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A STRATEGIC ANALYSIS OF BUDGETING FOR
INTEGRATED LOGISTIC SUPPORT OF DEFENSE SYSTEMS

A Project
Presented to the
Faculty of
California State University,
San Bernardino

In Partial Fulfillment
of the Requirements for the Degree
Master
of
Public Administration

by
Bruce Richard Suchomel


March 1991

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ABSTRACT

Supporting our military systems after being built and deployed is very costly. Approximately two-thirds to three-fourths of the total life cycle costs of a weapons system are committed to its operation and support. These costs are budgeted under the Operations and Maintenance (O&M) appropriation, which accounts for 30 percent of the defense budget. Successfully interfacing system support requirements into the design of the product is crucial in preparing the system for operations and maintenance tasks once deployed. Department of Defense (DOD) policy states that logistics planning for systems will be interfaced into system design. These requirements are only minimally addressed. Strict enforcement of this policy is a must, and can be done within the budgeting process. This study thus proposes to examine design interface problem impacts on logistics costs, particularly O&M.

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I. INTRODUCTION

The effective operation and support of military systems consumes a major portion of the annual defense appropriation. Between 60 and 80 percent of the total life cycle costs of a weapons system, including acquisition costs, are committed to its operation and support.¹ In other words, if \$10 million are spent on procurement of a system, then approximately another \$20 million will be spent on operating and supporting this system during its life cycle. These costs are budgeted under the Operations and Maintenance (O&M) appropriation, which accounts for 30 percent of the total defense budget.² The management of this support, and a major share of the defense dollar, are concerns of those involved with budgeting for Integrated Logistics Support (ILS) of defense systems.

The process to ensure that all support elements are properly planned, acquired, and sustained is called ILS, which is a disciplined approach to the activities necessary to:

- Cause support considerations to be integrated with system and equipment design.
- Develop support requirements that are consistently related to design and to each other.
- Acquire the required support.
- Provide the required support during the operational

and support phases of procurement at minimum cost.

Design Interface is a crucial logistics element within the ILS world. Of the ten elements of ILS, design interface is the one element which allows for early consideration of all elements of support to be incorporated into the design of a system. Design Interface is the discipline which allows specific system aspects to be "designed" into the product. Once a system is built and delivered it is deployed. Outyears refers to the time frame beyond system deployment. Supporting the system from this point in time until the life of the system expires is necessary to keep the system functioning properly. Supporting the system during this time frame is referred to as "outyears support." The opportunity to interface outyears support characteristics into the design of a system is essential in enabling the system to maximize its operational time, and more importantly minimizing outyears support costs.

Once a system is deployed, the Operations and Maintenance (O&M) appropriation funds the system to the extent of allowing the system to operate in accordance with program requirements. Maintenance jobs performed on the system are also funded by the O&M appropriation. During the research phase of building the system, funding is provided by the Research, Development, Test and Evaluation (RDTE) appropriation, which encompasses all research efforts and

testing/evaluating prior to actual government procurement. During this phase the government may allow more than one contractor to perform RDTE type work on a program, and select the most qualified contractor (based on performance criteria) to advance to the procurement phase. During the RDTE phase, the contractor is designing a product which must meet government specifications.

Support, maintenance, and ILS characteristics of the system should be designed into the product during this phase. Often, however, this consideration is given minimal attention. The contractor concentrates on winning the procurement contract by giving the government the product they want. Integrated Logistic Support considerations are often addressed during the procurement phase, after the procurement contract has been earned (during the competitive RDTE phase). A problem with this is the product has already been designed. All ILS considerations addressed at this point in time are after the fact. Systems are not redesigned (unless changes are minor) for increasing supportability features. This paper analyzes the cost impacts of insufficiently considering ILS in system design. The O&M appropriation is utilized to fund operations, maintenance, and support characteristics of a system once it is deployed. This paper looks at costs of funding logistics support during system design versus paying exceedingly large support

costs later in order to keep the system functioning properly.

Since taxpayer's dollars are utilized to procure defense systems, it is ethically sound that those systems procured be used to their fullest potential. This involves minimizing system down-time with maximum reliability, and cost effectively operating and maintaining those systems. In order to cost effectively operate and maintain those systems, relatively small investments in support planning at system start-up will provide significant Operations and Maintenance (O&M) savings later.

Presently the Department of Defense is undergoing budget cuts. Dramatic changes in political, economic, and social structures of eastern European countries, particularly to the Soviet Union, have reduced the scope of threats to the United States and its allies. With a diminished scope of threats opposing the United States, the justification to fund our military correspondingly diminishes. Thus, a reduced level of funding is now possible to maintain forces facing fewer threats. The military branches, however, desire to perform at their present levels, even with reduced funds. Saving funds wherever and whenever possible is a genuine interest amongst all services. The purpose of this research project is to analyze an area within the Department of Defense which offers the op-

portunity to save significant funds. This area is Integrated Logistic Support, its interface into system design, and the corresponding outyears spending associated with the system.

Department of Defense policy has established that ILS considerations be addressed during the design of a system. Unfortunately ILS considerations are given only minimal attention (described in detail in the Model and Budgeting Impacts sections). Results of minimal ILS considerations interfaced within system design are increased outyears problems with maintaining and supporting the system. The appropriation responsible for funding outyears support of systems is the Operations and Maintenance (O&M) appropriation. This appropriation accounts for 30 percent of the entire defense budget.³ This large percentage of funds makes this appropriation susceptible to researching savings methods. The need for such research has prompted this research project which focuses on more stringent enforcements on early ILS planning in the acquisition process, which will correspondingly save O&M funds during system outyears.

Need for Research

Past research within this particular problem area is not abundant. In fact, no studies have been found examining

this issue. A thorough review of literature indicates no evaluations have been performed which analyze the effectiveness of established Department of Defense (DOD) policy which requires outyears support considerations be undertaken when designing weapons systems.

The national debt is in need of reduction. Means of reducing this deficit must be devised. Saving funds where unnecessary funds are spent is a way of reducing this deficit. If organizations can perform their tasks with less funds, then the savings can assist in the deficit reduction process. The search for areas within the budget that can save money prompts a need for research

Research Objectives

This study proposes to examine design interface problem impacts on logistics costs, particularly O&M. Design interface is the process in which all system considerations are evaluated for functional performance impacts. If a system is required to perform a specific operation, then those operational characteristics must be interfaced into the design of the system so that the system can perform the way it is meant to perform. This holds true for ILS or support characteristics as well. A system can be designed to be supported and maintained the way it is meant to be supported and maintained. This research project discusses the im-

plications of interfacing ILS concepts more seriously into the design of a system and the corresponding reduction in O&M funds that will be utilized during system outyears.

The hypotheses tested during this research project is: If appropriate logistics planning, and respective funding, is incorporated into a system from the earliest phase of design through system production, then significant O&M savings will result during system outyears. A discussion on why insufficient funding is provided for ILS planning during system design takes place in section VII, Management of Design Interface.

Research Design and Methods

Research methods utilized include (1) a document and text study on the defense budget, which involved analyzing defense budget figures by appropriation over the past ten years (1980-89), (2) literature library research on technical aspects of the design interface process, and the ten ILS elements (defined in the logistics definitions section), which involved a thorough study of the background, definitions and history of logistics as well as the technical details associated with them (technical and public libraries, and information available on-the-job at the Naval Warfare Assessment Center in Corona, CA were utilized), (3) two interviews, one with a Navy sponsor in Washington, DC,

and one with a defense contractor design engineer. The interview with the sponsor assisted in understanding the funding process while the design engineer interview assisted in understanding design priorities and concerns designers have over designing for support convenience. Within this scope of research methods, the constraints on conducting this research project are minimal.

II. THE CHANGING DEFENSE BUDGET

Moderating defense expenditures and changing the allocation of resources available is a task which is embedded in legality. The President maintains a commitment to the Gramm-Rudman-Hollings law, which requires the federal budget to be in balance by 1993. This involves somewhat of a "flexible freeze" in federal spending for defense, meaning zero real growth, some reallocation of resources within the rest of the budget, and no tax increases.⁴ The flexible freeze entails halting procurements and expenditures for a specified period of time, which entails no growth during this time. Sometimes only certain branches of the military are effected while other times all branches are effected. The reallocation of resources pertains to cutting some programs but adding to others, which changes the complexion of some programs without negatively effecting the taxpayer.

Nearly half of the budget is devoted to entitlements (some 46 percent),⁵ which are legal obligations created through legislation that requires the payment of benefits to any person or unit of government that meets the eligibility requirements established by law. Examples of some entitlement programs include Social Security, Medicare, Guaranteed Student Loans, Federal Civilian and Military Retirement, Food Stamps, and Farm Price Support. This leaves the

Defense Department to take the majority of cuts, or sequestration, required to reduce the deficit. Given congressional reluctance to reduce other parts of the federal budget, increases in defense spending would prove unacceptable or would bring about a sequestration order that would cut the budget to the mandated level and would leave defense in even worse shape, since defense spending would have to bear half of the total cuts and the reductions would apply equally in percentage terms to all accounts left unprotected by the President.

The entire U.S. budget and budgeting process may be affected somewhat by the recent historic crumbling of the Berlin wall. The rest of the eastern block countries followed suit, and the Soviet Union may not pose the threat to the U.S. it once did. The big Capitalism vs. Communism rivalry no longer lives. With both sides being very open about reducing the arsenal of weapons in the European theatre, we are now faced with an overall reduced scope of threats. These recent east European developments will certainly aid the Gramm-Rudman-Hollings law. Reductions in defense spending will now be more easily justified even though the 1991 Persian Gulf war with Iraq poses an imminent danger. The war in the Persian Gulf has not altered plans to reduce defense spending, as the limited military of third world countries, such as Iraq, poses lesser of a threat to the

United States and its allies than did the Soviet Union during the cold war.

Bush's 1991 \$1.23 trillion budget is tabbed as a budget that will help America save, be more productive, and keep its edge in the competitive world.⁶ The chief emphasis is being placed on investment in the future. The Democrats are arguing for deeper defense cuts and higher domestic spending, while the Bush budget asks for big increases for space exploration, high technology, scientific and medical research, the war on drugs, environmental protection, and early childhood education.⁷ A manned mission to Mars would be NASA's new objective.

Bush seems to lean toward some type of arms reductions and respective defense cuts in the near future, but the Democrats are suggesting immediate defense cuts. Patience in DOD slashing may be required, as the Soviet Union's military might has not vanished, and war in the Persian Gulf is ongoing, with a U.S. troop commitment of 500,000. It would seem that the more capitalistic the Soviets become the more of an ally they become. (Of course this is highly theoretical.) We must remain cautious and perhaps skeptical in the DOD area, due to the present political unrest in the Soviet Union and war in the Mideast. We cannot be premature in supporting defense reductions given the existence of unstable economic, social, and political conditions in the

USSR as well as other nations. Bush takes a cautious and skeptical approach, as he favors continuing research and development efforts in the Space Defense Initiative (SDI) program, otherwise known as the "Star Wars" program, which itself could blow any budget out of context. The challenge will be to fund the SDI program, sporadic wars and low intensity conflicts, and reduce overall DOD spending simultaneously. From the layman's standpoint this is quite impossible, as SDI, and wars, promote tremendous costs. (This is where optimal integrated logistics support, via design interface, becomes a must.) From the standpoint of favoring technological advances, the Defense Department views SDI as a must program that will have us moving into the 21st century. Without increasing taxes, however, it seems next to impossible. Possibly some type of compromise is in order, where a reduced scope of effort and lesser R&D may be called upon to get SDI off the ground. This might be difficult to do, though, since we are pushing state-of-the-art technology in SDI.

Some disagreements exist between the congressional majority and President Bush that may produce a stalemate over which direction to take the budget. These disagreements stem from some of Bush's proposed cuts of numerous domestic programs, which includes Medicare, mass transit, and federal retiree benefits, by more than \$18 billion.

Foreign aid spending will go up much more than \$1 billion to respond to the new demands from eastern Europe, Panama, and the Mideast conflict. Financially assisting eastern Europe in their capitalism debut is a topic open to debate. Rather than once again play the "rebuilding" role, perhaps we should consider some additional domestic spending. Also, to spur domestic investment the budget calls for a capital gains tax cut, a new savings incentive plan that offers tax-free interest on deposits held for seven years, and current holders of Individual Retirement Accounts could make penalty-free withdrawals of up to \$10,000 to buy their first home. We must not neglect problems at home in favor of equivalent problems abroad. Bush's budget does, however, meet the 1991 Gramm-Rudman-Hollings deficit reduction target.⁸

The overall budget plan should not consider harsh defense cuts until we are absolutely positive the right decisions are being made. An analysis of overall defense considerations will take time to assist in determining funding requirements. Recent developments in Iraq may cause postponing defense cuts. However, cuts are inevitable, and branches of DOD must cope with these reductions. Methods of cutting costs are becoming more important than ever. The method of saving funds analyzed within this project considers better planning of supporting defense systems via in-

terfacing the logistics support elements into the design of the system. This will in turn save time and money during system outyears when maintaining and repairing those systems.

III. HISTORY OF LOGISTICS

The history of logistics dates back to about 700 B.C.⁹ The Assyrians (in what is today Iraq) were known as early masters of military logistics. Their ancient (but advanced for the time) industrial base allowed for a transformation from bronze to iron weapons. Deployed armies supposedly reached a size 50,000 men. No prior civilizations were noted as establishing prominent logistics networks for what are considered to be large armies.

Later, Rome developed an efficient system to supply its legions.¹⁰ Superb roads were built, providing lines of communication throughout the vast Roman empire which were conducive to quick mobilization during times of strife. Each legion on the move was known to contain over 500 mules.

Poor mobility but extensive supply systems characterized the Middle Ages.¹¹ Storage depots were actually castles, and the surrounding rural areas supported them. Wars were often fought over a castle. The besieging force usually needed a long supply train over a period of months or years. The outcome of a siege often depended on whose logistics system failed first.

The industrial revolution brought changes in logistics. For the first time, highly potent weapons were mass-produced. Lines of communication included the use of ships

and the railroad. The Union's victory over the Confederacy was the first real example of the decisive role an established industrial base plays in the outcome of a major war.¹² The outcome of this war set the pace for wars to come on the necessity of a modern logistical industrial base.

World War I saw further exploitation of national industrial capabilities. The internal-combustion engine gave rise to widespread use of motor transport.¹³ Aircraft were not yet sufficiently developed for logistic support.

World War II saw dramatic advances in weapons, transportation, and communication.¹⁴ The most significant logistic accomplishment was the ability of the U.S. to develop and defend its ocean lines of communication. More than 7 million troops and hundreds of millions of tons of cargo were dispatched by sea from the U.S. to 330 ports of debarkation.

U.S. shipyards performed at an unprecedented pace to expand the merchant marine. From 1942 to 1945 they built 5,593 merchant vessels, consuming 30 percent of the output of the nation's steel industry - an amazing feat, considering that the U.S. active merchant fleet by 1970 consisted of fewer than 800 ships.¹⁵

The logistics of the Korean War in many ways resembled those of World War II. Surplus supplies and equipment from

World War II were pressed into service on both sides. The bulk of the supplies and equipment used by U.N. forces was furnished by the U.S. Some 94 percent of the U.N. military cargo was moved to Korea in ships. The Communist Chinese, with primitive logistic networks using primarily railways and highways, showed a surprising capability to supply troops during the Korean War.¹⁶

The Vietnamese War was characterized initially by a primitive but effective logistic effort by the Vietcong and the North Vietnamese. Using boats, human porters, animals, carts, and bicycles, the North Vietnamese infiltrated South Vietnam and over several years established supply areas. In later stages of the war, North Vietnam's logistic strategy was to establish supply depots and lines of communication in Laos and Cambodia, close to Vietnamese battlefields, but in the temporary sanctuary of different nations.

Presently our war in the Persian Gulf area concerns cutting the logistic support of Iraq's army so that their forces in Kuwait will be left without supplies, weapon replenishments, and food. The strategy is to force the dug-in army to withdraw, surrender, or be so drastically weakened that the allied armies will have an easier road to victory as opposed to invading an area occupied by a well supplied Iraqi army.

A brief history of logistics is necessary for readers

to grasp the overall broad picture of what logistics is all about. This section allows the reader to grasp the fundamentals of logistics. The next section describes modern day logistic definitions as well as the logistics mission of each branch of the services.

IV. BACKGROUND

This section defines ILS terms and describes the logistics process. Also discussed are the U.S. military branches and their logistics concerns.

Logistics Definitions

Logistics is the operation and support of military personnel, equipment, and supplies. As one of four elements of military science (grouped with tactics, strategy, and intelligence), logistics encompasses all of the planning and operational functions associated with military supply, movement, and services. This includes the design, procurement, and maintenance of military material; the movement, evacuation, and hospitalization of military personnel; the transportation and storage of military supplies and equipment; and the design and construction, maintenance, and operation of military facilities and installations.

ILS is the integrating of all support elements to ensure optimal planning, acquisition, and sustainability of all equipment and material. The Department of Defense defines ILS as a structured sequence of activities required to involve support concerns to be interfaced with system design; develop support requirements that are consistently related to design and to each other; acquire the required

support; provide the required support during the operational and support phase at minimum cost.¹⁷

There are ten elements of logistics which, when integrated, make up the ILS scenario.¹⁸ These elements are

Supply Support: All management actions, procedures, and techniques required to determine requirements to acquire, catalog, receive, store, transfer, issue, and dispose of secondary items.

Support Equipment: All equipment (fixed and mobile) required to support the operation and maintenance of a system.

Technical Data: Recorded information of a scientific nature regardless of form or character.

Training and Training Support: The processes, procedures, techniques, and equipment used to train personnel to operate and support a system/equipment.

Manpower and Personnel: The identification and acquisition of military and civilian personnel with the skills required to operate and maintain a system/equipment over its lifetime at peacetime and wartime rates.

Facilities: The permanent or semipermanent real property assets required to support the system/equipment.

Packaging, Handling, Storage, and Transportation: The resources, procedures, design considerations, and methods to ensure that all system, equipment, and support items are preserved, packaged, handled, and transported properly.

Maintenance Planning: Ascertain the maintenance concepts and requirements over the lifecycle of a system/equipment.

Computer Resources: The facilities, hardware, software, documentation, manpower, and personnel needed to operate and support embedded computer systems.

Design Interface: The relationship of logistics-related design parameters, such as reliability and maintainability, to readiness and support resource requirements.

Integrated Logistics Support managers' responsibilities include ensuring all elements obtain consideration and attention warranted to satisfy overall mission objectives. If properly applied and monitored through the design and production phases of the acquisition process, these elements will optimize the supportability of the equipment over its life. Failure to provide time and resources to consider and coordinate the development of these elements early in the acquisition process will increase life-cycle ownership costs and reduce operational readiness.

Integrated Logistics Support has been recognized as a management discipline since the mid-1960s. Earlier, military support planning was characterized by various separate groups that planned and managed what came to be recognized as the elements of ILS. The ILS concept sought to draw these separate efforts together, recognizing the significance of the following driving concepts to the sup-

port planning process:

- Decisions made in the design process drive the support process and its potential efficiency, as well as total life-cycle costs.

- The maintenance plan is the foundation document for all other maintenance-related support planning.

- All elements are related to one another, and decisions about support planning must not change one element without considering what impact the decision will have on the other elements.

When the first nine elements of logistics are interfaced into the design of a system via element number ten (design interface), the system is suited for optimal out-years support. That is, the system is more reliable, is more easily maintained, and most importantly will be less costly to the government during the life of the system.

United States Military Logistics

A vast and extensive logistic system has been developed by the United States. With a highly developed economic and industrial base, the United States has served as a source of military supply for much of the western world. Designed to support the security of the United States and the free world and to establish and maintain world peace, this immense logistic network assists America's foreign policy (and

similar military policy) in carrying out their respective missions. Discouraging armed force action against the U.S. and its allies, this logistic system has indeed been structured to maintain land, sea, and air power, and also provides military equipment, supplies, training, and established lines of communication to threatened Western nations. Its commitment to world order has involved the United States in many defense agreements, ranging from those with NATO to commitment to individual countries, such as the one with South Vietnam.

Planning for U.S. logistic support begins in the Office of Emergency Planning (this office is in the Office of the President). The types and numbers of required inventory to be stored is determined within this office. Also, plans for the movement of the nonmilitary industrial plant and transportation system are effected from the reigns of this office.

Subject to congressional authorization and appropriation, many Department of Defense (DOD) responsibilities falls upon the president, such as decisions for the procurement of weapons, supplies, facilities and equipment. The president has at his direction the actual mobilization of forces and securing of lines of communication.

U.S. Department of Defense. The U.S. secretary of defense controls logistics for all three services - Army, Navy, and

Air Force. The assistant secretary of defense for installations and logistics is the primary staff assistant responsible for overall logistic planning requirements and scheduling. General coordination and control of supplies and supply services are effected for the three services through the Defense Supply Agency, which is directly subordinate to the secretary of defense.

Responsibility for formulating strategic logistic plans is vested in the Logistic Directorate of the Joint Staff of the Joint Chiefs of Staff, which is in turn responsible to the secretary of defense.¹⁹ Responsibility for operational logistics in the field flows from the Joint Chiefs of Staff to the appropriate elements of the three services.

U.S. Army. The Army provides equipment, facilities, and supplies for all Army personnel. It is also responsible for all Department of Defense traffic management through the Military Traffic Management and Terminal Service (MT-MTS).²⁰ The Army Material Command contains the Army logistic management center. Management of combat logistics is handled through lines of communication by logistic commands of service units. In actual combat areas, supply becomes the responsibility of the combat forces.

The Army uses all available means of transport. Lines of communication to the combat zone can be provided by air or sea under the management of Navy or Air Force commands.

Movement within combat zones, whether by highway, waterway, or air, is normally under Army control. Mass movement of soldiers and equipment by helicopter was developed by the Army in the Vietnam War.

U.S. Navy. All Navy personnel and facilities not in the operating forces are considered to be part of the logistic support. The Chief of Naval Operations and the Commandant of the Marine Corps are responsible for planning and forecasting logistic requirements of the operating forces.²¹ The Chief of Naval Material manages the procurement and production aspects of naval logistics. The Chief of Naval Operations is also responsible, through the Military Sealift Command, for sea transport of personnel and cargo for the Department of Defense.

Logistic support of the fleet consists of providing fuel, food, ammunition, and maintenance to ships, repair facilities, and bases. The Navy has developed techniques of underwater replenishment. By means of flexible pipeline and rigging, a ship can take on fuel, ammunition and supplies from a supply ship steaming nearby on a parallel course. This method is augmented by helicopters that carry supplies between ships. There is continuous research toward improving underway-replenishment methods.

U.S. Air Force. Logistics in the Air Force is under the overall control of the Air Force Logistics Command and is

concerned primarily with ensuring the combat readiness of all weapons systems and operating units.²² Through its military Airlift Command, the Air Force is responsible for all Department of Defense air transportation.

The Air Force and its Navy flying counterparts have developed the logistics technique of in-flight refueling. A tanker aircraft streams one or more hoses, and a combat aircraft attaches itself to each hose for fuel. This technique has greatly extended the capabilities of fighter and bomber aircraft.

Nuclear Warfare and Logistics. The advent of nuclear warfare added new burdens to logistic systems. Broad dispersal of supply depots is the only way to ensure that a successful enemy nuclear attack on a single locality will not destroy all reserves or stockpiles. Production units and plants must also be dispersed, and excesses of both supplies and production capacity are required to ensure adequate supplies during war. Dispersal of supplies and industries can cause delay, inefficiency, and extra expense, due to the necessity for long-distance transport of materials.

Balanced alternative transportation systems are a necessity in planning for survival in a nuclear conflict, since a nuclear blast in a terminal area could cripple a mode of transportation. In the United States, vast highway and rail networks complement each other. Either could carry

the whole military load if necessary. Those networks are augmented by air, inland, and coastal waterway transport.

The possibility that entire storage areas might be destroyed during a nuclear attack has led to overproduction of some military items. Stockpiles of nuclear bombs and some other weapons are far in excess of potential needs. Stockpiles of excess weapons in widely dispersed localities increases each area's problems of security, disaster potential, and eventual disposal.

With the broad scope of logistics now defined from the beginning of logistics through modern day U.S. military logistics, this project now focuses on a key issue - design interface. Definitions and detailing the scope of today's military logistics are essential in establishing a background of information prior to addressing the design interface issue and its relevance to outyears O&M costs.

V. DESIGN INTERFACE

Each of the ten elements of logistics involve key issues in the Integrated Logistics Support world. One of these elements, the design interface element, is focused upon by this project. It is through this element that the other nine elements can be properly interfaced into the design, manufacturing, and corresponding operations of the system.

This section describes in depth the design interface process.²³ Discussed within this section are the different aspects associated with design interface, the possible alternative designs which must be considered for purposes of choosing the best or optimal design to suit mission objectives, the reliability considerations which must be analyzed during product design, the maintainability aspects of fielding a system, and the human factors associated with maintaining a system.

The design of a product is normally done via a sequence of milestones which include conceptual, preliminary, and detail design and development, and test and evaluation phases. Design can be described as a lengthy process which involves the utilization of existing methodologies and technology to develop a desired product. The application of these existing technologies may involve the use of a stan-

standardized approach, or possibly evolve from research, or a combination of the two.

System design worthy of its mission is established through the system engineering process. This type of engineering involves efforts which combine the operational and maintenance needs into system performance through the use of logical steps of functional analysis, definition, synthesis, optimization, design, test, and evaluation. Functional analysis involves determining the particular operation or use of the system in terms of mission fulfillment. Definition involves clarifying the framework associated with the functional analysis. In other words, once the functional analysis is decided it must be broken down into parts and defined in detail. Synthesis is the assembling of separate or subordinate parts of the system into the whole system. Optimizing involves evaluating each portion of the system and determining whether or not each separate part can effectively function with the other parts of the system, and whether each part is defined to work in the best possible way in terms of fitting into the overall system scheme. Once these areas are decided, the actual system design is undertaken. Upon design completion a series of tests is conducted on the system for purposes of determining system suitability and effectiveness. The evaluation of these tests discovers whether or not the government is willing to

accept the system.

Conceptual design constitutes the first step in the overall design process, and generally includes a feasibility study directed toward defining a set of useful solutions to the problem being addressed. Alternative technical approaches are evaluated and a functional baseline is established. In defining various technical approaches, research projects are often initiated to verify possible technology applications. The output from the conceptual design phase usually includes the preparation of an "A" Specification (or functional baseline), the definition of system operational requirements, the system maintenance concept, and a preliminary system analysis and a top-level system functional flow diagram. Logistics requirements, or supportability criteria, are included in the functional specification. This involves the specification of quantitative factors covering availability and readiness objectives, as well as the requirements for the various elements of logistic support.

Preliminary system design (sometimes known as advance development) starts with the baseline configuration for the system identified through the functional specification in conceptual design and proceeds toward translating the established system-level requirements into detailed qualitative and quantitative design characteristics. Preliminary design

includes the process of functional analysis and allocation, the accomplishment of trade-off studies and optimization, the accomplishment of initial logistic support analysis, system synthesis, and configuration definition in the form of "B" and "C" specifications as required (includes subsystem, equipment, software, material, process, procurement, and other specifications). As is the case in conceptual design, logistic support requirements must be considered as an integral part of the preliminary system design process.

The functional analysis includes coverage of maintenance and support functions, as well as operational functions; the allocation of requirements includes supportability factors and the establishment of logistic support design criteria; and the analysis and trade-off process addresses logistic support as a major system parameter. The logistic support analysis is one of the main activities for ensuring that logistics is adequately addressed in the system design process.

The detail design phase begins with the concept and configuration derived through preliminary system design; that is, a configuration with performance, effectiveness, logistic support, cost, and other requirements has been described in the system specification. An overall system design configuration has been established, and now it is necessary to convert that configuration to the definition

and subsequent realization of hardware, software, and items of support. The process from here on includes:

1. The description of subsystems, units, assemblies, and lower-level components and parts of the prime mission equipment and the elements of logistic support.

2. The preparation of design documentation (specifications, analysis results, trade-off study reports, predictions, design data bases, detailed drawings), describing all elements of the system. The logistic support analysis record is included in the overall system design data package.

3. The definition and development of computer software (as applicable).

4. The development of an engineering model, a service test model, and/or a prototype model of the system and its elements for test and evaluation to verify design adequacy.

5. The test and evaluation of the system model that has been developed.

6. The redesign and retest of the system, or an element thereof, as necessary to correct any deficiencies noted through initial system testing.

Aspects of Design Interface

In assistance of the design objective, specific categories are developed to facilitate strict guidelines

overseeing certain areas such as mobility, packaging, transportation, accessibility, human factors, standardization, and many others. These criteria are directed toward incorporating the necessary characteristics compatible with the system goals for optimum logistic support.

Design criteria can be classified as general or specific. These are design approaches utilized by the design engineer to assist in performing all task steps. During a general criteria approach, appropriate checklists may be developed which serve to remind the designer of areas of particular concern. The designer will review appropriate factors, determine applicability, and assess the extent to which a design reflects consideration of these factors. If the designer desires to investigate further the meaning of certain checklist items, (s)he may call on a specialist for an interpretation. On the other hand, as design progresses, the designer may be faced with certain problems which require specific guidance. Data, consistent with overall system design objectives for logistic support and compatible with the general criteria mentioned above, may be developed in response to a particular need. Quite often, several alternative approaches may be feasible, and in such instances, the designer formalizes the decision through the accomplishment of trade-off studies.

Alternatives

The evaluation of alternatives is continuously undertaken in the design scenario utilizing analyses and trade-off approaches. Early in design, these trade-off evaluations are conducted at a relatively high level. As design progresses, evaluations are accomplished at a lower level in the systems hierarchy. For instance, it may be necessary to:

1. Determine alternative methods for mounting components in an assembly or on a designated surface. Once the system is deployed, O&M personnel are responsible for removing and replacing parts and components of a system. In order to minimize system down-time, it is essential that the system be designed for ease in mounting these components to enable quick removal and replacement of faulty components. System down-time must be minimized so that maximum use of tax dollars are given to defense systems.

2. Determine whether it is more feasible to design a repairable assembly internally within the organization or to purchase a comparable item from an outside supplier. When the magnitude of repair of a faulty component is beyond the abilities of the O&M personnel, the part is sent back to the Original Equipment Manufacturer (OEM). The more subcontractors or vendors involved with manufacturing of the system, the more complicated the supply system becomes, and thus the longer time required for replacement parts to arrive. This

can prove to be crucial in minimizing system down-time when spare parts on-site for a particular component are exhausted.

3. Determine whether to use standard components in a given application or to use new nonstandard components with higher reliability. Higher reliability reduces system down-time but nonstandard parts are more difficult to replace within the supply system. A standard part is used on multiple systems and is abundant in the supply system, whereas a nonstandard part is often a one-of-a-kind part produced by one vendor for one system and is usually more costly to the government and more difficult to acquire spares. An entire system can actually become non-functional until a replacement part is obtained for a failed part. If a vendor producing these nonstandard parts goes out of business, the government is in a bind, and must find a solution.

4. Determine whether it is desirable to use a light indicator or a meter on a front operator panel to provide certain information. Depending on the situation, a light indicator gives general indications to operators from a distance, whereas a meter gives more precise indications to an operator required to be close to the indicator. Designers must consult with the established maintenance philosophy for functional characteristics of their product for implementation of correct design criteria.

5. Determine the feasibility of repairing a given sub-assembly when a failure occurs or discarding it. A cost analysis must be conducted. If a part is quick and easy to remove and replace, inexpensive, and easily accessible, a discarding maintenance concept for a certain item is optimal. If the item is expensive, a remove and replace philosophy with a spare part on-site is required, with the faulty removed component becoming a spare part once repaired.

6. Determine alternative inventory stock levels for a given spare-part consumption. Reliability data will prove to be beneficial. If reliability levels of different parts change during the life of the system, the spare parts inventory must correspondingly change. Funds are required to purchase and stock spare parts, so an optimal level of spares must be stocked to make best use of taxpayer's dollars.

7. Determine whether automation is desired versus a manual approach in the accomplishment of maintenance actions. Automation may save time, but could be more costly. A system with high failure rates may be designed for automated maintenance. The cost of the automated system may be less than the long-term manual labor hours required to repair such a system. Again, designers must consult with ILS engineers during the design phase to evaluate the main-

tenance philosophy for this product.

8. Determine whether new test equipment should be developed or whether existing items should be used. Existing items save costs, but if the system utilizes new technology then new test equipment will be required.

9. Determine the extent to which built-in test should be incorporated versus the use of external support equipment. Built-in test features cannot be used on all types of systems.

All of these issues pertaining to ILS requirements must be interfaced into the design of the system. Indeed, military procurement policy calls for such interface.

Reliability

Throughout the system's defined mission many actions are undertaken in order to optimize system longevity and successful operation. The objective is to design a system that will meet all operational requirements in an effective and efficient manner. This is basically accomplished in design through the proper selection and application of components, the application of rating methods as appropriate, the specification of highly reliable processes, the incorporation of redundancy provisions in critical areas, and so on.

As the design process evolves, there are a number of methods/techniques that may be employed to facilitate the

design for reliability. These methods include utilizing techniques such as Reliability Functional Analysis; Reliability Allocation; Reliability Models; Selection of Component Parts; Failure Mode, Effects, and Criticality Analysis (FMECA); Critical Useful Life Analysis; Reliability Prediction; and Effects of Storage, Shelf Life, Packaging, Transportation, and Handling.

Throughout the design process, the tasks defined above are accomplished on a progressive basis, and the results of these tasks are extremely beneficial to the designer and are necessary for an early assessment of total logistic support. The importance of reliability (as a design discipline) to logistics is significant.

Maintainability

Convenience, precision, and financial aspects of maintenance tasks are considered within maintainability design, which includes those functions in the design process necessary to ensure that the ultimate product configuration is compatible with the top system-level objectives from the standpoint of the allocated maintainability factors, which are concerned with maintenance times, supportability factors in design, and projected maintenance cost over the life cycle.

From an optimization viewpoint, maintainability is perhaps the largest contributor in the design relative to

addressing logistic support. Much of logistic support stems from maintenance, and maintenance is a result of design. Maintainability is concerned with influencing design such that maintenance is optimized and life-cycle cost is minimized. The following maintainability areas have the greatest impact on logistics support:

Maintainability Functional Analysis.

The basic requirements for maintenance and support evolve from the system maintenance concept and the development of maintenance functional flow diagrams. These requirements are iterated from the top down, and the results lead into a number of maintainability design tasks that tie directly into supportability functions.

Maintainability Allocation.

Maintainability allocation is accomplished along with reliability allocation as one of the first steps in the design process.

Maintainability Prediction.

This commences early in the design process. The prediction is a design tool used to identify possible problem areas where redesign might be required to meet system requirements.

Logistic Support Analysis (LSA).

The LSA plays a major role in and throughout the system design process. Initially, the LSA serves as an aid in

defining the overall requirements for supportability and for the various elements of logistic support. Criteria are established and are provided as an input to the system design process.

Reliability-Centered Maintenance (RCM).

RCM is a systematic analysis approach whereby the system design is evaluated in terms of possible failures, the consequences of these failures, and the recommended maintenance procedures that should be implemented. The objective is to design a preventive maintenance program by evaluating the maintenance for an item according to possible failure consequences. The RCM analysis is very similar to the Failure Mode, Effect, and Criticality Analysis (FMECA) in many respects, should be accomplished in conjunction with the FMECA, and should constitute a major data input for the logistic support analysis. The emphasis here is on the establishment of preventive maintenance requirements (versus corrective maintenance requirements).

Related Analysis.

In support of the prediction and LSA tasks, maintainability design often includes the accomplishment of special studies related to test provisions, functional packaging, calibration requirements, and the like. These studies are generated on an "as required" basis.

Throughout the equipment design phase, the tasks

described above are accomplished on an iterative basis, and the results are a necessary input to the designer if the ultimate product is to be supported in an effective manner.

Human Factors/Ergonomics

Until fairly recently, human factors and ergonomics in systems design has received little priority in relation to performance, schedule, cost, and even reliability and maintainability aspects of systems. However, for the system design to be complete, the human element and the interface(s) between the human being and the machine needs to be addressed. Optimum hardware and software design alone will not guarantee effective results. Consideration must be given to anthropometric factors (human physical dimensions - a term used in the study of ergonomics), human sensory factors (sight, hearing, feel, etc.), human physiological factors (reaction to environment), psychological factors (need, expectation, attitude, motivation, etc.), and their interrelationships. Human factors in design deal with these considerations, and the results affect not only system operation but human beings in the performance of maintenance and support activities. Human physical and psychic behavior is a major consideration in determining operational and maintenance functions, personnel and training requirements, procedural data requirements, and facilities.

Thus, if logistics managers interface with design per-

sonnel and partake in the design reviews in a much more serious context than presently allowed, DOD will save tremendously in the long run. If support problems surface after the system is within the hands of the military (as often does), then additional costs are warranted (cost overruns) to allow the system to perform to the standards that it was designed to perform. The areas described within this section must be integrated into the system design and be seriously considered by the design engineers as well as the logistics program managers.

VI. MODEL

In order to test the hypothesis of whether or not ILS in the system design process saves the Defense Department O&M dollars, the use of a model, or example situation, is necessary. The model utilized is the Navy's actual procurement program budget for TACTS pods for FY 90-96. The program is the Tactical Aircrew Combat Training System (TACTS) Pods, which falls under the procurement appropriation of Aircraft Procurement Navy (APN). The TACTS system is otherwise known as the "Top Gun" system, which allows Navy pilots to receive the best combat training available. Pilots fight "electronic" battles in which hits and misses are simulated. When finished, the pilots land their planes and walk into the debriefing room where their simulated dog-fights are replayed on a data display system, or large screen display. The pod portion of the TACTS system relays information from the airplane, via a pod hanging from the wing of the aircraft, to the ground-based TACTS system.

Prior to analyzing the TACTS Pods procurement program budget, a preliminary model will be discussed which describes, in layman's terms, the support considerations of a system with which almost everyone is familiar. This system is an automobile.

The purpose of this model is to point out surprising

life-cycle costs of systems, of which 60-80 percent are required to operate and maintain that system. Let us assume the purchase price of a typical new car is \$12,500. Also assume the life-cycle of this car is ten years. That is, ten years elapse from the time the car is purchased to the time it is salvaged. Some of the operations and maintenance costs of a typical car are shown in Table 1.

Table 1
Typical Car Operations and Maintenance Costs

<u>Item</u>	<u>Yearly Cost</u>	<u>Ten Year Cost</u>
Insurance	\$ 1,000	\$ 10,000
Gasoline	1,040	10,400
Oil Changes	80	800
Tune-ups	80	800
Tires	100	1,000
Misc. Maintenance	300	3,000
Auto Taxes	300	3,000
TOTAL		29,000

The ten-year "O&M" costs of this car amounts to \$29,000. Add the purchase price of \$12,500, and the approximate total life-cycle costs of this car comes to \$41,500. Dividing the ten-year O&M costs (29,000) by the total life-cycle cost (41,500) shows that 70 percent of the total life cycle costs are accountable to operations and maintenance expenses.

$$29,000 / 41,500 = 0.70 \text{ or } 70 \text{ percent}$$

Weapons systems are the same: Between 60 and 80 percent of their total life-cycle costs are committed to O&M. A car is also a system, and as shown, the O&M costs (in terms of percentage) are not too different from military weapon systems.

With the O&M cost situation now described within a setting most everyone can relate to, the actual program model will now be discussed. Table 2 shows the budget profile for the TACTS Pods portion of the TACTS system. A procurement appropriation - Aircraft Procurement Navy (APN) funds the program.

Funding for ILS is minimal. In FY 91 the \$100,000 allotted for ILS is only 1.1 percent of the TACTS Pods program budget. This is the support planning which is to include interfacing support requirements into the design of the product. Considering O&M costs account for 30 percent of the entire defense budget (to be discussed further in the next chapter on Budgeting Impacts), a mere \$100,000 does not allow for enough government personnel and work efforts to assure all outyears support considerations are reflected with the system design. One-hundred thousand dollars roughly funds one man-year of work. This includes salary, travel expenses, and overhead. All ILS considerations cannot be addressed at this funding level. In this particular program, one man-year of effort will approximately be

Table 2
Aircraft Procurement Navy
Tactical Aircrew Combat Training System²⁴
(K denotes in thousands of dollars)

TACTS Pods Category	FY 90		FY 91		FY 92	
	QTY	\$K	QTY	\$K	QTY	\$K
AIS Pods	18	1,688	22	1,948	0	0
AIS Internal	TBD	4,200	42	3,929	30	2,170
Interface Units	0	0	0	0	22	4,725
ECP	0	0	32	2,100	70	2,194
Production Engr.	N/A	605	N/A	844	N/A	792
ILS	N/A	150	N/A	100	N/A	100
Pod Test Set	1	116	1	116	3	752
TOTAL FUNDS		6,759		9,037		10,733

TACTS Pods Category	FY 93		FY 94		FY 95		FY 96	
	QTY	\$K	QTY	\$K	QTY	\$K	QTY	\$K
AIS Pods	0	0	25	2,678	36	5,420	54	6,681
AIS Internal	50	3,306	51	3,476	66	4,638	91	6,593
Interface Units	36	7,700	36	5,751	0	0	0	0
ECP	76	2,198	61	1,819	130	3,997	TBD	750
Production Eng	N/A	868	N/A	935	N/A	967	N/A	964
ILS	N/A	100	N/A	100	N/A	100	N/A	100
Pod Test Set	13	1,575	0	0	0	0	0	0
TOTAL FUNDS		15,747		14,759		15,122		15,088

required of the ILS manager to interface with design engineers as well as program sponsors, and another two man-years of logistics support work will be required. Proper funding for adequate ILS support is thus only one-third of requirements.

The ILS manager's interfacing tasks with other personnel include obtaining appropriate drawings and reliability data from the contractor. These data are necessary to perform LSA tasks such as a Level of Repair Analysis (LORA), a life-cycle cost analysis, a spares and inventory analysis, a maintenance plan, a technical data plan, and a test equipment plan. The performance of these tasks requires many hours of work, at least two man-years.

The LORA entails defining the detailed maintenance concept and establishing criteria for equipment design in determining whether items should be repaired at the intermediate level (on-site personnel), the depot level (supplier facility), or discarded in the event of failure. Without this type of plan, system maintenance costs will become exorbitant during the system outyears. Deciding what to do without a plan only adds to system down-time, and costs of repair are higher when negotiating with contractors for support after the system is deployed, because contractors know they can raise prices since the government is in a bind - system parts must be repaired or it will be a non-

functioning system. Often such repair contracts can run into millions of dollars, whereas two man-years of work up-front (approximately \$200,000) with a fixed price contract for system repairs is much less expensive. Contractors without repair contracts who manufacture parts for a defense system have the government at their mercy. Contractors may have dismantled their manufacturing and repair set-up for this particular component, and will often charge five to ten times the normal amount (per part) to set-up shop.

An example of a life-cycle cost analysis involves computing costs of items by cost type (storage, repair, etc.), and summing costs for all items in the system.²⁵ A model could be used in support of detailed design, but would be primarily used for developing and specifying contract incentives regarding ILS elements. These incentives would in essence reward the contractor for efficiency and O&M savings.

Certain computer software programs are available that provide a spares and inventory analysis which calculates the optimal recommended spares and inventory numbers.²⁶ These optimal numbers can save the government hundreds of thousands, and even millions of dollars by having the required number of high-tech (and high priced) spare parts on-site. Too many spares on-site wastes funds and too few spares causes excessive system down-time. (In the case of a

pilot training system, too much down-time means pilots are grounded. In the event of war, proper training equates to war-readiness.)

Maintenance plans, technical data plans, and test equipment plans all provide guidance on maintenance, data and test equipment which pertain exclusively to a particular system. They describe maintenance procedures, pertinent data (information), and the type of test equipment needed to fault isolate parts and components of a system. (Fault isolation refers to discovering which component within a system is causing the system to fail the test.) Without these plans, repair and maintenance actions are left to the discretion of the O&M personnel. They take any action necessary to repair the system in as short a time as possible, which normally equates to extremely high costs. With no plans, a short lead-time repair philosophy means supporting vendors must set-up shop quickly. They charge the government accordingly. A quick set-up means high charges. A plan devised early in the program at relatively inexpensive costs saves the government tremendous amounts of money.

Much of the support considerations are analyzed via the Logistic Support Analysis (LSA) process, which is a systems engineering process conducted in accordance with Military Standard (MIL-STD) 1388-1A and 2A.²⁷ It includes actions taken to define, analyze, and quantify logistic support re-

quirements throughout system development. A principal objective of LSA is to influence and change the design process so that the final system is easily and economically supportable. The ILS element "design interface" refers to this process. The LSA is conducted on an iterative basis throughout the acquisition cycle as tradeoffs and test and evaluation lead to successive design ideas. During design, the analysis is oriented toward assisting the design engineer in incorporating logistics requirements into hardware design. The goal is to create an optimum system or equipment end item (or finished product) that meets specification requirements and is cost effective over its planned life-cycle. Logistics deficiencies identified as the design evolves become considerations in tradeoff studies. As the project progresses and designs become fixed, the LSA process concentrates on providing detailed descriptions of specific resources required to support a system throughout its life-cycle by providing timely, valid data for all areas of ILS. These data are used to plan, acquire, and position support resources (personnel, material, and funding) to ensure deployed systems meet their readiness requirements.

The LSA tasks described within MIL-STD-1388-1A and 2A must be accomplished during any support planning process. The detail and extent to which they are applied will vary. The tasks may be performed by the project manager, ILS

manager, contractor, or government field activity. Task results may be documented in reports, test plans, Navy training plans, and in data delivered under many support related data item descriptions. The use of the LSA approach to organizing support data should not be more expensive than ILS data provided by other means. If this is the case, either duplicative effort in the LSA or an insufficient ILS product under the other means should be suspected. It is Navy policy that the approach described for LSA within MIL-STD-1388-1A and 2A be used for all acquisition programs.

The obvious conclusion drawn from the data presented is that up-front planning for outyears support is an economical approach the government must utilize. Two to three man-years of planning (200 to 300 thousand dollars) drastically offsets exorbitant fees contractors will charge the government for short lead-time requests to set-up repair shops.

VII. MANAGEMENT OF DESIGN INTERFACE

Managing the interfacing of Integrated Logistic Support requirements into the design of a system is a demanding task. The logistics program manager works with the overall system program manager, lead government activity personnel (the activity responsible for administering the system contract and monitoring technical aspects of the project), and contractor personnel toward successful completion of a supportable, quality product that functions in conformance to the government specification and statement of work. Many constraints exist which hamper progress toward successfully addressing the elements of logistics within the system via design interface. Following are some of these constraints and their respective implications for program development.

The development of a defense system is placed on a schedule. Design reviews are generally scheduled prior to each major revolutionary step in the design process, and allow the government to interface with the contractors on design aspects. In some instances, this may entail a single review toward the end of each phase (i.e., conceptual, preliminary system design, detail design, and development). For other projects, where a large system is involved and the amount of new design is extensive, a series of formal reviews may be conducted on designated elements of the system. It is during these reviews that government personnel

may address or even "drill" the contractor with comments concerning the program and its up-to-date status on specification conformance. If a certain aspect of the program, such as one of the elements of logistics, is not satisfactorily included in the design of the system, then delays may develop which cause a schedule change. Time pressures often influences government decisions on whether or not to proceed with current development. If a support consideration will cause a substantial schedule delay, the government may elect to have the contractor continue system development, and adjust the contract accordingly. Such decisions can obviously alter the effectiveness of the logistics program for the system.

The system contract dictates what will and will not be performed by the contractor. It is up to the logistics manager to ensure that logistics provisions are included within the contract. If the elements of logistics are not addressed in the system specification or contract, the manufacturer is not obligated to design the product for supportability. Sometimes the program manager has limited funding available for the program, and often elects to limit logistic support considerations. This can make the logistics managers' job a frustrating one, as they will participate in design reviews and basically have their hands tied. If the contractor is not funded to conduct a tailored

logistic support analysis on the system and interface these considerations into the design of the product, then the contractor will not perform this work.

The system specification and the contract are similar with respect to their importance in establishing system requirements to which the contractor must conform. If the logistics considerations are not addressed within the specification, then they will not be designed into the product. Again, it is the responsibility of the logistics manager to ensure these areas are included in the specification. The contract and corresponding funding must coincide with specification requirements. The logistics manager must work with the program manager and lead field activity government personnel to assure funding is available for logistics considerations and incorporation into product design.

Interactions with contractors can also pose challenges for the logistics manager during design interface. The contractor will take advantage of any portion of the specification or contract that leaves room for discretion or interpretation. The government can occasionally be forced to negotiate with the contractor when interpretations differ. Sometimes the contractor will suggest that additional funds are required to comply with the misinterpreted portion of

the specification or contract. An engineering change proposal which requires government approval is often the result.

Managing the ILS program for inclusion in system design is a time consuming task. Program commitments from sponsors, funding levels, contract and specification interpretations, and program and design review schedules all pose constraints for the logistics manager. These constraints too often result in a mediocre or poor logistics program during system design, which correspondingly keeps the O&M funding requirements high during system outyears.

VIII. BUDGETING IMPACTS OF DESIGN INTERFACE

Included within the O&M budget are the operations and maintenance tasks for each system within DOD. This involves on-base contractor support as well as government and military personnel associated with the facility performing O&M functions. The ten elements of logistics, defined in the logistics definitions section, are all operations and maintenance type categories. Each of the ten elements involves work efforts required to keep a system active once deployed. These elements require prior planning measures for incorporation into system design so that the system is easily and economically supportable. ILS planning is essential during system acquisition in order to successfully operate and maintain that system during system outyears. The Chief of Naval Operations (CNO), as well as DOD, has established a policy and procedure for implementing ILS programs. The level of implementation, however, is at the discretion of the individual program manager at Command Headquarters.

Unfortunately, program managers are interested in materialistic results, as in hardware output "production units." Their interests are thus in "obligating" dollars by having as many weapons system units built as possible. Supporting the system once deployed is not their problem - it is the problem of the O&M personnel (funded from the O&M

appropriation). Satisfying the needs of the producers and having visible output via an acquisition contract is what nets a promotion for a program manager. The program manager's responsibility to acquire the production units are reflected through the acquisition contract. A specific number of production units is called for within the acquisition contract. The more units acquired by the program manager per dollars allocated to the program, the better (s)he is viewed in justifying the obligation of funds. (The program manager will thus receive more funds for additional projects the next fiscal year.) Sacrificing a very small percent of procurement units for optimal ILS planning does not bring glory to program managers. The program managers are actually "doing their job," as the present government acquisition structure allows for such individual discretion. Unfortunately, such a system is not conducive to efficient spending measures, as the O&M appropriation will always be "high" unless program managers are required to address ILS planning above the minimum levels presently used. Bare minimum ILS planning during the RDTE and Procurement appropriation phases of a program pays "lip service" to DOD policy which requires logistic support measures be addressed. Program managers are legally performing their task requirements. On the other hand, it is in the best interest of the contractor to have poor ILS planning. Contractors make

lavish profits from repair work and operations and maintenance contracts. The system presently does not encourage contractors to "design for support."

Planning up-front for outyears support does not require additional funding. Rather, it only slightly reduces production units (one to three percent). The total funds over the seven year period depicted in Table 2 is 87 million dollars. The total quantity of units (AIS Pods plus AIS Internal) during this same period of time is 485. This comes to \$180,000 in program funds used for each production unit developed. As stated earlier, approximately three man-years of ILS planning are required per year to adequately plan for system support, or \$300,000. The program is currently funding ILS at \$100,000 per year. The \$200,000 shortfall almost equals the \$180,000 in program funds spent for each production unit. In other words, only one unit per year, or seven units total over seven years, would be sacrificed for adequate ILS planning. This amounts to a mere 1.4 percent of the entire 485 planned production units. Three-hundred thousand dollars allocated to ILS planning per year for seven years equates to only 2.4 percent of the entire APN budget for this project. A slight reallocation of funds for ILS planning, such as this example, will promote immense savings during the outyear O&M tasks. The savings on the O&M appropriation would amount to millions. Such tedious

tasks as bringing vendors on line (as discussed earlier) to repair items after they are deployed costs the government five to ten times the amount had it been set up initially during system procurement. This amounts to tens of millions of dollars that could be saved in the O&M appropriation. With this low percentage of program funds going toward system support planning, it is no wonder the O&M budget is 30 percent of the overall defense budget, as depicted in Table 3.²⁸

The O&M budget pays for all operations and maintenance efforts of the system while it is deployed. These costs become maximized without appropriate up-front planning. With program managers paying "lip service" to ILS planning, the Navy and all of DOD is forced to maintain high budget levels within the O&M appropriation.

TABLE 3
Department of Defense Budget Authority, Operations and Maintenance (O&M) as a percentage of the overall defense budget (billions of FY 90 dollars), Fiscal Years 1980-1989

	<u>80</u>	<u>81</u>	<u>82</u>	<u>83</u>	<u>84</u>
O&M	62.6	68.0	72.3	75.5	79.4
Total Budget	205.3	229.3	256.8	278.7	291.0
Percent O&M	30.5	29.7	28.2	27.1	27.3
	<u>85</u>	<u>86</u>	<u>87</u>	<u>88</u>	<u>89</u>
O&M	91.1	86.7	89.2	88.6	89.3
Total Budget	329.6	315.1	306.5	302.1	298.9
Percent O&M	27.6	27.5	29.1	29.3	29.9

The Department of the Navy and DOD realize the importance of ILS in the acquisition process. DOD policy on ILS is contained in Department of Defense Directive (DODD) 5000.39, "Acquisition and Management of ILS for Systems and Equipment." This policy can be summarized in four broad categories: General Policy, ILS Planning and Resource Decisions, ILS Management, and Management Support Requirements. The general policy of DOD ILS, as stated within DODD 5000.39, is as follows:²⁹

Resources needed to support and maintain a system are equally important to those needed to achieve performance objectives. To ensure that support resources receive appropriate consideration, acquisition programs must have an ILS program from program initiation through system retirement. The primary objective of the ILS program is to achieve the desired readiness objectives at minimum life-cycle cost. ILS planning and resource decisions are used as inputs to the design considerations of the weapon system. ILS management must ensure that the acquisition program has an adequately funded and structured ILS program and that system support is addressed in all contracts and program plans.

Correspondingly, the general policy of the Chief of Naval Operations states (within OPNAVINST 5000.49A):³⁰

The policy, procedures, responsibilities, and actions of DODD 5000.39 apply to the determination of design, development, acquisition and life-cycle management of ILS for all Navy weapon systems and equipment, including modifications, and joint service use projects for which the Navy is lead service. The foremost concept of DODD 5000.39 is that system readiness is the final measure of ILS effectiveness and is a primary objective of the acquisition process.

Operating and maintaining a system so that it is "ready" for use is basically what ILS (and hence O&M) is all about (thus explaining the system readiness term used in the previous paragraph).

As described above, the Department of the Navy, as well as DOD, have established policy for ILS planning. But as Table 2 demonstrates, minimal funding is given to the ILS function. A lack of commitment by program managers in carrying out established policy has reduced funding levels for ILS planning programs. Such lack of commitment will not reduce the staggering level of the O&M budget. Defense departments will thus point at O&M costs, and request for O&M funds which will allow systems to remain functional and operational. Funds will have to be allocated for O&M, even if the amount is exorbitant. After all, a system is not effective if it is not operational. A high O&M budget is a sure way of having funds allocated to the armed services, and will easily be obligated by the respective service branch. Thus, with the money continuously coming in for O&M, there is not much incentive for DOD to plan for ILS at system start-up. Policy states that ILS will be incorporated into system acquisition through system design, and program managers adhere to this policy by minimally funding ILS.

Where can the problem of minimal ILS funding during system design be attacked? Strict enforcement of DOD policy on ILS can be accomplished through phases of the budgeting process.

Sponsors, such as the Naval Air Systems Command Headquarters (NAVAIR) in Washington, DC, in conjunction with the example presented in Table 2, have the opportunity to plead their case. Concerning ILS they can do one of two things: (1) Slightly reallocate funds within procurement appropriations which allows for adequate commitment to the ILS planning process, or (2) during the budgeting process plead an analytical case to the Pentagon (DOD budgeting center) which asks for additional funds for ILS planning that will in turn save O&M dollars later. The case will have to prove out-years O&M savings far exceeds additional ILS planning funds invested up-front. This would not be difficult to justify, as DOD already knows policy has established the LSA process as a means of incorporating support considerations into system design (as discussed earlier). Examples of support costs for systems with minimal ILS planning versus support costs for systems with extensive ILS planning would certainly help the case, but is not required since policy has already established LSA as a required function. The Naval Air Systems Command, however, is pursuing neither of the above two options, because they are not required to pursue

either of the two. Extremely high level DOD officials must get involved with the process by allowing for "earmarking" of funds for ILS planning for each program that policy states will have logistics planning performed.

Budget Formulation

Pentagon Defense budgeting officials must cover all expenditure requirements of their operating agencies. When formulating the budget, the DOD's guidelines (or in this case, specifically the Navy guidelines) must be thoroughly analyzed for purposes of considering all required program aspects. It is during this process that established policies, such as implementing the logistics planning process during system acquisition, are reviewed. Funding must thus be earmarked for required phases of program procurement. Guidance received from the budget director at the Office of Management and Budgeting (OMB), both formal and informal, should include policy requirements. These requirements should correspondingly be passed down from the Office of the Secretary of the Defense, and then from the Secretary of the Navy. It is within these high levels of government that ILS policy must be highlighted or emphasized. Leadership sets the standard. Policy in the form of directives leaves little room for the budget examiners. It's possible the budget examiners have little or no

knowledge of the impacts of ILS considerations within system design. Even so, effective emphasis by appropriate personnel must point out that ILS policy is in place and program impacts are extensive. Budget examiners require recommendations which remind them of policy priorities.

During the rough screening process,³¹ a critical stage of budget analysis, the budget director for the Department of the Navy has the opportunity to review data relevant to the total amount requested within the Navy. These data must include support estimates for new Navy systems. The more support required (in terms of funds) for a system, the more funds that should be earmarked for ILS support in the design phase of a system. Further studies are required for determination of methods for determining funding levels for ILS in the system acquisition process.

Within the detailed analysis phase of budget-making, considerations for an operating budget come to play. During the detailed analysis of the operating budget the efficiency and effectiveness of programs are discussed along with expense justifications for personnel, material, and operations and maintenance costs. When some of the O&M costs for systems are evaluated, decisions will have to be made which will determine specific funding levels for ILS planning,

rather than funding the entire program and allowing individual program managers to determine funding levels for different portions of the program.

A way for the budgeteers to gain essential information pertinent to programs requiring funding decisions is during the informal budget hearings. This hearing is one of the most significant stages in the budgeting process. Any tentative recommendations can be brought forth during this type of hearing. All preliminary reliability data can be utilized, which brings operations and maintenance problems into focus. Budgeteers can, and should, request as much information as they deem necessary to appropriately evaluate programs for funding considerations. Navy agencies (and all DOD agencies) can openly discuss past O&M problems which account for approximately 30 percent of the defense budget. In turn, corresponding ILS discussions can hash out the real needs of planning for support early in the life of a system.

In determining "earmarked" funding levels for ILS planning in the design phase of systems, program evaluation must be carried out. Programs (past, present, and future) must be evaluated in terms of quantitative and qualitative measures. It is through this process that the staggering level of the O&M appropriation should be placed under a "microscope" and thoroughly evaluated in both quantitative and qualitative areas. The design interface portion of the

total funds allocated to ILS planning is approximately one-third. (Refer to earlier discussion which estimates three man-years of work for ILS planning - one man-year involves the ILS manager's participation in meetings and design reviews which constitutes design interface.) Combine this evaluation with existing policy on ILS, and justifying up-front system support planning is automatic.

Budget Enforcement

There are eight major functions associated with the budget decision making process.³² Four of these functions apply to this project. They apply in terms of providing methods for enforcing ILS planning in the system acquisition process by earmarking funds via policy measures. These four areas are discussed below.

1. Allocating resources to achieve governmental priorities, goals, and policies.³³

Policy has been established within DODD 5000.39A requiring ILS planning for defense systems during system acquisition.³⁴ Once funds are allotted to a program, managerial discretion is allowed to "divvy up" the funds within the program. Too often this harms the ILS planning during system design and correspondingly keeps the O&M budget at staggering levels. Earmarking of resources for ILS planning within individual programs would ensure ade-

quate ILS planning levels are established which will respectively reduce O&M costs. By enforcing established policy via the budgeting process, overall program goals are more easily gained. Implementing savings methods in defense spending is becoming very important in light of the fiscal squeeze on the budget. The changing political situation in eastern Europe is significantly reducing the need for an arms race, and thus reduces the need for a significant arms build-up, even though instability exists in certain regions of the world, such as the Mideast. A reduction in the present-level arms build-up will require less spending. The need to save funds where possible is genuine, considering the defense services desire to maintain present capabilities.

2. Holding operating agencies accountable for the efficient and effective use of resources provided in the budget.³⁵

In holding each agency accountable for use of its resources, the executive and legislative branches of the government can use the evaluation of efficiency and cost effectiveness measures of programs for performance criteria. The more accountable a program is, the more funds that program can expect to receive the following year (if needed), or the more respectable that agency becomes. This portion of the budgeting process can be utilized to enforce

established policy. Logistics program funding data and corresponding O&M cost data would be required of the operating agency. O&M funds on operational programs can be analyzed, and compared with ILS funding during the RDTE and Procurement phases of the program. If high O&M costs are combined with minimal up-front logistics planning on a system, then the procuring agency would be penalized by receiving less funding for future procurements. When the agency demonstrates better planning through "designing for support" via design interface of the logistics elements, and shows reduced O&M costs, then increased agency funding levels can be justified.

3. Controlling expenditures to make certain they are legal, accurate, and compatible with the policies of political decision makers.³⁶

In order for this method to be a viable procedure in making program managers more adequately fund the logistics program, a specified percentage of program funds must be earmarked for ILS planning. The model section of this project recommended 2.4 percent of program funds be allocated to logistics planning. Assuming 2.4 percent is used as a program budget requirement for ILS planning, then the legality of program funding can be audited for assurance of ILS planning. The motive is to ensure support planning

provisions are funded in order to reduce the O&M funds which correspondingly relieves the burden of funding 30 percent of the defense budget (for O&M).

The allotment process of this budgetary function focuses on avoiding early extinguishing of funds. Poor logistics planning during system development adds to an already high O&M appropriation. It is possible that a continuing trend in this area could result in not enough funds available for system support during the outyears. This would be devastating to a program, and unacceptable for tax dollars to build a system which is not operational the last three months of the year due to an unavailability of support funds. With proper implementation of a logistics program, agencies will not need to support their systems at present O&M funding levels.

4. Providing leverage through the power of the purse to pressure operating agencies to make their programs more efficient, economical, and effective.³⁷

This budgeting function is the climax to budget decision making in enforcing logistics program planning in the system acquisition process. It is the task of budget analysis to challenge program claims of following established policy and being efficient. Political demands of the budget process often deny the budgeting office (OMB) proper time to monitor program expenditures. Incentives for

budgeting personnel may need to be devised for them to find the will to exercise their leadership roles and effective management of programs in performing program evaluations. Leaders who challenge the validity of a huge O&M defense budget will prompt operating agencies to implement preventive measures. An appropriate preventive measure is the interfacing of integrated logistic support requirements into the design of a system which will allow the system to be as easily and economically supported as possible. The will to utilize the power of the the purse through legal procedures is needed to exercise optimal budget planning.

IX. RECOMMENDATIONS

Additional studies are called for to expand concepts discussed in this project. This section provides recommendations which will assist in efficiently implementing existing Department of Defense policy for ILS planning during the system design phase.

Once a program is funded (through the RDTE or Procurement appropriation, depending on which phase the program is in) the program manager is given full discretion to determine the amount of ILS funding. An example of an APN program funding breakout was depicted in Table 2. The TACTS Pods program depicts a typical ILS planning shortfall which occurs too often in defense projects. The seven year ILS funding total (from fiscal years 1990-96) of \$750,000 amounts to only 0.8 percent of the program budget. As discussed earlier, approximately 2.4 percent of the program must be budgeted for ILS planning in order for adequate out-years support planning to be conducted. This only required reducing the pod inventory by one unit per year, which reduced the seven-year pod and internal unit total from 485 to 478, or only 1.4 percent. The increase of funds from 0.8 percent to 2.4 percent constitutes a mere 1.6 percent increase, while the production units decreased only 1.4 per-

cent, and will be more efficiently supported during system outyears such that hundreds of thousands and most likely millions of dollars of O&M funds will be saved.

Since program managers are minimally funding ILS in the acquisition process, the O&M appropriation will not be reduced. The current O&M portion of the entire defense budget (30 percent) will remain in tact. Navy (and DOD) policy has established that tailored LSAs will be conducted in accordance with the funding level of the individual program. It does not, however, enforce the funding level of the ILS portion of the program, which essentially communicates support requirements into the system design via the design interface channels. Thus, earmarking of funds for ILS in the system acquisition process is necessary to enforce existing policy. The amount of funds earmarked must be in accordance with overall funds allocated to the program. In reference to the Table 2 example, 2.4 percent of the budget will adequately provide for outyears support measures so as to reduce later O&M funds. Larger programs require proportionately larger ILS planning funds. This percentage will adequately allow for the ILS support elements to be interfaced into the design of the system.

Thorough studies, or audits, are recommended that will analyze ILS funding levels of past programs and compare with O&M funding levels required to support those programs.

These studies will be extremely time consuming, and will require full-time effort for an extended time period, as considerable data will be accumulated. These data include ILS funding levels (for each program audited) during the RDTE and procurement phases, as well as total program funding levels during the same period of time. The O&M funding data involve a more complicated situation. An O&M contractor often is awarded the overall operations and maintenance contract for the entire program. Determining the percent of their contract required to maintain a particular "audited" system is difficult, but can be done. All removal and replacements of parts and all repair work data will be documented. From here it will be necessary to split out all tasks by program in order to arrive at an annual O&M cost for a particular system.

These figures can then be used to calculate an optimal ILS funding level for defense programs during the RDTE and Procurement phases of these programs. The ILS considerations will correspondingly be interfaced into the design of the system. Audited systems with low ILS funding levels / high O&M funding levels should be compared to systems that had high ILS funding levels / low O&M funding levels. These figures can be analyzed in terms of proportions to arrive at an optimal recommendation for ILS funding in relation to overall system funding. A standardized ILS funding proce-

ture can then be incorporated into the system acquisition process which will strictly enforce established defense policy on ILS, and no longer allow program manager discretion to decide ILS funding levels for a particular system and its interfacing into the design of the system.

As discussed in the Budget Enforcement section of Budgeting Impacts on Design Interface, the budget decision making process must focus on (1) allocating resources to programs and projects designed to achieve governmental priorities, goals, and policies; (2) holding operating agencies accountable for the efficient and effective use of resources provided in the budget; (3) controlling expenditures to make certain they are legal, accurate, and compatible with the policies of political decision makers; and (4) providing leverage through the power of the purse to pressure agencies to manage their programs and projects more efficiently and effectively. For purposes of reducing the O&M appropriation used for funding outyears support of systems, it is pertinent that program evaluation via the budgeting process be conducted to provide incentives for efficient program management. If effectively implemented, these four budget decision making functions will better enforce established policy by forcing program managers to consider designing systems for support as well as designing for functionality.

X. CONCLUSION

Considering the recent events that have taken place in eastern Europe, the need for a continuing arms race is somewhat reduced. One of our biggest threats to freedom, communism, is a vastly descoped threat. The changing political structure of the Soviet Union may allow the United States the opportunity to shift funds from the defense sector to other areas. Granted, a drastic defense cut is unwise due to world instability. However, some DOD cuts are warranted. In light of these cuts, the various branches of the military desire to maintain their present capabilities. In order to accomplish this goal, the military services must find ways to reduce costs. One area prone to reductions is the O&M appropriation, which is utilized to fund outyears systems support. It constitutes 30 percent of the defense budget. Reductions in the O&M appropriation can be accomplished via optimal system design. Designing a system to meet mission objectives is a necessity. Designing a system that is easily and economically supportable must also be a priority of system development. Interfacing the ILS elements into system design is a must considering the Department of Defense must become more efficient. By interfacing ILS elements into the design of a product, the product is built for supportability considerations and tasks during outyears, and correspondingly reduces the time and cost required to sup-

port the system. This time and cost reduction will significantly reduce the requirements for O&M funds which are utilized to operate and maintain weapons and training systems.

Considering the skyrocketing costs of weapons and training systems, we must today and in the future be prepared to meet the challenge of efficiently and affordably providing system readiness and sustainability to operational forces as well as ensuring that logistics capability is incorporated into systems acquisition. This concept must be filtered down throughout the vast network of contractor manufacturing and support as well as all DOD levels. The foundation of this concept resides within the budgeting process. It's up to the central budgeting office (OMB) to require the Pentagon to perform program evaluations. In light of defense budget cuts, the Pentagon may have no option other than to perform program evaluations which analyze funding / work levels for logistics planning during system acquisition and compare with O&M costs. Pentagon leaders must exercise their political leadership and leverage of budgeting when planning the upcoming fiscal year budget. After all, they are looking for ways to save in order to maintain present defense capabilities. By evaluating

programs for support planning and corresponding O&M reductions, the Pentagon can essentially optimize the capability of the military services with respect to funding levels.

New incentives for budget leaders to evaluate programs for logistics implementation into system design must be developed. Top level policy must be established which requires budgeting officials to evaluate ILS program performance for all defense systems. Operations and Maintenance costs will correspondingly be reduced with effective design interfacing of the ILS elements. These O&M funding requirements must be respectively noted for performance checks. If the system is functioning properly, meeting mission objectives, and requires minimal support costs, then the system will be considered to be functioning within the optimal range of performance.

The military can essentially operate to its present potential with less costs. Planning ahead for support by interfacing ILS elements into system design means more efforts during system acquisition. Established policy states these planning measures must be incorporated into the system acquisition process. However, enforcement of these measures should be required. The long term results are favorable. Minimal system down time, ease of system repair measures for personnel, and overall less costs will be the results. These goals can be monitored through the budgeting process.

The power of the purse can be utilized to reward agencies for making headway towards achieving these goals. The funds saved can in turn be reallocated to non-defense agencies, used for domestic programs, or returned to the taxpayers.

XI. ENDNOTES

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² Booz, Allen, and Hamilton 1.

³ Office of the Assistant Secretary of Defense, National Defense Budget Estimates for FY 1988/89. 94.

⁴ Bush, George. "Text of President Bush's Address to Congress (Federal Budget 1990)," Washington Post 10 Feb 1989: A20 col.1.

⁵ Wildavsky, Aaron. The New Politics of the Budgetary Process. (Glenview, IL: Scott, Foresman and Company, 1988) 259.

⁶ Redburn, Tom. "\$1.23 trillion budget has no major changes," Los Angeles Times 30 Jan 1990: A1 col.1.

⁷ Wessel, David and Michel McQueen. "Bush's budget team is still looking for answers to multibillion-dollar defense, thrift questions," The Wall Street Journal 3 Feb 1989: A14(w) col.1.

⁸ Staff Reporter. "Bush's first budget (editorial)," The Christian Science Monitor 15 Feb 1989: 20 col.1.

⁹ Dyer, George. Naval Logistics. (U.S. Naval Institute, 1962) 16.

¹⁰ Dyer 17.

¹¹ Dyer 17.

¹² Dyer 18.

¹³ Dyer 18.

¹⁴ Dyer 23.

¹⁵ Dyer 24.

¹⁶ Dyer 24.

¹⁷ MIL-STD-1388-1A, Military Standard, Logistic Support Analysis, (Washington, DC: Department of Defense, April 1983) 1.

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- 19 Blanchard, Benjamin S. Logistics Engineering and Management. (Englewood Cliffs, NJ: Prentice-Hall, 1986) 4.
- 20 Blanchard 4.
- 21 Blanchard 5.
- 22 Blanchard 5.
- 23 Author's present employment position requires knowledge of the design interface process, which is discussed within the design interface section.
- 24 Information obtained during interview with Mr. Dan Brooks of the Naval Air Systems Command Headquarters, Washington, DC, on 25 October 1990.
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- 30 Naval Operations (OPNAV) Instruction 5000.49A. Navy Integrated Logistic Support Management. (Philadelphia: Naval Publications Center, 1983) 3.
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- 34 DODD 5000.39, 8.
- 35 Axelrod 12.
- 36 Axelrod 13.
- 37 Axelrod 15.

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