed are for specific applications and generally do not meet the diversity of weapon systems being fielded. The tools/methods are currently evolving and it will take years for them to mature to the point where all weapon systems are addressed. The rapid growth in available ESH software makes the Capstone study somewhat dated. SMC funded a more recent study in 1997 that performed a search for potential ESH cost estimating tools. Appendix M provides a brief overview of the potential tools.

Program Cost Estimate

The CIPT may have experience and preferences for certain models. There may be certain tools that are more readily accepted by the various levels of review for a major program cost estimate. These factors should be considered in tool selection.

Trade Studies

Planning for ESH trade studies should likewise consider the tools to be used. Be careful to select a tool that can address the sensitive costs; it will be the core of your trade estimate. Consider the roles that risk will play in the trade study. If there is a significant difference in the risk associated with each alternative, then consider models that display and quantify risk in clear measurable terms. Look for models that can translate exposure risk to dollar values. Additionally, consider the use of models that will address contingency liabilities such as fines and penalties where a significant risk is involved with the use of hazardous materials. A final item to consider in tool selection is the ability of the models to display the differences in alternatives in such financial terms as return on investment, pay back period, and net present value.

Risk Assessments

Treatment of risk is a subject with dual meaning for a cost analyst. It may refer to the error of the cost estimate from uncertainty. It is also a term often used in the ESH world and associated with the exposure of personnel to hazardous materials, noises or other ESH effects.

Risk management is an organized process of identifying potentially undesirable program events and then establishing and executing the appropriate risk mitigation actions. ESH risk management is a subset of program risk management with focus on ESH events. The goal of ESH risk management is scientifically sound, cost effective, integrated actions that reduce or prevent risks while taking into account social, cultural, ethical, political, and legal considerations. ESH events include, but are not limited to, health risks from exposure to harmful elements, ecosystem damage, injury or death to personnel, and damage to or loss of equipment. The consequences of ESH risk will vary and can include cost (fines, penalties, repairs, and replacement), schedule delays, degraded performance, and the loss of public goodwill.

Although the evaluation of cost, technical, and schedule risk occurs after the calculation of the point estimate, it is important to plan early and search for the potential high and medium risk activities that may determine a methodology for risk analysis. The inclusion of ESH risk is required for both program cost estimates and trade studies. There is no distinction in the application between cost estimates and studies.

Cost Sensitivity Analysis

A part of the cost analyst's job is to identify the sensitivities associated with each estimate. Simply put, this means identifying the variables, which if changed, significantly impact the cost estimate. For example, a data collection effort at Ogden Air Logistics Center (OO-ALC) by SMC in 1997 found that approximately three percent (3%) of the depot maintenance rate was attributable to ESH activities. Of the 3% ESH activities, 74% were environmental related, 13% were safety related, and 13% were health related. Some ESH costs were directly attributable to cadmium. If cadmium plating were eliminated from the maintenance processes, an analysis could be performed on the reduction in the overall ESH costs for elements such as hazardous material and hazardous waste, physicals, PPE, and health monitoring.

Although the cost sensitivity analysis typically occurs during excursions after the calculation of the point estimate, it is important to plan early and search for the ESH activities that may impact the element selection for cost sensitivity analysis. Since there is no distinction between treatment of sensitivities in program cost estimates or cost trade studies, no separate breakout paragraphs are provided.

Steps Three through Seven

Steps three through seven in the cost estimating process are not treated any differently in the case of ESH cost estimating.

Appendix A – Program Cost Estimate Examples

Delta II (MLV III) Space Launch Vehicle

Summary

This Program Cost Estimate (PCE) of the Life Cycle Costs for a Space Launch Vehicle is included as an example of a full and complete LCC estimate for a system which included ESH cost impacts in the PCE. The purpose of this exercise was to determine the Life Cycle Cost for the Delta II / Medium Launch Vehicle (MLV) III program and review the methods used to determine if and where ESH costs were considered in the most recent Program Office Estimate (POE). The results of the analysis of this PCE indicate an inclusion of appropriate ESH costs and that they are in concert with the expected values of similar launch vehicle PCEs researched in preparation for this guide. This investigation found approximately 0.5% of the program cost was attributable to ESH impacts. This percent varies by phase of the program, but in general will total that amount for this launch vehicle program with the heaviest application in the O&S arena.

Step One - Define and Plan the Cost Estimate

Establish the Technical Baseline to be Estimated

The MLV III Program Office previously established the MLV III technical baseline in the PCE (also known as the Bluebook). The following is a brief overview of the weapon system. This effort is necessary in order to provide the analyst with some knowledge of the system and its operating environments in order to obtain a feel for where the ESH costs might need to be included. Also, a knowledge of the system will provide some indication of the types and efforts to allocate to the E, S, and/or H elements to be aware of.

Program Background

Following the 28 January 1986 loss of the Space Shuttle Challenger, Global Positioning System (GPS) Satellites were left without a means of launch. In reaction, the government produced a Space Recovery Plan, which designated the MLV I program to provide launches for the GPS constellation. In competitive contracting, the McDonnell Douglas Aerospace Corporation (now Boeing) was awarded a turnkey contract. The MLV program uses Delta II vehicles and derivations thereof. The first option was exercised in January 1988 with a total planned procurement of 20 vehicles. In August 1991, an MLV I follow-on contract again was awarded to Boeing for the MLV III program, allowing for up to six (6) vehicles per year through FY99.

Weapon System Description

The MLV III system is used by the Air Force to deploy government space vehicles to their required orbits in support of global military operations. The Delta II (7925 booster design) core launch vehicle was selected to satisfy the MLV III mission requirements.

Since the Delta II launch vehicle has been tested and successfully flown under the MLV I program, minimal development testing was required for MLV III. The Delta 7925 is a three-stage rocket system modified from the existing Delta 6925 booster design. The first stage is powered by a single Rocketdyne RS-27A using liquid oxygen and RP-1 propellants and is thrust-augmented by nine stretch graphite epoxy motors (GEM) manufactured by Hercules. The second stage contains the guidance system and is powered by a single Aerojet AJ10-118K engine using storable hypergolic propellants. The engine is capable of multiple restarts and is a variant of the Titan Improved Transtage Injector Program engine. The third stage is a spin-stabilized, standard commercial Payload Assist Module which uses a Morton-Thiokol STAR 48B solid rocket motor (SRM). Modifications made to the existing Delta II 7925 booster design to upgrade to MLV III specifications include a new Flight Termination System (FTS) and a Redundant Inertial Flight Control Assembly (RIFCA) manufactured by Bendix.

The Delta II launches a single GPS IIR satellite per launch vehicle. The vehicle flies to a parking orbit and the satellite is inserted into a 100-by-10,998 nautical mile transfer ellipse orbit by the third stage. Insertion into the final drift orbit is accomplished by an integral Thiokol STAR 37XFP Apogee Kick Motor (AKM) in the GPS IIR spacecraft.

The MLV III system has a baseline launch rate of at least four missions per year and is capable of launch within 60 days from notification. In any given year, the MLV III system is capable of responding to a launch rate fluctuation (based on the status of the on-orbit constellation) from 0 to 6 launches without impacting subsequent year's operations. The system is capable of a 24-hour turnaround cycle in the event of a launch delay (exclusive of a flight or ground equipment failure). The ground-based elements of the system have a design service life of at least 20 years, starting at the time of site activation, with an operating duty period of 24 hours per day, seven days per week during periods of launch processing.

Weapon System Program Support

The concept of operations and support includes activities and other costs incurred at the launch site. The activities are performed by the MLV III prime contractor, Boeing, Air Force Space Command (AFSPC), and any contractor hired by AFSPC to support the launch base and its operations. Responsibility and budget (except as noted below) for these activities was recently transferred from AFMC to AFSPC.

The MLV III prime contractor performs the launch operations at the launch base that are required to receive, inspect, store, process, checkout, test, and launch the vehicle. The MLV III prime contractor also maintains and refurbishes the facilities and equipment at the launch base as required during the life of the system.

AFSPC manages the MLV III prime contractor's launch operations activities. In addition, AFSPC is responsible for the range support at the launch site. Range support includes supplies, travel duty, missile flight analysis, custodial services, scheduling, logistics support, grounds maintenance, communications systems operations, program management, National Aeronautics and Space Agency (NASA) contract support, launch complex operations, maintenance and corrosion control on structures and vehicles, sanitation, security police, photography, telemetry, pad safety, data processing and evaluation support, ordnance storage, and trailer leases. The budget for range support and launch propellants has been transferred to AFSPC. However, the budget for the prime contract launch operations has remained with AFMC. Launch operations is a separate Contract Line Item Number (CLIN) on the MLV III prime contract and is managed by AFSPC and administered by AFMC SMC/CLP.

Determine the Appropriate WBS for the Estimate

The following table shows the Work Breakdown Structure for the MLV III Launch Vehicle as established in the PCE.

LEVEL	ELEMENT	TITLE
1	**0000**	**MLV III SPACE SYSTEM**
2	**1000**	**LAUNCH VEHICLE (LV)**
3	1100	LV STAGE 1
3	1200	LV STAGE 2
3	1300	LV STAGE 3
3	1400	STRAP-ON PROPULSION SYSTEM
3	1500	PAYLOAD FAIRING (PLF)

LEVEL	ELEMENT	TITLE
3	1900	LV INTEGRATION, ASSY, TEST, & CHECKOUT
2	**2000**	**SYSTEM ENG/PROG MANAGEMENT (SEPM)**
3	2100	SYSTEM ENGINEERING PROGRAM **
3	2200	PAYLOAD INTERFACE (CLIN 1 – Non-Recurring (N/R))
3	2300	PROGRAM MANAGEMENT
3	2400	ADVANCED DEVELOPMENT & INTEGRATION
3	2500	PERFORMANCE UPGRADE
2	**3000**	**OPERATIONAL SITE ACTIVATION**
3	3100	PLANNING, INTEGRATION, TEST & CHECKOUT
4	3110	Qualification Activities
4	3120	Acceptance Tests
3	3200	FACILITY ACTIVATION
4	3210	Facility Support
4	3220	Mission Equipment (ME)
4	3230	Support Equipment (SE)
3	3300	TECHNICAL SUPPORT
4	3330	Technical Support Training
4	3340	Technical Library
4	3350	Resource Management & Scheduling System
2	**4000**	**LAUNCH OPERATIONS**
3	4200	LAUNCH PROCESSING **
3	4300	PAYLOAD MATING
3	4400	MISSION CONTROL
3	4500	MAINTENANCE **
4	4510	Maintenance Support PIT&C (Basic)
4	4520	Standardized Support System
2	**5000**	**DATA**
2	**6000**	**TRAINING**
2	**7000**	**GROUND MISSION/SUPPORT EQUIPMENT**
2	**8000**	**OTHER GOVERNMENT COSTS**
3	8100	Award Fee
3	8200	GSAC (3600)
3	8300	Aerospace Corporation Support
3	8400	Propellants **
3	8500	Engineering Change Orders (ECO) **
3	8600	System Program Office (SPO) Support
2	**9000**	**OPERATIONS AND SUPPORT**
3	9100	Vandenberg Air Force Base (VAFB)
4	9110	Launch Propellants **
4	9120	Range Operations **
4	9130	Other **
3	9200	Cape Canaveral Air Force Station (CCAS)

LEVEL	ELEMENT	TITLE
4	9210	Launch Propellants **
4	9220	Range Operations **
4	9230	Other **
** - Denotes those WBS elements where the analyst will find ESH cost elements		

Table 2, MLV III WBS

Step Two - Specify Estimating Methodology

Data Sources and Data Collection

Sorting through the POE, its supporting data, contractor files, and government reporting systems revealed most of the ESH information needed. The following is a list of the data sources used:

1. SMC/CLM Bluebook for 1997 & 1998
2. Boeing Company (Huntington Beach, CA) Data Files and Records
3. MLV III Cost Performance Reports (CPRs), Contract Funds Status Reports (CFSRs), Contractor Cost Data Reports (CCDRs)
4. 1 SLS Financial Management System Reports, Job Order Cost Accounting System (JOCAS)
5. Boeing Company (CCAS) LPAD-L410 Report, Launch Support Totals
6. MLV III Program Office Estimate (POE) Bluebook

The Program Office was able to provide most of the sources of information. When the Program Office did not have the data sources requested, they played a vital role in assisting the cost analyst to contact the appropriate people. The “assistance” role was very vital since much of the cost detailed information was located at government facilities at the launch sight (CCAS) as well as with Boeing at CCAS.

Review of the Technical Baseline (included in the Bluebook) and WBS dictionary provided the key areas to look for ESH elements. The technical baseline mentioned EA studies (WBS 3020), Safety Plans (WBS 3030), Vehicle Production (WBS 1000), Systems Integration and Site Activation (WBS 2000/3000), Launch Operations (WBS 4000), as well as Operations and Support (WBS 9000). All of these areas were considered during the Data Evaluation phase.

The Bluebook also provided total Life Cycle Cost (LCC) for the duration of the MLV III by appropriation and by WBS. The following is a summary of the Delta / MLV III LCC.

3600 - Research Development, Test & Evaluation

	PY	FY98	FY99	FY00	FY01	FY02	FY03	Total
TOTAL 3600 REQUIRED	29.405	6.426	6.194	6.323	5.382	5.499	1.877	61.106
TOTAL 3600 APPROVED	29.666	4.317	6.403	5.891	6.072	5.446	1.989	59.784

3020 - Missile Procurement

	PY	FY98	FY99	FY00	FY01	FY02	FY03	Total
TOTAL 3020 REQUIRED	486.886	191.720	152.033	37.494	38.557	27.361	11.034	945.085
TOTAL 3020 APPROVED	487.387	192.189	157.443	37.968	38.307	28.021	6.988	948.303

3400 - Operations and Support

Cost in $M	PY	FY98	FY99	FY00	FY01	FY02	FY03	Total
VAFB Estimate 3400		1.520						1.520
CCAS Estimate 3400	6.577	6.772	5.528	5.644	5.765	2.945		33.231
Total Required	6.577	8.292	5.528	5.644	5.765	2.945		34.751

Table 3, MLV III Program Costs

Notes: (1) AFSPC is responsible for 3400 funding, (2) Required: Life Cycle Cost Estimate (LCCE), (3) Approved: MLV III BES

Date of Estimate: 15 December 1997

Point of Contact for the Estimate: SMC/CLPM (Capt. Mark Eichelberger; DSN 833-0970)

Point in Life Cycle at Time of Estimate: Production

Data Evaluation and Selection of Estimating Methodology

Evaluation of the MLV III data consisted of identifying the ESH costs for all appropriations and where applicable, by WBS. The methodology for estimating the ESH portion varied by appropriation.

Since the MLV III is currently in Production, any 3600 Appropriation (Development) ESH costs were already completed. Therefore, historical actuals were used and the costs by WBS were taken from the Bluebook.

The 3020 appropriation (Production / Launch Services) ESH costs were somewhat more difficult to determine. The actual Hardware is Firm Fixed Price (FFP) on the contract. Statistical regression was used to develop Launch Costs using actuals to-date. Historical factors furnished by the Prime Contractor were used to determine ESH Hardware and Launch Operations cost.

For the 3400 Appropriation, actuals from the JOCAS runs were used to develop a per launch cost. The total ESH requirement was based on the per launch average and 25 launches from CCAS.

Risk Assessments and Cost Sensitivity Analysis

Since the purpose of this exercise was to determine the ESH contribution to the Life Cycle Cost for the Delta II / MLV III program, ESH risk was assessed at the same 70% confidence level as the MLV III program. The Formal Risk – Assessment of System Cost Estimates (FRISK) Model, developed by the Aerospace Corporation, was the tool used to determine the MLV III program risk values. It was determined that a total of $4.697M over the total program (less than 0.45% of the total program) was required to increase the confidence interval for the program from the 50% to the 70% confidence level. Since the ESH costs were 0.5% of total system cost, the ESH risk was calculated to be 0.5% of the $4.697M or $0.023M.

Step Three - Summarizing the Identifiable Delta II (MLV III) ESH Costs

<u>ESH Values:</u>

3600 Appropriation: Research & Development (R&D)

The following are the WBS elements in R&D that contained ESH costs. They have been completed and closed out, and are no longer carried in the WBS Structure.

WBS 3020: EIS AND ENVIRONMENTAL IMPACT STUDIES; 3600 Appropriation; Source of data: Actual Funding Documents; Then Year (TY)$ 297K.

WBS 3030: ENVIRONMENTAL ASSESSMENT EXPLOSIVE SAFETY PLAN; 3600 Appropriation; Source of data: Actual Funding Documents; TY$ 120K.

Total 3600 Approved - TY$59.784M.; ESH Spent - TY$0.417M. % ESH = 0.7%. This value is consistent with similar launch programs analyzed for ESH costs in development efforts.

3020 Appropriation: Procurement

WBS 1000: LAUNCH VEHICLE (LV). The ESH costs incurred in the production of the hardware for the Delta II, 7925 configuration, are included in the price of the hardware. The MLV III Launch Vehicle is procured off a commercial production line by the USAF as a Firm

Fixed Price (FFP) Option Exercised. The vehicle is procured as required to launch the GPS IIR satellites. It is produced in Pueblo and shipped to Cape Canaveral Air Force Station (CCAS) where it is integrated, checked out, erected and launched. Since the vehicle is procured as a FFP item, visibility into the costs as they are built up is severely limited. Conversations with the Boeing Program Manager and his Financial Staff assure us that the ESH Costs are included in the costs of the hardware as applicable, based on a standard allocation scheme established through negotiation within the organization. This equates to factors applied to the cost to develop a price for the deliverable, otherwise known as "burden", and this factor is estimated to be ½ of 1%. (0.45% per Sue Blodgett, Boeing Financial Management)

WBS 2000: SYSTEM ENG/PROG MANAGEMENT (SE/PM). Included above in the FFP CLIN.

WBS 3000: OPERATIONAL SITE ACTIVATION. Included above in the FFP CLIN.

WBS 4000: LAUNCH OPERATIONS. This effort is Cost Plus Award Fee (CPAF), and is priced based on the actual hours required to perform the launch activities at CCAS. It includes the hours for Launch Processing Documentation, Delta Missile Check-Out, Solid Rocket Motor buildup and assembly, Upper Stage Integration and check-out, and On-Pad Integration and Testing. ESH activities are a natural part of the launch operations activity and, as such, are included in the hours required to perform the activity. The cost of any discrete element is not separately identified to that level in the hours report, however, the Boeing Business Manager (Mr. R. B. Holder) estimates the ESH effort to be approximately ½ to 1% of the total hours required for Launch Operations at the Cape. This suggests that on the average, ESH cost per launch range from 240 hours to 480 hours, or $18,000 to $36,000. The mid-point ($27,000) was assumed for ESH calculations

To determine the total ESH costs for Production, one must sum the individual launch costs for Hardware and for Launch Operations for the number of launches. Once one has this value, it can be divided by the Total Approved Program Funding for the Production program to arrive at a percentage value for ESH costs in Production.

Hardware: Twenty launch vehicles at an Average Unit Cost of $33.9M is $3.4M for ESH during hardware Production. ($33.9 x 20 = $678M x 0.5% = $3.4M)

Launch Operations: Twenty-five launches at the average value of $27,000 per launch totals $675K for ESH during Launch Operations.

The Total Approved Program Budget, TY $ is $948.303M for Production. **$3.4M + 0.675M = $4.1M for ESH during Production**, or approximately **0.43% of the total Approved Program**. This is consistent with similar launch programs analyzed for ESH costs as a percentage of the total.

3400 Appropriation: Operations and Support

This WBS category contains the ESH-related costs associated with the Operations & Support activities at the Launch Complex. These activities include, but are not limited to, Safety Inspections, Personnel Safety & Security, Environmental checks, spill cleanup and/or monitoring, Disaster Preparation Planning and Operations, etc. The Base Financial Management System that is used to accumulate these costs is the Job Order Cost Accounting System (JOCAS). This system collects costs by hours and dollars to each Resource Center or Cost Center (RC/CC) as appropriate.

WBS 9100: Vandenberg Air Force Base (VAFB). The costs for Vandenberg were developed in the same manner as those for Cape Canaveral. The annual Operating and Support requirements are the same, however there are significantly fewer DoD launches from Vandenberg. The funding for these operations are borne by Space Command, and will be the same, percentage-wise, as the Cape. Functions are the same for both ranges as each is governed by the same regulations and policies with almost identical manning. However, due to the USAF not launching Delta II's at VAFB under the current contract, these costs are not included in the MLV III Bluebook. If further research is deemed necessary, the effort to acquire and include documentation of these costs will require only the gathering of the data from that location and sorting it to the proper RC/CC. The data systems for both ranges are the same.

WBS 9200: Cape Canaveral Air Force Station (CCAS). The annual Operating and Support requirement for the CCAS Delta Flight averages $4.88M per year. This requirement can vary with the number and type (Commercial or DoD) of payloads launched, but has remained rather constant over the Delta II Vehicle launch years. These factors presented here are a result of projecting the costs per launch as were accumulated in the JOCAS to the launches scheduled for the remaining program years. They were then corroborated with AFSPC's "Delta II Cookbook" compiled by Major J. Bachman of the Space Command Program Element Monitor (PEM) group. This requirement, annualized, matches the Budget Estimate Submission for the Launch Vehicles Program Element.

WBS 9220 Range Support & WBS 9230 Other. The following table summarizes the actuals for JON 770001, CCAS. The RC/CCs are those applicable to ESH at CCAS Launch Complex 17A & B.

RC/CC	EEIC	WBS	Description	$K, 1997
40494A	555B3	9230	Security Service	0.4
40494A	555BT	9230	Security Service	0.2
201061	392	9220	Systems Safety	1.3
201064	59913	9220	Flight Safety Analysis	2.6
201064	599923	9220	Flight Safety Analysis	8.4
252MDC	554T2	9220	Weather Systems	1.8
252MDF	554T2	9220	Radar Systems	0.4
40491D	555B5,R,X	9220	Disaster Prep Planning	11.1
40493A	555B4	9220	Fire Protection Services	1.8
			TOTAL ESH	28.0
			O&S Cost Per Launch	1329.2
			ESH % of Requirement	2.11

Table 4, MLV III WBS/RC/CC Matrix

Total 3400 Approved - TY$34.751M; ESH Spent - TY$0.028M times twenty-five launches totals **TY$0.700M. ESH % = 2.11%.**

<u>Summary of ESH Values</u>

ESH costs as a percent by Appropriation:

		ESH Costs	Total Program Cost	ESH % of Total
Development (3600):	TY$	0.417 M	59.784 M	0.70%
Production (3020):	TY$	4.065 M	948.303 M	0.43%
Opns & Suppt (3400):	TY$	0.700 M	34.751 M	2.01%
Total	**TY$**	**5.182 M**	**1,042.838 M**	**0.50%**

Remarks

Upon review, the cost estimating techniques for the launch vehicle and operations provided good insight into the total weapon system life cycle ESH costs. Since this system was already in the middle of production, launch operations had begun and AFSPC provided detailed information regarding activities at CCAS through the JOCAS system. A large amount of information was available for ESH considerations if the cost analyst knew where and was given permission to search for the data. The Delta launch vehicle example may be an exception rather than the rule for the level of data collected. This is because the cost estimating support contractor for the Delta II Program Office is the same support contractor that published this guide. This direct contact opened many doors and made some of the analyses easier to determine.

Fighter Aircraft

Summary

The purpose of this example is to estimate and determine the magnitude of the ESH costs in the operating and support (O&S) phase (including Demilitarization and Disposal) for the life cycle of a fighter aircraft. The effort included data collection from the system program office, an Air Logistics Center, the Visibility and Management of Operating and Support Costs (VAMOSC) database, and a Government Accounting Office (GAO) report on demilitarization and disposal costs for aircraft. The specific type of VAMOSC database query was key for determining the detail of ESH costs. Using the standard report format, the ESH costs were determined to be approximately one percent (1%) of the O&S cost. When a more detailed and time consuming ESH specific query of VAMOSC was performed, the ESH costs were determined to be approximately two percent (2%) of the O&S cost. The VAMOSC database includes ESH costs within the O&S cost framework and provides the flexibility for increased detail given sufficient time and resources.

Step One – Define and Plan the Cost Estimate

Establish the Technical Baseline to be Estimated

An existing fighter aircraft was chosen as an example because there are significant numbers in the inventory, all phases of the life cycle have been reached, and because there are hazardous materials involved in construction and operation of the aircraft. The fighter aircraft selected has one of the longer production runs for Air Force systems. The aircraft entered full-scale development in 1975 and the first production aircraft was delivered in 1978. Production has continued since that date. While production continues, the earliest aircraft have started to be deactivated so that demilitarization and disposal cost data have become available. The aircraft is produced in multiple models with a number of different configurations of production. Over 50 different block configurations have been produced. The technical baseline was limited to the C and D models of the aircraft. No attempt was made to track at the block configuration level. This would have required tracking at the aircraft serial number level.

Determine the Appropriate WBS for the Estimate

The O&S cost WBS format includes the CAIG recommended O&S cost breakdown structure and the Weapon System Support Cost (WSSC) format. The CAIG format approximates the MIL-HDBK 881 format and was selected for this estimate. Table 6 in Step Three of this example illustrates the WBS structure.

Step Two – Specify Estimating Methodology

Data Sources

Data sources included the aircraft Program Office which provided the C/D model System Level Baseline O&S Cost Estimate. We also received a Program Cost Estimate (Blue Book) which provided representative estimates of O&S costs at the squadron level derived from the Cost Oriented Resource Estimating (CORE) model. None of the material collected at Aeronautical Systems Center (ASC) contained a breakout of ESH costs.

Data collected from VAMOSC included specific O&S costs by unit. In addition to that which is available online via the Internet, special queries were made to further explore cost categories that contained ESH costs. There is a fairly significant amount of the aircraft O&S costs in the VAMOSC database. Although it is hampered by visibility into exact cost elements, there is some extrapolation possible with additional information. For example, it is possible to capture the command element costs for a fighter unit. Then by interviewing unit personnel or by reviewing manning documents, it is possible to determine the number of personnel in the safety or environmental management divisions within that command element and a percentage of costs can be determined as applicable to ESH.

For the depot portion of the O&S costs, we were able to reasonably estimate the percentage of the depot maintenance labor rate that contained the ESH costs by collecting the actual costs from the financial management budget organization. This was determined for Ogden ALC which is a primary support ALC for the aircraft.

Data used for the O&S estimate came from the VAMSOC database for the C/D aircraft versions in 1996. Aircraft belonging to Air Education and Training Command (AETC) were used to derive a per aircraft estimate of ESH costs. AETC flies peacetime sorties in the Continental United States (CONUS), potentially the most stringent ESH regulations.

Data on the demilitarization and disposal costs were obtained from the Government Accounting Office. This agency had been citing the Services for claiming that they were unable to estimate the costs of demilitarization and disposal (D&D) of weapon systems. One research study was devoted to estimating the costs for a variety of Army, Air Force and Navy aircraft. The cost figures in that report were used due to the absence of any other D&D data. Those numbers lacked clear identification of a reference cost year.

Data Collection

Operating and Support Costs were collected during visits to the aircraft Program Office at Aeronautical Systems Center, Ogden Air Logistics Center, and the Prime Contractor's Facility. The samples of questions asked during the data collection effort are located in Appendix J.

Selection of Estimating Methodologies

The predominate estimating methodology utilized was an engineering build-up of the costs from the cost data sources. Depot costs were the actual costs used for rate determinations. VAMOSC data is actual cost data from operating unit and supporting unit cost reports.

Planning for Tool Use and Availability

Since the compilation of ESH costs in the O&S phase of an aircraft had not been performed previously, tool use and availability would depend upon the data sources and formats of the data. VAMOSC was a known and use of the tool was planned from the start. Data gathering of depot level costs revealed that much of the depot level costs would have to be extracted for organization cost reports and transferred to spreadsheets.

Risk Assessment

No risk assessment was performed with this magnitude estimate.

Cost Sensitivity Analysis

No sensitivity analysis was performed with this magnitude estimate.

Step Three – Summarizing the Fighter Aircraft O&S ESH Costs

The ESH O&S costs were calculated using two methodologies. The first took the CAIG O&S structure and determined the O&S cost for a single aircraft. The average for AETC was used. Then for each of the cost elements, applicability of ESH costs were determined and estimated as a percent of the cost element. A combination of head count (HC), depot rate factors (Rate) and engineering estimates were used to estimate the ESH cost in each O&S cost element value. This technique yielded a value of $21,908 per aircraft per year in FY 1996 dollars. This value included the D&D costs presented as an average cost per O&S year. As a crosscheck, the VAMSOC query for Shaw AFB was adjusted to a per aircraft value for the same FY96. This value was $45,603. Since this query used more specific Expense Element/Investment Code (EEIC), Program Element Code (PEC), and Responsibility Center/Cost Center (RC/CC) elements, we believe the larger value better represents actual ESH costs.

The following table summarizes the results from the VAMOSC standard report query.

		O&S Cost	ESH Cost	Allocation
CAIG Level 1	CAIG Level 2			
Mission Personnel	Operations(Aircrew)	$ 81,911	$ 328	HC
Mission Personnel	Maintenance	$ 480,918	$ 1,443	HC
Mission Personnel	Other Mission Personnel	$ 85,749	$ 857	HC
Unit Level Consumption	Aviation POL	$ 175,381		
Unit Level Consumption	Consumable Supplies	$ 64,702		
Unit Level Consumption	Depot Level Reparables	$ 238,533	$ 3,459	Rate
Unit Level Consumption	Training Munitions	$ 46,453		
Unit Level Consumption	Other Mission Support	$ 437		
Depot Maintenance	Overhaul/Rework	$ 33,143	$ 961	Rate
Depot Maintenance	Other	$ 147,734	$ 4,284	Rate
Contractor Support	Other	$ 180		
Sustaining Support	Replacement Support Equipment	$ 41,081		
Sustaining Support	Mod Kit Procurement/Installation	$ 55,202	$ 552	4A mods
Sustaining Support	Other Recurring Investment			
Sustaining Support	Sustaining Engineering	$ 6,429	$ 186	Rate
Sustaining Support	Software Maintenance	$ 8,231		
Indirect Support	Personnel Support (Medical)	$ 119,108	$ 2,382	HC
Indirect Support	Personnel Support (Training)	$ 142,020	607.57	HC
Indirect Support	Personnel Support (PCS)	$ 16,468		
Indirect Support	Installation Support (BOS)	$ 138,485	$ 1,385	HC
Indirect Support	Installation Support (RPM)	$ 61,948	$ 3,097	HC
Indirect Support	Installation Support (IS)	$ 146,072		
D&D Avg			$ 2,365	GAO
O&S Cost per Aircraft	From VAMOSC standard report	$ 2,090,186	$ 21,908	
O&S Cost per Aircraft	From Shaw AFB Query		$ 45,603	

Table 5, Fighter Aircraft ESH Costs

We found that in addition to using the standard reports available from the VAMOSC database, specific queries are possible. The table below shows the detailed ESH costs that were extracted through a query of selected PECs, RC/CCs, and EEICs for Shaw AFB in 1996. Shaw AFB hosts the fighter aircraft Tactical Wing as well as Air Combat Command Headquarters.

Cost Element	**Amount in FY96$**
Environmental	
Compliance	
Contractor Environmental Services	643,106
Personnel	24,363
Real Property, Wastewater treatment*	443,944
Conservation	
Contractor Environmental Services	504,598
Pollution Prevention	44,998
Defense Environmental Restoration	1,190
War Reserve Material	
Contractor Environmental Services	440,429
Contractor Hazardous Waste Management	60,000
Contractor Hazardous Waste Treatment	785,014
Safety	
Headquarters Level	
Personnel (Civilian (CIV))	30,745
Personnel (Military (MIL))	546,414
Temporary Duty (TDY)	30,677
Supplies/Equipment	489
Unit Level	
Personnel (CIV)	100,162
Personnel (MIL)	320,826
TDY	16,710
Supplies/Equipment	16,527
Training	2,887
Total ESH Cost	4,013,079
ESH Cost Per Aircraft	45,603
* Wastewater treatment is not normally considered an ESH O&S Cost	

Table 6, Shaw AFB VAMOSC Cost Data

None of these costs should be used in an estimate without verification at the source of expenditure. These costs do however point out the level of detail available in O&S costs using existing databases such as VAMOSC. The authors are especially thankful to Mr. Karl Philips of The Analytical Science Corporation (TASC) for his support in this research.

The ESH O&S costs from the Shaw AFB VAMOSC query (the larger cost of the two methodologies) are illustrated in the figure below. The aircraft demilitarization and disposal costs, which were estimated by the GAO for a recent report on disposal costs, are also included in the O&S values.

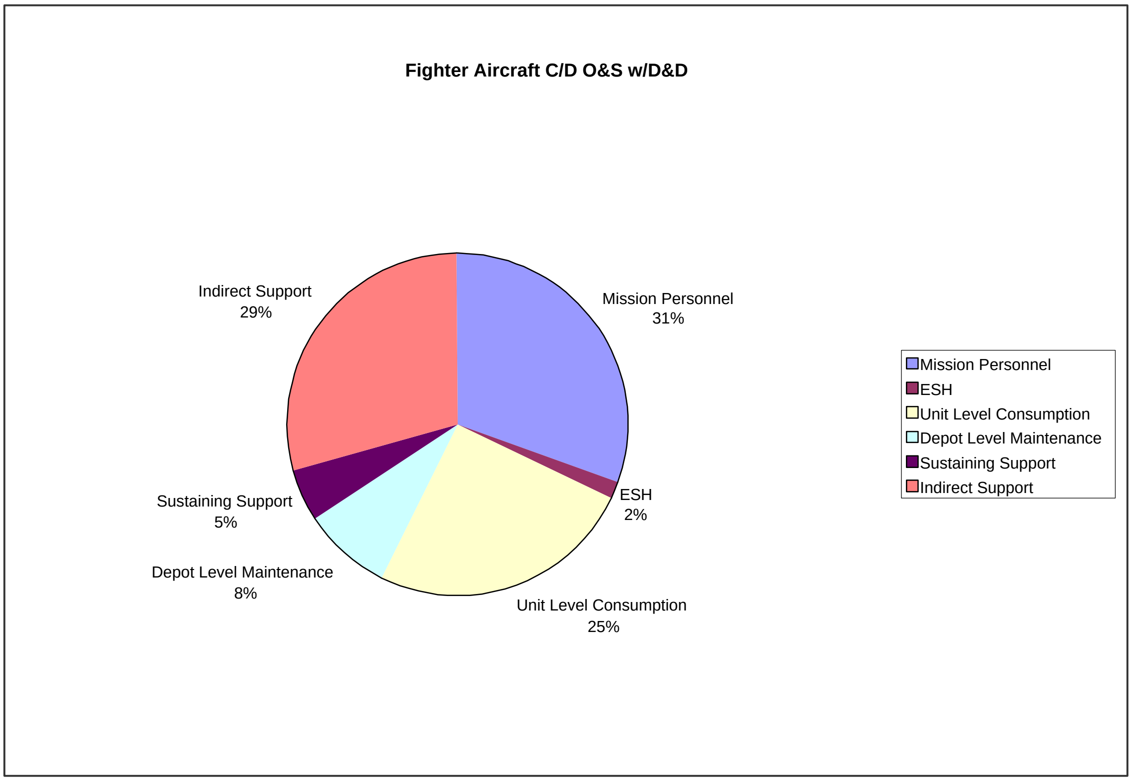

Figure 5, Fighter Aircraft O&S Costs

The figure shows that ESH costs occurring during the O&S phase of the system are two percent. To place these costs in perspective, we have tried to normalize the fighter aircraft costs to a per aircraft basis. The table below shows a rough extrapolation of costs.

Phase	Per Aircraft Cost	ESH cost	ESH Percent of O&S Cost
O&S w/D&D (10 Years)	20,900,000 (FY96$)	21,908 to 45,603	1.05% to 2.18%

Table 7, Fighter Aircraft ESH Percentages

Remarks

This estimate revealed that there is a considerable amount of usable ESH O&S cost data. Much of the cost data requires detailed investigation to get to the ESH portions of the costs. We often had to rely upon documents such as host tenant support agreements and inter-service support agreements to determine the allocation of specific costs. Much of the depot level information came from exercises that use actual costs to build-up depot overhead rates. The depot averaged approximately three percent of the labor rate charges for ESH activities.

The type of VAMOSC database query was key for determining the detail of ESH costs included in the fighter aircraft O&S estimate. Using the standard report format, the ESH costs were determined to be approximately one percent (1%) of the O&S cost. When a more detailed and time consuming ESH specific query of VAMOSC was performed, the ESH costs were determined to be approximately two percent (2%) of the O&S cost.

There was one interesting side note. If one were to use the Shaw AFB VAMOSC query and eliminate the base wastewater treatment costs, the ESH percentage of O&S equaled two percent. This was the consensus estimate of most Air Force personnel contacted during data collection.

NAVSTAR GPS Block IIF Space Vehicle

Summary

The purpose of this example was to perform an ESH sufficiency review of the current cost estimating techniques utilized to estimate the Program Cost Estimate (PCE) for the Navigation System Using Timing and Ranging (NAVSTAR) Global Positioning System (GPS) Block IIF Space Vehicle. The PCE was performed early in the development phase of the follow-on program and the estimating methodology did not separately identify the ESH costs. Through questioning of the program office/support contractor personnel and reviewing the GPS Block IIF contractor proposal, techniques were developed to estimate the identifiable ESH costs included in the PCE from the contractor estimate and to determine Government ESH costs that were not included in the PCE. Other ESH costs were known to be included in the PCE, however, there was insufficient data to analyze the specific costs in production and operations and support and quantify the total weapon system life cycle ESH costs.

Step One - Define and Plan the Cost Estimate

Establish the Technical Baseline to be Estimated

The NAVSTAR GPS Joint Program Office (JPO) previously established the GPS Block IIF Space Vehicle technical baseline in the PCE (also known as the Bluebook in the Air Force). Following is a brief overview of the weapon system.

In 1973 in order to combine their technical resources to develop a highly accurate space-based radio positioning, navigation, and timing distribution system, the Air Force, Army, Navy, Marine Corps, and Defense Mapping Agency (DMA) initiated the NAVSTAR GPS program. Due to the multi-agency participation, the GPS systems program office is known as a Joint Program Office or JPO.

The GPS system provides precise, continuous, all-weather, common grid worldwide positioning, navigation, and time reference capability to an unlimited number of suitably passive device users - both military and civilian. Mission areas supported include: navigation and position fixing; close-air support; special operations; counter-air and aerospace defense; strategic, theater, and tactical support; command, control, communications, and intelligence (C^3I); and ground and sea warfare.

The Air Force GPS Program Office at the Space and Missile Systems Center (SMC) in Los Angeles, manages the development, production, and deployment of the GPS satellites. The system is operated and controlled by members of the 50^{th} Space Wing located at Falcon AFB, CO. Other support for GPS management is provided by the Department of Defense, Department of Energy, the North Atlantic Treaty Organization (NATO), and includes allied nations.

Block IIA satellites were procured from the Rockwell Corporation. Block IIR satellites are currently being procured from Lockheed Martin Astro Space. The production of 21 satellites is approximately 70% complete with the first launch scheduled for January 1997. Block IIF satellites are being developed and produced by the Boeing Corporation (formerly the Rockwell Corporation). The following table illustrates the GPS contract history. The NAVSTAR GPS space vehicle (SV) design allows for launch by a medium-sized expendable launch vehicle (LV). The current launch vehicle for IIR SVs is the MLV3, which is a modified Delta II 7925. The IIF SVs are planned to launch on an evolutionary expendable launch vehicle (EELV).

Program Series	Contract Number	Award Date	Type of Contract	Flight Units	Contractor
Block I	F04701-74-C-0527	20 Jun 74	Phase I: Concept Validation	8	Rockwell
Block I	F04701-78-C-0153	31 Oct 79	Phase II: Full Scale Development	3	Rockwell
Block II	Modified F04701-78-C-0153	Modified Dec 80	Phase II: Full Scale Development	1 (Qual Unit)	Rockwell
Block II	F04701-83-C-0031	20 May 83	Phase III: Production	9	Rockwell
Block IIA	Modified F04701-83-C-0031	Modified Mar 84	Phase III: Production	19	Rockwell
Block IIR	F04701-89-C-0073	21 Jun 89	RDT&E, Prod., and Storage, Launch & On-Orbit Support (SLOS)	21	LMMS (Formerly General Electric)
Block IIF	F04701-96-D-0025	24 Apr 96	Development, Prod., and O&S	33	Boeing North American (BNA)

Table 8, GPS Contract History

Determine the Appropriate WBS for the Estimate

The NAVSTAR GPS Joint Program Office (JPO) previously established the GPS Block IIF Space Vehicle WBS in the PCE. Following are the WBSs, estimating methodologies, and costs for the Development (3600 appropriation), Production (3020 appropriation), and Operations and Support (3400 appropriation) efforts.

GPS Block IIF 3600 Appropriation		
WBS Elements	**Methodology**	**Cost (TY $M)**
Total 3600 Costs	Summary	344.19
IIF Contractor Costs	Summary	194.65
Space Vehicle Development	Summary	149.24
Basic Contract **	Contract Throughput	147.11
Civil Use Frequency	Contract Throughput	2.13
Operational Control System	Summary	45.41
AFSCN Development	SEER-SEM Software Estimate	1.31
OCS Development	SEER-SEM Software Estimate	18.04
System Simulation Development	SEER-SEM Software Estimate	1.59
CITIS	AFSCN Analogy	4.23
Training	ESC Factor	0.34
OCS IA&T	Factor	2.82
System Test and Evaluation	ESC CER	4.12
Operational Site Activation	ESC Factor	4.58
SE/PM	Factor	6.92
Civil Use Frequency	SEER-SEM Software Estimate	1.46
Advanced Integration Studies	Manpower Estimate	36.66

GPS Block IIF 3600 Appropriation		
WBS Elements	**Methodology**	**Cost (TY $M)**
ECO/TCO	-------------------------	0.00
Contingencies	Summary	112.84
SV Contingency/Liens	Summary	62.01
EELV Adapter	CER	4.52
SV 7-21 Modification	Factor	15.42
SV 22-33 Modification	Factor	42.07
OCS Contingency	Summary	50.83
IIF Initial Development	Risk Analysis	10.99
GOSC Integration	Manpower Estimate	3.34
GOSC ACA	Manpower Estimate	0.96
SV 7-21 OCS Upgrade	Factor	12.06
SV 22-33 OCS Upgrade	Factor	23.52
Other Government Costs	Summary	0.00
TDY Funds		
Training		
Falcon AFB		
Lab Support		
NiH2		
Phillips Lab		
** - Indicates cost element where identifiable ESH Costs are included		

Table 9, GPS 3600 WBS, Cost Estimating Methodologies, and Cost (TY $M)

GPS Block IIF 3020 Appropriation		
WBS Elements	**Methodology**	**Cost (TY $M)**
Total 3020 Costs	Summary	1,221.00
IIF Contractor Costs	Summary	1,008.86
Space Vehicle Production	Summary	968.81
Advanced Buy	Summary	356.07
Basic (SV 1-6)	Contract Throughput	59.38
Option 2 (SV 7-21)	Contract Throughput	156.33
Option 3 (SV 22-33)	Contract Throughput	140.36
Full Fund	Summary	589.68
Basic (SV 1-6) **	Contract Throughput	187.22
Option 2 (SV 7-21)	Contract Throughput	212.27
Option 3 (SV 22-33)	Contract Throughput	190.19
Civilian Use Frequency	Contract Throughput	23.06
Launch Operations Support	Manpower Estimate	40.05
Advanced Integration Studies	Manpower Estimate	36.66

GPS Block IIF 3020 Appropriation		
WBS Elements	**Methodology**	**Cost (TY $M)**
ECO/TCO	------------------------	0.00
Contingency/Liens	Summary	175.48
SV Production Contingency	Risk Analysis	156.51
SV Replenishment Spares	DISA Factor	2.93
PSE Maintenance (Material)	DISA Factor	3.57
Clin 17 Labor Rate	Rate Analysis	12.47
Other Government Costs (OGC)	Summary	0.00
Agency Support		
NIST		
NRL		
NSWC – Crane Labs		
Los Alamos National Laboratory		
45th SW		
Propellants		
CZS Contract Support		
PRC/ARINC		
AMCOMP		
Fed Sim		
Aerospace		
Schedule Support (CZS)		
Cost Support (Space, Ground & NDS) (CZP)		
Contract Reconciliation Support (CZP)		
** - Indicates cost element where identifiable ESH Costs are included		

Table 10, GPS 3020 WBS, Cost Estimating Methodologies, and Cost (TY $M)

GPS Block IIF 3400 Appropriation		
WBS Elements	**Methodology**	**Cost (TY $M)**
Total 3400 Costs	Summary	189.54
On-Orbit Support	Manpower Estimate	42.41
OCS Operations and Maintenance (O&M)	Manpower Estimate	64.06
MOSC O&M	Manpower Estimate	0.85
Contingencies	Summary	82.22
CLIN 18 Labor Rate	Rate Analysis	13.27
CLIN 19 Labor Rate	Rate Analysis	68.03
CLIN 20 Labor Rate	Rate Analysis	0.92

Table 11, GPS 3400 WBS, Cost Estimating Methodologies, and Cost (TY $M)

Step Two – Specify Estimating Methodology

Data Sources, Data Collection, and Data Evaluation

An iterative process was required for the data sources, data collection, and data evaluation steps to perform the sufficiency review of the PCE. The initial data collection step was to contact the NAVSTAR GPS JPO and review the existing GPS Block IIF PCE (Draft NAVSTAR GPS Block IIF Program Office Estimate (POE) Bluebook, December 1996) for ESH costs throughout the life cycle of the system. The data evaluation provided the technical baseline and WBS that were shown in step one. However, the estimating methodology utilized did not separately identify ESH costs contained in the PCE. Further investigation was warranted to address the ESH costs. Conversations with the JPO financial management and engineering personnel (sample questions asked are shown in Appendix J) revealed that there were two other sources to investigate for ESH costs. The first source was the contractor proposal that was utilized as a throughput for the space vehicle development and production costs in the PCE. The second source was the Government activities supporting the Environmental Impact Analysis Process (EIAP) and Systems Engineering and Technical Assistance (SETA) contractor support for ESH related studies that were **not included in the PCE**.

1. Contractor ESH Costs

By reviewing the technical baseline and WBS dictionary, one could see that the majority of the ESH costs were included in the contractor costs for space vehicle development and production. Since these were throughputs, it would be necessary to review the contractor proposal that was used in the PCE for more detailed data. Following are the contractor proposal documents that were pertinent in the review.

- Cost Volume
- Contract & Documentation Volume: Integrated Master Plan - Environmental Engineering and Pollution Prevention Section
- Contract & Documentation Volume: Integrated Master Plan - System Safety Section
- Contract & Documentation Volume: Introduction to Environmental Information Section
- Contract & Documentation Volume: System Requirements Document (SRD)
- Systems Management Volume: System Engineering Section
- Systems Management Volume: Government Insight Within the IPT Structure Section

Taken individually, the documents above did not illuminate much insight into the ESH costs within the contractor estimate. However, by reviewing the documents as a whole, identifiable ESH related activities were traced to cost elements within the cost proposal. The contractor identifiable ESH costs were included in the system engineering efforts for the System Engineering / Program Management (SE/PM) and Space Vehicle (SV) cost elements of the contractor costs. Within the system engineering effort for the SE/PM and SV cost elements, there are lower level cost elements for Space Vehicle Preliminary Design (CLIN 0001), Space Vehicle Final Design (CLIN 0002), Space Vehicle Functional Design (CLIN 0003), and Space Vehicle Production (CLINs 0100-0103). The specific ESH activities performed by the contractor were found in the System Engineering and Integration Integrated Master Plan (IMP) and the Space Vehicle System Engineering and Integration IMP. The details of these activities include topics such as: Updating the GPS II/IIA Environmental Assessment; Ensuring that the GPS IIF program is compliant with all environmental laws and regulations throughout the life cycle of the program; Assuring that the GPS IIF will have safe disposal at its end-of-life, including being boosted to a more distant orbit where it will be turned off and considered dead; Provide for manufacturing and processing record keeping required for federal or local environmental compliance; Implementing policy for pollution prevention and ODS elimination; Maintaining a Hazardous Materials Management Program (HMMP); Keeping up to date regarding new ESH laws and regulations and; Minimizing hazard risk design for GPS IIF assembly, test, launch, and on-orbit operations and to assure that GPS IIF systems meet requirements for range safety and environmental protection. Following are tables that illustrate the specific ESH activities identified, the CLIN the ESH activity is performed against, and the funding appropriation associated with the activity as well as the WBS elements and costs where they are included.

It should be noted that there are other ESH related costs already included in the production (3020 appropriation) and operations and support (O&S) (3400 appropriation) of the spacecraft, but they are not broken out with any detail. Further cooperation and time would be needed from the spacecraft contractor and Air Force Space Command to fully understand the magnitude of the cost impact the ESH requirements have on their respective costs.

System Engineering and Integration Integrated Master Plan ESH Activities
• System Safety & Environmental Protection Program Implemented (CLIN 0001, 3600 App.) - System Safety & Environmental Protection Program Defined - Preliminary Safety Analysis Competed - Preliminary Environmental Assessment Completed
• System Performance Analysis Reports (SPARs) Developed (CLIN 0001, 3600 App.) - Preliminary Human Factors Analysis Completed
• System Safety & Environmental Protection Program Updated (CLIN 0002, 3600 App.) - System Safety Analysis Competed - Environmental Analysis Completed
• System Performance Analysis Reports (SPARs) Updated (CLIN 0002, 3600 App.) - Update of Human Factors Analysis Completed
• System Safety & Environmental Protection Program Updated (CLIN 0003, 3600 App.) - System Safety Analysis Competed - Environmental Analysis Completed
• System Performance Analysis Reports (SPARs) Updated (CLIN 0003, 3600 App.) - Update of Human Factors Analysis Completed
Space Vehicle System Engineering and Integration Integrated Master Plan ESH Activities
• Preliminary Space Vehicle Specialty Engineering Analyses Complete (CLIN 0001, 3600 App.) - Preliminary Safety Analysis Completed
• Space Vehicle Specialty Engineering Analyses Updated (CLIN 0002, 3600 App.) - Final Safety Analysis Completed
• Space Vehicle Specialty Engineering Analyses Updated (CLIN 0003, 3600 App.) - Final Safety Analysis Completed
• Space Vehicle Specialty Engineering Analyses Updated (CLIN 0102, 3020 App.) - Safety Analyses Updated

Table 12, Identifiable GPS Contractor 3600 and 3020 Appropriation ESH Activities

3600 Appropriation	
Activity	**Cost (TY $M)**
• System Engineering (SE/PM)	8.206
• System Engineering (SV)	10.566
3020 Appropriation	
Activity	**Cost (TY $M)**
• System Engineering (SE/PM)	28.511
• System Engineering (SV)	79.405

Table 13, Identifiable GPS Contractor Elements Where ESH Costs Included

2. Government ESH Costs

The Government effort related to the Environmental Impact Analysis Process (EIAP) was derived by contacting the Space and Missile Systems Center Civil Engineering organization (SMC/CEV). SMC/CEV previously performed the Environmental Assessments (EAs) for the GPS Block II, IIA, and IIR. The EA for both the GPS II and IIA was performed in December 1993 for $75,000. The GPS IIR EA was estimated to cost $75,000, however, it was actually performed in December 1994 for $40,000. Based on previous actual costs, SMC/CEV estimated the December 1997 EA to cost $40,000. The effort for the SETA contractor support for ESH related studies was specifically defined in their statement of work (SOW) for Environmental, Bioenvironmental, and Pollution Prevention support to the NAVSTAR GPS JPO engineering organization (SMC/CZE). The table below illustrates the SMC/CEV and SETA Contractor ESH costs for the tasks and products supporting the NAVSTAR GPS IIF program.

SMC/CEV Efforts	**Cost (FY97$)**
Perform Environmental Assessment (EA) for GPS IIF	$40,000
SETA Contractor Tasks	
Respond to ESH / Pollution Prevention (PP) Surveys	$1,800
Oversee the Phase-out of Class I ODSs and the Reduction of Hazardous Materials	$6,000
Provide ESH / PP Inputs to Acquisition Contracts	$18,000
Prepare Request for Environmental Impact Analysis Forms (AF Form 813)	$12,000
SETA Contractor Products	
Programmatic Environmental Safety Health Evaluation (PESHE) Document	$18,000
GPS Block IIF Environmental Assessment (EA) – Pending	$24,000
Semi-Annual Pollution Prevention (PP) Metric Reports	$1,200
Environmental / PP Audits of GOGOs & GOCOs	$18,000
Hazardous Materials Management Program (HMMP) Plan	$7,200
Total Government ESH Costs	$146,200

Table 14, Government SETA and SMC/CEV ESH Costs for NAVSTAR GPS IIF

Data Evaluation and Selection of Estimating Methodology

1. Contractor ESH Costs

For the contractor space vehicle development and production efforts, the identifiable contractor ESH costs for the 3600 and 3020 appropriations were determined with the following methodology. The number of ESH IMP activities was divided by the total number of IMP activities in the system engineering function for the SE/PM and SV cost elements. This number was then multiplied by the total dollars for their respective system engineering effort. The table below illustrates the application of the methodology utilized. Although this estimating methodology is not exact (not all IMP activities are the same duration and complexity), it should provide a reasonable cost bound for the ESH activities identified.

3600 Appropriation					
	# ESH IMP Activities	# IMP Activities	ESH Factor	Total Sys Eng $ (TY $M)	Total ESH $ (TY $M)
SE/PM	10	108	0.0926	8.206	0.76
SV	3	66	0.0455	10.566	0.48
Total ESH $					1.24
3020 Appropriation					
	# ESH IMP Activities	# IMP Activities	ESH Factor	Total Sys Eng $ (TY $M)	Total ESH $ (TY $M)
SE/PM	0	108	0.00	28.511	0.00
SV	1	140	0.0071	79.405	0.57
Total ESH $					0.57

Table 15, Methodology Utilized for Estimating Identifiable GPS Contractor ESH Costs

2. Government ESH Costs

The cost data gathered for the Government ESH related activities required no further data evaluation or cost estimating methodology other than including in the information in Step Three.

Selection of Cost Estimating Tool

The tool utilized to calculate the ESH costs for the GPS IIF program was an Excel spreadsheet. No special model/tool was required.

Risk Assessments and Cost Sensitivity Analysis

Since the purpose of this exercise was to perform an ESH sufficiency review of the current cost estimating techniques utilized to estimate the Program Cost Estimate (PCE) for the NAVSTAR GPS Block IIF Space Vehicle, no risk assessment or cost sensitivity analysis was performed.

Step Three – Summarizing the Identifiable GPS IIF ESH Costs

1. Contractor ESH Costs

The following tables illustrate the identifiable GPS IIF space vehicle 3600 and 3020 appropriation ESH costs and magnitude of the identifiable contractor ESH costs to the total contractor cost and total appropriation cost.

3600 Appropriation	
Activity	**ESH Cost (TY $M)**
• System Engineering (SE/PM)	0.76
• System Engineering (SV)	0.48
Total 3600 ESH Cost	1.24
3020 Appropriation	
Activity	**ESH Cost (TY $M)**
• System Engineering (SE/PM)	0.00
• System Engineering (SV)	0.57
Total 3020 ESH Cost	0.57

Table 16, Identifiable GPS Contractor ESH Costs

	3600 Appropriation	3020 Appropriation
ESH Cost (TY $M)	1.24	0.57
Contractor Cost (TY $M)	194.65	1,008.86
Total Appropriation Cost (TY $M)	344.19	1,221.00
ESH Cost to Total Contractor Cost	0.64 %	0.06 %
ESH Cost to Total Appropriation Cost	0.36 %	0.05 %

Table 17, Magnitude of Identifiable GPS Contractor ESH Costs

2. Government ESH Costs

A total of $146,200 (FY97$) was identified as Government ESH costs. This cost was not included in the PCE. The identifiable Government ESH costs were for supporting the developmental effort associated with the GPS IIF space vehicle. The total 3600 appropriation converts to $315.12 (FY97$M). This yields a ratio of identifiable Government ESH cost to total 3600 appropriation cost of 0.05%.

Remarks

Upon final review of the NAVSTAR GPS IIF PCE, the current cost estimating techniques for the space vehicle do not provide much insight into the total weapon system life cycle ESH costs. No data was readily available to analyze the contractor related ESH costs in production and operations and support. Topics such as hazardous material handling and the related personal protective equipment and health care costs are buried in the existing estimating methodologies. Further cooperation and time would be needed from the spacecraft contractor and Air Force Space Command to fully understand the magnitude of the cost impact the ESH requirements have on their respective costs.

Another observation from this sufficiency review was that all Government ESH costs may not be included in the weapon system PCE. With the NAVSTAR GPS IIF space vehicle, ESH related activities performed for the space vehicle were funded with the program office engineering funds and therefore were not included in the PCE.

Radar System

Step One – Define and Plan the Cost Estimate

The purpose of this study was to investigate the ESH costs associated with a very large, ground-fixed radar system. This provides the reader with an insight into the types of ESH costs associated with the siting of the radar, the ESH operational costs, and the potential costs decommissioning the system. This analysis does not delve into the ESH costs associated with the fabrication of the system itself because the system has been in operation since the early 1970s and much of the cost data has been archived and is hard to retrieve. The study also does not include the ESH related costs for the depot maintenance parts in the system. This estimate will provide examples of ESH costs for the operation of the system that could assist future ESH cost estimators to identify ESH costs of their system or site.

Background Information

Weapon System: This is a very large, ground-fixed radar system. It is one of many systems strategically situated to cover wide areas of the United States coastline. It is in operations 24 hours/day, seven days/week, 52 weeks/year. A site was visited for the purpose of (1) gaining insight into the complexity of operations and maintenance issues of this type of radar system, and (2) obtaining ESH related data during the operations and maintenance (O&M) phase. A visit was also made to the Bioengineering Flight Line at Peterson AFB, Colorado, which maintains the operating, maintenance, and support services contracts for many of the Air Force bases.

Date of Estimate: September 1997
Office Symbol: ESC/FMC
Phase: Operations and Maintenance

Findings

The result of this analysis was that in typical operating mode, ESH costs are not a significant portion of operational cost for the radar site. Once safeguards were in place and ESH considerations were taken into account, the routine ESH O&M cost proved to be minimal. The average annual ESH cost is approximately $330K, not including one time items such as training or the vaulted tanks, and represents approximately 10% of the total O&M budget (1993-1996 data points), not a significant factor. Initial siting costs associated with ESH were approximately $750K (FY97$) for environmental impact analysis (site analysis, radiation analysis, etc.). This analysis focused on the operational costs associated with ESH and have touched on some of the processes and estimated the cost of disposing of the system and decommissioning the site.

Of the O&M costs associated with ESH, the greatest portion is staffing. The environmental and safety staff consisting of 2 environmental engineers (1 prior to 1998) and 1 safety engineer is required to perform routine analysis, documentation, hazardous material pharmacy management, inspection support, and have a proactive approach and take precautionary measures to avoid ESH risk to cost and schedule of the program (such as the 1990 oil spill). The ESH support is two to three personnel out of the approximate 130 operating and maintaining the site.

In absence of environmental precautions (single hull storage tanks in the ground), the consequences proved costly to the program. In 1990, there was an oil spill that resulted in an additional cost to the program of $1.7M (FY90$) for the initial repair and clean-up costs. Additional costs are still mounting for continual monitoring and testing, and staff time to support various inspections are also a result of the spill.

The operations of the radar site is not hazardous material intensive, therefore the disposal cost of these materials is minimal. The breakout of hazardous material disposal illustrated that the most costly disposal (cumulative over 4.5 years) materials were oil and fuel related (filters, rags, empty drums, soil), paint waste (empty cans, rollers, etc.), and antifreeze disposal. The most expensive disposal material on a per pound basis was paint aerosols.

Demilitarization and disposal (D&D) cost is based on similar radar sites that were decommissioned. A decommissioned site normally is placed on warm caretaker status which means the site can go back into operation in 18 months or on cold caretaker status which means the site will not be used again as a radar site. Warm caretaker status involves placing a crew of eleven contractors at the site 24 hours/day, 365 days/year, to maintain the engineering systems. To place a site on cold caretaker status means the following activities need to be performed:

- cancel permits (part of environmental engineer/coordinator's tasks)
- turn off utilities
- perform an environmental baseline survey (EBS) which costs around $32K to look at past contamination, if any, in preparation for selling the real estate
- perform an environmental assessment (EA) which costs around $28K to see what environmental consequences are involved with removing the radar faces

The following sections show the ESH costs in more detail, what documents were reviewed, what were the lessons learned, and what questions were asked to help flush out ESH issues and concerns.

Determine the Appropriate WBS for the Estimate

The Fielding/Deployment and Operational Support portion was based on the MIL-HDBK-881 WBS, the Operating and Support (O&S) portion was based on the Office of the Secretary of Defense (OSD) Cost Analysis Improvement Group (CAIG) Operating and Support Cost Estimating Guide, and the D&D portion was based on Environmental Cost of Hazardous Operations (ECHO) WBS. The WBS is as follows:

- Fielding/Deployment and Operational Support
  - Operations and Support
    - Mission Personnel
      - Operations
      - Maintenance
        - Organizational Maintenance
        - Intermediate Maintenance
        - **Other Maintenance Personnel: Inspections and tests - ESH Cost**
      - Other Mission Personnel
    - Unit Level Consumption
      - **Fuel and POL - Not ESH Cost**
      - Consumable Material Repair Parts
      - Depot Level Reparables
      - **Other: Hazardous waste disposal - ESH Cost**
    - Contractor Support
      - Interim Contractor Support
      - Contractor Logistics Support
      - **Other: 2 environmental and 1 safety engineers plus training - ESH Cost**
    - Sustaining Support
      - Sustaining Engineering Support

Software Maintenance Support
Simulator Operations
Other: ESH related permits, penalties/fines, plans and other ESH documentation - ESH Cost
Indirect Support
Personnel Support: Specialty training for ESH - ESH Cost
Installation Support

Demilitarization and Disposal
Facilities
Facilities Deactivation/Equipment Dismantlement - Not ESH Cost
Facility Decontamination - ESH Cost
Equipment/Systems/Materials
Demilitarization and Disposal Process Equipment/Facility Design and Construction
Interim Storage
Disassembly, Disposition, and Disposal - ESH Cost

Step Two – Specify Estimating Methodology

ESH Estimating Methodologies Used

There were no factors or CERs used in this analysis. The methodology for the analysis was data research through interviews, document search and research into disposal costs (utilizing DRMO actuals for cost of the hazardous waste transport and disposal costs). The following sections will elaborate on beneficial portions of the research found, specific questions asked, that may prove useful to estimators of other such systems and lessons learned from this effort.

Data Sources

- Hazardous Waste Management Plan, 27 March 95 - provided the purpose, goal, objectives, and scope
- Spill Prevention and Response Plan, 28 March 95 - provided the policies and training levels
- Asbestos Management and Operations Plan, 15 February 95 - provided the requirements, responsibilities, training, and budget
- Hazardous Materials Manifests, 1986 through 1996 - provided list of HAZMATs that were shipped from Site R for disposal
- 1995 Air Emissions Inventory, January 97 - provided the 1995 chemical usage by chemical composition

Questions Posed to the Site Environmental Engineer and Functional Area Representatives

Many of these questions lead to other questions that were not apparent until the answers from the initial questions were received. This process involved many rounds of contacting the site and asking questions during the analysis period.

1. How is the water treated for human consumption? With what chemicals? Is the water treated for any other use?
2. What hazardous materials (HAZMATs) are used and what hazardous wastes are generated? Examples would be:
   a) How many pounds of paints/thinners and what are the types and uses?
   b) How many pounds of used solvents and what are the types and uses?

c) How many pounds of lead/acid batteries and what are the types and uses?
d) How many pounds of used oil and what are the types and uses?
e) How many pounds of primer and adhesives and what are the types and uses?
f) How many pounds of acid and what are the types and uses?
g) How many pounds of misc. solid/liquid waste and what are the types and uses?

3. How are the hazardous wastes disposed of?
4. Are you a small-quantity generator of hazardous waste (200 to 2200 lb./month)? If not, do you have a RCRA permit?
5. How are solid wastes disposed of?
6. Do you have a Spill Prevention and Response Plan? What is the cost of this plan?
7. Do you have a HAZMAT pharmacy system?
   a) What is the status and cost of this system?
   b) What are the pros and cons encountered so far?
8. Are there satellite accumulation points (SAPs) for temporary storage of HAZMATs and hazardous wastes? If yes, how are the SAPs maintained? How are the hazardous wastes handled and stored?
9. Do you have a Hazardous Waste Management Plan? How much did this plan cost or how much staff effort did it take to complete this plan?
10. How is the power plant fueled? What and how much waste does it generate? How is the waste disposed of?
11. Do you burn any of your used waste such as waste oil, rags, etc.?
    a) What about air pollution? What is being done about it?
    b) Do you do emission testing? How often? Results? Cost of the testing?
    c) Do you have a list of air pollutants? How much are attributed to the radar operation?
12. Safety and health:
    a) Do you have a Radiation Protection Program?
    b) What is the status, frequency, and cost of this program?
       i) Training cost? How often are classes held and where?
       ii) Manual preparation, update, and reproduction cost?
       iii) Monitoring cost? Cost of dosimeter badges?
       iv) Medical examinations cost? How often are they given?
    c) Where do you measure for ground-level radiation? How far is the radiation security fence from the radar face? Cost of radiation study?
13. What is the cost for the contract for environmental support? How much is attributed to the O&M of the radar itself?
14. Ditto for the Hazardous materials program managed by a contractor?
15. Are there above and underground storage tanks? Is there a leak detection monitoring system for the tanks? If none, how are leaks handled?
16. Do you have any sites of potential contamination? If yes, where are and what is the status of these sites? The cost of cleaning up these sites?
17. Do you have an Asbestos Management Plan and Asbestos Operating Plan? If yes, what is the cost and status of these plans?
18. Do you have PCBs? Are there plans to remove and/or replace these PCBs? Schedule? How much will this cost?
19. Is there lead paint? What will be done about the lead paint situation? Do you have a lead paint management plan? What is the cost?
20. Are HAZMATs disposed of through DRMO? Do you have the data for cost for the DRMO disposals?
21. Does the radar operation cause nearby interference? If yes, what if any, action is taken? What is the cost? Do you have restricted air space near and above the radar range?
22. Are there any other environmental, safety, and health issues/concerns?
23. Aviary/wildlife studies conducted? What are the costs of these studies?

Step Three - Summarizing the ESH Costs

ESH Values Cost Summary

Some of the costs mentioned, initially thought would be ESH related, upon further definition, turned out to be operating costs. These costs are identified in the cost summary as "Not ESH Cost".

1. Recurring
   - Resources (Not ESH Cost)
     - electricity: $100K/mo
     - oil, fuel: 60K gal/yr.
       - 5 locomotive-type generators: 45K gal/yr.
       - heating: 15K gal/yr.
     - water: 5.5 M gal/yr.
   - Hazardous Waste Disposal Costs in FY97$K (ESH Cost): See the Table on following page
   - Permits (ESH Cost)
     - EPA air permit: $1,000/yr.
     - Small Quantity Generator (SQG) Hazardous Waste Permit: $300/yr.
   - Inspections
     - ground water test, soil VOC & Test pH, 1/yr for 5 years (1993 to 1997), performed by a contractor: $8,000 - ESH Cost
     - emission testing 1/mo (in-house, but an air emission study was performed early 1997 to measure emissions in 1995) - part of environmental engineer's tasking - ESH Cost already included in Personnel
     - radiation testing conducted every 2-3 years - 2 people for 2 days of testing plus 2 days travel and per diem: 2 people * 4 days @ $160K (this rate includes TDY costs) - ESH Cost
     - PCB investigation - $75/sample for 11 samples plus 2 people for 3 days of sampling plus 2 days travel (from SPACECOM, Colorado) and per diem: 2 people * 5 days @ $160K + $75/sample * 11 samples - ESH Cost
     - Industrial Hygiene Program - part of environmental engineers' tasking - ESH Cost already included below in Personnel
     - no lead paint sampling has been done - normally project specific (will do sampling only if the item needs to be scraped and repainted and normally the sampling is included in the A&E's SOW)
     - environmental IG - part of environmental engineers' tasking - ESH Cost already included below in Personnel
     - mobile QA - part of environmental engineers' tasking - ESH Cost already included below in Personnel

Hazardous Material Disposal Cost Summary (FY97$K):	1993	1994	1995	1996	1997 To-Date	1998 Budgeted	Total
Aerosol cans, flammable gas	2.44	-	-	-	-	-	**2.44**
Spill debris and items w/ diesel fuel & oil (sand, rags, filters, etc.)	8.16	2.76	1.32	0.11	0.02	-	**12.38**
Ethylene glycol	1.30	0.57	0.04	0.15	-	-	**2.05**
Waste corrosive scale inhibitor	0.93	-	-	-	-	-	**0.93**
Batteries & battery acid	0.04	0.25	1.41	-	0.32	-	**2.02**
Paint thinner, brushes, pans, rollers, cans, waste paint	1.26	4.97	0.55	0.02	-	-	**6.80**
Waste oil, diesel fuel, solvents, and water	2.16	1.45	0.68	4.11	0.83	-	**9.23**
Non-hazardous soda bath	-	0.06	-	-	-	-	**0.06**
Diluted sulfuric acid electrolyte	-	-	0.10	-	-	-	**0.10**
Cleaning compound	-	-	0.05	-	-	-	**0.05**
Waste antifreeze	-	-	-	2.66	1.51	-	**4.16**
Surcharge for expedited removal	-	-	0.99	0.77	0.80	-	**2.56**
Total (FY97$K)	**16.28**	**10.05**	**5.15**	**7.82**	**3.48**	14.69	**57.47**

Table 18, Hazardous Waste Disposal Costs in FY97$K

        - drinking water 5 locations 1/mo (plumber) - Not ESH Cost
        - cooling water 1/mo - Not ESH Cost
        - oil in generators for metal particles 4/yr - Not ESH Cost
        - visual inspection of generators for leaks, level, etc. 1/day - Not ESH Cost
    - Personnel
        - 2 Environmental Engineers (2 in 1998, 1 in prior years) - ESH Cost (each at $160K/yr.)
            - ½ year effort for Hazmat Pharmacy Management - ESH Cost
        - 1 Safety - ESH Cost ($160K/yr.)
    - Training (ESH Cost)
        - ½ day ESH training for all new contractor personnel (½ day * 60 current employees * 30 days for current force * $160K)

2. Non-Recurring (ESH Cost)

        - Penalties, liabilities, fines
            - Jan 24, 1990, 11,000 gal oil spill resulted in building of vaults for the oil storage: $1.5M (FY90$) for building new vaults & removal of old tanks
            - oil spill clean-up costs: $190K (FY90$) for removal of 350 yards contaminated soil, investigative core drilling, repair damaged SATCOM utilities, fuel loss
        - TV Filters to public: $25 each
        - Plans, Documentation - the cost for the following is included in Personnel since they are part of the environmental engineer's tasking - ESH Cost
            - Hazardous Waste Management Plan
            - Spill Prevention and Response Plan
            - Asbestos Management and Operations Plan
            - Industrial Hygiene Program
            - National Cultural Resource Plan
            - Technical Orders - change orders to 'clean' the TOs
        - Oil spill containment for tanker: $60K - ESH Cost Estimate for FY98
        - Supplies for spill control team: $2.8K - ESH Cost Estimate for FY98
        - Other, Miscellaneous
            - 1995 Air Emission Study: $5K - ESH Cost
            - Wastewater Discharge Study: $35K - ESH Cost
            - Power Plant Trench Monitoring System: $6K - Not ESH Cost
            - Environmental Impact Statement (done in mid 1970s): $750K - ESH Cost

3. D&D
    - Warm Caretaker Status
        - 11 people working around the clock maintaining the engineering systems (11 people * 24 hours * 365 day * approximately $160K each) - Not ESH Cost
        - disposal: $10K to ship HAZMATs to nearest AFB plus disposal costs (these costs depend on what/how much need to be disposed of) - ESH Cost
    - Cold Caretaker Status
        - cancel permits (part of environmental engineer/coordinator's tasks) - ESH Cost
        - turn off utilities (part of operating crew) - Not ESH Cost
        - perform an environmental baseline survey (EBS): phase I will cost approximately $32K to identify contaminated sites; phase II covers the sampling and analysis and

the cost depends on the magnitude of the contamination, number of samples, etc. - ESH Cost

- perform an environmental assessment (EA): estimated $28K - ESH Cost
- disposal: $10K to ship HAZMATs to nearest AFB plus disposal costs (these costs depend on what/how much need to be disposed of) - ESH Cost

Item	Prior Yrs	1993	1994	1995	1996	1997	Estimated 1998	Total
Haz Waste Disposal		16.28	10.05	5.15	7.82	3.48	14.69	57.47
EPA Air Permit		1.00	1.00	1.00	1.00	1.00	1.00	6.00
SQG Haz Waste Permit		0.30	0.30	0.30	0.30	0.30	0.30	1.80
Ground H2O Test/Sampling		1.60	1.60	1.60	1.60	1.60		8.00
Air Emission Test					5.00			5.00
Radiation Testing			3.28			3.28		6.56
PCB Investigation				4.43			4.43	8.85
Environmental Engineer(s)		160.00	160.00	160.00	160.00	160.00	320.00	1,120.00
Safety Engineer		160.00	160.00	160.00	160.00	160.00	160.00	960.00
ESH Training					576.00			576.00
New Vaulted Oil Tanks	1,787.84							1,787.84
Oil Spill Clean-Up	226.46							226.46
TV Filters				0.30	0.30			0.60
Oil Tanker Spill Containment							60.00	60.00
Spill Control Team Supplies							2.80	2.80
Wastewater Discharge Study							35.00	35.00
Environmental Impact Statement	750.00							750.00
								-
Total ESH Related Costs (FY97$K)	2,764.30	339.18	336.23	332.77	912.02	329.66	598.22	5,612.38

Table 19, Summary of Only the ESH Related Costs in FY97$K

O&S Costs: Estimated annual O&S budget for 1997 is $3.6M per the site manager and covers material and labor associated with the O&S of the radar.

D&D Costs: Although this site is still in operation, when it is time to decommission the site, the related ESH costs, at a minimum, could be as follows:

Warm caretaker status

- $10,000 to ship HAZMATs to nearest AFB for disposal
- plus disposal cost which could be in the $10-20K range depending on what and how much needs to be disposed of

Cold caretaker status

- $32,000 for a Phase I environmental baseline survey to identify contaminated sites
- plus Phase II which can run in the hundreds of thousands depending on the magnitude of contamination, number of samples, and clean-up procedures
- $28,000 for an environmental assessment
- $10,000 to ship HAZMATs to nearest AFB for disposal
- plus disposal cost which could be in the $10-20K range depending on what and how much needs to be disposed of

Remarks/Lessons Learned

A visit to the site proved beneficial because it provided the cost analyst with the first hand look at the operation of the system and where potential problems could occur. Reviewing programmatic documentation before the site visit is essential. Documents such as the CARD and Environmental Assessment proved particularly useful to formulate questions for the environmental engineer and maintenance staff. In many cases, the environmental coordinator at the site is a contractor personnel. It is important to get their contracting officer's approval well in advance so that you can get the data from the coordinator. Another recommendation is that the cost analyst become familiar with the pertinent laws and regulations that may affect the program. Please refer to the appendix with the summary of ESH laws and regulations offers brief descriptions of these laws and regulations, or contact the program office pollution prevention or environmental representative for insights into regulatory concerns.

A note of warning: in this estimate it was difficult to get the cost data. As mentioned above, contractor personnel were reluctant to give out information. When the cost data was obtained, there were no accompanying explanation of what these costs represented. Extrapolations/allocations had to be done since in many cases, the cost of an individual item was lumped in with many other costs.

One of the positive results of this research was that we were able to tell the radar site that there is an alternative to paying for the disposal of their large quantities of lead acid batteries (564 total, each roughly weighing 40 lbs.). DRMO will find buyers for large quantities as long as the site is willing to store these batteries on-site until a buyer is found (usually 1-1/2 to 2 months). The money from the sale can either go back to the site or back to the treasury. In this particular instance, instead of paying approximately $9K for disposal of the batteries, the site can receive $1K for selling them (if they are able to store the batteries in accordance with EPA guidelines until a buyer can be arranged, which may prove more costly, but theoretically, it is an alternative for the program).

Satellite Communication Terminal

Step One - Define and Plan the Cost Estimate

The purpose of this study was to investigate the ESH costs associated with a satellite communication system. This provides the reader with an insight into the types of ESH costs associated with the life cycle of electronics systems.

Background Information

Weapon System: This is a satellite communication system that provides secure, jam resistant worldwide communications to meet the essential wartime requirements for high priority military users. For this analysis, the analysts were concerned with just the terminal segment of the satellite communication system. The terminal is comprised of roughly 15 to 20 line replaceable units (LRUs). These LRUs are electronic boxes (modems, printers, receiver, time code generator, high power amplifier, processors, display consoles, etc.) and an antenna with radome, depending on the configuration type (ground fixed, transportable, airborne, etc.) the number of boxes and antenna/radome types vary.

Date of Estimate: September 1997
Office Symbol: ESC/FMC
Phase: Production and Operations and Maintenance (O&M)

Findings

The initial analysis of the test bed terminal and production costs associated with ESH and the electronic system has found insignificant costs. To date, research shows ESH-related costs represent only a few dollars of the average annual O&M cost (FY1993 to FY1997) per terminal. The ESH-related costs on the program as a whole represent approximately 0.005% of the O&M costs from FY1993 to FY1997. The research team is pursuing the O&M costs and DRMO disposal costs per terminal, but have found minimal ESH costs. Programmatic schedule slip costs that may have occurred due to an ESH issue have not been included in this estimate.

This analysis assumed that the contract is paying the majority of the costs associated with ESH in production. Those costs will in some form be passed back to the government, but it is in the best interest of the production contractors to run a ‘clean shop’ (economically and for reputation). The researchers did not have insight into the ESH costs allocated solely to this program at the production sites. In general, the production of electronic boards involves many hazardous materials from photo-related chemicals to cleaning and etching acids/solutions. A cost that was captured which was directly related to the program was the identification and elimination of ozone depleting substances (ODSs) from all program documentation drawings. The program was re-competing additional production terminals and used the original drawings for the technical definition of the system. FAR Subpart 23.8 prohibits the Government from requiring a contractor to use ODSs in the performance of a contract. Therefore, the drawings could not require the use of ODSs in any of the drawings in the contract. The cost of “cleaning” the procurement drawings was approximately $2M in FY93 dollars.

There were two incidents in the production of the system that could have, or did affect the cost and schedule of the system. In the production of the radome, there was an air emissions compliance issue because the contractor was in a non-attainment area and the coating had a high volatile organic compound

(VOC) content. The contractor had implemented a process where they bought VOC credits so that the radomes could be painted. Through careful planning, the contractor was able to avert schedule slips and cost growth.

There are few hazardous materials contained within the terminal. The system includes typical hazardous materials associated with electronics. EPA 17 HAZMATs in the terminal include: tin/lead solder, strontium chromate primer, cadmium plating, chromic acid anodize, nickel plating, zinc chromate primer, nickel/iron alloy, and other HAZMATs include NiCad batteries and beryllium oxide in the traveling wave tube (TWT). Of these hazardous materials identified, there are few operational costs associated with them. Batteries are first reconditioned, then at the end of their useful life, are disposed of via DRMO at approximately $0.43/lb. Approximately 3-5 batteries, each weighing approximately one pound, are disposed of annually on a per terminal basis. The beryllium oxide is completely enclosed within the TWT and laser sealed and does not require special handling procedures. The beryllium is not hazardous in normal operations procedures; the health hazard exists during machining because the fine airborne particles are carcinogenic. At this stage of our system, the TWTs are under warranty, so disposal is the manufacturer's responsibility. When the warranty expires, the disposal costs associated with the TWT will be charged to the depot, but those costs are unclear at this time.

There are no significant safety and health issues during the O&M of the terminals. The system contains many safeguards against accidental exposure to RF radiation or shock from the high voltage cables. The antenna has an automatic shut off when the hatch to the roof (antenna location) is open. At the test facility, where the terminals are not in the closed door cabinets and sound dampened, there is a constant loud humming, so there is potential for slight hearing loss. At the test site a safety-training course is conducted every year for the contractor O&M staff, estimated at ½ hour per person.

The following sections show the ESH costs in more detail, what documents were reviewed, what were the lessons learned, and what questions were asked to help flush out ESH issues and concerns.

Determine the Appropriate WBS for the Estimate

The following Development and Production portion was based on the MIL-HDBK-881 WBS, the Operating and Support (O&S) portion was based on the Office of the Secretary of Defense (OSD) Cost Analysis Improvement Group (CAIG) Operating and Support Cost Estimating Guide, and the D&D portion was based on the Environmental Cost of Hazardous Operations (ECHO) WBS. The WBS is as follows:

Electronic/Automated Software System Development
- **Systems Engineering/Program Management (SE/PM): Environmental Assessments - ESH Cost**

Electronic/Automated Software System Production
- PMP
- Platform Integration
- Systems Engineering/Program Management (SE/PM)
    - **Systems Engineering (SE): Environmental engineer - ESH Cost**
    - Program Management (PM)
- System Test and Evaluation (ST&E)
- Training
    - Equipment
    - **Services: Safety training - ESH Cost**
    - Facilities
- Data

Technical Publications
Engineering Data: Identification of ODSs in specifications and drawings - ESH Cost
Management Data
Support Data
Data Depository
Peculiar Support Equipment (PSE)
Test and Measurement Equipment
Support and Handling Equipment
Common Support Equipment (CSE)
Test and Measurement Equipment
Support and Handling Equipment

Operations and Support (O&S)
Mission Personnel
Operations
Maintenance
Organizational Maintenance
Intermediate Maintenance
Other Maintenance Personnel
Other Mission Personnel
Unit-Level Consumption
Fuel and POL
Consumable Material/Repair Parts
Depot-Level Reparables
Other: Disposal of hazardous waste - ESH Cost
Intermediate Maintenance (External to Unit)
Maintenance
Consumable Material/Repair Parts
Other
Contractor Support
Interim Contractor Support
Contractor Logistics Support
Other: ESH training - ESH Cost
Sustaining Support
Sustaining Engineering Support
Software Maintenance Support
Simulator Operations
Other: Penalties, fines, documentation, plans - ESH Cost
Indirect Support
Personnel Support
Installation Support

Demilitarization and Disposal
Facilities
Facilities Deactivation/Equipment Dismantlement **-** Not ESH Cost
Facility Decontamination - ESH Cost
Equipment/Systems/Materials
Demilitarization and Disposal Process Equipment/Facility Design and Construction
Interim Storage
Disassembly, Disposition, and Disposal - ESH Cost

Step Two - Specify Estimating Methodology

ESH Estimating Methodologies Used

There were no factors or CERs used in this analysis. The methodology for the analysis was data research through numerous interviews, document search and research into disposal costs. This section will elaborate on beneficial portions of the research found, specific questions asked, that may prove useful to estimators of other such systems and lessons learned from this effort.

Data Sources

- Identification of Ozone Depleting Substances (ODSs) in Procurement Documentation, 2 March 94 - listed all ODSs in terminal drawings and documentation
- Identification of Hazardous Materials in Procurement Documentation, 25 April 94 - listed all HAZMATs in terminal drawings and documentation

Questions Posed to SPO Engineers and the Test Site Manager

1. How is the terminal maintained, i.e., what are the maintenance procedures?
   a) Are HAZMATs used? What solvents, paints, paint thinners, lead/acid batteries, oil, etc., are being used? What about PCBs?
   b) Are hazardous wastes generated?
   c) How are HAZMATs handled, stored, disposed of?
   d) At which Depot is the terminal maintained?
   e) Who is the vendor for the radome?
   f) Are there air emissions testing or inspections?
   g) Are there radiation studies or tests performed?
   h) Do you have training for handling HAZMATs and hazardous wastes? Or any other training related to safety?
2. How are HAZMATs/hazardous wastes disposed of?
   a) What happens when something is not repairable? Where does it go and who takes it away?
   b) Are any spent solvents, oily rags, etc. disposed of through DRMO? What are the costs associated with these actions?
   c) Do you recycle some of your wastes? What are the recycling efforts associated with above?
3. Do you have a HAZMAT management plan? Are there other plans, documents, procedures for ES and/or H?
4. Any other environmental issues/concerns?
5. Any safety and health issues/concerns?
6. What health and safety precautions are taken by the technicians when fabricating the TWTs? For example, do they wear protective garments, masks (so they inhale the beryllium oxide dust), ear mufflers (if there are loud machining, etc.)? Are industrial hygiene surveys required? What about medical exams? Roughly what percent of the overhead can be attributed to environmental, safety, and health (ESH) issues and concerns?
7. How are TWTs disposed of? Is the beryllium oxide removed first? Are the procedures different after the warranty period?
8. Are any parts recycled?
9. Who pays for disposal? If the US government (SPO), then what amount, if any, was in the contract?

Step Three - Summarizing the ESH Costs

ESH Value Cost Summary

Some of the costs mentioned, initially thought would be ESH related, upon further definition, turned out to be operating costs. These costs are identified in the cost summary as “Not ESH Cost”.

Development:
- Programmatic Environmental Assessment (EA): $80K
- Two site specific EAs : $50K each for a total of $100K - ESH Cost

Production:
- SPO ESH staff: 1/4 staff year per year in Production (1993, 1994), 1/8 staff year (1995 – 1997) - ESH Cost
- Production Contractor identified ODSs and EPA 17 in drawings, documents, and TOs: $2.036M in FY93$ or $2.2M in FY97$ - ESH Cost
- Safety training: ½ hour each year per person per year (test site ~60 people) - ESH Cost

O&M:
- Estimated O&M of a terminal: approximately $400K/year - Not ESH cost
- Depot ESH costs for electronic system: unknown at this time. The amount of ESH cost for avionics at the depot was relatively small. Some percentage of the Depot business is related to ESH regulations, requirements and use of hazmats in the electronic system maintenance, but the percent attributed to this terminal has not been tracked.
- Battery disposal per terminal: 5 NiCad batteries per terminal disposed of each year each weighing approximately 1 lb. - disposal cost is approximately $0.43/lb - rate varies per DRMO site (where terminal is fielded) - ESH Cost
- Radome re-paint: $2000 to repaint a radome (Not All ESH Cost – some percent of this cost is associated with ESH precautions and regulations)

D&D
- Radome disposal: currently there is no disposal plan but an engineering assessment is that the radome will be ground up and compact after removing the base aluminum ring;
- TWT disposal: per overseas vendor - cost unknown at this time - ESH Cost
- Electronics disposal cost (lead solder issues) - ESH Cost

The table below displays the Programmatic ESH Costs. Values have been rounded to the nearest 1000 dollars. Values are in FY97$.

Programmatic ESH Cost	**Prior Yrs**	**1993**	**1994**	**1995**	**1996**	**1997**	**Total**
KTR ODS Identification		2,203					2,203
Programmatic EA	80						80
Site EAs	100						100
Environmental Engineer(s)	40	40	40	20	20	20	180
Safety Training – Test Site		2	2	2	2	2	12
Total (FY97$K)	**220**	**2,246**	**42**	**22**	**22**	**22**	**2,575**

Table 20, Summary of ESH Related Costs in FY97$

O&M Costs: Estimated annual O&S budget for 1997 is $400K per terminal. On a per terminal basis, only the annual battery disposal cost has been identified. Further research is needed to establish the O&S cost for ESH of the electronics system at the depot and an operational site.

Remarks/Lessons Learned

A terminal test site was visited to gain insight into the operations and maintenance of the terminal and the use of HAZMATs during this segment of O&M. This site visit was beneficial because it provided the cost analyst with the visual picture of what the weapon system is and what potential problems could occur. Becoming knowledgeable about the weapon system prior to any site visit is strongly recommended. Obtain copies of documents such as the CARD and Environmental Assessment and formulate questions to ask of the environmental engineer and operations staff. In many cases, the environmental coordinator at the site is a contractor personnel. It is important to get their contracting officer's approval well in advance so that you can get the data from the coordinator. Another recommendation is that the cost analyst become familiar with the pertinent laws and regulations that may affect the program. Contact the program office pollution prevention or environmental representative for insights into regulatory concerns.

These terminals are sited on both air and ground locations which made tracking of disposal issues difficult (as many sites have different DRMO office locations). The TWT is supplied by an overseas vendor, so the vendor's host country's environmental rules and regulations apply to the manufacturing and disposal process.

Overall, the researchers found that the ESH costs associated with most electronic boxes are insignificant when compared to the total costs over the life cycle of the system. Remember the D&D and O&M ESH costs have not been captured in this study.

Appendix B – Trade Studies

Hush House Fire Suppression System Modification Program

Summary

This example will attempt to demonstrate the manner in which effective integration of ESH costs in both trade studies and PCEs can significantly influence and support Program Manager's informed management decisions. Halon 1301 is a Class I Ozone Depleting Substance (ODS) and has been out of production since 1995. Most of the 100 Hush Houses in the United States inventory use almost 3,000 pounds of Halon 1301 each for fire suppression. A number of inadvertent discharges recently resulted in the search to develop a modification program to replace the Halon 1301 systems with a more supportable and cost effective fire suppression system. Twenty-three potential fire suppressants were initially reviewed that could possibly meet the technical and cost requirements. These were screened down to four final candidates: Hydroflorocarbon (HFC) 227ea, HFC 23, Inert Gas, and Aqueous Film Forming Foam (AFFF)/Clean Gas. A detailed analysis was then performed on the final four alternatives that determined the Inert Gas was the most cost effective fire suppressant over the life cycle of the system. Four key issues were noted in this example. The cost analyst was an integral part of the Integrated Product Team (IPT); ESH cost contributions were significant contributions to informed decision-making during the trade study; Life cycle cost information (including ESH contributions) was available but not necessarily in the program office and; A computer-based life cycle cost model was not required to develop quality life cycle cost estimates.

Step One – Define and Plan the Trade Study

Establish the Technical Baseline to be Estimated

Background Information

Hush Houses are large hanger-like structures that are used to minimize noise pollution from aircraft engines. Aircraft engines are run in Hush Houses to ensure flight worthiness after an engine overhaul or maintenance action. Because Hush Houses support maintenance, they are managed as special purpose maintenance equipment. There are three types of Hush Houses: T-9, T-10, and T-12. These vary in size and quantities in the inventory with the T-10 being the largest and most numerous.

The T-9 is actually a test cell for testing large aircraft engines (e.g., C-135, C-17, and C-5). There are twenty-three T-9s subject to modification in the inventory. The T-10 can accommodate a fighter aircraft or an engine on a test stand. There are eighty-five T-10s subject to modification. The T-12 is a smaller version of the T-10 and can accommodate trainer aircraft. There are six T-12s, all of which are candidates for modification.

The probability of a fire is most significant after an engine overhaul or major maintenance action. A Halon 1301 fire suppression system is installed in Hush Houses to protect the cockpit maintenance personnel controlling the aircraft engine, the aircraft, and the Hush House structure itself. Halon 1301 is a Class I Ozone Depleting Substance (ODS) and has been out of production since 1995. Most of the one hundred Hush Houses in the inventory have almost 3,000 pounds of Halon 1301 installed for each system. At current prices, the replacement value of this Halon is over $100,000 per Hush House. Recently, a number of inadvertent discharges resulted in the User Major Commands (MAJCOMs) requesting the Hush House Single Manager (SM) to develop a modification program to replace the Halon 1301 systems with a more supportable and cost effective fire suppression system.

The Hush House SM formed an Integrated Product Team (IPT) comprised of representatives from User MAJCOMs and specialists in systems engineering, fire protection, environment, safety, health, and cost estimating. The cost analyst participated in all IPT meetings to ensure other members considered life cycle cost considerations in their analyses and to ensure he understood the technical issues that affect life cycle cost. The IPT generated a series of analytical and management documents that will support an informed Air Force decision to replace the Halon 1301 fire suppression system with the most cost effective system. The documents included a draft Operational Requirements Document (ORD); Analyses for Fire Hazards, Environmental, Safety, and Health; a Life Cycle Cost Report; and a Single Acquisition Management Plan (SAMP).

Alternatives Considered

Due to the time constraints imposed by the operational need to replace the Halon 1301 systems, the SM identified certain narrowing criteria:

- The candidate system must meet the draft ORD
- Only commercially available candidates would be considered
- Only candidates that met the current EPA Significant New Alternatives Policy (SNAP) for Halon 1301 replacements in normally occupied spaces would be considered (when operating, there will be at least one person in the hush house)
- Only candidates that would pose no increase in ESH risks over those imposed by Halon 1301 would be considered (per AFI 32-7086)

Table 21 lists the initial twenty-three potential fire suppressants that could possibly meet these requirements.

The IPT first did an overall technical and life cycle cost assessment (i.e. trade study) of these initial twenty-three chemicals to include a general assessment against the SM's identified requirements. The trade study eliminated ("screened") all but four alternatives. Inert gas candidates were combined into a representative suppressant (IG-541) because they had similar characteristics. Some were eliminated because they did not meet performance requirements. One tended to suppress the fire too slowly and could result in the safety-related loss approaching $100M (e.g., loss of an F-22). Others were eliminated because they were too toxic for a normally occupied area and were not approved for occupied areas under the EPA SNAP. Two were eliminated because dispensing systems were not considered Commercial-Off-The-Shelf (COTS).

The IPT next conducted detailed analyses on the final four candidates. Conceptual designs were postulated to establish the technical baseline. From this technical baseline, a WBS structure was established.

Determine the Appropriate WBS for the Estimate

Table 22 is the detailed WBS used for this program. This structure provided the detailed life cycle costs for each of the final four candidate suppressants and will be used to build the Program Objective Memorandum (POM) submission for this modification program. ESH costs were not as significant in this step because these suppressants had already passed the first screening and were judged effective, safe, and environmentally friendly (in a relative sense). All costs are for the inventory of the various types of Hush Houses and are constant FY98 dollars.

Candidate Suppressant	Made the Final Four Candidate List	Rationale For Elimination
HFC-227ea	Yes	
HFC-23	Yes	
HFC-125	No	Not on SNAP for occupied area
HFC-236fa	No	Not on SNAP for occupied area
CF3I	No	Not on SNAP for occupied area
PFC-218	No	Not on SNAP for occupied area
PFC-410	No	Not on SNAP for occupied area
PFC-614	No	Not on SNAP for occupied area
IG-541	Yes (one representative IG was used, IG-541)	
IG-55	Yes, see note above	
IG-01	Yes, see note above	
IG-100	Yes, see note above	
CO2	No	Not on SNAP for occupied area
Water Mist	No (still pending additional data)	
Water Sprinkler/Deluge	No	Effectiveness
AFFF	No	Effectiveness
AFFF with ABC Dry Powder	No	Effectiveness
AFFF with PKP	No	Effectiveness
AFFF with CO2	No	Effectiveness
AFFF with HFC-227ea	Yes	
HEF	No	Fire out time
ABC Dry Powder	No	No COTS Flooding System
PKP	No	No COTS Flooding System

Table 21, Initial Trade Study (Screening) Results of Candidate Suppressants

Alternative Suppressants	**HFC 227ea**			**HFC 23**			**Inert Gas**			**AFFF/Clean Gas**		
Hush House Types	T-9	T-10	T-12	T-9	T-10	T-12	T-9	T-10	T-12	T-9	T-10	T-12
Initial Materials	731,000	9,945,000	281,700	714,000	9,066,695	319,998	952,000	12,155,000	342,000	1,077,800	13,472,500	399,420
Initial Installation	731,000	9,945,000	281,700	714,000	9,066,695	319,998	952,000	12,155,000	342,000	1,077,800	13,472,500	399,420
Heaters	0	0	0	0	0	0	0	0	0	34,000	170,000	12,000
Oil Water Separator	0	0	0	0	0	0	0	0	0	0	0	0
Initial Agent	748,000	9,945,000	281,700	714,000	9,066,695	318,000	189,635	2,433,975	67,836	100,640	1,258,000	37,296
NET	61,200	306,000	21,600	61,200	306,000	21,600	0	0	0	0	0	0
Testing	100,000	100,000	100,000	100,000	100,000	100,000	45,000	45,000	45,000	100,000	100,000	100,000
Procurement	2,371,200	30,241,000	966,700	2,303,200	27,606,085	1,079,596	2,138,635	26,788,975	796,836	2,390,240	28,473,000	948,136
Maintenance												
Periodic Agent Servicing	0	0	0	0	0	0	0	0	0	0	0	0
Utilities	0	0	0	0	0	0	0	0	0	0	0	0
Refilling-Accidental Discharge	7,480	99,450	2,817	7,140	90,667	3,180	1,896	24,340	678	1,006	12,580	373
Preventative Maintenance	51,000	255,000	18,000	51,000	255,000	18,000	42,500	212,500	15,000	85,000	425,000	30,000
Six Month Op. and Pre-test	13,600	68,000	4,800	13,600	68,000	4,800	13,600	68,000	4,800	13,600	68,000	4,800
Total Maintenance Costs	72,080	422,450	25,617	71,740	413,667	25,980	57,996	304,840	20,478	99,606	505,580	35,173
Environmental Costs												
Chemical Treatment	0	0	0	0	0	0	0	0	0	10,200	51,000	3,600
Permits	0	0	0	0	0	0	0	0	0	0	0	0
Other Environmental Costs	0	0	0	0	0	0	0	0	0	17,000	85,000	6,000
GWP Costs	39,352	196,759	13,889	39,352	196,759	13,889	0	0	0	39,352	196,759	13,889
Total Environmental Costs	39,352	196,759	13,889	39,352	196,759	13,889	0	0	0	66,552	332,759	23,489
Safety Costs												
Potential Loss (equipment)	0	0	0	0	0	0	0	0	0	0	0	0
Potential Loss (personnel)	0	0	0	0	0	0	0	0	0	0	0	0
Training For O&M	17,000	85,000	6,000	54,400	272,000	19,200	17,000	85,000	6,000	20,400	102,000	7,200
Downtime	0	0	0	0	0	0	0	0	0	0	0	0
Externalities	0	0	0	0	0	0	0	0	0	0	0	0
Total Safety Costs	17,000	85,000	6,000	54,400	272,000	19,200	17,000	85,000	6,000	20,400	102,000	7,200
Health Costs												
Protective Clothing	0	0	0	0	0	0	0	0	0	0	0	0
Medical Treatment/Testing	0	25,500	1,800	0	0	0	0	0	0	0	0	0
Total Health Costs	0	25,500	1,800	0	0	0	0	0	0	0	0	0
Total Annual O&S	128,432	729,709	47,306	165,492	882,426	59,069	74,996	389,840	26,478	186,558	940,339	65,862
Total O&S (20 years)	2,568,637	14,594,185	946,118	3,309,837	17,648,524	1,181,378	1,499,927	7,796,795	529,567	3,731,165	18,806,785	1,317,237
End Of Life Disposal Cost	73,100	994,500	28,170	71,400	906,670	32,000	95,200	1,215,500	34,200	107,780	1,347,250	39,942
Salvage Value Of Agent	0	0	0	0	0	0	0	0	0	0	0	0
Total LCC (FY 98 $)	5,012,937	45,829,685	1,940,988	5,684,437	46,161,279	2,292,974	3,733,762	35,801,270	1,360,603	6,229,185	48,627,035	2,305,315
Total LCC for total inventory		52,783,610			54,138,689			40,895,635			57,161,535	

Table 22, Hush House Fire Suppressant Life Cycle Cost Structure

The first block shows the four final candidate suppressants on the top line and the three types of Hush Houses on the second line.

The second block shows the initial (non-recurring) costs associated with the procurement of the fire suppression systems and includes acquisition of the system and suppressant, the cost of ancillary equipment, the installation costs, New Equipment Training (NET), and first article testing.

The third block contains the recurring Operational and Support (O&S) costs. ESH costs are identified where applicable. Each suppressant and corresponding dispensing system had its own ESH cost drivers. For example, Aqueous Film Forming Foam (AFFF) had some costs associated with risks to the environment from Biochemical Oxygen Demand (BOD). The two HFCs had some costs associated with Global Warming Potential (GWP) risks. The only health costs associated with the four were from accidental exposures at high operational temperatures from HFC 227ea. Maintenance costs were the over-riding O&S cost drivers. The AFFF/Clean Gas system had more moving parts (pumps, proportioners, valves, water tanks, concentrate tanks, etc.) and tended to have higher maintenance costs of the four. The annual O&S costs are multiplied by the projected twenty-year useful service life of the Hush Houses to arrive at the Total O&S costs.

The fourth block includes the one-time costs for disposal. The second line is listed as a "place holder" for the potential salvage value of HFCs if they become controlled substances under any future Global Warming regulations. This situation would be analogous to the significant increase in the value of Halon 1301 since the Clean Air Act Amendments of 1990 went into effect. As production ceased in this country and domestic users were unable to import Halon 1301 under the law, the cost of a pound of Halon 1301 went from approximately $5 per pound in 1989 to $35 to $75 per pound today – an excellent example of the "Supply and Demand" principle. Until Global Warming Gases are regulated, there is no way to know if the HFCs will have a salvage value. In contrast, if any new Global Warming regulation mandates the destruction of HFCs, there could be a disposal cost impact. Because both possibilities are real but speculative, entries are included at this time.

The fifth block sums the totals for blocks two, three, and four. The last line, "Total LCC for total inventory" represents the total life cycle cost for each of the four candidate suppressants. These entries are the totals for the three types of Hush Houses.

Step Two – Specify Estimating Methodology

Data Sources, Data Collection, and Data Evaluation

In the trade study phase, a number of sources were used to assess overall cost impacts associated with each of the twenty-three initial candidates. These sources are shown in the table below along with the information each provided. Probably the most important data collected were the actuals from the on-site visits to five Hush Houses and from the surveys of commercial users of similar structures. Also of importance was the after action reports of actual Hush House fires and damage estimates. Two examples of how these data were integrated to influence informed trade study decisions are provided for illustrative purposes:

- Example #1 - Factors based on actual fire data to assess projected loses of new aircraft.

Hush House fire data from the DoD Fire Mishap Database date back as far as 1987 and therefore the associated loss costs reported must be escalated for inflation. These costs must also be scaled for the higher costs of more complicated/expensive aircraft/engines at risk in the Hush Houses today and over the next two decades. In addition, increased fire damage susceptibility of composite aircraft when compared with existing metal aircraft must also be considered.

Sources	*Data Obtained*
AFI 65-503	Cost & planning factors to support O&S labor costs
AFI 91-204	Costs for personnel injury, illness, and fatalities for safety and health-related cost estimates
MIL-STD-882C	Methodology for assessing probability versus severity and the related costs
SMC LCC Guide	Provided insight and guidance for conducting effective LCC estimates
Joint Group on Acquisition Pollution Prevention (JG-APP)	When completed JG-APP will provide a DoD-wide methodology for conducting ESH portions of LCCs
On-site visits	Actual costs associated with Procurement and O&S of current fire suppression systems
DoD Fire Mishap Database	Actual fire losses from which aircraft value versus projected damage factors were established
Aircraft Program Offices & SAMPs	Current estimates for aircraft costs used for loss projections
Engine Program Office	Current estimate for aircraft engines used for loss projections
Hush House Technical Orders	O&S requirements associated with maintenance intervals used for recurring maintenance costs
Surveys of Commercial Users and Suppliers	Actual installation and O&S costs of similar structures from which analogies could be drawn

Table 23, Sources and Data Obtained from Each

For example, the 1992 aircraft fire report lists the total value of the aircraft at $39,000,000 with a loss of $200,000. Assume this aircraft was a metal aircraft (e.g., F-15, F-16, etc.). The fire damage ratio for this fire scenario is .5%. This is arrived by calculating the ratio of "damage incurred" to "aircraft value" (i.e., $200,000/$39,000,000). For a similar fire involving a more expensive aircraft (such as the F-22), the projected damage is $493,000. This figure is arrived by multiplying the "fire damage ratio" (i.e., .5%) by the "aircraft value" (i.e., $98,500,000 from the latest SAMP). This calculation is conservative because it assumed a linear extrapolation of metal aircraft damage to composite aircraft damage for the same fire. Analyses concluded that composite aircraft could experience significantly more fire damage than metal aircraft for the same fire scenario. Even if a 10% damage increase was assumed for composite aircraft compared to metal aircraft, the projected damage would be $542,000 (i.e., $493,000 + [$493,000x.10]). In addition to this tangible cost risk, the intangible costs to the Air Force from the loss of a new F-22 or Joint Strike Fighter (JSF) prototype in a Hush House fire could be significant. Programmatic risks associated with this intangible loss must be a consideration in the informed decision dealing with how and when to implement the Hush House fire protection effort.

- Example #2 - Factors for health losses associated with exposure to burning composites.

One-time $7,000 health-related costs are associated with First Responders' exposures to aircraft composite pyrolysis products. This is based on the F-117 crash and fire in Baltimore, Maryland. Fifteen First Responders were hospitalized for one day and released [15 people x $466/day from AFI 91-204].

Selection of Estimating Methodology

An activity based management and cost estimating methodology was selected based on the following reasons. First, the knowledge that no single computer-based model existed to support the effort and second, the requirement to include direct as well as indirect life cycle costs. A "stubby pencil" approach was used that provided a quality estimate from which an informed decision could be made.

Step Three – Summarizing Life Cycle Cost Drivers and Supporting Informed Program Decisions

After the initial screening, the PCE was generated on the four final candidates. The PCE used an activity based management and cost approach. This approach provided the necessary framework and mindset to determine direct as well as indirect life cycle costs. The SM will use the PCE to generate a POM wedge for this modification program.

The PCE provided the necessary information for the Financial Management section of the Program's SAMP and served as the foundation for the POM submission data. The trade study and PCE are critical steps in the final cost estimating products in support of informed decisions. The ESH life cycle cost contributions to the overall PCE were minimized by a thorough and well-executed trade study effort. Without this trade study effort, the choice of the wrong suppressant could have resulted in a safety-related loss that is twice the value of the current PCE.

Remarks

The Hush House Fire Suppression System Modification Program provides a good example of integrating ESH life cycle cost considerations into the trade study process and the overall PCE. This program demonstrates the importance for the cost estimator to be fully integrated into the IPT. Lastly, this program demonstrates that the lack of a computer-based model does not preclude effective life cycle cost estimates. Following are key issues to note realized from this trade study.

- **The cost estimator was an integral part of the Integrated Product Team.** This brought about two important results. First, the cost estimator ensured the technical members of the IPT considered life cycle costs (to include ESH contributions) in their analyses supporting the trade study. Second, the cost estimator became familiar with technical issues that could drive the life cycle costs. The cost estimator in this case had no technical background in fire fighting or Hush Houses but gained sufficient knowledge from the IPT to generate a quality estimate.
- **ESH cost contributions were significant inputs to informed decision-making during the trade study.** Safety-related life cycle cost drivers dwarfed all other life cycle costs (even environmental and health life cycle costs combined) during the trade study portion of the effort. A safety-related loss approaching $100M was identified. This loss was likely with some of the candidate suppressants considered in the trade study. This impact is more than double the entire life cycle cost of more effective suppressants.
- **Life cycle cost information (to include ESH contributions) was out there – but not necessarily in the program office.** The cost estimator had to collect data from a very wide range of sources. The technical members of the IPT played a critical role in "pointing" the cost estimator in the right direction. This integration and interface of the cost estimator with the technical members of the IPT saved time during the data collection phase and resulted in a higher quality estimate than if the cost estimator had to research this information from scratch.
- **A computer-based life cycle cost model is not required to develop quality life cycle cost estimates.** This life cycle cost effort was done without reliance on a computer-based life cycle cost model. A single model for determining life cycle costs, particularly the ESH-related portion, does not exist. Most life-cycle models are focused on environmental life-cycle costs. The United States Army Center for Health Promotion and Preventative Medicine (USACHPPM) developed a health-related database that provided the best data for health costs. No DoD safety-related life cycle cost model exists.

Coating Removal Process for Helicopter Remanufacture

Summary

The purpose of this trade study was to integrate ESH costs and considerations into a cost-benefit analysis comparing the FLASHJET® process, bicarbonate of soda system (BOSS) and a conventional liquid chemical stripper for coatings removal on the remanufacture of the Apache (AH-64) model helicopters into the Longbow models. A simple comparison analysis of the cost and technical evaluation criteria was utilized to determine the "optimum" alternative. The selection of the FLASHJET® process was an excellent example of how pollution prevention and worker safety can be incorporated into a manufacturing process that reduces production costs.

Step 1 - Define and Plan the Trade Study

Establish the Technical Baseline to be Estimated

Background Information

With the growing concern in industry over environmental, safety, and health issues, all aspects of aerospace processing are being reviewed for safer ways of producing aircraft. One process under intense study is the removal of coatings from aircraft and aircraft parts. Whenever a surface requires recoating, whether due to damage, wear, or weight concerns, the old coatings must be removed to provide a surface on which the new coating can adhere. In the past, paint removal has required toxic chemicals or some mechanical abrasion. The chemicals used have included methylene chloride and phenol. Mechanical abrasion involves manual sanding or abrasive blasting. These processes are labor intensive. They also generate large amounts of hazardous waste and can be unsafe for personnel performing the work. New environmental rules are constantly being promulgated in the air, water, and waste disposal areas. These new rules are making it increasingly difficult and expensive to use liquid strippers and then dispose of the waste they generate. The National Emission Standard for Hazardous Air Pollutants (NESHAPs) for the aerospace industry, promulgated in September 1995, prohibits the emission of non-exempted organic hazardous air pollutants from chemical strippers or softeners. In the future, liquid strippers may only be allowed for touch-up work and not for use in full-scale stripping. As workers become more aware of the nature and hazards of stripping media, they are justly demanding more and better Personal Protective Equipment (PPE). Acceptable PPE for liquid and abrasive stripping includes a sealed suit, gloves, boots, and a helmet supplied with breathing air. Care must be taken to monitor personnel for hypothermia while they are wearing appropriate PPE. It is also important to have the operations performed in dedicated areas so that the waste generated can be more easily contained and controlled.

Alternatives Considered

Chemical strippers work by dissolving or chemically breaking molecular bonds. Unfortunately, the same types of compounds used to make aircraft paints, polyurethanes and epoxies, are also used to make resin systems for advanced composites. Any chemical that can destroy these paints will also deteriorate the resin/fiber-based composite substrate materials. Methylene chloride-based strippers have been used for many years. Consequently, a significant amount is known about using these materials. There are a large number of chemical stripper formulations, so a stripper can usually be found that will work well at removing any given coating.

The **BOSS process** is known as an abrasive or mechanical blasting system. Abrasive blasting systems operate by mechanically blasting surface coatings with high-velocity air or water that is carrying an abrasive. Besides the sodium bicarbonate media, other abrasive media that can be used range from walnut shells and plastic beads to wheat starch.

The **FLASHJET® process** uses a combination of pulsed-light energy and low velocity carbon-dioxide pellets to remove paint from metal and composite surfaces. A high-intensity lamp, flashing at a controlled rate, heats the surface coating to the point where the coating becomes ablated and easily removed. A constant stream of carbon dioxide pellets are then forced across the work surface while the lamp is flashing. The gas stream velocity is kept low since the carbon dioxide is only intended to sweep away the debris and keep the underlying surface from overheating.

Determine the Appropriate WBS for the Estimate

A relative coating removal process comparison for environmental impact was developed as a common evaluation criteria for the three alternatives. The table following illustrates the coating removal steps required for each process. The more steps required for a process is directly proportional to the direct (i.e., more waste disposal, more PPE, etc.) and indirect (i.e., more chances of worker exposure increases probability of health or safety incident) ESH costs incurred.

	Wash	Mask	Apply / Dwell	Strip	Rinse	Demask	Cleanup
Flashjet™				X			
BOSS		X		X	X	X	X
Chemicals	X	X	X	X	X	X	X

Table 24, Coating Removal Process Comparison for Environmental Impact

Step Two - Specify Estimating Methodology

Data Sources, Data Collection, and Data Evaluation

Listed below are the data sources used:

1. *Organization*: Boeing - McDonnell Douglas Helicopter Systems
2. *Point of Contact for the Study*: Boeing - McDonnell Douglas Helicopter Systems (MDHS), Mr. Dennis Stearns (602) 891-5074; Boeing-St Louis, FLASHJET® Process, Mr. Wayne Schmitz, (314) 232-2921

Following is a summary of the data collection and evaluation highlights for each process with respect to the ESH cost estimating concerns.

Chemical Stripping Process:

Most chemical stripping systems have significant health concerns and are detrimental to the environment. As a result, there has been a gradual phase-out of these materials over the past several years. New chemical strippers are being produced which are environmentally safer, but most of them require a longer dwell time to work.

BOSS Process:

The BOSS system is safer for workers using it because the abrasive media is not a hazardous chemical. However, there is still a problem with airborne particles. The process must be performed inside an enclosed chamber with an air filtration system and personnel performing work inside the chamber need to wear PPE. Other drawbacks to the BOSS system are that the process is very labor intensive and extreme care must be taken when performing the blasting operation to ensure that only the coating layers are removed and not the underlying metal or composite material.

FLASHJETâ Process

The FLASHJET® Process requires no hazardous chemicals. The aircraft need not be cleaned before or after the operation. The only Personal Protective Equipment (PPE) required while performing the work are hearing protection and UV-resistant sight protection, and with its' process computerized, it also allows for much better coating removal than previous systems.

Selection of Estimating Methodology

The estimating methodology utilized for the process costs were determined from vendor quotes and internal company databases. Actual costs utilized, however, will not appear in this report due to the competitive nature of the aerospace manufacturing industry. Relative cost impacts (low, medium, high) were used for the selection the coating removal process.

Selection of Cost Estimating Tool

No special computerized model/tool was required for this analysis. A table was constructed to perform a simple comparison analysis of the cost and technical evaluation criteria.

Cost Sensitivity Analysis

Sensitive cost elements included capital investment and recurring costs. The table below illustrates the relative capital investment and recurring costs along with ESH impact and meeting technical performance for each process. It should be noted that the recurring cost reflects the inclusion of the ESH impact to cost for each process.

	Capital Investment	Recurring Cost	ESH Impact	Technical Performance
Flashjet™	High	Low	Low	Yes
BOSS	Medium	High	High	No
Chemicals	Medium	High	High	No

Table 25, Coating Removal Process Cost, ESH and Performance Comparison

Step Three - Summarizing the Results of the Trade Study

After a preliminary review, the **Chemical Stripping process** was dropped from consideration. The rationale for rejecting this system included: Amount of waste generated; cost of waste disposal; need for a specially built facility; large number of labor hours required; impending regulatory restrictions and; the potential for hazardous chemical exposure to both personnel and the environment.

The initial capital expenditure to install the **FLASHJET® Process** system was in excess of $2 million. Although this cost was higher than for the other systems considered, the FLASHJET® Process was selected because it was less costly to operate and is environmentally safer than the other coating removal processes. Over the life of the initial 232-aircraft contract, Boeing-MDHS will save more than $1 million in materials and disposal costs and over $2.5 million in labor costs by using the FLASHJET® Process system. It was also estimated that the system will allow Boeing-MDHS to generate a quarter of a million pounds less waste than would have been produced using the **BOSS system**.

Remarks

The FLASHJET® Process system was selected because it produces less waste, is less costly to operate, is not detrimental to aircraft surfaces, and is safer for the personnel performing the operation. The FLASHJET® Process is an excellent example of how pollution prevention and worker safety can be incorporated into a process that reduces production costs.

Canopy Replacement for the F-15E

Summary

The purpose of this trade study was to illustrate the integration of ESH costs and considerations into a selection process for the replacement of the canopy on the F-15E due to damage and losses resulting from birdstrikes. Four alternatives were considered that reduced the probability of a birdstrike by a factor of at least three. The total delta life cycle cost for each alternative was estimated in comparison to the existing canopy system. The total delta cost was then used with nine other evaluation criteria to select the "optimum" canopy replacement option.

Step 1 - Define and Plan the Trade Study

Establish the Technical Baseline to be Estimated

Background Information

This trade study was conducted to examine alternatives to the current transparency system (canopy) to reduce the damage to property and loss of personnel from birdstrikes on the F-15E system. The trade study was part of a concept comparison analysis that was recommended from an accident safety board following a F-15E birdstrike incident at Lakenheath, England. The cost associated with the birdstrike at Lakenheath was $500K. If an aircraft were lost due to a birdstrike, the cost would then be $50M.

Alternatives Considered

1. Increase canopy strength and eliminate Through-The-Canopy (TTC) ejection
2. Increase canopy strength and add a canopy severancing system
3. Use a low profile canopy
4. Change to a relofted windshield/canopy

Determine the Appropriate WBS for the Estimate

The table below illustrates the cost elements and costs considered for the trade study. Key drivers were the non-recurring cost, retrofit cost, delta life cycle cost above the existing canopy procurement cost (applies only to options 1 and 2 since they are modifications to existing canopy), and the total delta cost compared to the existing system. Also included are the associated predicted birdstrike penetrations.

Options for 200 Aircraft over a 20 year period	Option 1	Option 2	Option 3	Option 4	No Change
Non-recurring Cost	$3.7M	$6.2M	$2.7M	$4.3 - $6.3M	$0
Retrofit Cost	$0.2M	$2.2M	$0.6M	$4.0M	$0
Delta Life Cycle Cost	$0.1M	$2.5M	$0M	$0M	$0
Total Delta Cost	$4.0M	$10.9M	$3.3M	$8.3 - $10.3M	$0
Predicted Penetrations	1.6	1.6	2.1	1.6	6.2

Table 26, F-15E Canopy Option Costs

Step Two - Specify Estimating Methodology

Data Sources, Data Collection, Data Evaluation, and Selection of Estimating Methodology

Listed below are the data sources used:

1. *Organizations*: F-15 System Program Office, Wright Laboratory, and the University of Dayton Research Institute
2. *Point of Contact for the Study*: WL/FIV (Lt. Michael Hill)

The F-15 system program office collected the associated costs for each alternative. Estimates were obtained via vendor quotes. The cost buildup for each option included such elements as prototypes, testing, integration, and engineering support from other organizations.

Selection of Cost Estimating Tool

No special computerized model/tool was required for the cost estimating with this analysis. A table was constructed to perform a simple comparison analysis of the costs for each option.

Step Three - Summarizing the Results of the Trade Study

The table below shows the overall concept comparisons for each option. The 20 year delta cost was one of ten evaluation criteria. After reviewing the performance for each option, the F-15 system program office selected option 3, the low profile canopy, as the preferred option. As shown in table 26, option 3 provide the lowest total delta cost.

Evaluation Criteria	Option 1	Option 2	Option 3	Option 4
Birdstirke Risk Reduction	G	G	G	G
Ejection Issues	P	P	F	F
Visibility	G	F	F	G
Optics	G	G	G	G
Maintenance	F	P	G	G
Weight	P	P	G	F
Aerodynamic Performance	G	G	G	F
Technical and Schedule Risk	F	P	G	F
Aviator Feedback	P	F	F	G
20 Year Delta Cost	G	P	G	P

G = Good F = Fair P = Poor

Table 27, Overall Concept Comparison

Remarks

This trade study was very useful because it focused solely on safety. One consideration that may have contributed to the costing would have been to take the birdstrike projections and couple them with the probability of aircraft loss due to penetration. Then the cost of potential lost aircraft could have been included in the cost figures. At $50M per aircraft, a single aircraft saved would more than cover the most expensive option costs. This was not done due to the differences in the assessment of those probabilities. Aircrew losses could similarly have been included in the cost benefit numbers. The events were mentioned in the study performed but the costs were not calculated. If an O&S WBS had been used and other cost deltas for elements such as training and technical manual changes been identified, the additional costs could have been included with the four options. It is important to remember when performing trade studies to consider all cost elements that may vary across the range of alternatives.

Replacing Cadmium Plating with IVD Aluminum Coating for Corrosion Protection of Non-Standard Parts on the C-17 Weapons System

Summary

The following trade study provides the life cycle cost analysis for the replacement of cadmium plating with IVD aluminum coating for corrosion protection of non-standard parts on the C-17 weapons system. The development costs for the implementation of the IVD aluminum coating project were estimated along with the Operation & Support (O&S) cost savings compared with the cadmium plating process. The payback time for the investment in the IVD aluminum coating project was 22 months and the return on the investment over a 10-year period was 450%.

Step 1 - Define and Plan the Trade Study

Establish the Technical Baseline to be Estimated

Historically, cadmium plating has been the process used for corrosion protection of alloy steel parts including high strength alloy steels. Although cadmium performs well in the role of preventing corrosion, it is a Hazardous Material (HAZMAT). Cadmium is a toxic heavy metal, a carcinogen, and on the Environmental Protection Agency's list of 17 HAZMATs which are targeted for reduction or removal from the workplace. The cadmium electroplating process also has health hazards associated with cyanide products in the plating bath. Consequently, the EPA and Occupational Safety and Health Administration (OSHA) are restricting its usage by tightening environmental and safety directives. IVD aluminum coating also provides corrosion protection for alloy steel parts including high strength alloy steels, however, it does not have many of the associated dangerous ESH issues.

Determine the Appropriate WBS for the Estimate

Table 28 illustrates the WBS and life cycle cost results for the cadmium plated versus IVD aluminum coated non-standard parts. The development costs are for the implementation of the IVD aluminum coating project. The Operation & Support costs reflect the annual increment savings and life cycle (25 years) increment savings compared with the cadmium plating process. Table 29 shows the redistribution of the Operation and Support (O&S) cost savings from Table 28 into the Program Office Estimate (POE) format.

Step Two - Specify Estimating Methodology

Data Sources, Data Collection, Data Evaluation, and Selection of Estimating Methodology and Tool

The C-17 system program office, prime contractor (MDA/Boeing), and the Pollution Prevention IPT worked together to collect and evaluate the pertinent data for this study. This effort utilized the vast amount of existing data to qualify IVD aluminum coating as a direct replacement for cadmium plating and is part of the overall effort to eliminate HAZMATs from the C-17 weapons system. The Pollution Prevention IPT performed tests to address those areas where data was lacking. All existing C-17 cadmium plating applications ("bright" and "low embrittlement") were evaluated for conversion to IVD aluminum for McDonnell Douglas Aerospace (MDA/Boeing) controlled, nonstandard part drawings. Attachment 1 provides the MDA life cycle cost HAZMAT model inputs for the cadmium plated versus aluminum coated non-standard parts comparison. Attachment 2 provides the pertinent ground rules and assumptions and the basis for the calculations of the O&S cost savings.

	COST CATEGORY		ANNUAL INCREMENT		LIFE CYCLE INCREMENT
1.0	**DEVELOPMENT COST**				
1.1	TECHNICAL PUBLICATIONS			$	0
1.2	MAINTENANCE TASK ENTRY			$	9,067
1.3	DRAWING CHANGES			$	904,702
1.4	SUPPLIER NON-RECURRING COST			$	500,000
	DEVELOPMENT COST SUBTOTAL			**$**	**1,413,769**
2.0	**WEAPON SYSTEM COST**				
	WEAPON SYSTEM COST SUBTOTAL	**$**	**0**	**$**	**0**
3.0	**OPERATION & SUPPORT COST**				
3.1	PROCUREMENT		0		0
3.2	DIRECT MAINTENANCE		0		0
3.3	INDIRECT SUPPORT		0		0
3.4	TECHNICAL PUBLICATIONS		0		0
3.5	SUPPORT EQUIPMENT		0		0
3.6	PACKAGING, HAND., STOR., TRANS.		0		0
3.7	TRAINING		0		0
3.8	INITIAL SPARES		0		0
3.9	REPLENISHMENT SPARES		0		0
3.10	FACILITIES		0		0
3.11	PROTECTIVE EQUIPMENT				
3.11.1	EQUIPMENT	$	-51,960	$	-1,299,000
3.11.2	WORK LOSS	$	-518,918	$	-12,972,960
3.11.3	DISPENSING & TRACKING		0		0
3.12	MEDICAL				
3.12.1	OCCUPATIONAL PHYSICAL EXAMS		0		0
3.12.2	INJURY / ILLNESS		0		0
3.12.3	INDUSTRIAL HYGIENE SURVEYS	$	-8,576	$	-214,400
3.12.4	MEDICAL SURVEILLANCE	$	-38,280	$	-957,000
3.13	DISPOSAL				
3.13.1	MATERIAL DISPOSAL	$	-155,540	$	-3,888,500
3.13.2	RECYCLING		0		0
3.14	LEGAL LIABILITY				
3.14.1	DISPOSAL LIABILITY		0		0
3.14.2	EMISSIONS LIABILITY		0		0
3.15	OSHA REQUIRED RECORD KEEPING	$	-4,928	$	-271,040
	OPERATION & SUPPORT SUBTOTAL	**$**	**-778,202**	**$**	**-19,602,900**
	TOTAL LIFE CYCLE COST INCREMENT			**$**	**-18,189,131**

Table 28, WBS and IVD Aluminum Coating Development Cost and O&S Savings

COST RESOURCE CATEGORY		TOTAL INCREMENT (25 Years)
OPERATION & SUPPORT COST		
1.0 MISSION PERSONNEL		
1.1 AIRCREW		0
1.2 MAINTENANCE		0
1.3 UNIT STAFF		0
1.4 SECURITY		0
2.0 UNIT LEVEL CONSUMPTION		
2.1 FUEL		0
2.2 BASE MAINTENANCE SUPPLIES		0
2.3 DEPOT LEVEL REPARABLES		0
2.5 OTHER UNIT LEVEL CONSUMPTION		0
3.0 INTERMEDIATE MAINTENANCE		0
4.0 DEPOT MAINTENANCE		
4.1 OVERHAUL / REWORK	$	-12,972,960
4.2 OTHER DEPOT		0
5.0 CONTRACTOR SUPPORT		
5.1 INTERIM CONTRACTOR SUPPORT		0
5.2 CONTRACTOR LOGISTICS SUPPORT		0
6.0 SUSTAINING SUPPORT		
6.1 SUPPORT EQUIPMENT REPLACEMENT		0
6.4 SUSTAINING ENGINEERING SUPPORT		0
6.5 SOFTWARE MAINTENANCE SUPPORT		0
7.0 INDIRECT SUPPORT		
7.1 PERSONNEL SUPPORT	$	-2,470,400
7.2 INSTALLATION SUPPORT		0
8.0 OTHER HAZMAT IMPACTS	$	-4,159,540
TOTAL O&S COST INCREMENT	$	-19,602,900

Table 29, O&S Costs in the Program Office Estimate (POE) Format

Risk Assessments and Cost Sensitivity Analysis

A risk assessment was prepared to summarize extensive laboratory and in-service testing results, which show IVD aluminum's functional advantages over cadmium plating. It presented both a positive life cycle cost analysis as well as a positive risk assessment analysis summary. It was therefore the recommendation of this project that, all convertible non-standard C-17 parts which are currently cadmium plated be converted to IVD aluminum coating.

Step Three - Summarizing the Results of the Trade Study

Following are the estimates for the investment amount to implement the IVD aluminum coating process, the annual savings, 10-year savings, payback time and return on investment over a ten year period in constant FY96$. Tables 28 and 29 provide the cost data for the information listed below.

Investment Amount (Total cost to implement project):

Maintenance Task Entry	$9,067
Drawing Revisions	$904,702
Supplier Non-Recurring Cost	$500,000
Total	$1,413,769

Savings:	**Annual Savings**	**10-Year Savings**
Personal Protective Equipment	$570,878	$5,708,780
Medical	$46, 856	$468,560
Hazardous Waste Disposal	$155,540	$1,555,400
Record Keeping	$4,928	$49,280
Total	$778,202	$7,782,020

Payback Time:
1 Year, 10 Months

Return on Investment Over 10-Year Period:
450%

Remarks

The positive technical and life cycle cost data generated by this project will support other DOD maintenance facilities efforts to further reduce/eliminate cadmium processing. Some of these facilities are already using the IVD aluminum coating process for some applications and can use the data from this project to extend their efforts. This includes all Air Force Air Logistics Centers (ALCs), all Naval Aviation Depots (NADEPs), and several Army depots. IVD aluminum coating has replaced cadmium plating on 100 percent of the steel alloy parts at the Warner Robins ALC and the Sacramento ALC (over 400 parts at these two facilities). San Antonio and Oklahoma City ALCs use IVD aluminum coating extensively for cadmium plating replacement. The Ogden ALC, a consortium of landing gear manufacturers, and Boeing St. Louis have an Air Force sponsored program titled "Elimination of Environmentally Hazardous Materials from the Landing Gear Overhaul Process." IVD aluminum is the leading replacement finish for cadmium plating for landing gear usage. In addition to cadmium replacement, IVD aluminum is used extensively on high strength, fatigue critical aluminum parts for corrosion protection and elimination of fatigue debits associated with anodizing of aluminum. IVD aluminum coatings can be applied to high-strength steel without fear of hydrogen embrittlement and can be used in contact with fuels; cadmium is prohibited for these applications. Additionally, IVD aluminum can be used in space applications, whereas cadmium is limited because of sublimation.

There are inherent advantages to the substitution of IVD aluminum for cadmium, in addition to hazardous waste reduction and worker safety. IVD aluminum adds value since it outperforms cadmium in preventing corrosion in acidic environments and more importantly, actual service tests. Also, aluminum coating can be used at temperatures up to 950 degrees F, whereas cadmium is limited to 450 degrees F. This expands IVD use to higher temperature applications typical of aircraft engine needs. Since IVD aluminum coatings can be applied to high-strength steel without fear of hydrogen embrittlement, the twenty-four hour bake associated with cadmium plating for high strength steel is eliminated, a significant reduction in processing cycle time. As IVD aluminum coating parts are recycled through the overhaul process, they are reported superior in appearance over similar cadmium plated parts. Based on improved coating adhesion and corrosion resistance qualities, overhaul intervals can be lengthened, thereby further reducing life cycle cost.

Attachment 1

MDA Life Cycle Cost HAZMAT Model Inputs

For

Cadmium Plated vs. IVD Aluminum Coated Non-Standard Parts

	Inputs	Baseline Process (Cad)	Alternative Process (IVD)	Notes (See Next Page)
	PROCUREMENT / PRODUCTION			
1	Equipment Cost (Non-recurring) ($):	0	0	
2	Qty of substance disposed /year (lbs):	0	0	
3	Substance cost ($/lb):	0	0	
	PROCUREMENT / SUPPORT			
6	Qty of media used per process /year (Depot, lbs):	106,000	0	1
7	Qty of substance used per process /year (Org/Int, lbs):	40,000	0	2
8	Substance cost ($/lb):			
	PERSONAL PROTECTION			
10	Qty workers in process using protection (Production):	0	0	
11	Qty workers in process using protection (Support):	44	0	3
12	Cost of protective equipment /person /process /year ($):	$447	0	4
13	Labor rate of worker in process (Production $/hr):	0	0	
14	Labor rate of worker in process (Support $/hr):	$81	$81	5
15	Time lost factor per worker / year (0 -1.0):	0.28	0	6
16	Portion of time workers perform stripping (0 -1.0):	0.25	0	7
	MEDICAL			
18	Qty of workers in process (Production):	0	0	
19	Qty of workers in process (Support):	44	44	
24	Qty of injuries / worker / process / year:	0	0	
25	Cost / injury (avg. time lost /injury)(hrs):	0	0	
26	Qty of hygiene surveys / process / year (Production):	0	0	
27	Qty of hygiene surveys / process / year (Support):	32	0	8
28	Cost / hygiene survey ($/ hygiene survey):	$268	0	9
29	Surveillance Cost / person / year:	$870	0	10
	DISPOSAL			
30	Portion of hazmat disposed (0 -1.0):	1.00	0	
31	Dilution of hazmat during process (disposed-recycled/used)(Depot):	1.09	0	11
32	Dilution of hazmat during process (disposed-recycled/used)(Org/Int):	1.00	0	
33	Disposal cost per lb. of hazmat (Production $/lb):	0	0	
34	Disposal cost per lb. of hazmat (Depot Support $/lb):	$1.00	0	12
35	Disposal cost per lb. of hazmat (Org/Int Support $/lb):	$1.00	0	13
36	Recycle cost per lb. of hazmat (Production $/lb):	0	0	
37	Recycle cost per lb. of hazmat (Support $/lb):	0	0	
	LEGAL/ENVIRONMENTAL LIABILITY			
38	Percent of hazmat escaped into air (%):	0	0	
39	Liability cost for hazmat escaped into air (Production $/lb):	0	0	
40	Liability cost for hazmat escaped into air (Support $/lb):	0	0	
41	Liability cost for hazmat disposed (Production $/lb):	0	0	
42	Liability cost for hazmat disposed (Support $/lb):	0	0	
44	Maintenance task entry (non-recurring hours):	0	116	14
45	Drawing changes (non-recurring hours):	0	11,575	15
46	Technical publications (non-recurring hours):	0	0	
47	Technical publications (recurring hours):	0	0	
48	Unscheduled maintenance (delta mmh/fh):	0	0	
49	Support equipment ($):	0	0	
50	Packaging, handling, storage, transportation (hours):	0	0	
51	Training (Production hours):	0	0	
52	Training (Support hours):	0	0	
53	Initital spares($):	0	0	
54	Replenishment spares ($):	0	0	
55	Handling ($):	0	0	
56	Facilities ($):	0	0	
57	OSHA required record keeping ($/worker/year:):	$112	0	16

Table 30, MDA Life Cycle Cost HAZMAT Model Inputs

MDA Life Cycle Cost HAZMAT Model Input Notes

1. 106,000 Ibs/year = 9.6 aircraft de-paintings per year times 11,032 Ibs plastic media used per aircraft (based on C-5 plastic media blasting operations at SA-ALC). Plastic media quantity for C-17 aircraft was obtained by rationing the C-17 to C-5 surface areas).
2. 40,000 Ibs/year = 10,000 Ibs. waste/year per base times (1,200 gal/year ~ 8.33 Ib/gal) times 4 bases.
3. Number of workers exposed to cadmium at (3) depots is:
   a) De-painting aircraft: 18 x 2 shifts = 36 workers.
   b) Structural repair/maintenance of parts removed from aircraft: 2 x 2 shifts = 4 workers
   c) Landing gear rework / repair: 2 x 2 shifts = 4 workers.
4. Cost of PPE at depot is based on (44) workers:
   a) (36) workers for aircraft de-painting ~ $1,344/ year/worker (Based on life cycle cost data in C-17 Task Order 021).
   b) (8) workers at (2) detail part/assembly rework depots ~ $460/year/worker (Preamble, Section Vl11- Regulatory Impact Analysis, Federal Register 29 CFR 1910.1027, section C).
5. Labor rate at SA-ALC.
6. Workers in PMB stripping process remove and replace personal protective equipment (PPE) each time they leave the work area. The resulting PPE productivity loss (including washing and showering) is 135 minutes per shift per worker, resulting in a 28% productivity loss. More information on the PPE work loss estimate is contained in C-17 Task Order 017.
7. Based on Task Order 021. 1,950 man-hours per C-17 aircraft de-painting by (18) workers per (2) shifts = 54 hrs per worker. De-painting (9.6) aircraft per year (average) results in 518 hrs per year per worker performing de-painting operation. Assuming 2,080 man-hours per worker per year, this results in 25% of worker time spent de-painting (when PPE is worn).
8. Preamble, Section VIII - Regulatory Impact Analysis, Federal Register 29 CFR 1910.1027, section C requires (1) survey per (10) workers. At Repainting depot, (2) surveys per shift = (4). At (2) other depots, (1) survey per shift = (4). Based on worst case requiring quarterly surveys, this results in (32) surveys / year.
9. Preamble, Section VIII - Regulatory Impact Analysis, Federal Register 29 CFR 1910.1027, section C.
10. Preamble, Section VIII - Regulatory Impact Analysis, Federal Register29 CFR 1910.1027, section C, assuming PEL is exceeded.
11. Ratio of paint plus spent plastic media weight to spent plastic media weight per aircraft (1,000 lb paint + 11,032 lb media) / (11,032 lb media). Paint removed per aircraft is 1,000 lb.
12. Cost of plastic media/paint waste disposal is based on plastic media lease fees at NADEP Jacksonville, Cheery Point, and SA-ALC.
13. Based on Defense Reutilization and Marketing Office (DRMO) disposal costs of cadmium contaminated waste water.
14. Logistics Support Analysis (LSA) estimate in desktop analysis.
15. Estimated hours to change drawings (25 hours per drawing times 463 drawings which can be easily converted to IVD aluminum coating).
16. Preamble, Section VIII - Regulatory Impact Analysis, Federal Register 29 CFR 1910.1027, section C, required medical records be retained for (30) years. Life cycle increment calculated for (55) years.

Attachment 2

Pertinent Ground Rules and Assumptions and the Basis for the O&S Cost Savings

In Support of Savings Estimates
(Adjusted for 10-Year Period)

Pertinent general ground rules and assumptions for the entire cost analysis are shown below.

1) Costs are in GFY 1996 dollars.
2) All costs extracted from the Preamble to 29CFR 1910.1027 (Expanded OSHA Standard for Cadmium) are inflated to GFY 1996 dollars.
3) Plastic media blasting (PMB) is the paint stripping process used at depots which creates exposure to cadmium. Paint stripping includes: complete aircraft de-painting, landing gear de-painting, and detail part de-painting.
4) Over the 25 year Operations & Support (O&S) period, 240 aircraft de-paintings will be performed.
5) For aircraft and detail part/assembly de-painting processes, the costs of work loss for wearing PPE, OSHA compliance, and waste disposal are incurred in the baseline option and not incurred in the IVD alternative option.

Cost elements 3.11 and 3.12 assume the number of workers performing de-painting, structural repair/maintenance, and landing gear rework is (44). This was derived as follows:

A	De-painting aircraft moldline	18 workers x 2 shifts	= 36 workers
	Structural repair/maintenance of parts removed from aircraft	2 workers x 2 shifts	= 4 workers
	Landing gear rework	2 workers x 2 shifts	= 4 workers
	Total workers in analysis		**44**

3.11.1 - Protective Equipment Cost

A worst case scenario is assumed where the level of cadmium dust present during de-painting using Plastic Media Blasting (PMB) will exceed the “Expanded OSHA Standard for Cadmium” action level of 2.5 $\mu g/m^3$. Based on the C-17 Task Order 021 study, the cost of personal protective equipment (PPE) required for aircraft de-painting using PMB is $1,344 per worker per year. Based on cost estimates contained in the “Preamble, Section VIII - Regulatory Impact Analysis, Federal Register 29 CFR 1910.1027, Section C”, the PPE cost for workers performing repair/maintenance and rework on cadmium plated equipment is $447 per year per worker.

Using information from “A” and cost data above results in:

Annual Protective Equipment Cost = (36)($1,344) + (8)($447) = $51,960
10-Year Increment = ($51,960) (10 years) = $519,600

3.11.2 - Work Loss Due to PPE

This cost is estimated at $5.2M over 10 years, or $519,000 per year.
This is the cost of lost labor to put PPE on and off, and is derived in C-17 Task Order 017 (Enhanced Life Cycle Cost Model, pp.4-5) as summarized below:

Based on "A" above, SA-ALC labor rate of $81/hr, and 145 hrs. lost per worker per year:
Annual labor cost lost due to PPE= (44 workers) ($81/hr) (145hrs/yr) = $519,000

The hours lost per year per worker (145) was derived in C-17 Task Order 021 (Aircraft De-painting Life Cycle Cost) as shown below:

Time Lost putting PPE on and off = 28% of time worker performs de-painting operation (C-17 Task Order 017). Therefore, (.28)(518 hrs/worker/yr performing de-painting)=145hrs/yr. The number of hours/worker/yr was derived as follows:

$$518 \text{ hrs / worker / yr.} = \frac{(1950 \text{ hours/aircraft})}{(18 \text{ workers}) \times (2 \text{ shifts})} \times 9.6 \text{ aircraft per yr.}$$

An assumption was made that the workers performing repair/maintenance and rework experience the same lost labor as those performing aircraft de-painting.

3.12.3 Industrial Hygiene Survey Costs

Assuming the worst case that the action level of 2.5 $\mu g/m^3$ of cadmium dust will be exceeded in all de-painting/rework operations, quarterly hygiene surveys will be required per the "Preamble, Section VIII - Regulatory Impact Analysis, Federal Register 29 CFR 1910.1027, Section C". Also referenced in the "Preamble" is the requirement that (1) survey is required per shift per (10) workers, and that the national average to collect and analyze each sample is $268. Based on this information and the number of workers in "A" above, a total of (32) surveys will be required per year. As shown below:

\# of surveys = [(2 surveys per shift @ de-painting)(2 shifts)+(1 survey per shift @ repair/maintenance and rework facilities)(2 shifts)] (4 per year)
= [(4)+(1+1)(2)] (4)
= 32

Resulting in:

Annual Cost	= (32)($268) = $8,576
10-Year Cost Increment	= ($8,576) (10 years) = $85,760

3.12.4 Medical Surveillance Cost

A worst case scenario was again assumed. Costs for presence of cadmium (medical surveillance) were obtained from the "Preamble, Section VIII - Regulatory Impact Analysis, Federal Register 29 Code of Federal Regulations (CFR) 1910.1027, Section C" and MDA-St. Louis Medical Services. MDA-St. Louis Medical Services uses an independent lab, Corning Clinical Laboratories, St. Louis, MO. The laboratory cost is $870 per year per worker potentially exposed above the action level of cadmium.

Annual Cost	= ($870) (44 workers)	= $38,280
10-Year Cost Increment	= ($38,280) (10 years)	= $382,800

- *It is important to note that the "Expanded OSHA Standard for Cadmium" also lists numerous additional requirements when the action level for cadmium dust is exceeded which are not included in this analysis. The cost for compliance with these requirements are difficult to estimate, but are considered to be significant.*

3.13.1 - Material Disposal Cost

Assumptions pertinent to cost element 3.13.1 Material Disposal:

1) Hazardous waste disposal costs associated with cadmium plating and chemical stripping are not included. These costs at MDA are relatively insignificant due to infrequency of tank dumping.
2) Excluded from the life cycle cost estimate are costs associated with cadmium exposure and waste generation at Organizational and Intermediate (O/I) levels of maintenance except for wheel and brake parts washing at the Intermediate level. For this reason, the cadmium disposal cost estimate is most likely underestimated.
3) IVD coated parts, when stripped, do not incur hazardous waste disposal cost.
4) The quantity of cadmium contaminated wastes from plastic media blasting is based only on wastes from moldline PMB and not PMB of off-aircraft components. Therefore, disposal costs are underestimated in this respect.
5) For the cadmium option, there is a risk of legal liability cost due to potential accidental release of spent media during transport, handling, and/or processing. No cost was estimated for this liability risk.

The cost to dispose of cadmium contaminated wastes = $1.6 M over 10-year period = the cost to dispose of depot level cadmium contaminated PMB wastes + cost to dispose of Intermediate level wastes from wheel and brake parts washing = $1.2 M + $0.4M.

<u>Depot Disposal Cost</u>

Depot level waste disposal cost = $1.2 M = ($116,000 /yr)(10 years) where,
Cost per year = Quantity of plastic media replaced per year x dilution factor x disposal cost per pound = 106,000 lbs/yr x 1.09 dilution factor x $1.00/lb.
(The dilution factor is the combined weight of plastic media plus the weight of paint debris divided by the weight of plastic media).
Quantity of plastic media which is replaced by media leasing company =106,000 lbs/year = 9.6 aircraft de-paintings per year times 11,032 lbs of plastic media used per aircraft (based on C-5 plastic media blasting operations at San Antonio Air Logistics Center (SA-ALC)).

11,032 lbs/ac = 300,000 lb plastic media replaced /yr for (18) C-5 ac/yr,
times the ratio of C-17 to C-5 surface areas (22,241 ft^2 for C-17 vs 33,600 ft^2 for C-5).

Therefore, 11,032 lbs/ac = (300,000/18) X (22,241/33,600).

Derivation of 1.09 dilution factor = Ratio of paint plus plastic media weight to plastic media weight per aircraft (1,000 lb paint + 11,032 lb media) /(11,032 lb media). Paint removed per aircraft is 1,000 lb which takes into account 640 lb paint /ac at delivery + 360 lbs estimated as additional paint applied between 10 year corrosion control cycle.

Derivation of $1.00/lb disposal cost of spent plastic media results from the difference between the leasing company's fee per pound of media replaced and the cost of new virgin media. Therefore, disposal cost = $1.00/lb = $2.00/lb media leasing fee - $1.00/lb media purchase price. The leasing fee is based on an average of the plastic media leasing fees at Naval Depot (NADEP) Jacksonville, Marine Corps Air Station (MCAS) Cherry Point, and SA-ALC.

Intermediate Level Disposal Cost

Intermediate level disposal cost for cadmium contaminated liquid waste generated from C-17 wheel and brake parts washing = $0.4 M over 10 years = ($40,000/yr)(10 years). The cost /year of $40,000 = 40,000 lbs per year parts washer hazardous waste, containing cadmium, x $1.00 /lb disposal (based on Defense Reutilization and Marketing Office (DRMO) disposal costs).

Hazardous waste disposal quantity = 40,000 lbs/year = 10,000 lbs. waste/year per base times 4 bases where 10,000 lbs/yr = 1,200 gal/year @ 8.33 lb/gal. The waste disposed per base was obtained from maintenance personnel at the C-17 Intermediate level wheel and brake shop at Charleston AFB.

- *It is important to note that many more cadmium contaminated waste streams exist than are reported in this Task Order. It is beyond the scope of this Task Order to identify all sources of cadmium waste streams existing at all levels of maintenance. The actual cost for disposal of cadmium contaminated hazardous waste is difficult to estimate, but would be significantly higher than this report suggests.*

CFC 114 Refrigerant Replacement Study

Step One -Define and Plan the Trade Study

This example will attempt to demonstrate the manner in which the decision to continue using a Class I Ozone Depleting Substance (ODS) makes economical sense when faced with the options that were available to the SPO at the time.

Establish the Technical Baseline to be Estimated

Background Information

The Joint STARS vapor cycle system uses CFC-114 as a refrigerant. A fully halogenated chlorofluorocarbon compound (CFC), it was initially chosen for aircraft use due to low operating and storage pressures that result in low system weight and ease of handling. When it was established that CFCs were ozone depleting substances (ODS), the Montreal Protocol established the timetable for eliminating CFCs from the environment. Production of all CFCs was to be stopped by 1 January 1996. The study, performed in April 1995 by Northrop Grumman, analyzed the overall impact on the Joint STARS vapor cycle system of the discontinued production of CFC-114, a Class I ODS. It evaluated several system design and logistics options that allow the continued use of vapor cycle cooling on Joint STARS aircraft while maintaining life cycle compliance with EPA regulations.

Alternatives Considered

The options studied were the stockpiling and continued use of CFC-114, and the use of environmentally compatible alternate refrigerants (HCFC-124, HFC-134a, and HFC-236). Each option had the following evaluations performed:

- overall performance analysis
- development, modification, and documentation impacts
- schedules and risks
- estimated subcontractor costs
- assessment of qualification status
- logistics impacts
- flight test requirements
- overall assessment of program impact

Determine the Appropriate WBS for the Estimate

No WBS was used for each of the options because the estimates were all provided by the contractor as lump sum figures. There were no further breakouts.

Step Two - Specify Estimating Methodology

Data Sources, Data Collection and Data Evaluation

Northrop Grumman, the prime contractor for Joint STARS, performed this study. The data collection and data evaluation were completed by Northrop Grumman (thus, utilizing their data sources and subcontractor's information). For two of the options (HFC-134a and HFC-236), the study was based on preliminary studies by the Navy. Some of the federal, state and local regulations that affected this study were:

- Montreal Protocol - policy set timetable for elimination of CFCs into the environment

- 1990 Clean Air Act - Title 5 established procedures and timetables for elimination of ODS in the US, including the complete halt of CFC production by 1 January 1996
- ARI 700-1988 - set purity standards for reclamation of refrigerants

Selection of Estimating Methodology

Stockpiling Option

For the stockpiling option, the cost of the CFC-114 is based on vendor quotes. The quantity needed for stockpiling was calculated by Northrop Grumman based on 19 aircraft (now there will be 13) and a life cycle of 20 years. The total estimate of approximately $300K (FY95$) include reclamation costs.

HCFC-124 Conversion

For this modification, only the refrigeration unit portion of the vapor cycle machine would be effected. The estimate was based on subcontractor hardware, data, and documentation costs. It was estimated to cost approximately $2.6M (FY95$) for the development and design of refrigeration unit. It should be noted that approximately 35% of the cost stem from data requirements (changes to technical orders, drawings, etc.).

HFC-134a Conversion

The estimate was based on subcontractor hardware, data, and documentation costs. It was estimated to cost approximately $14.8M (FY95$) for the development and design of a new control system (which will also increase the cooling capacity) and for modifications to the aircraft installation. The lower end of the estimate of $4.2M (FY95$) assumed using previously developed hardware from the Navy's E-2C or the Air Force's F-22 programs. In either case, approximately $1M is attributable to data requirements.

HFC-236 Conversion

The estimate was based on subcontractor hardware, data, and documentation costs. It was estimated to cost approximately $3.0M (FY95$) for the development and design of a new compressor and over-pressure switch. The majority of the CFC-114 vapor cycle system components are compatible for use with the HFC-236. Approximately 20% of the cost is attributable to data requirements.

Step Three - Summarizing the Results of the Trade Study

The following table summarizes each of the options studied and the results of their impact.

	Option			
Parameter	**Stockpiling**	**HCFC-124 Conversion**	**HFC-134a Conversion**	**HFC-236 Conversion**
Aircraft impacts including drawings	none	low	low - high, depending upon E-2C unit usage	low
Schedule lead time	immediate	18 months	35 months	38 months
Technical risk	low, but no growth capacity is available	low, but no growth capacity is available	low	high (refrigerant not yet developed)
Political risk	medium - high	low - medium	low	low
Logistics impact	low	low - medium	medium - high, depending upon E-2C unit usage	low
Pubs impact	low	low - medium	medium	low - medium

	Option			
Parameter	**Stockpiling**	**HCFC-124 Conversion**	**HFC-134a Conversion**	**HFC-236 Conversion**
Flight test impact	none	low	medium	low
Subcontractor material ROM	$300K (FY95$) for refrigerant and recycling - does not include storage or E-8A usage	$2.6M (FY95$) development and design of refrigeration unit only ($2.1M if using previously developed H/W) - 35% due to data requirements	$4.2M to $14.8M (FY95$), depending upon E-2C commonality	$3M (FY95$)
Recommended?	no - most vulnerable to future legislation, changes to service life and/or total number of aircraft	with reservation (availability, heat exchangers may need modification, qualification analysis of new compressor, new pressure settings could introduce small perturbations into control system)	yes	no* - theoretical tests show this to be the most promising replacement but this is still in development stages

Table 31, CFC 114 Options

*not recommended because of availability in 1995, however, that has changed now - see note below

Based on the results of this study, the Joint STARS SPO acquired a lifetime supply of CFC-114.

NOTE: The results reported below are based on the April 1995 study. The situation has changed in that the recommended option (use HFC-134a as a replacement) back in 1995 is no longer viable because of the major redesign of all pressure and flow sensitive elements in the system, the high cost associated with the redesign, and because HFC-134a is a global warmer. Although the 1995 study estimated approximately $3M for the HFC-236 conversion, there were many unknowns: uncertainty of its future status because of the developmental stages of the material; small commercially available quantities; and unknown modifications necessary to be made to the system. Since then, HFC-236 has become more commercially available and tests show that this would be a promising replacement with very little modification to the vapor cycle system. To mitigate potential risks associated with uncertainties, such as a newer and stronger Montreal Protocol, the Joint STARS SPO has initiated a follow-on study with Northrop Grumman to identify the retrofit and modifications required to convert to a non-ODS Class I solution. Northrop Grumman is currently studying the HFC-236 conversion and the Phase I results will be available in May 1998. It is important to note that this study is costing the government a little over $500K, roughly $200K more than the cost of stockpiling the CFC-114.

Remarks

This trade study demonstrated that even though the existing refrigerant in the Joint STARS vapor cycle system is a Class I ODS, it made economical sense, at the time of the study, to stockpile the material over the life cycle of the Joint STARS. This study would have been better, from an ESH life cycle cost perspective, if it had addressed additional handling or disposal costs associated with these alternatives (although it is uncertain whether this would have changed the recommendation).

Appendix C – List of Acronyms

ABC	Activity Based Costing
ABM	Activity Based Management
ACA	Associate Contract Agreement
ACAT	Acquisition Category
ACEIT	Automated Cost Estimating Integrated Tools
AEDC	Arnold Engineering and Development Center
AETC	Air Education and Training Command
AF	Air Force
AFB	Air Force Base
AFCAA	Air Force Cost Analysis Agency
AFCEE	Air Force Center for Environmental Excellence
AFCESA	Air Force Civil Engineering Support Agency
AFDTC	Air Force Development Test Center
AFFF	Aqueous Film Forming Foam
AFFTC	Air Force Flight Test Center
AFI	Air Force Instruction
AFMC	Air Force Materiel Command
AFMCP	Air Force Materiel Command Pamphlet
AFMCR	Air Force Materiel Command Regulation
AFOSH	Air Force Occupational and Environmental Safety, Fire Protection, and Health
AFPD	Air Force Policy Directive
AFRL	Air Force Research Laboratory
AFSC	Air Force Safety Center
AFSCN	Air Force Satellite Control Network
AFSPC	Air Force Space Command
AKM	Apogee Kick Motor
ALC	Air Logistics Center
AMARC	Aerospace Maintenance and Regeneration Center
ANSI	American National Standards Institute
AOA	Analysis of Alternatives
ASC	Aeronautical Systems Center
AXZ	Acquisition Health and Safety Division for SMC
A&E	Architecture and Engineering
BOD	Biochemical Oxygen Demand
BOS	Base Operating Support
BOSS	Bicarbonate of Soda System
BP	Environmental Management Division for ESC
BRAC	Base Reallocation and Consolidation
C3I	Command, Control, Communications and Intelligence
CAA	Clean Air Act
CAE	Component Acquisition Executive
CAIG	Cost Analysis Improvement Group
CAIV	Cost As an Independent Variable
CALS	Continuous Acquisition Lifecycle Support
CARD	Cost Analysis Requirements Description
CATEX	Categorical Exclusion
CCAS	Cape Canaveral Air Force Station

CCDR	Contractor Cost Data Report
CDRL	Contract Data Requirements List
CE	Concept Exploration
CER	Cost Estimating Relationship
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CEV	Civil Engineering Organization
CFR	Code of Federal Regulations
CFSR	Contract Funds Status Report
CI	Commercial Item
CI	Configuration Item
CIV	Civilian
CIPT	Cost Integrated Product Team
CITIS	Contractor Integrated Technical Information Service
CLIN	Contract Line Item Number
CLS	Contract Logistics Support
COEA	Cost and Operational Effectiveness Analysis
CONUS	Continental United States
CORE	Cost Oriented Resource Estimating
COTS	Commercial-Off-The-Shelf
CPAF	Cost Plus Award Fee
CPAT	Critical Process Assessment Tool
CPR	Cost Performance Report
CSCI	Computer Software Configuration Item
CSE	Common Support Equipment
CWA	Clean Water Act
CWG	Center Working Group
D&D	Demilitarization and Disposal
DAB	Defense Acquisition Board
DCAA	Defense Contract Audit Agency
DENIX	Defense Environmental Network & Information Exchange
DISA	Defense Information Systems Agency
DLA	Defense Logistics Agency
DMA	Defense Mapping Agency
DMBA	Depot Maintenance Business Area
DoD	Department of Defense
DoDD	Department of Defense Directive
DoDI	Department of Defense Instruction
DOPAA	Description of Proposed Action and Alternatives
DPRO	Defense Plant Representative Office
DRMO	Defense Reutilization and Marketing Office
DRMS	Defense Reutilization and Marketing Service
DT&E	Development Test and Evaluation
EA	Environmental Assessment
EBS	Environmental Baseline Survey
ECHO	Environmental Cost of Hazardous Operations
ECHOS	Environmental Cost, Handling Options and Solutions
ECO	Engineering Change Order
EEIC	Expense Element/Investment Code

EELV	Evolved Expendable Launch Vehicle
EIAP	Environmental Impact Analysis Process
EIS	Environmental Impact Statement
ELCCM	Environmental Life Cycle Cost Model
EM	Environmental Management
EMD	Engineering and Manufacturing Development
EO	Executive Order
EPA	Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-To-Know Act
ESC	Electronic Systems Center
ESH	Environmental, Safety, and Health
ESOH	Environmental, Safety, and Occupational Health
FAR	Federal Acquisition Regulation
FFCA	Federal Facilities Compliance Act
FFP	Firm Fixed Price
FMB	Financial Management, Budget
FMC	Financial Management, Cost
FONSI	Finding of No Significant Impact
FRISK	Formal Risk – Assessment of System Cost Estimates
FTS	Flight Termination System
FY	Fiscal Year
G&A	General and Administrative
GAO	General Accounting Office
GEM	Graphite Epoxy Motor
GFY	Government Fiscal Year
GOCO	Government Owned Contractor Operated
GOGO	Government Owned Government Operated
GOSC	GPS OCS Support Center
GPS	Global Positioning Satellite
GS	General Schedule
GWP	Global Warming Potential
HAP-PRO	Hazardous Air Pollutant Program
HAZMAT	Hazardous Material
HB	Huntington Beach
HC	Head Count
HFC	Hydoflorocarbon
HHA	Health Hazards Assessment
HMMP	Hazardous Material Management Program
HSC	Human Systems Center
HSIP	Human Systems Integration Plan
HTMA	Hazardous Materials Transportation Act
IA &T	Integration, Assembly, and Test
IAW	In-Accordance-With
ICS	Interim Contractor Support
IG	Inspector General
I-Level	Intermediate Level

ILS	Integrated Logistics Support
ILSP	Integrated Logistics Support Plan
IMP	Integrated Master Plan
IMPACTS	Integrated Manpower, Personnel and Comprehensive Training and Safety
IPD	Integrated Product Development
IPR	Integrated Program Review
IPT	Integrated Product Team
IS	Installation Support
ISO	International Standards Organization
JG-APP	Joint Group on Acquisition Pollution Prevention
JON	Job Order Number
JPATS	Joint Primary Training Aircraft System
JPO	Joint Program Office
JOCAS	Job Order Cost Accounting System
JSF	Joint Strike Fighter
KTR	Contractor
LCC	Life Cycle Cost
LCCE	Life Cycle Cost Estimate
LMAS	Lockheed-Martin Astronomic Systems
LRIP	Low Rate Initial Production
LRU	Line Replaceable Unit
LSA	Logistics Support Analysis
LSAR	Logistics Support Analysis Record
LV	Launch Vehicle
MAIS	Major Automated Information System
MAJCOM	Major Command
MCAS	Marine Corps Air Station
MCP	Military Construction Program
MDA	McDonnell Douglas Aerospace
MDA	Milestone Decision Authority
MDAP	Major Defense Acquisition Program
MDHS	McDonnell Douglas Helicopter Systems
MDS	Mission Design Series
ME	Mission Equipment
MHE	Material Handling Equipment
MIL	Military
MIL-STD	Military Standard
MIL-HDBK	Military Handbook
MIRS	Material Inventory Report System
MLV	Medium Launch Vehicle
MOSC	Mission Operations Support Center
MSDS	Material Safety Data Sheet
NADEP	Naval Aviation Depot
NAS	National Aerospace Standard
NASA	National Aviation and Space Administration

NATO	North American Treaty Organization
NAVSTAR	Navigation System Using Timing and Ranging
NDI	Non-Developmental Item
NEPA	National Environmental Protection Act
NESHAPS	National Emission Standard for Hazardous Air Pollutants
NET	New Equipment Training
NiCAD	Nickel Cadmium
NIST	National Institute of Science and Technology
N/R	Non-Recurring
NRL	Naval Research Laboratory
NSWC	Naval Surface Warfare Center
O&M	Operations and Maintenance
O&S	Operating and Support
OC-ALC	Oklahoma City Air Logistics Center
OO-ALC	Ogden Air Logistics Center
OCBB	Operating Cost Based Budget
OCS	Operational Control System/Segment
ODS	Ozone Depleting Substance
OGC	Other Government Costs
O/I	Organizational and Intermediate
O-Level	Organizational Level
ORD	Operational Requirements Document
ORM	Operational Risk Management
OSD	Office of the Secretary of Defense
OSH	Occupational Safety and Health
OSHA	Occupational Safety and Health Act
OT&E	Operational Test and Evaluation
PA	Public Affairs
PA&E	Program Analysis and Evaluation
PCB	Polychlorinated Biphenyl
PCE	Program Cost Estimate
PCS	Permanent Change of Station
PDRR	Program Definition and Risk Reduction
PEC	Program Element Code
PEL	Permissible Exposure Limit
PEM	Program Element Monitor
PEO	Program Executive Officer
PESHE	Program Environmental, Safety and Health Evaluation
PHST	Packaging, Handling, Storage, and Transportation
PLF	Payload Fairing
PM	Program Manager
PMB	Plastic Media Blasting
PME	Prime Mission Equipment
PMP	Prime Mission Product
POE	Program Office Estimate
POL	Petroleum, Oils and Lubricants
POM	Program Objective Memorandum
PP	Pollution Prevention

P2	Pollution Prevention
PPA	Pollution Prevention Act
PPE	Personal Protection Equipment
PSA	Principal Staff Assistant
PSE	Peculiar Support Equipment
QA	Quality Assurance
QOT&E	Qualification Operational Test & Evaluation
RACER	Remedial Action Cost Engineering and Requirements System
R&D	Research and Development
RC/CC	Responsibility Center/Cost Center
RCRA	Resource Conservation and Recovery Act
RF	Radio Frequency
RFP	Request For Proposal
RIFCA	Redundant Inertial Flight Control Assembly
RI/FS	Remediation Investigation/Feasibility Study
ROD	Record of Decision
RRI	Refunds and Reimbursements
SA-ALC	San Antonio Air Logistics Center
SAMP	Single Acquisition Management Plan
SAP	Satellite Accumulation Point
SARA	Superfund Amendments and Reauthorization Act
SATCOM	Satellite Communication
SCAQMD	Southern California Air Quality Management District
SE	Systems Engineering
SE	Support Equipment
SEER	System Evaluation and Estimation of Resources
SEER-SEM	System Evaluation and Estimation of Resources Software Estimating Model
SE/PM	System Engineering/Program Management
SEMP	System Engineering Management Plan
SETA	System Engineering/Technical Assistance
SIP	Standard Industry Procedure
SLOS	Storage, Launch, and On-Orbit Support
SM	Single Manager
SMC	Space and Missile Systems Center
SNAP	Significant New Alternatives Policy
SOW	Statement of Work
SPACECOM	Space Command
SPAR	System Performance Analysis Report
SPO	System Program Office
SQG	Small Quantity Generator
SRD	Systems Requirement Document
SRM	Solid Rocket Motors
SSP	System Safety Plan
ST&E	System Test and Evaluation
SV	Space Vehicle
SW	Space Wing

TAD	Temporary Additional Duty
TASC	The Analytical Science Corporation
TB	Technical Baseline
TCO	Technical Change Order
TDY	Temporary Duty
TEAG	Tactical Environmental Safety and Health Action Guide
TEMP	Test and Evaluation Master Plan
TO	Technical Order
TPIPT	Technology Planning Integrated Product Team
TRACES	Tri Service Automated Cost Engineering Requirements System
TRI	Toxic Release Inventory
TSCA	Toxic Substances Control Act
TTC	Through-The-Canopy
TWT	Traveling Wave Tube
TY	Then Year
UDMH	Unsymmetrical Dimethyl Hydrazine
USACHPPM	United States Army Center for Health Promotion and Preventative Medicine
USAF	United States Air Force
USD(A&T)	Under Secretary of Defense (Acquisition and Technology)
VAFB	Vandenberg Air Force Base
VAMOSC	Visibility and Management of Operating and Support Costs
VOC	Volatile Organic Compound
WBS	Work Breakdown Structure
WG	Wage Grade
WSSC	Weapon System Support Cost

Appendix D - Glossary of Terms and Definitions

ACAT - Acquisition category. There are several categories.

ACAT I programs are Major Defense Acquisition Programs (MDAP). An MDAP is defined as a program estimated by the Under Secretary of Defense (Acquisition and Technology) (USD(A&T)) to require eventual expenditure for research, development, test, and evaluation of more than $355 million (FY 1996 constant dollars) or procurement of more than $2.135 billion (FY 1996 constant dollars), or those designated by the USD(A&T) to be ACAT I**.** Additional letter designator A refers to Major Automated Information Systems (MAIS), C refers to Component Acquisition Executive (CAE) where the Milestone Decision Authority (MDA) is the Component head, D refers to Defense Acquisition Board (DAB) where the MDA is USD(A&T)

ACAT II programs are defined as those acquisition programs that do not meet the criteria for an ACAT I program, but do meet the criteria for a major system. A major system is defined as a program estimated by the DoD Component Head to require eventual expenditure for research, development, test, and evaluation of more than $135M in fiscal year (FY) 1996 constant dollars, or for procurement of more than $640M in FY 1996 constant dollars, or those designated by the DoD Component Head to be ACAT II

ACAT III programs are defined as those acquisition programs that do not meet the criteria for an ACAT I, an ACAT IA, or an ACAT II. The MDA is designated by the CAE and shall be at the lowest appropriate level. This category includes less-than-major automated information systems.

Acquisition Life Cycle - The acquisition life cycle consists of four phases or stages, They are in order: (1) concept exploration, (2) program definition and risk reduction, (3) engineering and manufacturing development, and (4) production, fielding/deployment and operational support.

Acquisition Strategy - The conceptual framework for conducting systems acquisition, encompassing the broad concepts and objectives which direct and control the development through deployment of a system.

Alternatives - Ways of reducing the adverse effects of hazardous materials including substitution, elimination, restricting use, and other techniques.

Categorical Exclusion (CATEX) - A category of actions that do not individually or cumulatively have a significant effect on environmental resources and that have been found to have no such effect in procedures adopted by a Federal agency.

Clean Air Act (CAA) - Act which created federalized regulatory system in an attempt to protect health. Established in 1970 and amended in 1977 and 1990. Established emission standards for air pollutants.

Code of Federal Regulations (CFR) - The repository for standards and procedures established after public laws have been enacted which establish a regulatory agency's authority.

Commercial-Off-The-Shelf (COTS) - A product, such as an item, material, component, subsystem or system, sold or traded to the general public in the course of normal business operations at prices based on established catalog or market prices.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) - Federal statute which addresses the identification, characterization, and cleanup of releases of hazardous substances into the environment.

Cost Analysis Requirements Description (CARD) - A document prepared by the developer of a weapon system that establishes, as a basis for cost-estimating, a description of the salient features of the program and of the system being acquired.

Cost As an Independent Variable (CAIV) - A concept of setting aggressive, realistic cost objectives for acquiring defense systems and managing risks to obtain those objectives.

Defense Acquisition Board (DAB) - The senior general management DoD acquisition board is used by DoD to provide advice, assistance and recommendations, and to resolve issues regarding all aspects of the DoD acquisition system.

Demilitarization - The process of converting a weapon system and its components into a state such that the weapon system or its components can no longer be used for the original intended purpose.

Description of Proposed Action and Alternatives (DOPAA) - The first document required by the proponent of an action to initiate the environmental impact analysis process. Documented on Air Force Form 813, and is the basis for all follow-on environmental analysis.

Disposal - The act of disposing of excess, surplus, scrap, or salvage property and/or waste under proper authority. Disposal may include but is not limited to transfer, donation, sale, declaration, abandonment, or destruction.

Economic Analysis - An evaluation of the costs associated with the use of hazardous materials and potential alternatives.

Environment - Includes water, air, or land, and the interrelationship which exists among and between water, air and land and all living beings.

Environmental Assessment (EA) - The addressing of the environmental impact of a proposed action, unavoidable adverse environmental effects, alternatives, the relationship between the local short term uses of the environment and the maintenance and enhancement of long term productivity, and irreversible and irretrievable commitments of resources.

Environmental Compliance - Compliance includes prevention, control, abatement, documentation, and reporting of pollution from stationary and mobile sources. May also include the reduction or elimination of emissions and the control of new pollution sources.

Environmental Cost - Costs that may arise in any or all of the major segments of a program cost estimate that stem from requirements for pollution prevention, compliance, hazardous waste management and disposal, conservation, site cleanup, or final demilitarization and disposal. (See definition of ESH Cost in Section 1.11.)

Environmental Impact Analysis Process (EIAP) - The process established by NEPA that requires federal agencies to analyze the potential environmental impacts of proposed actions and alternatives and use those analyses in making decisions or recommendation on whether and how to proceed with those actions.

Environmental Impact Statement (EIS) - A document, prepared when the proposed action exhibits the possibility of generating significant environmental impacts, which provides full and fair discussion of potential environmental impacts and informs decision makers and the public of the reasonable alternatives that would minimize or avoid adverse impacts.

ESH - Environmental, Safety, and Health. This is an initiative within the Department of the Air Force that treats Environmental, Safety, and Health issues in an integrated manner.

Executive Order 11514 - Protection and Enhancement of Environmental Quality. Oldest active environmental executive order implemented NEPA by establishing responsibilities for federal agencies. It requires federal agencies to develop programs and measures to protect and enhance environmental quality.

Executive Order 12114 - Environmental Effects Abroad of Major Federal Actions. Guidance to take into account environmental considerations when authorizing or approving major actions in places outside the United States.

Executive Order 12196 - Occupational Safety and Health Programs for Federal Employees. Guidance to federal departments to protect DoD personnel from death, injury, or occupational illness by exposure to stressors beyond established limits.

Executive Order 12856 - Federal Compliance with Right-To-Know Laws and Pollution Prevention Requirements, describes the requirements for establishing pollution prevention programs in Federal agencies. Executive orders are policy directives for DoD.

Executive Order 12873 - Federal Acquisition, Recycling, and Waste Reduction. This EO requires all federal agencies to incorporate use of recovered materials, reuse of product, life cycle cost, recycleability, use of environmentally preferable products, waste prevention, and disposal in acquisition planning.

Executive Order 12969 - Federal acquisition and community right-to-know. Establishes the requirement for federal acquisitions to report toxic releases.

Federal Facilities Compliance Act (FFCA) - Act that amends the waiver of sovereign immunity granted by RCRA.

Finding Of No Significant Impact (FONSI) - A document based upon an Environmental Analysis that briefly presents the reasons why an action, not otherwise excluded will not have a significant effect on the human environment and for which an EIS will not be prepared.

Hazardous Material (HAZMAT) - Anything, that due to its chemical, physical, or biological nature, causes safety, public health, or environmental concerns resulting in an elevated level of effort to manage it.

Hazardous Materials Transportation Act (HTMA) - Authorizes the Department of Transportation to regulate shipping, marking, and documentation of all hazardous materials.

Human Systems Integration Plan (HSIP) - A document prepared initially by the using community which addresses potential manpower, personnel, training, and safety constraints.

Integrated Logistics Support Plan (ILSP) - A management plan developed and used to manage the integrated logistics support (ILS) process. This plan includes horizontally integrating ILS elements (that is, with each other) and vertically integrating the various aspects of program planning, engineering, designing, testing, and evaluating during production and operation. It also includes integrating support elements with mission elements of a system throughout its life cycle.

Integrated Manpower, Personnel and Integrated Comprehensive Training and Safety (IMPACTS) - The Air Force implements and fulfills the reporting requirements human system integration through the Integrated Manpower, Personnel and Comprehensive Training and Safety Program.

Integrated Product Development (IPD) - The use of multidisciplinary teams to manage and integrate critical processes by acquiring the appropriate staff at the right time and place to make effective decisions.

Life Cycle Cost (LCC) - The total cost to the government of acquisition and ownership of a system over its useful life, including disposal.

Logistics Support Analysis Record (LSAR) - A uniform, organized and flexible database for consolidating the engineering and logistic data needed to identify and justify a system's logistic support requirements.

Mitigation - Avoidance of an environmental impact or minimization of an environmental impact by limiting the magnitude of the action, rectifying the impact, and/or reducing or eliminating an impact by replacing or providing substitute resources or environments.

Modification - A configuration change to a produced item that updates or upgrades the weapon system in response to deficiencies or the need to improve the system capability.

NAS-411 - A hazardous materials management standard created by the Aerospace Industries Association to be applied to government acquisitions of systems, system components, associated support items, and facilities.

National Environmental Protection Act (NEPA) - Act which requires federal agencies to consider the environmental impact of its actions.

Occupational Safety and Health Act (OSHA) - Act which provides for the Secretary of Labor to set mandatory occupational safety and health standards for work places.

Ozone Depleting Substances (ODS) -Compounds that contribute to stratospheric ozone depletion. ODSs include CFCs, HCFCs, halons, methyl bromide, carbon tetrachloride, and methyl chloroform. ODSs are generally very stable in the troposphere and only degrade under intense ultraviolet light in the atmosphere. When the breakdown occurs, they release chlorine or bromine atoms, which then depletes the ozone.

Pollutant - Any element, substance, compound, mixture, which after release into the environment and upon exposure, ingestion, inhalation or assimilation into any organism, either directly or indirectly will or may reasonably be expected to cause death, disease, behavioral or psychological malfunctioning, or physical deformation.

Pollution Prevention - Source reduction and other practices that reduce or eliminate the creation of pollutants through increased efficiency in the use of raw materials, energy, water, or other resources; or by protection of natural resources by conservation.

Program Cost Estimate (PCE) - The program manager's official estimate of the cost to effectively execute the program contained in the program direction. The PCE is developed by the program office. It is the estimate reflected in the program office's formal reports and financial reviews.

Program Manager (PM) - General term sometimes used to describe system program directors, product group managers, and material group managers who are the individuals responsible for a system, product group or material group.

Resource Conservation and Recovery Act (RCRA) - Establishment of comprehensive cradle-to-grave control of the treatment, storage, and disposal of hazardous wastes. Includes criminal sanctions and fines for violation.

Reclamation - The reclaiming or recovery of serviceable and economically separable components and materials from excess or surplus property.

Record Of Decision (ROD) - The decision document, prepared after the EIS, that states what the decision is, identifies all alternative considered by the lead agency and status whether all practicable means to avoid or minimize environmental harm have been adopted, and if not, why not.

Remediation - Cleanup or restoration of sites and facilities whose past activities created contamination from toxic and hazardous substances.

Request for Proposal (RFP) - A solicitation document used in negotiated procurement when the government reserves the right to award without further oral or written negotiation.

Risk Analysis - Part of a hazards analysis process which assesses the likelihood of an accidental release of a hazardous material and the consequences that might result, based on the estimated vulnerable zones. The analysis is based upon the history of previous events, experience at the installation, and the best available information.

Risk Assessment - The qualitative and quantitative evaluation performed to define the risk posed to human health or the environment by the presence or potential presence and/or the use of pollutants

Risk Management - the process of evaluating alternative responses to risk and selecting among them. The selection process requires consideration of impact to human health and the environment, legal, economic and social factors.

Superfund Amendments and Reauthorization Act (SARA) - Re-authorized the funding provisions of CERCLA and established a nationwide community right-to-know and emergency planning program.

Single Manager (SM) - General term sometimes used to describe system program directors, product group managers, and material group managers who are the individuals responsible for a system, product group or material group.

Statement of Work (SOW) - That portion of a contract which describes the actual work to be performed by means of specification, minimum requirements, quantities, performance dates, and a statement of the requisite quality.

Test and Evaluation Master Plan (TEMP) - An overall plan designed to identify and integrate objectives, responsibilities, resources and schedules for all test and evaluation to be accomplished in support of key decision points.

Toxic Substances - Toxic substances are chemicals that can cause harm to human or other living systems at very low concentrations, either by inhalation, ingestion, injection, or skin contact. More specific legal definitions can include chemicals listed as toxic chemicals in specific laws or environmental regulations such as the toxic chemicals listed in Section 313 of the Emergency Planning and Community Right to Know Act of 1986.

Toxic Substances Control Act (TSCA) - Regulates the manufacture, import, processing, distribution in commerce, use and disposal of chemical substances. Goal is to ensure that the EPA has an opportunity to review and asses a chemical’s potential risk before it is entered into commerce.

Appendix E – Sections 3.3.6 and 4.3.7 of DoD 5000.2-R

3.3.6 Environmental, Safety, and Health Considerations

The acquisition strategy shall include a programmatic environmental, safety, and health (ESH) evaluation. The PM shall initiate the ESH evaluation at the earliest possible time in support of a program initiation decision (usually Milestone I) and shall maintain an updated evaluation throughout the life-cycle of the program. The ESH evaluation describes the PM's strategy for meeting ESH requirements (see 4.3.7), establishes responsibilities, and identifies how progress will be tracked.

4.3.7 Environment, Safety, and Health

All programs, regardless of acquisition category, shall comply with this section and be conducted in accordance with applicable federal, state, interstate, and local environmental laws and regulations, Executive Orders (EOs), treaties, and agreements.

Environmental, safety, and health (ESH) analyses shall be conducted, as described below, to integrate ESH issues into the systems engineering process and to support development of the Programmatic ESH Evaluation (see 3.3.6).

4.3.7.1 National Environmental Policy Act

The PM shall comply with the National Environmental Policy Act (NEPA) **(42 USC 4321-4370d**[i]**)**, implementing regulations **(40 CFR 1500-1508**[ii]**),** and executive orders (**EO 12114**[iii] **and EO 11514**[iv] by analyzing actions proposed to occur in upcoming program phases that may require NEPA or EO analysis and providing the MDA with milestones and status for each planned analysis. Any analysis required under either NEPA or EO must be completed before the appropriate official may make a decision to proceed with a proposed action that may affect the quality of the human environment. NEPA and EO analysis is tied to proposed, program-specific actions. NEPA and EO documentation shall be prepared in accordance with DoD Component implementation regulations and guidance. The CAE is the final approval authority for system-related NEPA and EO documentation. The PM shall forward a copy of final NEPA documentation for ACAT I programs to the Defense Technical Information Center for archiving.

4.3.7.2 Environmental Compliance

Environmental regulations are a source of external constraints that must be identified and integrated into program execution. To minimize the cost and schedule risks that changing regulations represent, the PM shall regularly review environmental regulations and shall analyze the regulations and evaluate their impact on the program's cost, schedule, and performance.

4.3.7.3 System Safety and Health

The PM shall identify and evaluate system safety and health hazards, define risk levels, and establish a program that manages the probability and severity of all hazards associated with development, use, and disposal of the system. All safety and health hazards shall be managed consistent with mission requirements and shall be cost-effective. Health hazards include conditions that create significant risks of death, injury, or acute chronic illness, disability, and/or reduced job performance of personnel who produce, test, operate, maintain, or support the system.

Each management decision to accept the risks associated with an identified hazard shall be formally documented. The CAE shall be the final approval authority for acceptance of high risk hazards. All participants in joint programs shall approve acceptance of high risk hazards. Acceptance of serious risk hazards may be approved at the PEO level.

EO 12196[v] and **DoDI 6055.1**[vi] make Federal Occupational Safety and Health Act regulations applicable to all federal employees working in non-military-unique DoD operations and workplaces, regardless of whether work is performed by military or civilian personnel. In the case of military-unique equipment, systems, operations, or workplaces, Federal safety and health standards, in whole or in part, apply to the extent practicable.

4.3.7.4 <u>Hazardous Materials</u>

The PM shall establish a hazardous material management program that ensures appropriate consideration is given to eliminating and reducing the use of hazardous materials in processes and products rather than simply managing pollution created (**EO 12856**[vii]). The selection, use, and disposal of hazardous materials shall be evaluated and managed so the DoD incurs the lowest cost required to protect human health and the environment over the system's life-cycle, consistent with the program's cost, schedule, and performance goals. Where a hazardous material use cannot be avoided, the PM shall plan for later material replacement capability in the system design, if technically feasible and economically practical and shall develop and implement plans and procedures for identifying, minimizing use, tracking, storing, handling, and disposing of such materials and equipment.

4.3.7.5 <u>Pollution Prevention</u>

In designing, manufacturing, testing, operating, maintaining, and disposing of systems, all forms of pollution shall be prevented or reduced at the source whenever feasible. Pollution that cannot be prevented shall be recycled in an environmentally safe manner. Pollution that cannot be prevented or recycled shall be treated in an environmentally safe manner. Disposal or other releases to the environment shall be employed only as a last resort and must be conducted in an environmentally safe manner. The PM shall establish a pollution prevention program to help minimize environmental impacts and the life-cycle costs associated with environmental compliance. The PM shall identify the impacts of the system on the environment, wastes released to the environment, ESH risks associated with using new technologies, and other information needed to identify source reduction and recycling opportunities.

Many opportunities for pollution prevention can be incorporated into contract documents. In developing work statements, specifications, and other product descriptions, **EO 12873**[viii] requires PMs to consider elimination of virgin material requirements, use of recovered materials, reuse of products, life-cycle cost, recyclability, use of environmentally preferable products, waste prevention (including toxicity reduction or elimination), and ultimately, disposal, as appropriate.

Appendix F - Summary of ESH Laws, Executive Orders, DoD and Air Force Requirements

ESH Law	Description	Impact To Program/Single Manager
National Environmental Policy Act (NEPA), 1970	Requires Federal Agencies To Consider Environmental Impacts In Decision Making	PM/SM Are Proponents Of NEPA Documentation; SAF/AQRE Approves All AF Weapon Systems NEPA Documentation; Failure To Comply With NEPA May Cause Program Delays And Stoppages
Clean Air Act (CAA), 1963, ..., 1990	Established Air Quality Standards For Six (6) Criteria Pollutants And Requires Control Technology And Programs In-Accordance-With (IAW) Standard Industry Procedures (SIPs)	CAA Drives State and Local Air Regulations Which May Impact Basing Locations For Weapon Systems
Clean Water Act (CWA), 1972	Controls Discharge Of Pollutants Into Waters If The United States, Wastewater Treatment	CWA May Impact Basing Locations For Weapon Systems
Public Law 102-484, Sections 325 & 326	Evaluation Of Class I & II ODSs And Elimination Of Class I ODSs	Must Be Considered When Incorporating Pollution Prevention (P2) Studies Into The Systems Engineering Process
Public Law 103-337, Section 815	(1) How To Achieve The Purpose And Intent Of NEPA; (2) How To Analyze Life Cycle Environmental Costs; (3) Analyze MDAP Environmental Costs No Later Than March 31, 1995	Must Analyze MDAP ESH Costs
Resource Conservation And Recovery Act (RCRA), 1976	Regulates On-Going Hazardous Waste Handling And Disposal, Including Permitting Requirements	RCRA Should Be Considered When Incorporating Pollution Prevention (P2) Studies Into The Systems Engineering Process
Pollution Prevention Act (PPA), 1990	Institutes National Policy Of US That Pollution Should Be Prevented Or Reduced At The Source Whenever Feasible	PPA Should Be Considered When Incorporating Pollution Prevention (P2) Studies Into The Systems Engineering Process
Toxic Substances Control Act (TSCA), 1976	Regulates Manufacture, Distribution, Use And Disposal Of Chemicals	TSCA Should Be Considered When Incorporating Pollution Prevention (P2) Studies Into The Systems Engineering Process
Occupational Safety And Health Act (OSH Act), 1970	Ensures Safe And Healthful Conditions For The Nations Workforce	OSH Act Should Be Considered When Incorporating Pollution Prevention (P2) Studies Into The Systems Engineering Process
Federal Facilities Compliance Act (FFCA), 1992	Makes Federal Facilities And Workers Liable For Fines And Penalties Under RCRA	Minimal, Impacts Supporting And Using Community Primarily
Comprehensive Environmental Response, Compensation & Liability Act (CERCLA), 1980	Regulates The Cleanup And Remediation Of Hazardous Waste Sites	Minimal, Impacts Supporting And Using Community Primarily
Emergency Planning And Community Right-To-Know Act (EPCRA), 1986	Requires Toxic Chemical Release, Inventory Reporting And Emergency Planning	Minimal, Impacts Supporting And Using Community Primarily. See EO 12969

Executive Order (EO)	Description	Impact To Program/Single Manager
EO 11514, Protection And Enhancement Of Environmental Quality, 05 Mar 1970	Federal Agencies Shall Initiate Measures Needed To Direct Their Policies, Plans And Programs So As To Meet National Environmental Goals	Must Be Considered For Incorporation Into The Systems Engineering Process
EO 12114, Environmental Effects Abroad Of Major Federal Actions, 04 Jan 1979	Federal Agencies Shall Apply NEPA With Respect To The Environment Outside The United States, Its Territories And Possessions	Must Consider NEPA Impacts When Weapon System Is Based Outside United States
EO 12196, Occupational Safety And Health Programs For Federal Employees, 26 Feb 1980	Federal Agencies Must Furnish Employees Places And Conditions Of Employment That Are Free From Recognized Hazards That Are Causing or Are Likely To Cause Death Or Serious Physical Harm	Must Be Considered For Incorporation Into The Systems Engineering Process
EO 12780, Federal Agency Recycling And The Council On Federal Recycling And Procurement Policy, 31 Oct 1991	Requires Federal Agencies To Promotes Cost Effective Pollution Prevention, Cost Effective Waste Reduction, And Immediate Implementation Of Cost Effective Federal Procurement Preference Programs	Must Be Considered For Incorporation Into The Systems Engineering Process
EO 12856, Federal Compliance With Right-To-Know Laws And Pollution Prevention Requirements, 03 Aug 1993	Describes The Requirements And Provisions For The Establishment Of Pollution Prevention Programs Within Federal Agencies	Must Be Considered For Incorporation Into The Systems Engineering Process
EO 12873, Federal Acquisition, Recycling, And Waste Prevention, 20 Oct 1993	Federal Agencies Shall Comply With Executive Branch Policies For The Acquisition And Use Of Environmentally Preferable Products And Services And Implement Cost Effective Procurement Preference Programs	Must Be Considered For Incorporation Into The Systems Engineering Process
EO 12969, Federal Acquisition And Community Right-To-Know, 08 Aug 1995	Invokes EPCRA Toxic Release Inventory (TRI) Reporting For Contracts Expected To Exceed $100K	Must Be Considered For Incorporation Into The Systems Engineering Process

DoD Requirement	Description	Impact To Program/Single Manager
DoD 5000.2-R, Part 3, Section 3.3.6 - Environmental, Safety, and Health Considerations, 15 Mar 1996	The Acquisition Strategy Shall Include A Programmatic Environmental, Safety, And Health (ESH) Evaluation. The PM Shall Initiate The Evaluation At The Earliest Possible Time In Support Of A Program Initiation Decision (Usually Milestone I) And Shall Maintain An Updated Evaluation Throughout The Life-Cycle Of The Program.	Must Perform A Programmatic ESH Evaluation. The Programmatic ESH Evaluation Describes The PM's Strategy For Meeting ESH Requirements (Section 4.3.7), Establishes Responsibilities, And Identifies How Progress Will Be Tracked
DoD 5000.2-R, Part 4, Section 4.3.7 - Environmental, Safety, and Health, 15 Mar 1996	All Programs, Regardless Of Acquisition Category, Shall Comply With This Section And Be Conducted In Accordance With Applicable Federal, State, And Local Environmental Laws And Regulations, Executive Orders (Eos), Treaties, And Agreements. ESH Analyses Shall Be Conducted To Integrate ESH Issues **(NEPA, Environmental Compliance, System Safety And Health, Hazardous Materials, Pollution Prevention)** Into The Systems Engineering Process And To Support Development Of The Programmatic ESH Evaluation (Section 3.3.6).	Must Be Incorporated Into The Systems Engineering Process
DoDD 4210.15 - Hazardous Material Pollution Prevention (HMMP), 27 Jul 1989	Hazardous Materials Shall Be Selected, Used, And Managed Over Its Life Cycle So That The Dod Incurs The Lowest Cost Required To Protect Human Health And The Environment.	Must Generate A Hazardous Material Management Plan
DoD 5000.4M - Department of Defense Manual Cost Analysis Guidance Procedures, Dec 1992	Cost Analysis Requirements Description (CARD) • Provides A Basis For Cost Estimating Weapon System • Provides A Description Of The Salient Features Of The Program And Of The System Being Acquired	Must Generate A CARD And Provides PM Opportunity To Reflect And Quantify The ESH Requirements Into The Weapon System
MIL-STD-882C - System Safety Program Requirements, 19 Jan 1993	This Standard Provides Uniform Requirements For Developing And Implementing A System Safety Program Of Sufficient Comprehensiveness To Identify The Hazards Of A System And To Impose Design Requirements And Management Controls To Prevent Mishaps	Applies To All DoD Systems And Facilities As Well As To Every Activity Of The System Life Cycle

Air Force Requirement	Description	Impact To Program/Single Manager
AFPD 32-70 - Environmental Quality, 15 Oct 1993	Specifies Steps Air Force Will Take In Regards To: Cleanup, Compliance, Conservation, And Pollution Prevention	Must Be Implemented Into Weapon System Over Life Cycle
AFI 32-7061 - The Environmental Impact Analysis Process, 24 Jan 1995	Air Force Procedural Implementation Of NEPA And Council On Environmental Quality (CEQ) Regulations	Must Be Implemented Into Weapon System Over Life Cycle
AFI 32-7080 - Pollution Prevention Program, 12 May 1994	Provides Framework On How Air Force Does Business To Comply With Requirements According To AFPD 32-70 And Outlines Structure For Pollution Prevention Management Plans, Measurement, Hazardous Substance Management, And Research And Development	Must Be Implemented Into Weapon System Over Life Cycle
AFPD 91-2 - Safety Programs, 28 Sep 1993	The Air Force Is Committed To Providing Safe Healthful Environments Both For Air Force People And For Those Affected By Air Force Operations	Must Be Implemented Into Weapon System Over Life Cycle
AFPD 91-3 - Occupational Safety and Health, 27 Sep 1993	The Air Force Is Committed To Providing Safe And Healthful Workplaces To Preserve Their Human Resources	Must Be Implemented Into Weapon System Over Life Cycle
AFI 91-301 - Air Force Occupational and Environmental Safety, Fire Protection, and Health (AFOSH) Program, 01 Jun 1996	Minimize Loss Of Air Force Resources And To Protect Air Force People From Occupational Deaths, Injuries, Or Illnesses By Managing Risks	Must Be Implemented Into Weapon System Over Life Cycle
Eastern and Western Range Regulation 127-1, Range Safety Standards, Nov 1995	To Provide For The Public Safety, The Ranges, Using A Range Safety Program, Must Ensure That The Launch And Flight Of Launch Vehicles And Payloads Present No Greater Risk To The General Public Than That Imposed By The Overflight Of Conventional Aircraft	Must Be Implemented Into Weapon System Over Life Cycle
Environmental, Safety, and Health (ESH) Evaluation Guide, Nov 1996	Provides Overview Of What Is An ESH Evaluation; Who Should Be Involved In Performing The ESH Evaluation; Where ESH Information Should Be Contained; Documenting The ESH Evaluation And; Strategy For Preparing The ESH Evaluation	Must Be Performed For Weapon System Over Life Cycle

Appendix G - Functional Support Organizations for the Cost Analyst

Organization for ESH Management

This section will discuss the organization roles and responsibilities for ESH at the various levels from HQ USAF down to operating base level. ESH Management is vested in three interrelated functions: The ESH Disciplines, Financial Management, and Systems Engineering.

HQ USAF

At HQ USAF there are five agencies that participate in ESH Management and Cost Activities:

- SAF/AQRE is the agency under the Assistant Secretary of the Air Force for Acquisition that is responsible for ESH issues during the weapon system acquisition process. They participate in the HQ USAF ESOH Committee and when requested, in weapon system Integrated Product Teams (IPTs).
- SAF/MIQ is the agency under the Assistant Secretary of the Air Force for Manpower, Reserve Affairs, Installations, and Environment that is responsible for ESH issues in operations. They integrate the best ESH practices into all Air Force Activities.
- HQ USAF/SG is the agency that advises the Secretary of the Air Force and Air Force Chief of Staff, as well as the Assistant Secretary of Defense (Health Affairs), on matters affecting the health of Air Force personnel and the public. This includes policy and resolving issues involving occupational health, industrial hygiene, bioenvironmental engineering, radiation exposures and radioactive materials, community health, and public health.
- HQ USAF/IL is the Air Staff agency for installations and logistics. This includes the Office of the Civil Engineer (HQ USAF/ILE), the Air Force Center for Environmental Excellence (AFCEE), and the Air Force Civil Engineering Support Agency (AFCESA), all of which are active in ESH activities.
- SAF/FMC is the financial agency under the Assistant Secretary of the Air Force for Financial Management and Comptroller. The Air Force Cost Analysis Agency (AFCAA) under this agency is responsible for developing and implementing policy and procedures for cost estimating and analysis and developing cost factors used in the Air Force budget process.

HQ AFMC

At Headquarters AFMC there are eight agencies that participate in ESH Management and Cost:

- HQ AFMC/FMPC is the cost estimating and analysis arm of the command financial management function. The cost studies and analysis organization within FM sponsors and approves this Guide.
- HQ AFMC/DRI is the product support side of the requirements directorate. Their responsibilities include management of command participation in the Joint Group of Acquisition Pollution Prevention and participation in the Center Working Group (CWG) for Acquisition Pollution Prevention.
- HQ AFMC/SE is the safety office for the command with responsibilities for system safety, flight safety, and ground safety. They track accidents, mishaps, incidents and resource losses from safety hazards.
- HQ AFMC/SGC is the command bioenvironmental engineering office. Their responsibilities include monitoring the exposure of personnel to hazardous materials and policies and procedures for the protection of personnel.
- HQ AFMC/ENBE is the environmental branch of engineering and technical management office. Their responsibilities include integration, management, and support for the Single Manager to incorporate ESH policy into the systems engineering process.
- HQ AFMC/LG-EV is the logistics environmental office. Their responsibilities are to provide command level policy, guidance, support and coordination on all pollution prevention activities within logistics and review, coordinate, and develop policy on cross-cutting environmental issues

with other directorates. They serve as the Air Force lead of the Joint Depot Environmental Panel and act as the Command leader for all logistics environmental issues.

- HQ AFMC/CEV is the environmental office of the command Civil Engineer. This office is responsible for the environmental management program within the command. Their focus is on compliance.
- AFMC LO/JAV is the Judge Advocate environmental law division. Their responsibilities are to provide expert legal counsel to the commander, SAF/AQ, PEOs, HQ STAFF, and AFMC field units on environmental issues.

Following is a current list of HQ AFMC functional contacts for ESH issues that may provide assistance to the cost analyst.

Financial Management			
Cost Studies & Analysis Branch	HQ AFMC/FMPC	787-4736	Ms. Judy Collins
Financial Mgmt Policy Branch	HQ AFMC/FMPM	787-3084	Mr. Chuck Braden
Civil Engineer			
Environmental Division	HQ AFMC/CEV	787-5873	Col Emmitt Smith
Restoration Branch	HQ AFMC/CEVR	787-7053	Mr. Jeff Mundy
Compliance Branch	HQ AFMC/CEVC	787-5878	Ms. Clare Mendelsohn
Pollution Prevention Branch	HQ AFMC/CEVV	787-7414	Lt Col Richard Ashworth
Env. Operations Branch	HQ AFMC/CEVO	787-4920	Maj Alex Peat
Safety	HQ AFMC/SE	787-6128	Col Michael Scott
Ground/Contract Safety	HQ AFMC/SEG	787-7131	Mr. John Russell
Flight Safety	HQ AFMC/SEF	787-1366	Lt Col Bill Gilespie
Systems/Materiel Safety	HQ AFMC/SES	787-6007	Mr. Chuck Dorney
Weapons Safety	HQ AFMC/SEW	787-6618	Mr. Gene Larkin
Surgeon General			
Biomedical Sciences	HQ AFMC/SGB	787-6210	
Public Health			
Bioenvironmental Eng. Services	HQ AFMC/SGC	787-2618	Col Robert Cappell
Occupational Health Eng.	HQ AFMC/SGCO	787-2618	Capt Darrell Sumrall
Environmental Programs	HQ AFMC/SGCP	787-2618	Maj Lyn Gemperle
Health Physics	HQ AFMC/SGCR	787-2618	Maj Larry Donovan
Law Office			
Environmental Law Division	AFMC LO/JAV	787-4482	Col John Abbott
Public Affairs			
Environmental Public Affairs	HQ AFMC/PAC	787-6946	Ms. Libby VanHook
Requirements			
Pollution Prevention Branch	HQ AFMC/DRIE	787-6220	Mr. Ray Olfky
Logistics			
Logistics Environmental Office	HQ AFMC/LG-EV	787-8082	Ms. Debbie Meredith
Engineering			
Env. Integration Branch	HQ AFMC/ENBE	787-0011	Mr. Terry Black

Centers

Centers include product centers (ASC, ESC, HSC, and SMC), logistics centers (Ogden ALC, San Antonio ALC, Warner Robins ALC, Sacramento ALC, and Oklahoma City ALC), Test Centers (AEDC, AFDTC, and AFFTC), and specialized centers such as the Aerospace Maintenance and Regeneration Center (AMARC). While the organizations at these centers may vary considerably in title and office symbol there are a number of common functions that participate in ESH activities.

- Financial Management. Most have their own FM organization and the remaining centers are supported by FM functions at host bases. These FM organizations provide any needed cost estimating, analysis or budget preparation support. Typical office symbols include FM, FMC or FMB.
- Environmental Management (EM). The office symbol and location of this function varies from Center to Center. At ASC and several of the ALCs, it is EM. At ESC, it is BP. At SMC, both AXZ and AXFV provide assistance on environmental issues. The functions are fairly similar being responsible for the four principle functions of environmental management (planning, compliance, restoration, and pollution prevention). In some organizations, portions of the EM functions may be performed by the Civil Engineering organization, normally CEV. Typically the CEV organization is focused on the National Environmental Protection Act (NEPA) requirements and will accomplish or assist in such activities as Environmental Assessments (EAs) or Environmental Impact Statements EISs).
- Safety. Safety is most often managed as an installation function. That is to say the host organization provides a set of services to all organizations on the base. The services include system, flight, and ground safety. Safety functions are often augmented by part time appointees within each organization at an installation. At some Product Centers, the Safety function may reside in a Staff Support activity. For example, at SMC all Safety function are within the Directorate of Systems Acquisition.
- Occupational Health and Public Health. This function is most often a subset of the medical services provided to an installation. Installation activities normally carry an office symbol beginning with "SG." Depending upon the size of the organization and the host/tenant relationship, the Hospital and its Bioenvironmental Engineering (SGPB) and Public Health (SGPM) functions may be part of another Wing or Group. At some Product Centers, the Bioenvironmental Engineering support for Occupational Health activities may be a staff function separate from installation level activities. For example, Bioenvironmental Engineers at ASC reside within the Environmental Management (EM) office and at SMC they reside in the Acquisition Health and Safety division (SMC/AXZ).
- Engineering. The engineering function in a weapon system will normally be in a program office. If the system has been fielded the engineering function may reside under the Single Manager at an ALC. The engineering function has the responsibility to integrate performance, ESH requirements and come up with the lowest cost solution.

Air Force Research Laboratory (AFRL)

In 1997 all of the Air Force Research Laboratories were organized as a single laboratory under HQ AFMC S&T. Directorates were established by basic research categories (i.e. space, aircraft, materials, human effectiveness etc.). A support directorate, AFRL/DS, contains ESH staffing to assist the directorates. The research staff manages ESH issues on individual research projects, within the research directorates, with assistance from product center organizations such as ASC/EM.

Operating Bases

Operating bases have the same financial management, environmental management, safety and occupational health organizations that you would find at a center. The difference is that the design emphasis will not be at the operating bases and the operational emphasis will replace the design emphasis. More than likely the environmental management organization will be in the civil engineering organization rather than on the command staff.

Appendix H - Electronic/Automated Software Systems Work Breakdown Structure Dictionary, April 1998

Introduction

The Electronic/Automated Software Systems Work Breakdown Structure (WBS) and Definitions as presented in MIL-HDBK-881 dated 2 January 1998, the Office of the Secretary of Defense (OSD) Cost Analysis Improvement Group (CAIG) Operating and Support Cost Estimating Guide dated May 1992, and the Environmental Cost of Hazardous Operations (ECHO) WBS Dictionary dated August 1996, was expanded to include environmental, safety, and health (ESH) language, as well as include WBS elements for the other phases of a system's life cycle such as concept exploration and operations and support IAW DoD 5000.2-R. This WBS and definitions along with the WBSs and definitions of the other systems as presented in MIL-HDBK-881 will form the new ESH WBS Dictionary The other system WBSs and definitions will be updated at a later date by the appropriate centers to include the appropriate ESH language. The other systems are aircraft, missile, ordnance, ship, space, and surface vehicle. For further ESH definitions and explanations, refer to the Tactical ESH Action Guide (TEAG), a living document which provides the single managers with the information necessary to comply with ESH requirements during the acquisition of weapon systems. The TEAG is located in the following Internet address:

http://www.hanscom.af.mil/Orgs/O_Orgs/AX/pollprev/products.htm

The new ESH WBS Dictionary will consist of the following sections:

Section	System
1	Aircraft
2	Electronic/Automated Software
3	Missile
4	Ordnance
5	Ship
6	Space
7	Surface Vehicle

Electronic/Automated Software System WBS

1 Electronic/Automated Software System Concept Exploration
- 1.1 Prime Mission Equipment (PME)
  - 1.1.1 Subsystems 1…n
  - 1.1.2 PME Software

2 Electronic/Automated Software System Definition and Risk Reduction
- 2.1 PME - System Definition
  - 2.1.1 Subsystems 1…n
  - 2.1.2 PMP Software
- 2.2 PME Risk Reduction
  - 2.2.1 Analysis of Alternatives (AoAs)
  - 2.2.2 Risk Assessment

3 Electronic/Automated Software System Engineering and Manufacturing Development
- 3.1 PME
  - 3.1.1 Subsystems 1…n
  - 3.1.2 PME Software
    - 3.1.2.1 Application
    - 3.1.2.2 System Software
  - 3.1.3 Integration, Assembly, Test and Checkout
- 3.2 Systems Engineering/Program Management (SE/PM)
  - 3.2.1 Systems Engineering (SE)
  - 3.2.2 Program Management (PM)
- 3.3 System Test and Evaluation (ST&E)

3.3.1 Development Test and Evaluation (DT&E)
3.3.2 Operational Test and Evaluation (OT&E)
3.3.3 Mock-ups
3.3.4 Test and Evaluation Support
3.3.5 Test Facilities
3.4 Training
3.4.1 Equipment
3.4.2 Services
3.4.3 Facilities
3.5 Data
3.5.1 Technical Publications
3.5.2 Engineering Data
3.5.3 Management Data
3.5.4 Support Data
3.5.5 Data Depository
3.6 Peculiar Support Equipment (PSE)
3.6.1 Test and Measurement Equipment
3.6.2 Support and Handling Equipment
3.7 Common Support Equipment (CSE)
3.7.1 Test and Measurement Equipment
3.7.2 Support and Handling Equipment

4 Electronic/Automated Software System Production
4.1 PME
4.1.1 Subsystems 1…n
4.1.2 PME Software
4.1.3 Integration, Assembly, Test and Checkout
4.2 Platform Integration
4.3 Systems Engineering/Program Management (SE/PM)
4.3.1 Systems Engineering (SE)
4.3.2 Program Management (PM)
4.4 System Test and Evaluation (ST&E)
4.4.1 Development Test and Evaluation (DT&E)
4.4.2 Operational Test and Evaluation (OT&E)
4.4.3 Mock-ups
4.4.4 Test and Evaluation Support
4.4.5 Test Facilities
4.5 Training
4.5.1 Equipment
4.5.2 Services
4.5.3 Facilities
4.6 Data
4.6.1 Technical Publications
4.6.2 Engineering Data
4.6.3 Management Data
4.6.4 Support Data
4.6.5 Data Depository
4.7 Peculiar Support Equipment (PSE)
4.7.1 Test and Measurement Equipment
4.7.2 Support and Handling Equipment
4.8 Common Support Equipment (CSE)
4.8.1 Test and Measurement Equipment
4.8.2 Support and Handling Equipment

5 Fielding/Deployment, and Operational Support
5.1 Operational/Site Activation

- 5.1.1 System Assembly, Installation, and Checkout on Site
- 5.1.2 Contractor Technical Support
- 5.1.3 Site Construction
- 5.1.4 Site/Ship/Vehicle Conversion
- 5.2 Industrial Facilities
  - 5.2.1 Construction/Conversion/Expansion
  - 5.2.2 Equipment Acquisition or Modernization
  - 5.2.3 Maintenance of Facilities
- 5.3 Initial Spares and Repair Parts

6 Operations and Support (O&S)
- 6.1 Mission Personnel
  - 6.1.1 Operations
  - 6.1.2 Maintenance
    - 6.1.2.1 Organizational Maintenance
    - 6.1.2.2 Intermediate Maintenance
    - 6.1.2.3 Other Maintenance Personnel
  - 6.1.3 Other Mission Personnel
- 6.2 Unit-Level Consumption
  - 6.2.1 Fuel and POL
  - 6.2.2 Consumable Material/Repair Parts
  - 6.2.3 Depot-Level Reparables
  - 6.2.4 Other
- 6.3 Intermediate Maintenance (External to Unit)
  - 6.3.1 Maintenance
  - 6.3.2 Consumable Material/Repair Parts
  - 6.3.3 Other
- 6.4 Contractor Support
  - 6.4.1 Interim Contractor Support
  - 6.4.2 Contractor Logistics Support
  - 6.4.3 Other
- 6.5 Sustaining Support
  - 6.5.1 Sustaining Engineering Support
  - 6.5.2 Software Maintenance Support
  - 6.5.3 Simulator Operations
  - 6.5.4 Other
- 6.6 Indirect Support
  - 6.6.1 Personnel Support
  - 6.6.2 Installation Support

7 Demilitarization and Disposal
- 7.1 Facilities
  - 7.1.1 Facilities Deactivation/Equipment Dismantlement
  - 7.1.2 Facility Decontamination
- 7.2 Equipment/Systems/Materials
  - 7.2.1 Demilitarization and Disposal Process Equipment/Facility Design and Construction
    - 7.2.1.1 Interim Storage
    - 7.2.1.2 Disassembly, Disposition, and Disposal

8 Cost and Liability Risk

WBS Element Definitions

The following sections present the work breakdown structure and definitions for an Electronic/Automated Software System. New text that was incorporated into the WBS dictionary is presented in **bold** font.

1 Electronic/Automated Software System **Concept Exploration (Phase 0) - During this phase, competitive, parallel short-term concept studies and analyses are performed to define and evaluate the feasibility of alternative concepts and to provide a basis for assessing the relative merits of these concepts. Environmental, safety, and health (ESH) impacts should be considered during this phase. Activities associated with this phase include:**

- **environmental compliance**
- **National Environmental Policy Act (NEPA) compliance (Form 813)**
- **system safety and health identification and management**
- **hazardous materials (HAZMATs) management program (e.g., identification of potential HAZMATs, trade-off studies on impact of HAZMATs on design alternatives, etc.)**
- **pollution prevention programs.**

The above ESH activities will continue into Phases I and II.

This element refers to the complex of equipment (hardware/software), data, services, and facilities required to develop and produce an electronic, automated, or software system capability such as a command and control system, radar system, communications system, information system, sensor system, navigation/guidance system, electronic warfare system, support system, etc. The decision rule used to differentiate between the Electronic/Automated Software System category and other defense materiel item categories is: When the item is a stand alone system or used on several systems, but not accounted for in these other systems, the Electronic/Automated Software System category will be used. When the opportunity to collect lower level information on electronic and software items exists, regardless of which defense materiel item category is selected, the structure and definitions in this section apply.

The following details the elements that may occur during Concept Exploration, and the associated technical definitions:

1.1 Prime Mission Product (PMP) **- The following paragraph summarizes the technical definition presented for this element in the MIL-HDBK-881.** The PMP element refers to the hardware and software used to accomplish the primary mission of the defense materiel item. It includes all integration, assembly, test and checkout, as well as all technical and management activities associated with individual hardware/software elements. Also included are integration, assembly, test and checkout associated with the overall PMP. **See WBS Element 3.1 below for a more detailed description of PMP. Decisions made during this phase on types of HAZMATs to use could affect the life cycle cost of the system especially tracking and handling costs during testing, operations, and maintenance (O&M) and demilitarization and disposal (D&D) of the system.**

1.1.1 Subsystems 1...n (Specify Names) **- The following paragraph summarizes the technical definition presented for this element in the MIL-HDBK-881.** This element refers to all hardware and software components of the specific electronic/automated software subsystem, including all associated special test equipment, special tooling, production planning, and all technical and management activities. The software components consist of the applications and system software required to direct and maintain the specific electronic/automated software subsystem. It includes cables, conduits, connectors, shelters, and other devices associated with the operational electronic/automated software subsystem.

1.1.2 PMP Software **- The following paragraph summarizes the technical definition presented for this element in the MIL-HDBK-881.** The software element includes application and system software. Application software is software that is specifically produced for the functional use of a computer system (ref. ANSI/IEEE Std 610.12). System software is 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 example, operating systems, compilers, and utilities (ref. ANSI/IEEE Std 610.12).

2 Electronic/Automated Software System **Program Definition and Risk Reduction (Phase I) - During this phase, studies and analyses of the one or more concepts, design approaches, and/or parallel technologies are conducted, and assessments of the advantages and disadvantages of alternative concepts shall be refined. At this point, the ESH activities would include the continuation of the ESH activities from Phase 0 such as NEPA compliance, addressing of system peculiar safety and health issues and potential compliance issues, identification of potential HAZMATs, and pollution prevention results. Also included are the preparation of compliance documentation; systematic and interdisciplinary studies that support the documentation of ESH impacts; application fees and payments made to legally certify operations; and one-time surveys as well as recurring monitoring activities that support compliance documentation. The following details the elements that may occur during Program Definition and Risk Reduction, and the associated technical definitions:**

2.1 PMP - System Definition - The technical definition for this element is the same as element 1.1. In addition, it includes the design, development and production of complete units (i.e., the prototype or operationally configured units which satisfy the requirements of their applicable specification(s), regardless of end use).

2.1.1 Subsystems 1..n - The technical definition for this element is the same as element 1.1.1.

2.1.2 PMP Software - The technical definition for this element is the same as element 1.1.2.

2.2 PMP Risk Reduction - Prototyping, demonstrations, and early operational assessments shall be considered and included as necessary to reduce risk so that technology, manufacturing, and support risks are well in hand before the next decision point.

2.2.1 AOAs - Analyses of alternatives are conducted to determine which concepts, design approaches, and/or parallel technologies best meet mission requirements without impacting cost and performance. Each alternative in the AOA should be evaluated for its environmental, safety and health impacts, such as using a non-hazardous cleaning solution so that the hazardous material handling costs would not be incurred over the life of the system. Most of the ESH costing associated with the AOA will focus on comparing life cycle costs for several alternatives, including those that use less hazardous materials. The analysis aids decision makers in judging whether or not any of the proposed alternatives offer sufficient military and/or economic benefit to be worth the cost.

2.2.2 Risk Assessment - Cost drivers, life cycle cost estimates, cost performance trades, interoperability, and acquisition strategy alternatives shall be considered to include evolutionary and incremental software development. ESH risks, including compliance, health, and liability, should be assessed to see whether or not a given technology alternative or process can be implemented without generating an intolerable level of HAZMATs or unacceptable environmental damage.

3 Electronic/Automated Software System Engineering and Manufacturing Development (Phase II) - During this phase, the following activities are performed: studies and analyses, design development, evaluation, testing, and redesign for the system component(s) during the system development efforts, including preparation of specifications, engineering drawings, parts list, test planning and scheduling, raw and semi-fabricated material plus purchased parts, engineering test equipment, and preplanned product improvement efforts. Activities also include ensuring the producibility of the developmental materiel system,

inspection test and evaluation requirements, quality control procedures, and the activities of the lower level elements listed below. ESH activities during this phase include the continuation of similar activities from Phase I, such as NEPA compliance which may impact the test program, contractor compliance issues and possible inherited compliance issues at the depot, safety and health issues, identification and elimination of HAZMATs, and pollution prevention. What-if studies should be performed for hazardous materials (HAZMATs) alternatives (e.g., choosing HAZMATs that will be easier to handle, maintain, and dispose and that are cost effective - an example of this is the choice of enamel coating on the system that may cause compliance, cost, and handling/disposal problems for the paint stripping shop at the depot); development of pollution prevention and waste minimization programs as well as their implementation; hands-on control of HAZMATs for all processes throughout each phase (e.g., capital outlay for equipment used to capture and store waste, changes to manufacturing processes and other operations in order to minimize the use and production of HAZMATs, lost productivity due to personal protection equipment, cost of operating a HAZMATs pharmacy system); and fees paid for off-site disposal of waste material. Specific ESH activities are included with the associated elements described below (e.g., training).

3.1 Prime Mission Product (PMP) **-** The PMP element refers to the hardware and software used to accomplish the primary mission of the defense materiel item. It includes all integration, assembly, test and checkout, as well as all technical and management activities associated with individual hardware/software elements. Also included are integration, assembly, test and checkout associated with the overall PMP. When the electronic/automated software system comprises several PMPs, each will be listed separately at the next lower level. Also included are all whole and partial prime contractor, subcontractor, and vendor breadboards, brassboards, and qualification test units. It also includes the design, development and production of complete units (i.e., the prototype or operationally configured units which satisfy the requirements of their applicable specification(s), regardless of end use). It excludes only those "less than whole" units (e.g., test, spares, etc.) consumed or planned to be consumed in support of system level tests. This element also includes factory special test equipment, special tooling, and production planning required to fabricate the PMP. Duplicate or modified factory special test equipment delivered to the government for depot repair is excluded and should be included in the peculiar support equipment element.

3.1.1 Subsystems 1...n (Specify Names) **-** This element refers to all hardware and software components of the specific electronic/automated software subsystem, including all associated special test equipment, special tooling, production planning, and all technical and management activities. The software components consist of the applications and system software required to direct and maintain the specific electronic/automated software subsystem. This element includes all in-plant integration, assembly, test and checkout of hardware components and software into an electronic/automated software subsystem including the subsystem hardware and software integration and test. Also included are the interface materials and parts required for the in-plant integration and assembly of other level 4 components into the electronic/automated software subsystem and all materials and parts or other mating equipment furnished by/to an integrating agency or contractor. It includes, for example, cables, conduits, connectors, shelters, and other devices associated with the operational electronic/automated software subsystem. It also includes the design, development, production, and assembly efforts to provide each electronic/automated software subsystem as an entity. All effort directly associated with the remaining level 3 WBS elements and the integration, assembly, test and checkout of these elements into the PMP is excluded. **Costs include the acquisition, lease, or modification of all hardware and software necessary to design, engineer, develop, and modify hardware components and software of the system.**

3.1.2 PMP Software

3.1.2.1 Application Software **-** The applications software element is defined as software that is specifically produced for the functional use of a computer system (ref. ANSI/IEEE Std 610.12). Examples are battle management, weapons control, and data base management. This element refers to all effort required to design, develop, integrate and checkout the PMP applications computer software configuration items (CSCIs), not including the non-software portion of PMP firmware development and production. This excludes all software that is an integral part of any specific hardware subsystem specification. All software that is an integral part of any specific equipment system and subsystem specification or specifically designed and developed for system test and evaluation should be identified with that system, subsystem, or effort. It may be appropriate to collect lower level information when it exists. In such cases, the following structure and definitions should be used:

<u>Level 4</u>	<u>Level5</u>
Build 1...n (Specify Names)	CSCI 1...n (Specify Names) CSCI to CSCI Integration and Checkout
Integration, Assembly, Test and Checkout	

a. Build 1...n (Specify Names) **-** A software build is an aggregate of one or more CSCIs that satisfies a specific set or subset of requirements. When incremental, spiral, or other software development method is used, multiple builds may be necessary to meet program requirements. A build is a separately tested and delivered product. Within builds are CSCIs. When a build is complete, a portion or all of one or more CSCIs will be completed. Therefore, a CSCI may appear in more than one build, but will be successively more functional as each build is completed.

b. Computer Software Configuration Item (CSCI) 1...n (Specify Names) **-** An aggregation of software or any of its discrete portions which satisfies an end use function and has been designated by the government for configuration management. CSCIs are the major software products of a system acquisition which are developed in accordance with standard DoD or commercial practices and process. This includes reusable software components, such as commercial off-the-shelf software, government furnished software, or software specifically developed for reuse. This element includes Computer Software Components (CSCs) which are functionally or logically a distinct part of a CSCI, distinguished for convenience in designing and specifying a complex CSCI as an assembly of subordinate elements. It includes the effort associated with the requirements analysis, design, coding and testing, CSCs integration and testing, CSCI formal qualification testing, and software problem resolution of each CSCI.

c. CSCI to CSCI Integration and Checkout **-** Includes integration and test, verification and validation and the systems engineering and technical control of the CSCIs. Integration and test is the planning, conducting and analysis of tests that verify correct and proper performance of each CSCI operating as a whole with other CSCIs. Planning includes: (1) defining test scope and objectives, (2) establishing the test approach, acceptance criteria, verification methods, order of integration, inputs, and methods to record results, and (3) establishing test locations, schedules, and responsibilities of those involved. The conducting and analysis of tests encompasses: (1) developing test procedures, (2) preparing test data and expected results, (3) executing the test procedures and recording test results, (4) reducing test results, identifying errors, and preparing test data sheets, and (5) reporting results. Verification and validation is the effort that may be accomplished to insure the performance and quality of each CSCI with other CSCIs. This element excludes the software integration and checkout associated with the individual CSCIs.

(NOTE: The defined software structure for lower level information is appropriate whether it is associated with a specific system or subsystem or considered software intensive or stand alone.)

3.1.2.2 System Software **-** The PMP system software element is defined as 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 example, operating systems, compilers, and utilities (ref. ANSI/IEEE Std 610.12). This element refers to all effort required to design, develop, integrate and checkout the PMP system software including all software developed to support any PMP applications software development. It is defined as PMP system software which is required to facilitate development, integration, and maintenance of any PMP software build and CSCI. This excludes all software that is an integral part of any specific hardware subsystem specification or is specifically designed and developed for system test and evaluation. The structure shown in paragraph 1.1.2 should be used when lower level information is desired.

3.1.3 Integration, Assembly, Test and Checkout **- The following paragraph summarizes the technical definition presented for this element in the MIL-HDBK-881.** The integration, assembly, test and checkout element includes hardware and PMP software integration and test but excludes all systems engineering/program management and system test and evaluation which are associated with the overall system.

3.2 Systems Engineering/Program Management (SE/PM) **-** The systems engineering/ program management element is defined as the systems engineering and technical control as well as the business management of particular systems and programs. This element encompasses 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. **This element also includes ESH compliance and management.** SE/PM effort that can be associated specifically with the equipment (hardware/software) element is excluded. SE/PM elements to be reported and their levels will be specified by the requiring activity. Examples of systems engineering/program management elements and their definitions are provided as follows:

3.2.1 Systems Engineering **-** The systems engineering element is defined as the technical and management efforts of directing and controlling a totally integrated engineering effort of a system or program. This element encompasses the systems engineering 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. This element includes but is not limited to: the systems engineering effort to transform an operational need or statement of deficiency into a description of system requirements and a preferred system configuration; the technical planning and control effort for planning, monitoring, measuring, evaluating, directing and replanning the management of the technical program; and (all programs, where applicable) value engineering, configuration management, human factors, maintainability, reliability, survivability/vulnerability, system safety, environmental protection, standardization, system analysis, logistics support analysis, etc.. It specifically excludes the actual design engineering and the production engineering directly related to the WBS element with which it is associated. **ESH work should be an important part of the systems engineering process, and includes such activities as the development of plans and programs associated with safety and health, pollution prevention, compliance, and NEPA compliance. The professional support function associated with these plans, programs, and other ESH activities are also included in this element.**

Examples of systems engineering efforts include:

a. 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;

b. 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;

c. Reliability engineering defined as 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;

d. Maintainability engineering defined as 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;

e. Human factors engineering defined as 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; and,

f. Supportability analyses **-** an integral part of the systems engineering process beginning at program initiation and continuing throughout program development. Supportability analyses form the the basis for related desing requirements included in the system specification and for subsequent decisions concerning how to most cost effectively support the sytem over its entire life cycle. Programs allow contractors maximum flexibility in proposing the most appropriate supportability analyses.

g. **ESH activities include those ESH related efforts to support program activities, support RFP preparation, support source selection, review CDRL deliverables, attend IPRs, accept IPR actions, travel as required, support Cost Analysis Requirement Description (CARD) preparation and update, performing initial ESH analysis and planning, review environmental trade studies, system safety, Environmental Assessments and/or Environmental Impact Statements, NEPA and NAS 411 compliance, and update Life Cycle Environmental Documents.**

3.2.2 Program Management **-** The program management element is defined as 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. **ESH program management includes the development of plans and programs associated with environmental pollution prevention, compliance and conservation. The professional support functions associated with these plans, programs, and other ESH management activities are also included in this element.**

Examples of these **program management** activities are:

a. Cost, schedule, performance measurement management, warranty administration, contract management, data management, vendor liaison, subcontract management, etc.

b. 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. This element includes the planning and management of all the functions of logistics, e.g., maintenance support planning and support facilities planning; other support requirements determination; support equipment; supply support; packaging, handling, storage, and transportation (PHST); provisioning requirements determination and planning; training system requirements determination; computer resource determination; organizational, intermediate, and depot maintenance determination management; and data management.

c. **ESH activities include developing plans and programs to manage, procure, distribute, control, treat, store, dispose, monitor hazardous material and waste; compliance management; permit applications; and public relations which include the cost of public hearings for specific permits.**

3.3 System Test and Evaluation **(ST&E) -** The system test and evaluation element refers to 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. This element includes the detailed planning, conduct, support, data reduction and reports (excluding the Contract Data Requirements List (CDRL) data) from such testing, and all hardware/software items which are consumed or planned to be consumed in the conduct of such testing. It also includes all effort **and costs** associated with the design and production of models, specimens, fixtures, and instrumentation, **and HAZMATs or waste** in support of the system level test program**. NEPA compliance has the biggest impact here (e.g., sea trials had to be delayed because of whale investigation, program had to change test sites, schedule slipped because of additional environmental assessment due to NEPA issues (siting), etc.). In addition, test sites must have environmental impact statements (EISs), categorical exclusion (CATEX), and 813 Forms completed prior to start of testing. Air emission testing may also be required at test sites to ensure compliance with the Clean Air Act.** NOTE: Test articles which are complete units (i.e., functionally configured as required by specifications) are excluded from this work breakdown structure element. All formal and informal testing up through the subsystem level which can be associated with the hardware/software element are excluded. Acceptance testing is also excluded. These excluded efforts are to be included with the appropriate hardware or software elements.

3.3.1 Development Test and Evaluation **(DT&E) - The following paragraph summarizes the technical definition presented for this element in the MIL-HDBK-881.** The development test and evaluation element refers to that test and evaluation conducted to: (a) demonstrate that the engineering design and development process is complete; (b) demonstrate that the design risks have been minimized; (c) demonstrate that the system will meet specifications; (d) estimate the system's military utility when introduced; (e) determine whether the engineering design is supportable (practical, maintainable, safe, etc.) for operational use; (f) provide test data with which to examine and evaluate trade-offs against specification requirements, life cycle cost, and schedule; and (g) 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.). Development test and evaluation includes all contractor in-house effort and is planned, conducted and monitored by the developing agency of the DoD Component.

3.3.2 Operational Test and Evaluation (OT&E) **- The following paragraph summarizes the technical definition presented for this element in the MIL-HDBK-881.** The operational test and evaluation element refers to that 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. Initial operational test and evaluation conducted during the development of a weapon system will be included in this element. This element encompasses such tests as system demonstration, flight tests, sea trials, mobility demonstrations, on-orbit tests, spin demonstration, stability tests, qualification operational test and evaluation (QOT&E), etc., and support thereto, required to prove the operational capability of the deliverable system. It includes contractor support (e.g., technical assistance, maintenance, labor, material, etc.) consumed during this phase of testing. It also includes performing the 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).

3.3.3 Mock-ups **-** The mock-ups element refers to 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.

3.3.4 Test and Evaluation Support **-** The test and evaluation support element refers to all support elements necessary to operate and maintain systems and subsystems during test and evaluation which are not consumed during the testing phase and are not allocated to a specific phase of testing. This element includes, for example, repairable spares, repair of reparables, repair parts, warehousing and distribution of spares and repair parts, test and support equipment, test bed vehicles, tracking vessels, contractor technical support, etc. 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 therefore be included under that element of testing are excluded.

3.3.5 Test Facilities **-** The test facilities element refers to those special test facilities required for performance of the various developmental tests necessary to prove the design and reliability of the system or subsystem. This element includes, for example, test tank test fixtures, propulsion test fixtures, white rooms, test chambers, etc. The brick and mortar-type facilities identified as industrial facilities are excluded.

3.4 Training **-**The training element is defined as the deliverable training services, devices, accessories, aids, equipment, and parts used to facilitate instruction through which personnel will acquire sufficient concepts, skills, and aptitudes to operate and maintain the system with maximum efficiency. This element includes all effort associated with the design, development, and production of deliverable training equipment as well as the execution of training services. This element and its sub-elements exclude the overall planning, management, and task analysis function inherent in the WBS element Systems Engineering/Program Management. **This cost element includes increasing education and awareness in ESH, such as training personnel in the proper handling and disposal of HAZMATs, as well as the proper use and disposal of personal protection equipment (PPE). It also includes the cost of training materials such as videos, books, pamphlets.**

3.4.1 Equipment **-** The equipment element is defined as those distinctive deliverable end items of training equipment, assigned by either a contractor or military service, required to meet specific training objectives. This element includes: operational trainers, maintenance trainers and other items such as cutaways, mock- ups, and models.

3.4.2 Services **-** The services element is defined as the deliverable services, accessories, and aids necessary to accomplish the objectives of training. This element includes, for example, training course materials; contractor-conducted training including in-plant and service training; and the materials and curriculum required to design, execute and produce a contractor developed training program. It also includes the material, courses, and associated documentation (primarily the computer software, courses and training aids). This element excludes the deliverable training data associated with the WBS element Support Data.

3.4.3 Facilities **-** The facilities element refers to the special construction necessary to accomplish training objectives. It also includes the modification or rehabilitation of existing facilities used to accomplish training objectives. The installed equipment used for the purpose of acquainting the trainee with the system or establishing trainee proficiency is excluded. The brick and mortar-type facilities identified as industrial facilities are also excluded.

3.5 Data **-** The data element refers to all deliverable data required to be listed on a Contract Data Requirements List, DD Form 1423. The data requirements will be selected from the Acquisition Management Systems and Data Requirements Control List (DoD 5010.12-L). This element includes only such effort that can be reduced or will not be incurred if the data item is eliminated. If the data are government peculiar, include the efforts for acquiring, writing, assembling, reproducing, packaging and shipping. It also includes the effort for transforming into government format with reproduction and shipment if data are identical to that used by the contractor, but in a different format. **Also included in this element are the costs of gathering, storing, reproducing, and disseminating ESH data (as applicable), manuals, and documents such as system safety plans (SSPs), NAS 411, toxic release inventory (TRI) reports, material safety data sheets (MSDSs), etc.**

3.5.1 Technical Publications - The technical publications element is defined as technical data which provides instructions for the installation, operation, maintenance, training, and support of a system or equipment which is formatted into a technical manual. A technical manual normally includes operation and maintenance instructions, parts lists or parts breakdown, and related technical information or procedures exclusive of administrative procedures. This 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. This element includes the data item descriptions set forth in categories selected from the DoD 5010.12-L.

3.5.2 Engineering Data - The engineering data element is defined as recorded information (regardless of the form or method of recording) of a scientific or technical nature (including computer software documentation). Engineering data does not include computer software or financial, administrative, cost or pricing, or management data or other information incidental to contract administration.

a. Engineering data is required to define and document an engineering design or product configuration (sufficient to allow duplication of the original items) and is used to support production, engineering and logistics activities. This element 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.

b. A technical data package (reprocurement package) includes all engineering drawings, associated lists, process descriptions, and other documents which define the physical geometry, material composition, performance procedures. This element excludes the LSAR and support data delivered below.

3.5.3 Management Data - The management data element is defined as those 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 5010.12-L. This element includes contractor cost reports, cost performance reports, contractor fund status reports, schedules, milestones, networks, integrated support plans, etc.

3.5.4 Support Data - The support data element is defined as those data items designed to document the support planning in accordance with functional categories selected from DoD 5010.12-L. This element includes, for example, LSA documentation and LSA record maintenance and delivery, supply, general maintenance plans and reports, training data, transportation, handling, 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.

3.5.5 Data Depository - The data depository element is defined as a facility designated to act as custodian in establishing and maintaining a master engineering specification and drawing depository service for government approved documents that are the property of the U.S. Government. This element represents a distinct entity of its own and includes all effort of drafting, clerical, filing, etc., required to provide the service. As custodian for the government, the contractor is authorized by approved change orders to maintain these master documents at the latest approved revision level. 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. All similar effort for the contractor's internal specification and drawing control system, in support of its engineering and production activities, is excluded.

3.6 Peculiar Support Equipment (PSE) **-** The peculiar support equipment element is defined to include 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 not directly engaged in the performance of its mission, and which have application peculiar to a given defense materiel item. **It also includes the costs of acquiring and maintaining the PPE and equipment for handling and disposal of HAZMATs.** This element includes, for example, vehicles, equipment, tools, etc., used to fuel, service, transport, hoist, repair, overhaul, assemble, disassemble, test, inspect, or otherwise maintain the mission equipment. It also includes 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). It also includes any additional equipment or software that will be required to maintain or modify the software portions of the system. This element and its sub-elements specifically exclude the overall planning, management and task analysis functions inherent in the work breakdown structure element systems engineering/program management, and the common support equipment presently in the DoD inventory or commercially common within the industry which is bought by the using command and not by the acquiring command.

3.6.1 Test and Measurement Equipment **-** The test and measurement equipment element is defined as 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. It includes 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, tap(s), and related software, firmware and support hardware (power supply equipment, etc.) used at all levels of maintenance. It includes packages which enable a line or shop replaceable unit, printed circuit boards, or similar items to be diagnosed using automatic test equipment.

3.6.2 Support and Handling Equipment **-** The support and handling equipment element is defined as the deliverable tools and handling equipment used for support of the mission system. It typically includes 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).

3.7 Common Support Equipment (CSE) **-** The common support equipment element refers to those 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. **It also includes the costs of acquiring and maintaining the PPE and equipment for handling and disposal of HAZMATs.** This element includes all efforts required to assure the availability of this equipment for support of the particular defense materiel item. It also includes the acquisition of additional quantities of this equipment if caused by the introduction of the defense materiel item into operational service.

3.7.1 Test and Measurement Equipment **-** The test and measurement equipment element is defined as 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. It includes 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, tap(s), and related software, firmware and support hardware (power supply equipment, etc.) used at all levels of maintenance. It includes packages which enable a line or shop replaceable unit, printed circuit boards, or similar items to be diagnosed using automatic test equipment.

3.7.2 Support and Handling Equipment **-** The support and handling equipment element is defined as the deliverable tools and handling equipment used for support of the mission system. It typically includes 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).

4 Electronic/Automated Software System Production (Phase III) - During this phase, engineering efforts are performed to translate the most promising design approach into a stable, interoperable, producible, supportable, and cost effective design; validation of the manufacturing or production process; demonstration of system capabilities through testing; and low-rate initial production (LRIP) set-up. This element also includes the activities of the lower level elements listed below. It also includes initial hard tooling and production line; fabrication, assembly, and installation of tools, inspection equipment, fixtures, etc.; establishment of make-or-buy and manufacturing plans on nonrecurring tools and equipment, scheduling and control of tool orders; and programming and preparation of software for numerically controlled machine equipment. The ESH cost considerations during this phase include continuation of pollution prevention plans to ensure minimal ESH problems downstream, and efforts to address ESH litigation and liabilities. Some of the ESH activities started during Phase II will continue during this Phase (e.g., NEPA, environmental compliance, system safety and health, HAZMATs, pollution prevention and waste minimization programs, hands-on control of HAZMATs for all processes).

4.1 PMP - The technical definition for this element is the same as element 3.1.

4.1.1 Subsystems 1…n - The technical definition for this element is the same as element 3.1.1.

4.1.2 PMP Software - The technical definition for this element is the same as element 3.1.2, including elements 3.1.2.1 and 3.1.2.2.

4.1.3 Integration, Assembly, Test and Checkout - The technical definition for this element is the same as element 3.1.3.

4.2 Platform Integration - The platform integration element refers to all effort involved in providing technical and engineering services to the platform manufacturer or integrator during the installation and integration of the PMP into the host platform. This element includes: the labor required to analyze, design, and develop the interfaces with other host subsystems; drawing preparation and establishment of equipment requirements and specifications; and technical liaison and coordination with the military services, subcontractors, associated contractors, and test groups. Specifically excluded from this element is all integration effort not directly associated with the host vehicle and management liaison with the military services, subcontractors, and associated contractors.

The following lower levels of activities have the same technical definitions as in Phase II. ESH activities are listed only if they are different from those listed in Phase II.

4.3 Systems Engineering/Program Management (SE/PM)
- **4.3.1 Systems Engineering (SE)**
- **4.3.2 Program Management (PM)**

4.4 System Test and Evaluation (ST&E)
- **4.4.1 Development Test and Evaluation (DT&E)**
- **4.4.2 Operational Test and Evaluation (OT&E)**
- **4.4.3 Mock-ups**
- **4.4.4 Test and Evaluation Support**
- **4.4.5 Test Facilities**

4.5 Training
- **4.5.1 Equipment**

4.5.2 Services
4.5.3 Facilities
4.6 Data
4.6.1 Technical Publications
4.6.2 Engineering Data
4.6.3 Management Data
4.6.4 Support Data
4.6.5 Data Depository
4.7 Peculiar Support Equipment (PSE)
4.7.1 Test and Measurement Equipment
4.7.2 Support and Handling Equipment
4.8 Common Support Equipment (CSE)
4.8.1 Test and Measurement Equipment
4.8.2 Support and Handling Equipment

5 Fielding/Deployment, and Operational Support (Phase III) - This portion of Phase III includes the cost of provision of industrial facilities, depot maintenance plant equipment, and layaway of industrial facilities that are system specific; and procurement-funded costs of construction, conversion, or expansion of facilities for production, inventory, or maintenance required to accomplish the program. ESH issues to be addressed here include NEPA compliance for beddown, compliance for air logistics centers (ALCs), safety and health concerns for personnel, HAZMATs tracking/handling/disposal, pollution prevention, air emissions testing, noise compliance plans, etc. Environmental Baseline Surveys (EBSs) also need to be conducted on property being considered for a transaction with the government. Agreements of land use and land condition at end of mission would determine level of environmental cleanup which involves the remediation of soils, sediments, testing/monitoring of soils and water, structures contaminated with hazardous and toxic materials from past activity (e.g., capping and monitoring landfills, pumping and treating ground water, incinerating or biologically treating soils).

5.1 Operational/Site Activation **-** The operational/site activation element refers to 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. This element 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. It also includes contractor support in relation to operational/site activation.

5.1.1 System Assembly, Installation, and Checkout on Site **-** The system assembly, installation, and checkout on site element refers to the materials and services involved in the assembly of mission equipment at the site. This element includes, for example, installation of mission and support equipment in the operations or support facilities and the complete system checkout or shakedown to insure achievement of operational status. Where appropriate, specify by site, ship or vehicle.

5.1.2 Contractor Technical Support **-** The contractor technical support element refers to all materials and services provided by the contractor related to activation. This element includes repair of reparables, standby services, final turnover, etc.

5.1.3 Site Construction **-** The site construction element refers to the **costs of** real estate, site planning/preparation, **design and** construction, **environmental remediation, equipment**, and other special-purpose facilities necessary to achieve system operational status **and to provide all facilities required to house, service, and/or launch prime mission equipment at the organizational and intermediate levels. It also includes the design and construction or renovation of existing facilities to handle, store, treat, and/or disposal of HAZMATs.** This element also includes the construction of utilities, roads, and interconnecting cabling.

5.1.4 Site/Ship/Vehicle Conversion **-** The site/ship/vehicle conversion element refers to all materials and services required to provide for the conversion of existing sites, ships, or vehicles to accommodate the mission equipment and selected support equipment directly related to the specific system. This elements includes 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.

5.2 Industrial Facilities **-** The facilities element refers to the **design and** construction, conversion, or expansion of industrial facilities for production, inventory, and contractor depot maintenance required when that service is for the specific system. This element includes, for example, equipment acquisition or modernization, where applicable, and maintenance of these facilities or equipment. This element also includes industrial facilities **for handling, storage, disposal, and/or treatment of HAZMATs, as well as for** hazardous waste management to satisfy **ESH** standards.

5.2.1 Construction/Conversion/Expansion **-** The construction/conversion/ expansion element refers to the real estate and preparation of system peculiar industrial facilities for production, inventory, depot maintenance, and other related activities. **It also includes the design and construction or renovation of existing facilities to handle, store, treat, and/or disposal of HAZMATs. Site construction costs refer to the costs of real estate, site planning/preparation, design and construction, NEPA compliance, environmental remediation prior to siting of system, equipment, and other special-purpose facilities necessary to achieve system operational status and to provide all facilities required to house, service, and/or launch prime mission equipment at the organizational and intermediate levels. This element also includes the construction of utilities, roads, and interconnecting cabling.**

5.2.2 Equipment Acquisition or Modernization **-** The equipment acquisition or modernization element refers to production equipment acquisition, modernization, or transferal of equipment for the particular system. (Pertains to government owned and leased equipment under facilities contract.) **ESH concerns would be the ability of ALCs to handle new HAZMATs and/or processes due to the system.**

5.2.3 Maintenance of Facilities **-** The maintenance (industrial facilities) element refers to the maintenance, preservation, and repair of industrial facilities and equipment.

5.3 Initial Spares and Repair Parts **-** Initial spares and repair parts element is defined as the deliverable spare components, assemblies and subassemblies used for initial replacement purposes in the materiel system equipment end item. This element includes the 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. This element excludes development test spares and spares provided specifically for use during installation, assembly and checkout on site. The lower level WBS breakouts should be by subsystem. **Include also allowances for the restrictions on HAZMATs and possible future shortage issues of chemicals no longer in production or with restricted use.**

6 Operations and Support **(Phase III) - All Operations & Support (O&S) costs associated with operation and support of the materiel system are included in this element. The following WBS element definitions came from the May 1992 OSD CAIG O&S Cost Estimating Guide. ESH activities here include of above-ground/ underground tanks for storage of HAZMATs, hazardous wastes, fuel and POL; waste treatment and recycling efforts; environmental remediation and restoration; air emissions tests; permits; noise compliance plans; and cultural/historic resource preservation. Other ESH activities are also listed under the individual elements below.**

6.1 Mission Personnel **-** The mission personnel element includes the cost of pay and allowances of officer, enlisted, and civilian personnel required to operate, maintain, and support a discrete operational system or deployable unit. This includes the personnel necessary to meet combat readiness, unit training, and administrative requirements. The personnel costs will be based on manning levels and skill categories. **Labor costs for HAZMATs processes (e.g., paint stripping) may be higher due to higher risks, reduction of efficiency of work (productivity loss) due to PPE and conditions of work area.**

6.1.1 Operations - The pay and allowances for the full complement of personnel to operate a system.

6.1.2 Maintenance - The pay and allowances of military and civilian personnel who perform maintenance on and provide support to assigned system, associated support equipment, and unit-level training devices. Depending on the maintenance concept and organizational structure, this element will include maintenance personnel at the organizational level (O-level) and possibly the intermediate level (I-level). These maintenance categories are described as:

6.1.2.1 Organizational Maintenance - Personnel who perform on-equipment maintenance.

6.1.2.2 Intermediate Maintenance - Personnel who perform off-equipment maintenance. If I-level maintenance is provided by a separate support organization (e.g., a centralized intermediate maintenance support activity), the costs should be reported in 6.3, Intermediate Maintenance (External to Unit).

6.1.2.4 Other Maintenance Personnel - Personnel not covered above, including those personnel that support equipment maintenance, simulator maintenance, and Chief of Maintenance functions related to the system whose costs are being estimated.

6.1.3 Other Mission Personnel - The pay and allowances of military and civilian personnel who perform unit staff, security, and other mission support activities, such as utilities, repair of real estate, **emissions testing, environmental remediation and restoration, environmental site assessments, HAZMAT pharmacy operation**, minor construction, fire prevention, supply operations, maintenance of materiel, and transportation for site activation equipment installation and one-time BASOPS.

6.2 Unit-Level Consumption - This element includes the cost of fuel and energy resources; operations, maintenance, and support materials consumed at the unit level; stock fund reimbursements for depot-level reparables; operational munitions expended in training; transportation in support of deployed unit training; temporary additional duty/temporary duty (TAD/TDY) pay; and other unit-level consumption costs, such as purchased services for equipment leases and service contracts. **Also included here is the cost for painting, corrosion control, and tracking/disposal of HAZMATs used to operate, maintain, and clean the system.**

6.2.1 Fuel and POL - This includes the costs for fuel, oil, and lubricants to operate the system and support equipment. Examples are fuels for generators and vehicles and coolants for environmental central systems.

6.2.2 Consumable Material/Repair Parts - This element includes the costs of material consumed in the operation, maintenance, and support of a system and associated support equipment at the unit level, such as the consumable (nonreparable) individual parts, **paints, corrosion control,** assemblies, or subassemblies required on a recurring basis for the repair of major end items of equipment (including PME and support equipment) subsequent to fielding. **The cost of tracking and disposal of any HAZMATs and hazardous wastes associated with consumable materials/ repair parts is included here.**

6.2.3 Depot-Level Reparables - This element includes the cost of reimbursing the stock fund for purchases of depot-level reparable spares used to replace initial spares. It also includes the repairable individual parts, **paints, corrosion control,** assemblies, or subassemblies required on a recurring basis for the repair of major end items of equipment (including PME and support equipment) subsequent to fielding. **The cost of tracking and disposal of any HAZMATs and hazardous wastes associated with depot-level reparables is included here.**

6.2.4 Other - Included in this element are any significant unit-level consumption costs not otherwise accounted for but are related to the system whose operating and support requirements are being assessed, such as purchased services, transportation, and TAD/TDY. **The cost of tracking and disposal of any HAZMATs and hazardous wastes associated with any significant unit-level maintenance not otherwise accounted for is included here.**

6.3 Intermediate Maintenance (External to Unit) - This element includes the cost of labor and material and other costs expended by designated activities/units in support of a system and associated support equipment. Intermediate maintenance activities include calibration, repair, and replacement of parts, components, or assemblies, and technical assistance. **The cost of tracking and disposal of any HAZMATs and hazardous wastes associated with intermediate maintenance is included here.**

6.3.1 Maintenance - The pay and allowances of military and civilian personnel who perform intermediate maintenance on a system, associated support equipment, and unit-level training devices.

6.3.2 Consumable Material/Repair Parts - Included here are the costs of repair parts, **paints, corrosion control,** assemblies, subassemblies, and material consumed in the maintenance and repair of a system, associated support equipment, and unit-level training devices. **The cost of tracking and disposal of any HAZMATs and hazardous wastes associated with consumable materials/repair parts is included here.**

6.3.3 Other - This element includes any significant intermediate maintenance costs not otherwise accounted for, such as the cost of transporting subsystems or major end items to a base or depot facility. **The cost of tracking and disposal of any HAZMATs and hazardous wastes associated with any significant intermediate maintenance not otherwise accounted for is included here.**

6.4 Contractor Support - This includes the cost of contractor labor, materials, and overhead incurred in providing all or part of the logistics support required by a system, subsystem, or associated support equipment. Contract maintenance is performed by commercial organizations using contractor personnel, material, equipment, and facilities or government-furnished material, equipment, and facilities. Contractor support may be dedicated to one or multiple levels of maintenance.

6.4.1 Interim Contractor Support (ICS) - ICS includes the burdened cost of contract labor, material, and assets used in providing temporary logistics support to a weapon system, subsystem, and associated support equipment. The purpose of ICS is to provide total or partial logistics support until a government maintenance capability is developed.

6.4.2 Contractor Logistics Support (CLS) - CLS includes the burdened cost of contract labor, material, and assets used in providing logistics support to a weapon system, subsystem, and associated support equipment over the operational life of the system. CLS funding covers depot maintenance and, as negotiated with the operating command, necessary organizational and intermediate maintenance activities.

6.4.3 Other - This element includes any contractor support costs not otherwise accounted for, such as the burdened cost of contract labor for contractor engineering and technical services.

6.5 Sustaining Support - This element includes the cost of replacement support equipment, modification kits, sustaining engineering, software maintenance, and simulator operations.

6.5.1 Sustaining Engineering Support - Included in this element are the labor, material, and overhead costs incurred in providing continued systems engineering and program management oversight to determine the integrity of a system, to maintain operational reliability, to approve design changes, and to ensure system conformance with established specifications and standards,

as well as ESH compliance (safety and health, HAZMAT reduction, pollution prevention). Costs in this category may include, but not limited to, government and/or contract engineering services, technical advice, and training for component or system installation, operation, maintenance and support.

6.5.2 Software Maintenance Support **-** This element includes the labor, material, and overhead costs incurred after deployment by depot-level maintenance activities, government software centers, laboratories, or contractors for supporting the update, maintenance and modification, integration, and configuration management of software. It also includes operational maintenance, diagnostic software programs for the primary system, support equipment, training equipment, and operating and maintaining the associated computer and peripheral equipment in the software maintenance activity.

6.5.3 Simulator Operations **-** This includes the costs incurred to provide, operate, and maintain on-site or centralized simulator training devices for a system, subsystem, or related equipment, and may include the labor, material, and overhead costs of simulator operations by military and/or civilian personnel, or by private contractors.

6.5.4 Other **-** Any significant sustaining support costs not otherwise accounted for will be included here, such as the costs of follow-on operational tests and evaluation (e.g., test support, data reduction, test reporting). **Included here are costs for ESH related permits such as an EPA air permit and a Small Quantity Generator Hazardous Waste permit.**

6.6 Indirect Support **-** This element includes the costs of personnel support for specialty training, permanent changes of station, and medical care. It also includes the costs of relevant host installation services, such as base operating support and real property maintenance.

6.6.1 Personnel Support **-** This element includes the cost of system-specific and related specialty training for military personnel who are replacing individuals lost through attrition. Also included are permanent change of station costs and the cost of medical care. Descriptions of these costs are as follows:

a. Specialty Training **-** This is the cost of system-specific training (non-investment funded) and specialty training for military personnel who are replacing individuals lost through attrition, such as undergraduate pilot training, non-pilot aircrew training, non-aircrew officer training, and enlisted specialty training. **Include here the cost of training for handling of special HAZMATs and OSHA courses.**

b. Permanent Change Of Station (PCS) **-** This is the cost of moving replacement personnel to and from overseas theaters and within the continental United States.

c. Medical Care **-** This is the cost of personnel pay and allowances and material needed to provide medical support to system-specific mission and related military support personnel. **Also included here is the cost of industrial hygiene surveys, medical examinations, and other related medical costs due to exposure to and/or handling of HAZMATs.**

6.6.2 Installation Support **-** This consists of personnel normally assigned to the host installation who are required for the unit to perform its mission in peacetime, and includes only those personnel and costs that are directly affected by a change in the number of associated mission personnel. Functions performed by installation support personnel include:

a. Base Operating Support **-** The cost of personnel pay and allowances and material necessary to provide support to system-specific mission-related personnel. Base operating support activities include functions such as communications, supply operations, personnel services, installation security, base transportation, etc.

b. Real Property Maintenance **-** The cost of personnel pay and allowances, material, and utilities needed for the maintenance and operation of system-specific mission-related real property and for civil engineering support and services.

c. Industrial Readiness - This element includes manpower authorizations, peculiar and support equipment, necessary facilities, **ESH compliance, safety training**, and other associated costs specifically identifiable to management of end-item industrial preparedness activities.

7 Demilitarization and Disposal - This element captures the costs associated with disposing of a system or facility at the end of its useful life. Disposal is the process of re-distributing, transferring, donating, selling, or demilitarizating the system. Demilitarization is a subset of disposal and is the act of deactivating or rendering inoperable by destroying the military offensive or defensive advantage inherent in an item. Where applicable, this category includes salvage values as well as costs incurred during the phase-out period. The complete deactivation and demilitarization of a system entails not only the disposal of hazardous wastes but also the proper distribution of inert materials and support as well. Other ESH elements to be considered are remediation and restoration. The following WBS element definitions are from the Environmental Life Cycle Cost Model WBS dictionary.

7.1 Facilities - This element includes the cost of deactivating an operational or production facility. Include the cost to transition the facility to a caretaker status, preserve its capability in state (mothball), or complete razing to grade, as appropriate. It also includes the cost of tooling disposal.

7.1.1 Facility Deactivation/Equipment Dismantlement - This element includes the cost of facility deactivation. Equipment dismantlement is applicable to the facility tanks, utilities, and equipment. It is the physical removal of equipment from a building or structure, and includes the salvage value of any removed material. This element also includes the cost of those activities necessary to transition an active facility into mothballs. Examples of such efforts are draining plumbing, boarding windows, or removing electrical service. It also includes the cost of painting, maintenance of fire protection equipment, utilities, security, and consumables.

7.1.2 Facility Decontamination - This element includes the cost of decontamination of buildings, equipment, and structures which can increase a building's value, return it to usable status, or to minimize the volume of hazardous waste upon demolition. It also includes the cost of neutralizing, collecting, and containing the resulting waste liquid or the debris, but not waste treatment or disposal. This element also includes the cost to remove obstructions, and worker protection.

7.2 Equipment/Systems/Materials - This element includes the cost of disposing of mission equipment for a disposal phase demilitarization effort as well as disposal of waste stream material throughout the life cycle.

7.2.1 Demilitarization and Disposal Process Equipment/Facility Design and Construction - This element includes the cost of the study, analysis, design development, evaluation, testing, and redesign of the processes to demilitarize the system. It also includes the cost of real estate, design and construction, conversion, utilities, and equipment (e.g., tools, fixtures, test equipment) to achieve the demilitarization capability.

7.2.1.2 Interim Storage - This element includes the cost of storage after items have been removed from service and prior to disposition.

7.2.1.2 Disassembly, Disposition, and Disposal - This element includes the cost of demilitarization of prime mission equipment as well as any peculiar support equipment and trainers. It also includes the costs of disassembly, recovery, and/or salvage of the system or its constituent parts. This also includes the cost to check out or certify parts reclaimed for use as spares or other applications. It does not include treatment or disposal of waste as this is included elsewhere. This element

does include the salvage value of these materials sold as scrap through the Defense Reutilization and Marketing Office (DRMO).

8 Cost and Liability Risk - This element includes all the costs associated with Cost and Liability Risk such as the cost of settling legal claims from employees and public citizens who are injured as a result of exposure to HAZMATs; claims for wrongful deaths, pain and suffering; lost time due to disability; medical costs; and property devaluation resulting from contamination of private or public property. This WBS element definition is from the Environmental Life Cycle Cost Model WBS dictionary.

Appendix I - ESH Cost Identifying Questions (By Topic)

Listed below are questions designed to identify ESH costs. The questions are arranged alphabetically by ESH cost and map to the table presented in Part One, Section two of the Guide. The cost topics are derived from the list of potential ESH costs listed in the SMC ESH Management and Cost Handbook, dated 13 September 1997. This document is available on Defense Environmental Network & Information Exchange (DENIX). The format for presentation is cost topic, definition, discussion and questions.

Analysis, Environmental Impact: The costs of environmental assessments, environmental impact statements and the preparation of NEPA required documentation.

The product center (program office) normally bears these costs during the acquisition cycle. The analysis may be performed organically or contracted to specialists. These costs can run into the millions of dollars per acquisition phase. Operating bases may incur these costs as part of facility refurbishment or replacement activities. They are normally managed at the operating bases through the CE. Where logistics or test centers must adapt facilities and equipment for a new weapon system, they may incur such costs. Funds for these efforts are often included in the Military Construction Program (MCP) funding. Questions to research include:

- Do requests and cost tracking for MCP projects provide line items for ESH costs?
- Are ESH costs for other than the acquisition cycle centrally tracked such as at command or Air Force level?
- Are there any generally accepted estimating rules for EA and EIS costs?
- Do you have actual costs for EAs or EISs?

Analysis of ESH Alternatives: The costs of performing the trade studies of alternatives as required by DoD 5000.2R.

The prime contractor team will perform many of these trades as part of system design. The prime contractor will normally be reimbursed for these trades. Product and Logistics Centers may also perform or pay for additional analysis of alternatives. In addition, the various headquarters may fund studies for preferred methods and materials (see Contribution to common initiatives). Questions to research include:

- How do analyses of ESH alternatives qualify for central funding?
- Do prime contractors identify the studies they perform by Contract Line Item Number (CLIN) or task such that cost tracking is possible?
- What is the average amount spent on alternatives by system type (aircraft, ground electronics, space system)?

Analysis of System Safety Hazards: The costs of performing and reviewing the system safety analysis.

This task is normally performed by the prime contractor or a system engineering contractor. The cost is borne by the product center. Some analyses may be required at logistics centers for major modifications. Since this is not a new effort and has historically been included in program cost estimates, we are not sure how much additional cost research is required.

Assessments, ESH: These are costs for activities less detailed than analyses which are required for compliance.

The product center normally bears these costs during the acquisition cycle. The assessments are most often performed organically. Costs are fairly small (less than 200K). Operating bases may incur these costs as part of facility refurbishment or replacement activities. The assessments are normally managed at the operating bases through the CE. Where logistics or test centers must adapt facilities and equipment for a new weapon system, they may incur such costs. Funds for these efforts are often included in the MCP funding. Questions to research include:

- Do requests and cost tracking for MCP projects provide line items for ESH costs?
- Are ESH costs for other than the acquisition cycle centrally tracked such as at command or Air Force level?
- Are there any generally accepted estimating rules for these costs?

Contributions to Common Initiatives: These are the costs borne by command level and Services that solve problems common to more than one program or weapon system.

These costs can be calculated fairly well from command level sponsors. These questions need to be addressed:

- Should these costs be allocated to weapon systems?
- How should a program cost estimate address the dependency upon common initiatives?

Disposal Services, Specialized: The cost of other than normal trash collection services.

All of the listed agencies incur these costs. Other than for nuclear waste, the costs are small. Product Centers and the research labs may incur expenses as part of technology development. Testing centers may incur costs to clean up ranges. Logistics centers have by-products from maintenance activities. These questions should be posed:

- How are these costs accounted for at each of the agencies (for example, at a lab are they tracked by system)?
- Is the total cost for disposal services significant?

Disposal, Detoxification: The cost to detoxify a component or system in order to permit normal disposal.

These costs most often occur at base level and at the logistics centers. For example, coolant lines for the Minuteman system contained Dioxin residue. Prior to normal disposal, the lines had to be flushed. The expenses for detoxification may include labor and material. Questions to research include:

- Is there a tracking in the maintenance data collection system for detoxification (for shipment or disposal)?
- Are these costs significant at either the logistics centers or bases?

Disposal, Disassembly: The costs to disassemble a component or system in order that portions may be disposed of in a normal manner.

Portions of some systems may contain hazardous materials (such as a Beryllium spacer). The hazardous materials need to be removed so that more cost-effective normal disposal can be made of the remaining benign parts. These operations may occur at bases, logistics centers, laboratories, and test centers. Questions include:

- Is there tracking in the maintenance data collection system for disassembly (for shipment or disposal)?
- Are these costs significant at either the logistics centers or bases?

Emergency Response Deployment: The costs (labor and equipment) to respond to a hazardous materials related emergency.

At base level this may be performed by the base fire department. At other agencies this may use community resources on a reimbursement basis. If a new system being introduced generates the requirement for an emergency response team, it may make sense to charge the response team to the new system. The prime, bases, logistics and test centers are the likely places to incur these costs. Questions include:

- Is the need for a response team unique to one system?
- How many costs should be allocated to the weapon system (the incident and the standby time)?

Emergency Response Force Development: The cost to develop, train and equip a response force.

The costs to setup, field and train a team can be significant. Response time and availability of other teams may drive a system to develop its own team. Since bases, logistics and test centers already have these teams, they are the locations were new teams may be formed. Questions include:

- What are the drivers that require that the response team be formed?
- Does cost data exist about the formation of current teams?
- How often do you train for emergency responses?
- How much does the training cost?

Facility Construction: The costs of facility construction directly traced to ESH requirements.

Facility Construction costs associated with ESH may include those requirements over and above the user needs forced by compliance requirements (such as showers and eyewashes). ESH plans and permits are covered in other categories. The Air Force Civil Engineer Support Center has estimating methodology for almost any type of building. Questions to pursue include:

- Does CE construction estimating methodology take into consideration current ESH compliance requirements?
- Does CE facility estimating methodology separately identify ESH costs?

Facility Modification: The costs of modifying existing facilities directly related to ESH requirements.

Facilities may be modified solely for ESH purposes, in which case the total cost of the modification could be an ESH cost. Facilities could undergo a modification and as a result have to be upgraded to current ESH standards. Then the ESH costs would be those directly tied to the compliance requirements. Bases and centers are likely to have ESH costs associated with facility modifications. Questions to ask include:

- Does Air Force CE have any estimates for ESH compliance projects?
- What is the policy on upgrading to current ESH standards during modifications?

Hazardous Materials Procurement: This is the cost of hazardous materials.

Since most procurements require the contractor to identify the type and quantity of hazardous materials, this estimate should be fairly easy as the acquisition cycle moves along. If the prime contractor is providing the hazardous materials as part of system development and production, it can be assumed that the costs are included in the system estimate. Costs may be needed on a per unit basis to account for spares and the O&S years. Questions to ask include:

- What are the per unit costs and source of supply for any hazardous materials used in the system?
- Will a pharmacy system be required to manage the materials?

Insurance: The costs of liability insurance for claims, clean-up and remediation.

This cost category is most often associated with private contractors. Companies can avoid a large potential cost by buying ESH insurance. The cost of the insurance is generally small. Questions to ask include:
- How large are premiums for ESH insurance?
- Do contractors pass this cost along to the government as part of overhead or General and Administrative (G&A) expenses?

Labeling: The cost to prepare and label components and end items required by compliance regulations.

This cost is normally incurred by the contractor that is producing the components. Costs are generally small. Advances in automatic labeling machines have reduced the labor on this item. Perhaps only a significant cost occurs on large production run, small value items. Question to ask:
- What is an upper bound for cost of labeling as a percentage of production cost for weapon system items?

Labor to Manage ESH Programs: The labor cost of ESH personnel in program or staff positions.

The labor to manage ESH programs exists at base, center and headquarters levels. The prime contractor may have one or more personnel on a program to manage his/her responsibilities. In the case of the contractor, the costs may be directly charged or embedded in overhead rates. Within government agencies, the cost for this labor is carried as overhead for support organizations. Some charges directly within a weapon system program or single manager organization are also possible. The magnitude of the ESH labor force as compared to the overall development labor force is small. Questions to ask include:
- How many labor hours at a base or center are allocated to ESH activities?
- Are ESH labor hours managed as overhead or charged to weapon system programs?
- What are the criteria for charging decisions?

Legal, Claims, Penalties and Fines: The costs to settle claims for ESH accidents as well as any penalties and fines associated with accidents and inspections.

The Air Force policy has been to pay for penalties and fines out of base level O&S funding. Bases and centers are liable for claims, penalties and fines. For prime contractors, they have tried to include claims, fines and penalties in the overhead or G&A accounts. This has met resistance when there has been negligence on the part of the contractor. Contractors have tried to minimize these costs with insurance. Cost estimating for claims requires quantifying the likelihood of non-compliance as well as the consequence for non-compliance. Additional guidance for cost estimates reminds us not to include funds for contingencies. Questions to ask include:
- What is the policy about putting claims, penalties and fines in PCEs?
- What are contractors required to disclose regarding potential fines and penalties?
- What are the magnitude and frequency of ESH related claims across the Air Force?

Legal, Review of Plans: The costs associated with having a legal review of any ESH related plans and correspondence.

The cost of having the legal staff review and comment on ESH documents. This cost can occur at any of the locations or agencies. The cost is generally very small and perhaps not worth including in the data collection.

Lost Duty Time: The cost associated with the loss of direct charging time for personnel due to ESH related events.

Lost duty time can come from accidents and incidents which cause illness. They can come from time in court for ESH hearings. Lost duty time can also occur without illness to personnel when operations have to be ceased due to compliance problems. Contractors generally have charge numbers so that they can track lost duty time very easily. Military organization without timekeeping systems have a problem tracking lost duty time. Plant or base shutdowns are the most severe examples of lost duty time. Questions include:

- What is the most extensive ESH related incidence of lost duty time?
- Are there any tracking systems beside safety records to collect lost duty time?

Lost Productivity Due to Personal Protection Requirements: This is the cost in the form of inefficiency when personnel are forced to wear performance inhibiting equipment.

These costs are generally associated with the maintenance work force. As an example, following a car battery electrolyte splash that damaged an airman's eyes, checking lead acid battery levels now requires an apron, mask and gloves. The time to check the batteries has more than doubled. There is not a lot of manpower engineering data to show the impact of ESH compliance on productivity. One way to see all protective equipment requirements is to review the LSAR data, if a program has called for it. The total loss in productivity for extreme systems is probably less than 10%. Questions to ask:

- Are there any studies that estimate productivity loss from protective equipment?
- What models can best be used to calculate the personnel manning differences?

Manifesting: This is the cost to correctly identify any hazardous materials being transported.

This is a very small cost and probably not worth expending cost research effort. The Air Force has an automated manifesting systems that considers hazardous materials when load planning.

Material Handling, Specialized Equipment (MHE): This cost is for that MHE that is driven by ESH requirements.

Peculiar Support Equipment is identified by weapon system on the LSAR data sheets. Peculiar Support Equipment is normally a line item in a program cost estimate. The research for ESH will be to determine which items are solely required due to ESH and which items have their design driven by ESH requirements. This cost is normally incurred in the initial deployment of a system but replacement of Support Equipment (SE) occurs throughout the life cycle. Replacement SE usually complies with the most stringent requirements at the time the replacement is manufactured. Questions to ask include:

- What new design support equipment was required due to ESH requirements?
- Did any existing SE have to be modified to PSE due to ESH requirements?
- What is the dollar value of support equipment for the weapon system and how much is for ESH related activities?

Medical Examinations: The cost for medical examinations that are over and above normal examination requirements.

Medical examination often have accelerated frequencies when there is potential of exposure to hazardous elements (working around rocket propellants or nuclear waste). Normally this is a cost at the operating base but could also be incurred by the prime during development. The cost include lost duty time, medical center labor and equipment. This cost would be expected to be fairly small unless the entire workforce required annual examinations. Question includes:

- Are examination costs driven by ESH requirements tracked separately from routine physicals?

Modeling and Simulation: The cost to model and simulate ESH conditions. Often performed to enhance decision making or as part of assessments and analysis. Also includes tool development.

Where the use of new substances or the use of substances is in a non-traditional manner, it may be necessary to conduct simulations to determine the ESH impacts of the action. These are normally expenses of the prime contractor or the program office/product center. To do the simulation, tools and models may need to be developed. The development of common models and simulations would be addressed by the contribution to common initiatives. This cost is unique to a single system. The noise signature of large launch vehicles is an example where modeling and simulation can help to determine the extent of the problem. Questions to ask:

- What programs have had to develop special models or simulations?
- What is the range of costs for program unique models and simulations?

Modifications, Pollution Prevention: The cost of modifying existing systems or equipment to prevent pollution.

A modifications can be developed in response to more stringent requirements or as self initiated effort to reduce pollution. The Air Force has a modification program with classes of modification. Is should be fairly easy to track the cost of modifications that are performed solely for pollution prevention reasons. For modifications that improve performance and have side benefits of improving pollution prevention, the cost allocation may be somewhat difficult. Most modification occur after the programs have transitioned to the logistics centers. Some modifications may be managed at the product center, especially on long production run programs. Modification costs can be fairly substantial. Questions include:

- Which modifications have been performed solely for pollution prevention reasons and what were the costs of each?
- Do modification cost estimates have enough detail to identify the costs of the pollution prevention related portions?
- What percentage of the Air Force modification budget is perceived as pollution prevention related?
- Is there central funding for pollution prevention modifications?

Modifications, Safety: The costs of modifying existing systems or equipment to enhance safety.

Modification can be developed in response to more stringent requirements or as a self initiated efforts to enhance safety. The Air Force has a modification program with classes of modifications. Is should be fairly easy to track the cost of modifications that are performed solely for safety reasons as that is one class of modification. For modifications that both improve performance and have side benefits of improving safety, the cost allocation may be somewhat difficult. Most modifications occur after the programs have transitioned to the logistics centers. Some modification may be managed at the product center, especially on long production run programs. Modification costs can be fairly substantial. Questions include:

- Which modifications have been performed solely for safety reasons and what were the costs of each?
- Do modification cost estimates have enough detail to identify the costs of the safety related portions?
- What percentage of the Air Force modification budget is perceived as safety related?

Permits: The cost of ESH related permits for construction and operation.

The cost of permits is normally rather small. Sometimes the permit requires detailed analysis. Analysis is covered in other categories. Permits are obtained by prime contractors, as well as bases and centers.

Unless cost analysts can cite some examples of large permit costs, minimum research should be expended on this cost category. Questions:

- What agency normally processes applications for permits?
- What kind of permits do you need (i.e., air, water, etc.)?
- What is the average and high cost for ESH related permits?

Personal Protective Equipment (PPE): The cost of equipment used to protect personal health.

This cost category includes the cost of initial items, replacement items and the maintenance of personal protective equipment. It may also include the cost of design when new ESH threats require development of additional protective equipment. Prime contractors identify the need for personnel protective equipment as part of the LSA process during design. Initial equipment is purchased by the product centers as part of deployment. Using centers and bases are generally responsible for replacement of common items and the logistics centers responsible for the peculiar items. Questions include:

- What is the cost of annual support equipment procurement and how much of that is personal protective equipment?
- Does a life support organization centrally manage personal protective equipment?
- How do bases and centers budget for replacement and maintenance of personal protective equipment?
- Do you have a tracking system for the PPE?

Pharmacy Distribution Systems: The cost of setting up and maintaining a pharmacy distribution system for hazardous materials.

Pharmacy distribution centers have been shown to reduce use of controlled substances by limiting the amount drawn from stores to that required for a single task. There are some additional costs with setup, ordering, inventory, packaging, etc. Pharmacy distribution systems are normally established at bases and logistics centers. The cost is generally considered to be small, perhaps less than one additional person per organization. Questions to ask include:

- What was the cost of establishing and operating a pharmacy system?
- If a pharmacy supports multiple systems how are costs allocated?
- Who operates the pharmacy system?

Plans, Compliance and Safety Program: The cost of developing required ESH related plans.

There are a number of ESH related plans required at both base and system level. There are Pollution Prevention Management Plans, Hazardous Material Management Plans, System Safety Plans, etc. Some of these plans are prepared by the prime contractor, some by Systems Engineering and Technical Assistance (SETA) contractors and some organically by Air Force organizations. The costs of these plans may run from $10,000 to over $100,000 each. One approach could be to get actual costs for each type of plan and use the average cost as a plug in value for cost estimates. Many contractors have estimated costs for each type of deliverable. Questions to ask each agency:

- What ESH related plans do you prepare and what is the estimated cost of each?
- How often must these plans be updated and what is the estimated update cost?

Pollution Control Equipment: The cost of specific items of Pollution Control equipment.

Pollution Control Equipment includes such items as filters, incinerators, scrubbers, tanks, etc. This equipment is common at prime contractor manufacturing facilities, base maintenance shops, and logistics center repair facilities. The cost should include not only the cost for the initial items, but also for maintenance and replacement parts as well. Real Property Installed Equipment records may reveal the cost if these items. Real Property Installed Equipment maintenance records may show the cost of maintenance of these items. Most of the prime contractor costs for these items are passed to the government by line item or through overhead accounts. Questions to ask include:

- For contractors, how do you track and pass along the cost for pollution control equipment?
- For government agencies, what records are available for these items?
- Is maintenance manpower against these items tracked by any system?
- What is the cost for operating and maintaining this equipment?

Preservation, Natural/Cultural: The cost of maintaining ecosystems or cultural artifacts during weapon system development testing, deployment and operation.

These costs can become significant if not taken into consideration early in the design process. They can also be significant if workarounds require relocation or new facilities. These costs can extend into operation and maintenance where cultural representatives may be required to be present at any excavation. The costs of designing around natural or cultural preservation may be hard to quantify. Other costs such as relocation are easier. Bases with a history of natural and cultural preservation efforts include Vandenberg, Eglin, and the Minuteman or MX bases. There may not be any cases similar enough to enable cost estimating until the exact preservation options are known. All the analysts may get is a feel for the magnitude of the potential costs. Questions include:

- Do you have any examples of preservation efforts where the costs where significant?
- What are the most frequent preservation efforts and what do they typically cost?
- What studies were performed and what was their cost?

Public Relations/Community Image: The cost for public relations activities associated with ESH.

The Air Force spends a good portion of its public relations budget convincing neighboring communities that it is a good neighbor. The public relations investment helps EIS and other public reviews to go smoothly. Although the investment is small, it may be estimable as a portion of headquarters, base and center's Public Affairs (PA) staff activities. Questions include:

- How much of PA time is associated with ESH related base activities?
- How large is the PA budget?

Qualifying Vendors and Suppliers: The cost of ensuring that suppliers and vendors satisfy the same standards as the Air Force and Prime Contractor.

Flowing down ESH requirements to suppliers and vendors is mandatory in some cases, ethically required in others. The cost to ensure that the suppliers and vendors meet these requirements may require labor and materials for testing. Under the International Standards Organization (ISO) 14000 series, perhaps the cost can be reduced. It is probably small in any event. Questions include:

- How do you ensure that suppliers and vendors are complying with ESH requirements?
- How much labor do you spend over time to inspect and instruct the suppliers and vendors?

R&D, Alternatives to Unacceptable Materials: The cost of researching and developing alternatives to banned substances.

Finding alternatives for banned substances may require substantial research. Where common to more than one program, look for shared funding. For rare applications such as solid rocket propellant liners, it may be very difficult to develop alternatives that do not degrade reliability or safety. A variety of models have been developed to trade alternative solvents. Common trades in transportation, flightline maintenance, and civil engineering have been addressed by the Pollution Prevention Pilot Programs.

Generally if the cost is significant there will be a separate funding line. With the depot rewrite of technical manuals there may be some cost data on alternatives development. Questions to ask include:
- Were there any alternative projects that were separately managed that may have some cost visibility?
- Is there anything in the lesson learned database than can identify some of the more costly alternative searches?
- How many more alternatives must still be found?

Record-Keeping, Safety, Health, and Hazardous Materials: The cost of maintaining inventory records, preparing reports, disclosures and release reporting.

Record keeping cost are estimated as small. Some may be included in the pharmacy concepts. Reporting requirements are well documented. Record keeping requirements are also well understood. This effort is mainly labor. Questions include:
- How much time (in labor hours) is associated with record-keeping and hazardous material reporting?
- What are the record-keeping requirements as you understand them?
- Where do the reports go and what is the cost at the various headquarter levels to analyze the reports?

Recycling, Collection and Separation: The cost to operate recycling functions on a plant, facility or base. The receipts from recycling are included as credits to the net cost.

Net cost rather than net savings for recycling is often the reality. Many recycling efforts do not yield more than it costs the agency to establish and maintain the program. Costs include containers, delivery, separation, record keeping, and perhaps special equipment and vehicles to support the effort. Most bases manage their recycling program through the Civil Engineering organization. Questions to ask include:
- Does recycling cost more than it saves the organization?
- Where does funding for recycling efforts come from?
- How much is spent per base each year for recycling?
- What are the recycling requirements (film developing by-products, dental by-products, etc.)?
- Is recycling captured as a system expense or a general expense under base operating support?

Release Monitoring Equipment: The cost of developing, procuring and maintaining equipment used to monitor and measure toxic releases.

As part of the flow down of compliance reporting, prime contractors and bases must monitor and report on the release of toxic substances. Normally considered a low cost item, some research is required due to the differences in accounting for these costs. Questions to ask include:
- How are the costs for this equipment accounted for (overhead or tied to products and processes)?
- Are requirements for this equipment more stringent in some parts of the country?

Release Monitoring Labor: The costs to monitor the equipment and prepare the necessary release reports.

This category focuses on the monitoring and reporting side or releases. All aspects of the equipment are in the above category. This is perceived to be a very small cost. One could approach the costing by examining how many releases the Air Force had in one year and how many reports were prepared. Questions to ask include:
- What organization monitors for release?
- What is the organization's staffing?
- How many reports were prepared last year?

- How many labor hours were required?

Remediation Activities: The cost of remediation for an event.

Remediation costs normally begin after the emergency response (which is another cost category). Several excellent models exist to cost remediation. For inclusion into trades and program cost estimates, the likelihood of the event requiring remediation is the challenge. There may be a large number of remediation projects waiting for funding that have been estimated and their estimates can be used. Questions to ask include:

- What are some of the Air Force preferred remediation cost models?
- Are there any events that are not covered by these models?
- Does the base or center have a policy to include contingencies for remediation in PCEs?

Remediation, Design: The cost to design remediation provisions into the system.

The possibility of an accident or incident cannot be 100% eliminated. As part of good design, systems using controlled substances need to be designed to permit efficient and effective remediation. Most prime contractor design notebooks now include ESH related design features. In some cases additional equipment must be designed to support remediation. This cost can be expected at prime contractors as well at bases and logistics centers. Questions to ask include:

- Do you include ESH and remediation features in your design handbooks?
- Has anyone estimated the costs of these design features?

Restoration, Investigations Assessments, and Studies: The cost of all planning efforts for restoration projects.

For any restoration project there is a great deal of planning required. The planning procedures are laid out in restoration and remediation models. The cost of this planning is usually small compared to executing the restoration. Restoration can occur at contractors and all bases. There are many restoration projects that are backlogged for funding. Mapping restoration projects to specific weapon systems does not seem to have high priority. Often the weapon system has been deactivated before the remediation effort is identified. It may be that the centrally funded restoration projects reduce the emphasis on attaching restoration to weapon system. In fact, many of the restorations are planned after the system that caused them has been deactivated. Questions to ask include:

- How well do the restoration and remediation models address the planning costs?
- Could a restoration be required where the funding would be tied to the weapon system?

Risk, Cost of Not Meeting Requirements: The cost of failing to meet the ESH compliance requirements for the system.

Failing to meet ESH requirements means that the program or system will have to be redesigned after the initial design phase. The consequence of the risk is cost for design, change and production. The failure to meet requirements could come about for technical reasons as well. It could come as the result of requirements changing and becoming more stringent during the acquisition cycle. The situation can occur to the prime contractor or to the logistics centers during the operational years of the system. Questions to ask include:

- Have any systems required redesign during development or operations due to the failure to meet ESH requirements?
- What changes in requirements have forced system redesigns?
- How much have some programs added to their cost risk for ESH related items?

- Are more changes coming along that will force redesign (more stringent air standards)?
- Have you paid any fines and if so, how much?

Risk of Catastrophic Events and Hazards: The cost risk of events in the life of a system.

Catastrophic events occur more prevalently in the aircraft and launch vehicle worlds. The question is whether program cost estimates should include costs for catastrophic events. If for example, the Air Force averages one major fuel spill per base per year, should some funds be included in the estimate to account for events whose probability of occurence can be estimated? Questions to ask include:

- Have any programs included ESH catastrophic risk projections in the program cost estimate?
- Where should the probability of occurrence come from (program office or users)?

Sampling: The cost of sampling equipment, sampling staffing and sampling reporting.

Many compliance requirements dictate frequencies for sampling. Sampling is required at contractors and all applicable bases. The costs to sample are generally small for Air Force installations. The Army has some extensive sampling requirements over large areas such as proving grounds. Sampling is predominately an O&S cost. The cost of representative sampling equipment is available in pollution prevention trade magazines. On some bases, the bioenvironmental engineering organization conducts sampling as part of occupational surveys. Questions to ask include:

- At a base, generally how much of the staff is devoted to sampling?
- What sampling equipment has to be purchased to ensure compliance with NEPA?
- How often is the sampling performed?

Storage structures and containers: The cost of the development, procurement and maintenance of structures and containers required for ESH compliance.

Often the use of controlled substances will require containers, tanks and pumps to meet ESH requirements. These tanks may be different from normal tanks with dual liners, etc. Most will be classified as support equipment or real property installed equipment and we have categories for those items already. The containers required for the pharmacy system have their own category. This cost category may be duplicating others and can possibly be removed. Questions to ask include:

- Are any special containers required for ESH compliance?
- What is the cost of the design of the special containers?
- What is the operations and maintenance cost for the containers?

Supervision and Audits: The labor and related indirect costs of managing ESH compliance.

One way to check to see if this area is needed is to look at the Base Bioenvironmental Engineer. If the shop's time is not accounted for by the other categories, then this one could serve as a catch-all. Included could be staff assistance to program offices and other base agencies. This cost should be very small. Questions to ask include:

- Can the Bioenvironmental office account for all time without this cost category?
- How often do you audit program offices for the status of their programs?

Surveys, Industrial: The cost to perform ESH industrial surveys for production or maintenance processes.

Industrial surveys are often required for production or maintenance processes. A part of that survey should be the ESH related items. The on-site ESH engineer normally performs these surveys. The cost is certainly small. Questions to ask include:

- How often are the surveys taken?
- How much do they cost?

Surveys, Site: The cost to perform ESH portions of site surveys for future beddown locations.

Site surveys are often required for temporary operations. They are almost always required for new bases and new facilities. A part of that survey should be the ESH related items. Civil Engineering and the Bioenvironmental engineer normally participate on these surveys. The cost is certainly small. Questions to ask include:

- How long did the ESH portion of the site survey take?
- What were the results?

Technical Support, Contractors: The cost of SETA type contractors performing ESH related tasks.

A wide variety of contractors perform ESH related tasks for the prime contractor, centers and bases. One example is the participation in the Cost Guide for ESH. This effort is fairly easy to track since the developing contractor is issued specific tasks and task statements to perform the work. The percentage of outsourced technical support performed in the ESH area has been increasing. Questions to ask include:

- What percentage of the SETA efforts are related to ESH?
- What are some of the ESH tasks performed?
- How much do the centers or program offices budget for ESH SETA support?

Training, ESH: The cost for ESH training materials development and the conduct of ESH training.

There seems to be an emphasis on ESH training. ESH awareness training may become mandatory for all Air Force personnel. Specialty training may be needed on topics such as ISO 14000. AFMC has developed courses and sent them to all command bases. The total ESH training costs could be significant when the training time of attendees is considered. Questions to ask include:

- What classes do contractors, bases and centers offer on ESH?
- What is the duration, how often, and how much did they cost to develop?
- Have any new systems generated requirements for changes to or other ESH classes?
- Can ESH training be tied to weapon systems by virtue of the system characteristics?
- How many personnel are trained each time?

Transportation, Specialized Requirements: The cost of other than normal transportation due to ESH requirements.

The use of certain substances in weapon systems may require that extraordinary transportation methods be used. For example, movement of Unsymettrical Dimethyl Hydrazine (UDMH) to Vandenberg AFB for launch vehicles required special trucks and special routes. Specialized transportation requirements can be identified during the LSA process and documented on the LSAR. Warner-Robbins ALC is responsible for special purpose vehicles. Additionally specialized transportation services could be contracted through the traffic management office. Questions to ask include:

- Has this system identified any special transportation requirements on the LSAR?
- Does the base have any special purpose vehicles tied to ESH requirements?
- Do any authorizations for special purpose vehicles include references to ESH?

- What are the costs of these special purpose vehicles?

Water Treatment, Specialized: The cost of treating water over and above normal treatment for drinking purposes.

Military operations often use water for sound suppression and to wash down facilities after flight. Many times the water is too contaminated to dispose of normally. If specialized treatment is required, the cost could be ESH related. Specialized water treatment may come from a contractor providing the service. It may come from new equipment related to a particular system. Questions to ask include:

- Does the system generate any waste water that requires special treatment?
- Do you outsource any water treatment?
- Does any base water line interface with the local communities and require treatment?

Appendix J - ESH Cost Identifying Questions (By Organization / Function)

The following are questions designed to identify ESH costs. The questions have been arranged by organization. The questions will need to be tailored for the cost analysts specific tasks. Some questions can be used to ask lateral agencies to get a feel for comparable operations (e.g., a program office asking another the questions listed under program offices).

OPERATING BASE LEVEL QUESTIONS (FM, CE, SE, SG, LG. RM)

- When you prepare budget estimates for the base, do you have any specific line items for environmental, safety or health?
- What Elements of Expense/Investment Code (EEIC) or Responsibility Center/Cost Center RC/CCs contain these budget requirements?
- What is the staffing of the Base Safety office associated with the mission of the weapon system?
- What is the staffing of the Base Bioenvironmental Engineering office associated with the mission of the weapon system?
- What is the staffing of the Civil Engineering Environmental Management Unit associated with the mission of the weapon system?
- What is the total value of environmental related projects currently carried on the books for O&S projects by the base civil engineering function?
- Does the base civil engineering function have any contracts for specialized disposal of substances?
- Does the base have an emergency response team for ESH related hazards? How are the costs of this team allocated to other units?
- I will show you a list of ESH costs, please tell me if you have any of these costs (show list from a publication that lists potential ESH costs such as Appendix I)?
- How much ESH related training do base personnel receive?
- What type of ESH plans do you have at base level? Where are the planning costs reported?
- Do you have any pollution prevention projects in planning or implementation phases?
- Can Host Tenant Support Agreements or Inter Service Support Agreements be used to gain insight into ESH costs?
- Has the base received any ESH related claims, fines or penalties?

PROGRAM OFFICE LEVEL QUESTIONS

- Do you have a feel for the amount of ESH costs in the acquisition and O&S estimates?
- Did you individually identify any ESH costs in your latest PCE?
- Did you individually identify any ESH costs in your latest O&S estimate?
- Have you or your prime contractor performed any ESH related trades? Was cost a measure of merit?
- Is personal protective equipment required to operate or maintain the system? How is it identified and documented ?
- Have you or the contractors performed any estimates of lost productivity due to the requirements for protective equipment?
- What ESH related documents did the Program Office or the Prime Contractor prepare (i.e., HMMP, Pollution Prevention Plan, System Safety Plan)?
- What percentage of the program office staffing is working ESH?
- What level of support did you get from the Center Staff on ESH matters?
- What models did you use to estimate O&S costs?
- Do the models that you use, separately identify ESH related costs?
- Did the prime contractor separately estimate ESH related labor or materials in the proposals?
- Have any of your contractors passed the cost of ESH insurance to the government?

- Do you have to develop any alternative materials or processes as a result of ESH requirements?
- Have you included ESH related risk in the PCEs?

PRODUCT CENTER LEVEL QUESTIONS (FM, EM)

- The ASC O&S Cost Estimating Guide contains percentages for cost categories by weapon system. Has that information been updated since 1994?
- Have any of your programs provided separate LCC estimates of environmental or ESH costs?
- Can we see any of those estimates?
- Have you done any comparisons of ESH related costs across weapon systems?

AIR LOGISTICS CENTER LEVEL QUESTIONS (FM, SG, SE, MM, MA)

- Do you perform Industrial Process Environmental Assessments for new weapon systems?
- When you build up sales rates, how do you include ESH costs in those rates?
- Are ESH costs included in the Base Operating Support (BOS) portion of the sales rates?
- Where you have a host wing, do you get any estimates of the cost of ESH support that they provide?
- Do you have an ESH staff at the depot? What organizations are they in?
- Do you have visibility into the total O&S costs to support an individual weapon system?
- How much does it cost to operate the hazardous materials pharmacy?
- How is ESH risk introduced into rate projections?
- What percentage of modifications on systems are ESH related? Can the ESH costs be derived from the modifications?

AFMC COMMAND LEVEL QUESTIONS (FM, CE, LG, DR, EM, SE, SG)

- When reviewing depot level sales rates, do you get any insight to ESH related costs and percentages of sales rates related to ESH?
- Do you consolidate or analyze the total depot level costs to support an individual weapon system?
- During any program reviews do you get any insight into ESH related costs by weapon system?
- Are any weapon system modifications directly related to ESH? Is it possible to estimate the percentage of the aircraft modification budget that is ESH related?
- Who budgets and pays for the disposal of weapon systems when they are removed from the system for disposal (the operating base/command, AFMC, etc.)?
- Have any of the cost estimating guides been updated? Do they address ESH cost estimating?
- Do you have any accident, incident, or personal injury rates by weapon system?

AIR STAFF LEVEL QUESTIONS (AFCAA, SAF/AQRE)

- What weapon system estimates have you seen in the past 12 months that contain ESH costs separately identified?
- Have you separately estimated ESH costs on any system?
- Are there any plans to expand the O&S WBS to more clearly identify ESH related costs?
- We have heard that the total Air Force Environmental quality budget is $4 billion, is that figure broken down by appropriation, system or project?

AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE

- What is the status of the effort to develop an Environmental Cost Work Breakdown Structure?

- Do you have any research on alternatives that are being considered by the system being estimated? Do you have any cost/benefit analyses on those alternatives?

AIR FORCE CIVIL ENGINEERING SUPPORT CENTER

- Do any of your facility cost estimating tools specifically address ESH related requirements?
- Do these cost models generate any ESH cost line items?

SYSTEM LEVEL QUESTIONS

- New versus old system
  - What system or process is being replaced?
  - What is the new system or process?
  - How does the new system or process differ from the old system?
  - What are the similarities?
  - What will happen to the old system or process when the new one comes on line?
- Analogies to other systems
  - Are there analogies to other systems and/or other elements of these systems?
- ESH Specific
  - How are the current or similar systems being disposed?
  - Do the new systems/processes have similar HAZMATs?
  - How did the old system handle ESH issues?
  - What were the HAZMAT issues in the old system/process?
  - Is there a pollution prevention program in place to correct old system deficiencies?
  - What is the proposed demilitarization/disposal plan for the old and new systems?
  - Are there any high or medium/serious risks identified in the System Safety Plan? If so, what are they?
  - Are personnel in the work place exposed to hazardous, radiological, or toxic substances?
  - Is personal protective equipment (PPE) required in the workplace? If so, what are the productivity losses experienced compared with no PPE?
- Costs
  - Have you identified any ESH cost drivers?
  - What are the ESH cost drivers?
  - What did the ESH issues cost in the old system/process? Where were these costs accounted for?
- Funding
  - What are the correct appropriations for funding the different ESH activities?
- Alternatives
  - What alternatives were considered?
- How were they evaluated?

Appendix K - Making Smart Choices in Material Selection

MAKING SMART CHOICES IN MATERIAL SELECTION

Material selection for any system or process should be carefully considered during the design and acquisition phases. The use of materials during all phases of a process, including manufacture, operation, maintenance, and disposal, could have long lasting and significant impacts on environmental, safety, and health (ESH) issues, as well as on the life-cycle costs of the system. This article addresses all phases of a project and presents several questions that should be considered when making decisions regarding the life of a project.

These questions are meant to assist system engineers and program managers in making effective choices through an analytical process. This analytical approach will serve to clearly define the problem of material selection in terms of ESH concerns. Answers are needed for each material candidate and alternative. Decisions on ESH issues surrounding material choices must be integrated into a program manager's existing risk management and business-based decision making frame work. The final decision on material selection should minimize life-cycle costs and balance cost, performance, and schedule risks against the impacts to human health and the environment. Systems engineers and program managers must draw upon the expertise, evaluation, and recommendations of ESH personnel to ensure that all issues are adequately addressed. The questions are not all inclusive and may be a springboard to other ESH related questions.

Project Considerations:

1. Involve experts in the evaluation process: Materials selection and evaluation requires input from many different specialists including industrial hygiene, occupational health, toxicology, acquisition pollution prevention, materials science, process engineering, systems safety, ground safety, operational safety, explosive safety, environmental management, and environmental compliance. These experts should participate in any environmental or human exposure testing and/or review the results of this testing.

2. Define processes and tasks: To truly evaluate the hazards and risks from each material/chemical requires knowledge of the process and how the material is used in the process. A change in the material may cause a change in the process; i.e., multiple rinse cycles, longer drying times, additional capital equipment. Occupational health hazards, other than those related to chemicals and materials, should also be identified for each process. Workers may also be exposed to noise, radiation, heat/cold, safety, fire, and explosive hazards. The combinations of processes, materials, and hazards to perform a job/task/requirement can then be compared to make informed decisions.

3. Identify issues related to maintenance activities: Materials/Chemicals used to perform maintenance procedures and those contained within each sub-system can cause exposures. Exposures to maintenance personnel could occur during procedures which empty, purge, and refill materials and from the clean-up of spilled materials. Exposures could also occur from cleaning, washing, stripping, painting, lubricating, welding, brazing, soldering, plating, metal treating, cutting, sanding, grinding, rubbing, and other maintenance procedures. The materials may also have environmental impacts.

4. Consider accidental spills and discharges: If materials/chemicals are contained within the weapons system or its sub-systems, the potential for accidental spills or discharges must be considered. The site of the spill should also be considered (e.g., on the ground, in flight, in a storage facility, in a maintenance shop) as this affects the approach personnel would take to respond to a spill.

5. Special facilities requirements: The use of certain materials/chemicals often require the construction of special maintenance and storage facilities. These facilities may need special ventilation systems,

special waste containment or collection systems, special waste treatment or neutralization systems, or any other engineering controls.

6. Consider training requirements: Training may include: maintenance procedures, use of PPE, use of engineering controls, emergency response/evacuation procedures, spill clean-up procedures, hazard communication required by the Occupational Safety and Health Administration, safety hazards, health hazards, waste disposal, and record keeping.

7. Special pay requirements: Will Wage Grade/General Schedule (WG-/GS-) civil service employees be entitled to Environmental Differential Pay because of the hazards associated with any material or process?

8. Operational considerations: Since the materials/chemicals used in, on, and with the weapon system will go to war with the system, the designers must consider all ESH issues when applied to a bare base or pre-engineered deployment site and wartime scenario. The special facilities may not be there and the use of special PPE may slow down the maintenance process if work/rest cycles for heat or cold stress injuries/illnesses need to be implemented. Additionally, in the stress of the moment, from the Operations-Tempo of war fighting, ground crew and maintenance personnel may not exactly follow the required procedures or may take short-cuts which will increase the risk of potential exposures and other mishaps. The fewer the special procedures, special PPE, special facility requirements, etc. needed during wartime scenarios, the better. If designers make it easy for the people (ideally no PPE, no special procedures, no special facility), then workers will not forget something critical concerning ESH issues. The more complicated the procedure/process the more apt people are to forget something.

9. Manufacturing/Production: Each prime contractor and sub-contractor should be making smart business decisions about the use of hazardous materials which will minimize the manufacturing costs. This will, in turn, help to minimize the weapon system's life cycle cost.

10. Life-cycle costs: If the use of any of the material candidates and alternatives drive special handling, special PPE, special storage and maintenance facilities, environmental and exposure monitoring, additional medical surveillance, special training, special disposal, etc., the life-cycle costs of these items for both peacetime and wartime scenarios should be considered and included in the life-cycle cost of the weapons system. Any trade studies used to make decisions on the material selections should also be reviewed.

11. Disposal/Demilitarization of the system: The disposal/demilitarization procedures and processes for the weapons system need to be evaluated. Disposal and potential recycle opportunities should be identified.

Specific Questions to Ask:

1. Project definition phase:

   a. Have the appropriate experts been consulted?
   b. Have all material/chemical candidates and alternatives, and the quantities needed, which will be used in or on the weapon system and its sub-systems, or for its operation, been identified?
   c. Is there enough toxicological information known about the hazardous materials?

d. For complex materials, such as mixtures of solvents and cleaners, or for multi-step process which may mix chemicals, is enough information known about potential synergistic or antagonistic effects of the mixtures on humans?
e. Is any toxicological testing needed to characterize hazards to humans?
f. Will any qualification, acceptance, or flight testing be needed to select materials and processes?
g. Have all processes for storage, operation, use, maintenance, support and disposal of the weapon system and its sub-systems been identified and defined?
h. Have all subordinate tasks within these processes been identified and described?
i. For each task, have all material/chemical candidates and alternatives, the quantities needed, and the application method(s) been identified?
j. Are any of these materials hazardous materials or radioactive materials?
k. Are Material Safety Data Sheets (MSDSs) available on each hazardous material candidate and alternative?
l. Is enough information known about the effects each material/chemical/substance candidate and alternative will have on other materials used in or on the weapons system and its sub-systems?
m. Have other safety, chemical, physical, radiological, biological, and ergonomic hazards associated with each process and task been identified? (e.g., noise, lifting, repetitive motion, cutting, falling, microwaves).
n. Will any federal/state/local regulatory agencies require permits or licenses for the system operation, maintenance, materials, or processes? (e.g., air emission or waste water discharge permits, radioactive material licenses)

2. <u>ESH issues during operation and maintenance</u>:

a. What are the estimated exposures to maintenance personnel which may occur during the routine maintenance procedures?
b. What are the potential exposure routes (inhalation, skin contact, skin absorption, ingestion)?
c. Are any exposures likely to exceed existing exposure limits?
d. If any material has cumulative effects, then what is the life-time exposure to an individual worker from these exposures?
e. Is any testing needed to better characterize exposures to maintenance workers?
f. Will maintenance activities cause additional exposure monitoring by industrial hygiene and occupational health specialists?
g. Will they cause additional medical surveillance and occupational health training?
h. Will engineering controls (e.g.; exhaust ventilation) be needed to control exposures to maintenance workers?
i. Will the maintenance personnel be required to wear personal protective equipment (PPE)?
j. Will the PPE be routine (i.e.; eye protection, gloves, aprons, hearing protection, etc.) or will special PPE (e.g.; chemical resistant encapsulation suits, supplied air respirators) need to be developed and/or procured?
k. What are the waste disposal requirements for each material/chemical/substance candidate and alternative?
l. How much waste will be generated during each maintenance process or task?
m. Will any waste be recycled?
n. Will any of waste be a hazardous waste as defined in the Resource Conservation and Recovery Act (RCRA) (See 40 CFR 260-265) or similar state/local codes?
o. Can a release to the environmental (soil, water, air) occur from the maintenance process or task?
p. Is the release likely to exceed existing environmental contaminant limits/standards?
q. Is any testing needed to better characterize release to or impacts on the environment?

r. Will maintenance activities cause additional environmental monitoring to ensure compliance with regulatory requirements?
s. Will engineering controls (e.g., exhaust stack scrubbers, waste water treatment) be needed to control or prevent releases to the environment?
t. What special training will need to be given to the maintenance personnel, the aircraft ground crew, the storage facility personnel, and emergency response personnel?
u. When and where will this training take place?
v. Will periodic refresher training be needed?

3. Spills, discharges, disposal issues:

a. Where will the accidental spill/discharge occur?
b. How will each material candidate and alternative be treated or neutralized if spilled?
c. How will each material candidate and alternative and any treatment or neutralization processes or chemicals affect the materials used in the construction of the storage and maintenance facilities?
d. How much material is likely to be released? How will the remainder be captured?
e. Can exposure to ground crew, maintenance workers, storage facility occupants, emergency response personnel, or other workers occur from the accidental spill/discharge?
f. How often are accidental exposures likely to occur?
g. What are the potential exposures routes (inhalation, skin contact, skin absorption, or ingestion)?
h. What are the estimated exposures to personnel from each accidental exposures?
i. If any material has cumulative effects, then what is the life-time exposure to an individual worker from these accidental exposures?
j. Are any exposures likely to exceed existing exposure limits?
k. Is any testing needed to better characterize exposures to ground crew, maintenance workers, storage facility occupants, emergency response personnel, or other workers?
l. Can a release to the environment (soil, water, air) occur from the accidental spill or discharge?
m. What concentration is likely to be released to the environment?
n. What impact will this have on the soil, air, water, plants, animals, human receptors?
o. Is any testing needed to better characterize release to or impacts on the environment?
p. How will each material candidate and alternative and any treatment or neutralization process or chemicals affect the materials used in the construction of the storage and maintenance facilities? Will special construction materials need to be selected?
q. Will special safeguards be necessary to mitigate incompatibilities with surrounding activities?
r. What measures can be taken to mitigate or reduce possible spill scenarios? (e.g., smaller containers, pressure or check valves, alarms)
s. Do special emergency response or clean-up procedures need to be developed?
t. Will any chemicals/materials be needed to prepare the system for disposal, recycling, sale, or demilitarization?
u. What are the estimated quantities of materials generated during the disposal and demilitarization processes?
v. Will any of the system materials be recycled or sold for scrap?
w. Do any of the materials used in the weapon system require special handling?
x. Do any of the materials used in the system require disposal as a hazardous waste?
y. Do any of the materials used in the system require disposal as a radioactive material?

4. General questions:

a. Does any material have a shelf life? A shorter shelf life may lead to wasted materials which drive up disposal costs.

b. Can smaller containers be substituted to mitigate impact of exposure, spill, or waste?
c. Are there any special handling requirements for each material/chemical/substance candidate and alternative?
d. Will any special materials be needed on the weapons system, any sub-system, or for any maintenance equipment to contain or store hazardous materials?
e. Will the materials and quantities used initiate or add to reports required by federal/ state/local regulatory agencies? (e.g., Emergency Procedures and Community Right to Know Act, Toxic Release Inventory, Clean Air Act, Clean Water Act, National Pollution Discharge Elimination System)

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Appendix L - Selected Topics Related to ESH Cost Estimating

Activity-Based Costing (ABC) / Activity-Based Management (ABM)

Definition

ABC is a methodology that measures the cost and performance of resources, activities, and cost objects. Resources are assigned to activities, then activities to cost objectives based on their use. This procedure allows for Activity-Based Management by providing the decision-makers with accurate information on what existing processes actually cost. It identifies how resources are used, not merely what they are. The ABC model is especially effective in identification of component cost details, cost impacts, and savings from alternative courses of action.

Discussion

A little history and background information on ABC will be useful before exploring the application of ABC to ESH related activities. First, ABC is not as new a tool as some analysts may think. It was developed in the 1986-87 time frame. At the time of ABC development, the focus was on the manufacturing sector. It was not until the 1990s that the service sector began to use ABC. Within the DoD, ABC began in 1991 with a pilot Army Center for Public Works project at Fort Eustis, Fort Sill, and Fort Bragg. The results of the pilot program showed that ABC could help to fill the void in financial management information regarding basic support services. Second, use of ABC within the Air Force lags behind the other services. The Air Force has begun with a series of pilot applications using ABC on several weapon programs. The focal point for the Air Force is SAF/FM. Within HQ AFMC the focal point is XP. ABC is grouped into an initiative designed to improve decision making information for outsourcing and privatization efforts. The final point is that ABC is being more positively embraced by those organizations with profit like motivations. This includes contractors as well as government organizations that compete for workload with other government and industry organizations. As a result, the Air Logistics Centers are taking a careful look at the application of ABC for depot operations.

ABC is not a shrink-wrapped, no training required solution. There have been failures at implementation. The fact that private consultants are frequently employed for implementation and that Services have produced handbooks, guides, and lessons learned on ABC implementation should caution any potential user of the tool. A family of software has been developed around ABC, again with training in software application use. The message is clear, ABC implementation requires commitment, planning, and resources to be successful.

ABC can be used to identify ESH costs for programs and systems. The rationale for this consensus is that ABC is especially effective at identifying and allocating indirect or overhead costs to products. One of the uncertainties in ESH costing is the amount of ESH costs in overhead accounts. Thus, the ESH interest in ABC. The downside to the use of ABC for ESH costing is the investment. ESH costs in overhead accounts, while they may be significant, are currently included in depot sales rates. The identification costs may not be worth the cost of implementing ABC. However, if ABC is implemented at ALCs for other reasons, such as component sales rate build-up, then expanding it for ESH may be cost effective.

Recommendation

ABC is an excellent tool that could be very helpful at defining the ESH costs at ALCs and operational bases. It is premature to make a commitment to ABC just to pursue ESH costs, especially given the lack of insight into O&S phase ESH costs. If ABC is adopted for use at the ALCs, then regardless of the magnitude, the cost analyst should use ABC to get a better understanding of ESH costs.

Appendix M - Potential ESH Cost Estimating Tools

This appendix reviews on an evaluation of ESH related software. Two sources of potential application software were analyzed; (1) The database of Environment Software Resource Guide and (2) Existing ESH cost estimating tool studies. Software assessed in this section includes the following:

- Material Inventory Report System (MIRS) V3.4
- SoftBooks Cost Estimating Software
- DataPipe II
- BatchMaster 3
- Hazardous Air Pollutant Program (HAP-PRO) 2.0
- Environmental Life Cycle Cost Model (ELCCM) and Environmental Cost of Hazardous Operations (ECHO) Software Tool
- Remediation Tri-Service Automated Cost Engineering System (TRACES)
- Remedial Action Cost Engineering and Requirements System (RACER)
- M-CACES Gold
- HAZRISK 3.0

Environmental Software Resource Guide

Scott M. Johnson of Ventura, California developed the Environmental Software Resource Guide in February 1996. The guide includes two databases, a software vendor's database and a software product database. The software product database provides the following information for each software product: ESH media and issues addressed, program function (audits to training), computer hardware and software requirements, pricing, program features, and real-world applications. Searches can be made in a number of ways. The database was searched for software that had to do with cost and financial calculations. Most of the software in this database is single purpose. That is, it might track inventories or hazardous materials or leaking tanks. All obviously single purpose software was eliminated.

Material Inventory Report System (MIRS) V 3.4

Application: The Environmental media concerned are air, groundwater, hazardous materials, land use, occupational safety and health, surface water, transportation, waste disposal, waste water, and general environmental.
Package Use: Cost and financial calculations
Company: AV Systems Inc.
Remarks: The operating system is Windows. The Material Inventory Report System (MIRS) is an integrated compliance software package with modules for EPA approved Form R, Superfund Amendments Reauthorization Act (SARA) Title III, Occupational Safety and Health Act (OSHA) Hazcom, Air Emissions, Resource Conservation and Remediation Act (RCRA) Waste and Inventory, along with State and Local options. Developed for the IBM personal computer family, each MIRS module is a comprehensive implementation of the respective legislation with easy-to-use features to guide the user through the compliance steps. MIRS lets companies stay on top of their chemical inventory, and greatly facilitates their compliance reporting in the context of changing regulations.
Analysis: This suite of programs is typical of the ESH software available. The programs will calculate the cost of installing and maintaining ESH equipment but not the rest of the weapons system costs. Further, regardless of how well each module calculates its piece of the cost it is not automatic that the sum of the model cost will approximate the cost of performing all of the module tasks at the same time. The ability to do this must be examined separately. If the final product is to become an accepted product, the accuracy of the sum must be demonstrated.

SoftBooks Cost Estimating Software

Application: Environmental Restoration
Package Use: Cost and financial calculations
Company: Environmental Cost, Handling Options and Solutions (ECHOS)
Remarks: SoftBooks cost estimating software allows you to access cost data required to manage project changes and modifications, quickly and accurately. The SoftBooks application allows users to create as many different customized cost databases as they need. The number of database modifications is limited only by your computer's hard disk storage space. The ECHOS Environmental Restoration Cost Database can be modified by SoftBooks to: capture information by project or by sites within projects; modify cost data within restoration technology groups; create your own assemblies or add assemblies to a remediation technology; add, delete, or modify the unit cost lines comprising any assembly; and modify crew, equipment, man-hours, and productivity. It runs on PC's under Windows.
Analysis: The program is concerned with environmental problems. It will do cost and financial calculations and it manages data. The program appears to regard the acquisition cost as given and is more concerned with operating cost. It is therefore a major concern for the DoD cost analyst.

DataPipe II

Application: Environmental, Safety and Health
Package Use: Cost and Financial calculations
Company: Knorr Associates
Remarks: DataPipe is a comprehensive, modular, multi-user, PC-based program system for environmental, safety and health information. Each DataPipe system consists of the individual modules a particular customer needs for his or her tasks. A DataPipe system may include several environmental modules, some safety and industrial hygiene modules, and no medical modules. Another customer's system might be used only within an occupational medicine clinic, and therefore include no modules for hazardous waste inventory or manifests, underground storage tanks, etc. The modular design of DataPipe makes it easy to handle many different kinds of information. New modules can be added as customer requirements and regulations change and work with existing ones. If a module gets its information from one or more instruments, DataPipe routines can be added to directly interface with the devices to import the data from the external source. All DataPipe systems include a "core module" that includes several commonly used databases, a security system to control user access and operations, and several report writing systems covering ad-hoc as well as complex, formatted reports. DataPipe forms include fields for numeric, text (including free-format notes), date, time and images. Many DataPipe forms can store copies of permits, MSDSs, photos, etc. as images that can be recalled and reviewed.
Analysis: The product runs on PC's under Windows or OS2. The ESH media concerned are air, hazardous materials, occupational safety and health, waste disposal, waste water, and general environmental. The program does cost and financial calculations, provides graphics output, provides data on chemicals, assists in audits, manages data, helps manage facility operations, helps track ESH material inventory, assists in emergency planning, prints Material Safety Data Sheets. Support is via Bulletin Board, Internet, CompuServe and Email. Again this program probably does an excellent job of managing ESH problems but does not calculate the cost of designing, acquiring and managing the ESH equipment in a DoD environment.

BatchMaster 3

Application: Hazardous Materials, Occupational Safety, and Health
Package Use: Cost and Financial calculations
Company: Pacific Micro Software Engineering

Remarks: BatchMaster is a software system for process manufacturers that includes modules for inventory, production, costing, laboratory, MSDS/compliance, labeling, purchasing, order entry, and more. BatchMaster is fully integrated with the Platinum Series accounting software providing a full solution for both process manufacturing and accounting. The latest release of BatchMaster has been enhanced to include hundreds of new features including inventory quality control, lot tracking, formula revision history, multiple locations, unlimited alternate units of measure, user-defined calculations and much more. The MSDS/Compliance module addresses both MSDS and SARA reporting requirements. The module will automatically generate Material Safety Data Sheets in full compliance with the OSHA Hazard Communication Standard, SARA Title III, American National Standards Institute (ANSI), and virtually all similar government reporting requirements. The format is fully customizable, so users have total control over the MSDS design. Also, hazardous statements may be as long or brief as necessary, accommodating your needs for all products.
Analysis: The product runs on PC's under DOS. The ESH media concerned are hazardous materials, occupational safety and health. The program does cost and financial calculations, provides data on chemicals, assists in audits, manages data, helps track ESH material inventory, can print shipping labels and Material Safety Data Sheets. It is supported by a bulletin board system and a newsletter. The program has had software updates. This software package is only concerned with ESH problems. It is not capable of performing a complete system cost estimate.

Hazardous Air Pollutant Program (HAP-PRO) 2.0

Application: Air and Hazardous Materials
Package Use: Cost and Financial Calculations
Company: U.S. Environmental Protection Agency - CTC
Remarks: The Hazardous Air Pollutant Program (HAP-PRO) assists permit engineers in reviewing applications for controlling air toxics by calculating the capital and annual costs for six volatile organic compound and three particulate control devices, including selected engineering parameters which may be used to pinpoint errors in the engineering design. Calculations used by the program mirror those presented in the revised EPA handbook, "Control Technologies for Hazardous Air Toxics." A secondary purpose of HAP-PRO is generating lists of all facilities containing a specified pollutant in their emission streams or a specified type of emission stream. HAP-PRO's features include context-sensitive help to assist in data input, a windowed environment to provide a referential trail of the user's actions, look-up tables containing the characteristics of many common pollutants, and the ability to select air toxics either from an alphabetical list or by Standard Industrial Classification number.
Analysis: The product runs on PC's under DOS. The ESH media concerned are air and hazardous materials. The program helps control ESH problems, does cost and financial calculations, and does ESH system design. The product is supported by a bulletin board system and a newsletter. The program has had updates. This program is concerned with only air pollution. It will not perform a complete system cost estimate.

Other Software

The second source of software descriptions are selected packages from previous ESH tool studies reviewed by members of the Guide Development Team.

Environmental Life Cycle Cost Model (ELCCM) and Environmental Cost of Hazardous Operations (ECHO) Software Tool

Application: ESH cost estimating
Package Use: Developing DoD program cost estimates and ESH trade studies
Company: Tecolote Research, Inc.

Remarks: The ELCCM is being developed by Tecolote Research as a Phase II Small Business Innovative Research Project. The model and documentation are scheduled to be available in March 1998. The ELCCM bridges systems management, environmental management, and cost analysis. ELCCM builds three links. The first link is between system quantities and the hazardous substance quantities that are the primary cost drivers. The second link is the analysis of hazardous substance quantities as environmental cost drivers. Costs for ESH activities depend upon the regulatory status and inherent hazards of the substances involved. The third link is the correlation of the cost drivers to ESH costs. ELCCM maps the cost drivers to independent ESH cost categories. The significant contribution of the ELCCM and ECHO is breaking the problem down into manageable pieces for analysis. ECHO is developed from Microsoft Office business applications and interfaces to Automated Cost Estimating Integrated Tools (ACE-IT) and RACER the Remedial Action Cost Engineering Requirements Tool. Costs may be displayed in WBS or ESH activity categories.
Analysis: Not performed pending model availability.

Remediation Tri-Service Automated Cost Engineering System (TRACES)

Application: Management, Risk, Pollution Prevention
Package Use: Modeling
Company: Delta Research Corporation
Remarks: Construction cost estimating model. Use to estimate the cost of building or remediating buildings to meet environmental regulations. Supports all life-cycle phases.
Analysis: This is another of the single purpose estimating tools. This one does construction cost estimating with concern for ESH requirements. It would be inappropriate for entire system estimating.

Remedial Action Cost Engineering and Requirements System (RACER)

Application: Remedial Action Cost Estimating
Package Use: Modeling
Company: Delta Research Corporation
Remarks: Can be incorporated into the new modeling system directly. Price to commercial users is $4,000. Used to estimate Remedial Investigation/Feasibility Study (RI/FS) and Clean-up, primarily in the demilitarization and disposal life-cycle phases.
Analysis: This package handles only one aspect of the life cycle costs, demilitarization and disposal. Therefore, it would not be useable for a total system cost estimate.

M-CACES Gold

Application: Risk, Management
Package Use: Information Look-up.
Company: US Army Corps of Engineers
Remarks: Line item take off estimating using items in the database. Widely accepted cost estimator for construction. Supports some environmental estimating, and all life-cycle phases.
Analysis: This is another single purpose package. This system does take off construction cost estimating. It primarily gives data that is linearly related to some input factor such as cubic feet or miles. It is completely inappropriate for system level cost estimating.

HAZRISK 3.0

Application: Restoration, Management
Package Use: Cost and Schedule Analysis
Company: Independent Project Analysis, Inc.

Remarks: PC program used to develop cost, schedule and contingency estimates for environmental remediation projects at any project stage. Project based data.
Analysis: Another single purpose package. This one is concerned with remediation cost only. Not applicable for a system level cost estimate.

Application of Tools for Program Cost Estimates (PCEs)

The numerous tools mentioned in this study are primarily for one or two categories that fall within the ESH realm. There is still no one tool that incorporates all ESH activities or functions into a format that supports the financial management community requirement of including all "significant ESH" costs within the PCE.

Using Multiple Models for Program Cost Estimates (PCEs)

With the number of computer programs that have been listed for consideration, it is appropriate to consider if one might use these programs in performing a complete system cost estimate. The analyst might be tempted to select a series of programs each of which estimates the cost of constructing and maintaining a different mitigation medium. For example, one program might estimate the cost of procuring and maintaining underground tanks, another might estimate the cost of procuring and maintaining air treatment facilities used to clean air from paint booths. It is tempting to add the output of two models like this and assume that the total represents the total cost of these two sub systems. In fact, regardless of how careful the model builders were to list all of the assumptions they used, some assumptions will be omitted and these unstated assumptions may make the sum unrepresentative of the real total.

The problem is that certain assumptions are so fundamental to the work environment of the modeler that they will not be listed as assumptions. However, another user of the models who does not work in the same environment will have a slightly different set of basic assumptions. We have seen cases within the same service but at different locations, where the composition of such fundamental WBS elements as overhead are viewed very differently. If the various models handle things such as overhead differently, then adding them produces a sum that is incorrect but it is not clear whether it is too large or too small. Certainly it is not possible to adjust the sum, in any defensible way, to the correct answer.

Some will argue that the law of large numbers will rescue the analyst from the above situation. There are two problems with this argument. First the number of models used needs to be about 30 or higher for it to be effective. Fewer models will give skewed answers. Second, the results must be of nearly the same magnitude for the law of large numbers to work in small numbers. As any experienced DoD cost analyst knows, there are usually two or three WBS elements that account for 80% or so of the cost. In this situation, the law of large numbers will not rescue the analyst from the folly of using multiple models.

Application of Tools for Trade Studies

The best utilization of the tools listed in this study may be for supporting ESH cost trade studies. They provide a wide array of models that the financial management community may use to support cost trade studies identified by the systems engineer and/or the ESH specialist.

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