# THE A-7 ALOFT COST MODEL:
# A STUDY OF HIGH TECHNOLOGY COST ESTIMATING

Ronald Lloyd Johnson

# NAVAL POSTGRADUATE SCHOOL
Monterey, California

# THESIS

# THE A-7 ALOFT COST MODEL: A STUDY OF HIGH TECHNOLOGY COST ESTIMATING

by

Ronald Lloyd Johnson
and
Earle William Knobloch

December 1975

Thesis Advisor: C. R. Jones

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# A Study of High Technology Cost Estimating

by

Ronald Lloyd Johnson
Commander, United States Navy
M.S., U.S. Naval Postgraduate School, 1967

and

Earle William Knobloch
Lieutenant, United States Navy
B.S., Purdue University, 1967

Submitted in partial fulfillment of the
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This analytical study contains the development of an appropriate life cycle cost (LCC) model for the A-7 Airborne Light Optical Fiber Technology (ALOFT) system as defined in the Naval Electronics Laboratory Center Technical Document 435. The model was developed to support an A-7 ALOFT economic analysis which will compare the total systems costs and performance benefits of an A-7 fiber optic linked navigation and weapons delivery system to existing or proposed wire interconnect designs. Major features of this study include the development of: (1) a process to derive cost estimates of a high technological development in the early conceptual stage, (2) an appropriate LCC model for the A-7 ALOFT economic analysis, and (3) fiber optic costing methodology to support the LCC analysis. This analysis is a follow-on study to "An Approach to the Estimation of Life Cycle Costs of a Fiber Optic Application in Military Aircraft" by J. M. McGrath and K. R. Michna which is recommended reading for background information essential to this study.

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# I. INTRODUCTION AND INVESTIGATIVE APPROACH

## A. PURPOSE AND BACKGROUND

The major purpose of this study is to develop an appropriate life cycle cost (LCC) model to support the economic analysis of the A-7 Airborne Light Optical Fiber Technology (ALOFT) Project.

The A-7 ALOFT project is being planned and implemented by the Navy to: (1) confirm that fiber optics is a practical interface technology for internal aircraft signal transmission, and (2) demonstrate the feasibility of an electro-optic transmission system in a typical present day avionics suite through a full scale system application and evaluation. The A-7 ALOFT project is funded under AIRTASK A360360G/003C/4W 41X1-001. Under this task, the Naval Electronics Laboratory Center (NELC), San Diego, California is responsible for the project planning, systems integration, system test and evaluation, and coordination of all development and testing efforts associated with the program. A complete description of the A-7 ALOFT project can be found in "An Approach to the Estimation of Life Cycle Costs of a Fiber Optic Application in Military Aircraft" by J. M. McGrath and K. R. Michna.(44) Additional publications which consider one or more aspects of the A-7 ALOFT demonstration are:

"A-7 ALOFT Demonstration Program Plan," Control Data Corporation, Contract N00123-73-C-0141, 20 September 1974.(8)

"FIBER OPTIC Components for the A-7 ALOFT Demonstration," T. A. Meador, NELC TD 426, 11 April 1975.(45)

In brief, the A-7 ALOFT project consists of an extended ground and flight test demonstration of an A-7 navigation and weapons delivery system, (N/WDS) in which the signal wiring will be replaced with fiber optic data cables. Three hundred two twisted pair wires which interconnect the ASN-91 tactical computer and 9 remote units will be replaced by 13 fiber optic cables. This will be accomplished by incorporating time division multiplexing and fiber optic interface circuits to interconnect the N/WDS system. Information transmitted on the fiber optic channel is time division multiplexed and encoded into non-return to-zero Manchester format. The encoded data modulates the current source for a light emitting diode (LED) which transforms the electrical signal to an optical analog which is transmitted via the fiber optic calbe to a PIN photo diode where the optic signal is transformed back to electrical format, decoded and demultiplexed. In sum, the A-7 ALOFT demonstration utilizes state-of-the-art fiber optic technology to link a present day avionics system of remote sensors, command/control equipments and peripheral processors to a general purpose tactical computer.

An A-7 ALOFT economic analysis to compare the total system costs and performance benefits of this fiber optic system configuration to existing or proposed alternative wire interconnect designs is being conducted concurrently with

the A-7 ALOFT demonstration. NELC Technical Document 435, "A-7 ALOFT Economic Analysis Development Concept," J. R. Ellis and R. A. Greenwall, 7 July 1975,(19) outlines the approach, assumptions, and program plan for the conduct of the anlysis. Under this concept, a cost benefit analysis will be conducted, coordinated and directed by NELC through the joint efforts of, a contractor, and the Naval Postgraduate School (NPS), Monterey, California. To support this required analysis effort, the NPS has been primarily tasked to develop and provide an applicable LCC model for the economic analysis and costing methodology for fiber optics. The first NPS thesis(44) provided an initial investigation of fiber optic technology and outlined an initial approach to estimating life cycle costs of fiber optics by utilizing Delphi and experience curve techniques in conjunction with ordered scenarios. This analysis is a NPS follow-on-study directed specifically at the development of a LCC model to support the A-7 ALOFT economic analysis.

## B. A-7 ALOFT ECONOMIC ANALYSIS

The A-7 ALOFT Economic Analysis Development Concept, NELC TD 435, establishes the requirement and framework for the A-7 ALOFT economic analysis which will compare total system cost and performance benefits for the specified fiber optic/ coaxial cable alternatives under consideration. The economic analysis program plan consists of three major steps:

1. Develop life cycle cost estimates for each alternative.

2. Identify and quantify the benefits for each alternative.

3. Conduct a cost benefit analysis to compare, test, rank, and evaluate the alternatives.

The A-7 ALOFT economic analysis is conceived as a continuous cycle of the above steps, utilizing development and analytical feedback to improve and update the quality and accuracy of the continuous analysis within time and fiscal constraints.

The baseline configuration for this analysis is the A-7 ALOFT configuration consisting of signals listed in Appendix B of NELC TD 435.(19) The baseline configuration is representative of a small fighter attack aircraft navigation and weapons delivery system (N/WDS) with parallel-to-serial electronic multiplexing. The hypothesis of the analysis is to assume the pre-existence of the necessary electronic multiplexing for each alternative so that the only determination is whether to select coaxial cable or fiber optics as the point-to-point interconnect system. The alternative of twisted pair components was discarded due to inability to handle high data rates without extreme susceptibility to electromagnetic compatibility (EMC) problems.

The objective of the analysis is to compare total cost and performance benefits of the alternatives in order to support design and development decisions concerning the choice of a future avionics interface system. The economic analysis is also intended to provide the analytical basis for total aircraft fiber optic system projections and a

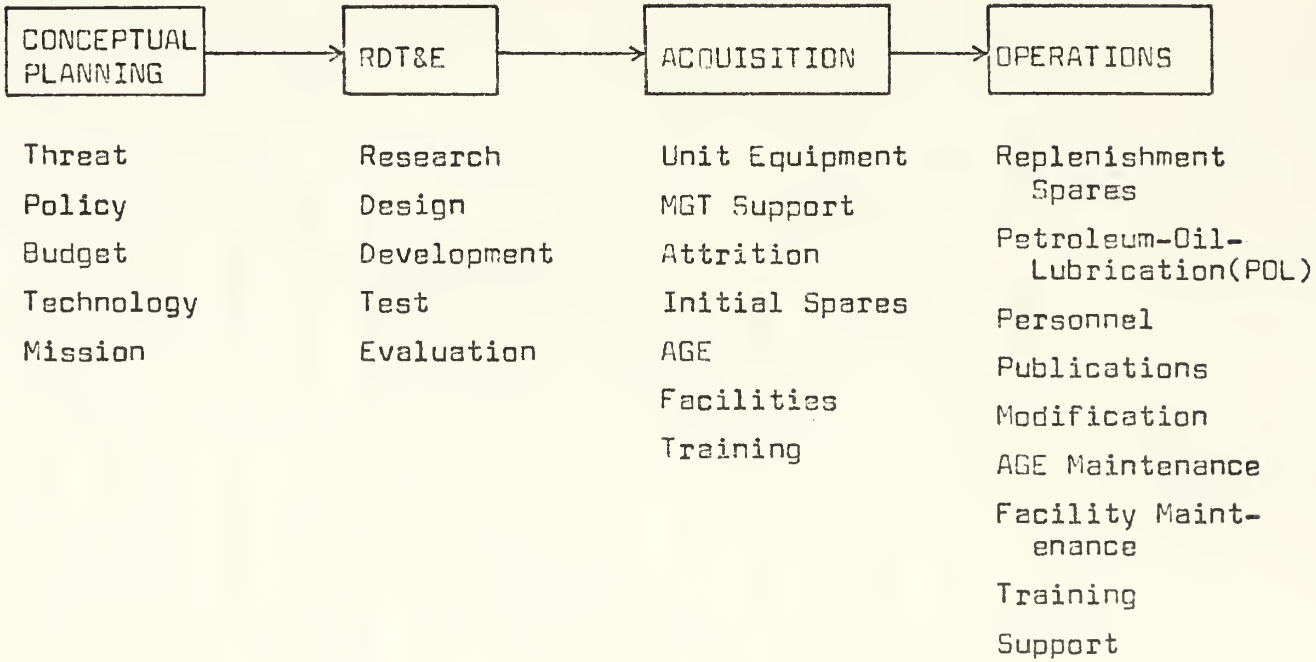
planned FY 77 cost benefit analysis of fiber optic data bus system design alternatives.

NELC TD 435 should be referenced if a more detailed description or additional information concerning the economic analysis plan, organization, tasks, schedule, or deliverables is desired.

## C. THE FIBER OPTIC DEVELOPMENT DECISION

The A-7 ALOFT economic analysis is being conducted to identify and evaluate the life cycle costs and benefits associated with a fiber optic point-to-point aircraft data transfer system in order to determine whether a follow-on full scale development program is warrented and can be justified. For purposes of cost estimating and discussion, the fiber optic development program can be described as an aircraft subsystem acquisition, consisting of conceptual, development, production and operational phases. A disposal phase will not be considered since each system is estimated to have a physical life greater than or equal to the specified 10 year economic life. Figure 1 outlines the sequence of these phases and identifies the basic functional elements within each. The A-7 ALOFT Project is a conceptual effort to develop, evaluate, and demonstrate the feasibility of a fiber optic data transfer system, and though an economic analysis determine the cost benefit tradeoffs needed to decide whether a full scale development should be undertaken.

The impetus for the A-7 ALOFT program rests in the potential of fiber optic technology to solve major aircraft



PROGRAM LIFE CYCLE PHASES

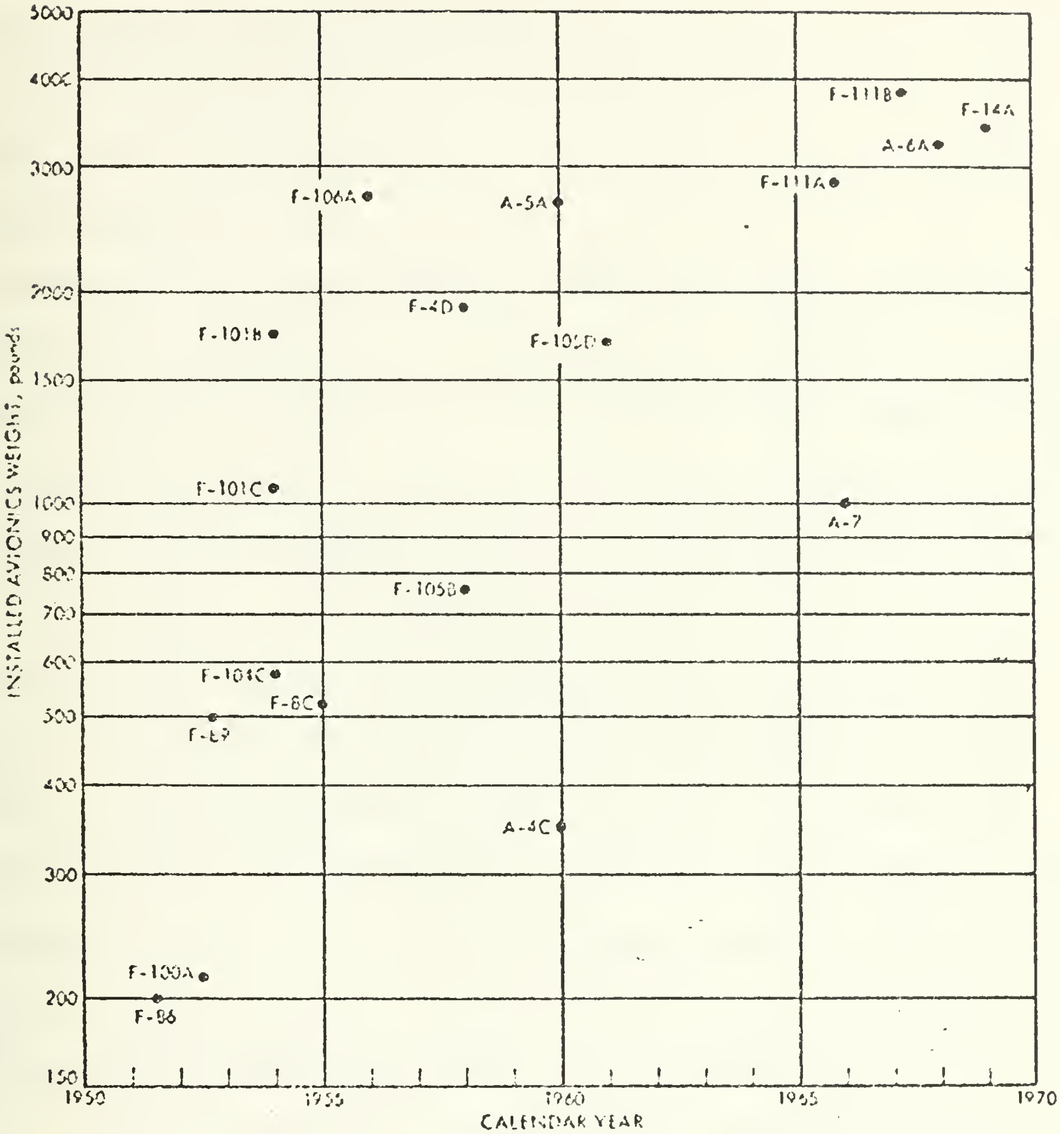
SOURCE: The BOEING Company publication D180-17648-1

Figure 1

interconnect system problems, reduce the weight and volume of the interconnect system, and improve system performance. Although a complete investigation of aircraft interconnect problems is beyond the scope and time permitted this study, an overview is essential in developing the cost estimating analytical approach.

Aircraft electrical power and interconnect system requirements have historically grown with the advances in speed, range, altitude, and in particular, the avionics capability of aircraft. It has been estimated that aircraft power requirements would double, and that distribution networks would triple in size during the 1970's, because of the increasing use of communication electronic detection, countermeasure, data processing and display equipments in aircraft weapons systems.(47) Figure 2, from the "Electronics X Study,"(24 and 25) demonstrates the avionics system weight growth trend in attack and interceptor type aircraft in the last two decades. This growth of weight and size has occurred despite concurrent progress in microminiaturization and reflects the increasing use and complexity of avionics in modern weapons systems. The implications of the above growth trends on future aircraft and electrical interconnect system design, are significant.

First, and of primary importance, is the increasing dependence of the military mission on the installed electric/electronic system. This trend is expected to continue and increasing avionics requirements required growth in both



Avionics System Weight Trend in Attack and Interceptor Aircraft.

Source: Electronic "X"

Figure 2

the size and capacity of interconnect systems. It is projected that current wire interconnect systems will not afford the required capacity for planned future requirements. In addition, the growth in size and weight of modern electrical interconnect systems to support increased electrical/electronic functions reduces the range and/or payload of the aircraft at all gross weights. Weight and volume constraints are particularly critical for fighter/attack type aircraft because of aircraft size and the direct relationship between weight and performance. Last, but not least, the increased use of sophisticated avionics requires increased utilization of shielded cables to protect sensitive circuits. This in turn, increases the weight of the interconnect system. To offset the above trends, major efforts in the past two decades have been primarily directed at reducing the size and weight of the electrical interconnect system. The F-4 aircraft system is a good case in point. The following history is excerpted and paraphrased for reference (56):

> Over 12 miles of electric wire (bewteen 65,000-75,000 feet) are utilized in the F-4 interconnect system. When introduced in the early 1960's, the F-4 Phantom utilized a conventional wiring installation with a 22 mil insulation wall which weighed 4.70 pounds per 1000 feet. This electical wire harness was so large that installation and repair proved difficult. A search for new materials and techniques resulted in selection of a wire with a 10 mil insulation wall weighing 3.72 pounds per 1000 feet. A protective jacket was used to encapsulate the harness to protect the thin wall insulated wire and this configuration became known as a "compact" harness and was used in over 4200 F-4's. By 1966, as the F-4 expanded its avionics capabilities, more and more wire was crowded in the "compact" harness and the interconnect harnesses were again becoming difficult to install and maintain. This led to the development in 1968 of a 7 mil, 1.5 pound per

1000 feet "minicomp" harness which was utilized on several flight test aircraft. Despite these efforts to reduce the size and volume of the interconnect system, F-4 avionics growth during the Viet Nam War necessitated the use of external waveguides for some equipment, because there wasn't any space left within the airframe. The above trends and factors have prompted the investigation of new designs and new technologies for aircraft interconnect systems.

The purpose of the A-7 ALOFT economic analysis is to evaluate two alternative interconnect technologies, coaxial cable and fiber optics, which when combined with data multiplexing have the potential to significantly reduce the weight and volume of today's systems and satisfy the projected data rate requirements of tomorrow's systems. In addition, fiber optic technology promises to reduce or eliminate current avionic system electrical problems such as electromagnetic interference (EMI), cross talk, short circuits, ringing, and electro-magnetic pulse (EMP) susceptability while enhancing safety and reducing vulnerability through elimination of spark hazards and damage overloads. It should be noted that the major advantages of fiber optics, in the data transfer application, are indeed based on disadvantages found in today's wire systems.

The A-7 ALOFT cost estimating problem is to develop appropriate life cycle costs of the alternative coaxial cable and fiber optic interconnect systems to assist in making the development decision on a cost benefit tradeoff basis. Since costs which are the same for either alternative will not add information to such a comparison, they will be eliminated. The resultant costs, differential costs, differ between the

two alternatives and are utilized to concentrate the analysis and decision making on the relevant cost categories. The specification of differential life cycle costs limits the cost estimating problem to the essentials. This is particularly important to this study, due to the time allowed, the conceptual stage of the A-7 ALOFT effort, and the uncertainties found in any new development, technology, or infant industry.

## D. THE ANALYTICAL APPROACH

The analytical approach is quite simple: (1) determine what must be costed, and (2) develop the means to specify such costs in the case of fiber optics. To do this an extensive literature search of life cycle costing and fiber optic technology was conducted utilizing the services of the Defense Documentation Center, Defense Logistics Studies Information Exchange, and Naval Postgraduate School Library.

The purpose of the initial literature search and review was to determine the availability of previous work in this area, gain insight and knowledge of the technologies, avoid duplication of past efforts, and benefit from past lessons learned. Upon completion of this review it was clear that dispite the emphasis and extensive work in both life cycle costing and fiber optic fields that:

(1) the economic aspect of fiber optic technology has not been addressed except in recent NELC/NPS efforts,

(2) That with few exception, LCC models and methodology (especially in aircraft area) are addressed to the system vice subsystem levels of aggregation,

(3) that this may be the first attempt to develop and specify a LCC model for an aircraft internal data transmission system. This preliminary conclusion is supported by further investigation of electrical system cost estimating techniques discussed in Chapter IV.

In view of the above findings it was concluded that an A-7 ALOFT LCC model would need to be developed from scratch. Such a model, or any LCC model, must be structured to support its intended use, and recognize such factors as the state of project development, technology, availability/unavailability of data, and accuracy of results. In addition, the model format should be selected to take advantage of existing data bases and support future costing efforts which may be required. Above all, and in view of the conceptual nature of this project, the analysis should be explicit, the assumptions specified, and the costing relationships identified for ease of future reference and updating. In view of these combined requirements the authors have developed a step-by-step, element-by-element analysis of the applicalbe A-7 ALOFT cost elements in Chapter II.

As indicated in the DoD Life Cycle Costing Guide for System Acquisitions the Total Life Cycle cost of a system may be thought of in terms of two parts:

$LCC_T = LCC_D + LCC_E$, where

$LCC_T$ = total life cycle cost

$LCC_D$ = that portion of $LCC_T$ which is relevant to the decision under consideration

$LCC_E$ = that portion of $LCC_T$ which is excluded in reaching the specific decision.

Chapter II identifies the excluded ($LCC_E$) elements, the total ($LCC_T$) life cycle cost elements, and the applicable differential ($LCC_D$) life-cycle cost elements of the fiber optic/coaxial cable alternatives. The differential life cycle costs ($LCC_D$) represents those life cycle costs which should differ between the two alternatives and are therefore relevant for the desired comparison; while those excluded life-cycle costs ($LCC_E$) are the same for each alternative. This process limits and directs the analysis to those cost elements which are not identical in order to compare the alternatives, while still identifying total life cycle cost elements which may be needed for budgetary purposes later in the development.

The next analysis step is to develop the costing methodology or means to specify the $LCC_D$ cost elements. In Chapter III, the authors restructure the $LCC_D$ model defined in Chapter II on an element-by-element basis with the basic substitution:

$C^*_{Fo} = A\ C_{cc}$, where

$C^*_{Fo}$ is the cost of the fiber optic alternate for the $LCC_D$ element,

$C_{cc}$ is the cost of the coaxial cable alternative for the same $LCC_D$ element, and

$A = \frac{C^*_{Fo}}{C_{cc}}$ represents the relative cost of the fiber optic alternative as a percentage of the coaxial cable cost.

The purpose of this transformation is to facilitate a direct comparison of model cost elements, at any level of aggregation, structure a supporting Delphi analysis, and better identify cost element estimating uncertainty.

The above procedure was developed from the following reasoning. Comparitive $LCC_D$ cost elements represent the cost of performing an identical function or a similar effort in different technologies. It seems logical when comparisons of new versus mature technologies are conducted, that the estimates of $LCC_D$ costs for a mature technology with previous cost applications will be more reliable and more readily determined then a similar estimate for a new technology. Intitively, it also seems reasonable, that an expert in the mature technology can better assess comparitive rather than absolute questions concerning the new technology. For example, in the A-7 ALOFT analysis, an aircraft electrical system designer familiar with coaxial cable applications might better address a compartive question such as: "Given the characteristics of fiber optics, would it take you more or less time to design this coaxial circuit using fiber optics? How much more? Twice as much? Half as much?" rather than, "How long would it take you to design this circuit using fiber optic cable?" The authors have constructed a matrix of the advantages/disadvantages of the fiber optic and coaxial cable alternatives and their probable general affect (see Table I) on each aggregate cost element to estimate the ratio of fiber optic to coaxial cable cost.

Analyst disagreement on the proper limits to assign, helps to identify those cost elements where greater uncertainty exists or additional background is required. In any event, such an analysis can help structure the problem, provide an initial estimate to evaluate identical costs established by different techniques, and structure a Delphi analysis.

In Chapter IV, the analysis turns to the investigation and evaluation of alternative techniques for developing costing methodology for each $LCC_D$ cost element. This effort consists of an initial review of existing LCC models to identify the applicability of a published costing relationship for this application. Then, the feasibility, applicability, and availability of various cost estimating techniques (cost estimating relationship, engineering methods, analogy, and Delphi methods) are considered for each element for which a previous relationship does not exist and an appropriate costing methodology established. Chapter IV concludes with an input analysis to determine the requirement for subsequent tests or data collection which may be needed to exercise the model, and the explicit specification of the A-7 ALOFT $LCC_D$ cost model developed.

Summary study results, considerations, findings and recommendations complete this phase of the A-7 ALOFT ecomonic analysis.

# II. COST ELEMENT IDENTIFICATION AND LIFE CYCLE COST MODEL DEVELOPMENT PROCESS

## A. PURPOSE

The purpose of this chapter is to identify and to classify cost elements according to their individual applicability to specific cost models. After cost elements have been identified and classified, two cost models will be developed; the TOTAL LIFE CYCLE COST MODEL and the DIFFERENTIAL LIFE CYCLE COST MODEL.

Total life cycle cost of an equipment or system is the total cost, to the government, of acquisition and ownership of that equipment or system over its full economic life. It includes development, acquisition, operating and, where applicable, disposal costs.

DEVELOPMENT costs are those program costs primarily associated with the development of a new or improved capability to the point where it is ready for procurement and operational use. Development costs commonly include costs for initial research and development of the equipment, prototype procurement and installation, test and evaluation and the management and support necessary to accomplish those tasks.

ACQUISITION costs are those program costs required beyond development to introduce into operational use a new capability, or to procure initial, additional or replacement equipment for operating forces. Acquisition costs include

equipment procurement, new facilities, production installation, initial spares and support equipment such as test instrumentation.

OPERATING costs are the recurring program element costs required to operate and maintain the capability as well as the costs associated with introducing improvement(s) to extend the equipment service life. Operating costs include those costs for personnel pay and allowances, equipment maintenance, training, logistics support and consumables.

DISPOSAL costs are usually considered to be the costs associated with retiring the equipment from the inventory, at the end of its economic life, minus any residual or scrap value this equipment may have left at that time. Often the two costs are assumed equal so that they cancel each other, making a net contribution of zero to the total life cycle cost.

Differential life cycle costs of an equipment or system are the relevant life cycle costs which must be evaluated when a comparison between alternative equipments or systems is desired. Development, Acquisition, Operating and Disposal costs are considered within the concept of differential life cycle costs but as explained earlier, the disposal cost for this analysis was set equal to zero.

Effective cost analysis requires that all costs associated with a system be identified and classified according to their applicability to the particular cost model of concern. The authors intent is to identify all cost elements and with the

use of a standard format systematically classify each identified cost element. Figure 3 represents the standard analysis format developed for this purpose, the use of which is described later in this chapter.

The determination concerning a specific cost elements applicability to one of the cost models is of course judgemental. This is not considered a problem since all cost elements have been identified and the future inclusion or exclusion of any specific element can be accomplished as the economic analysis progresses. Flexibility and universality are key features of this type approach to a cost analysis problem.

## B. ASSUMPTIONS

Assumptions pertinent to the analytical development of the model are specified for reference below. Use of these assumptions within the analysis have been keyed to the specified paragraph.

(1) One contractor will develop, produce and install either the fiber optic or coaxial cable interconnect system. This assumption enables a comparison of all program/contract factors on an equal basis to minimize contractor induced cost differences on the outcome, e.g., overhead rates, G & A costs, etc., will be developed identically for either alternative.

(2) The inherent qualities of an equipment or system using fiber optic echnology eliminates the requirement for on-site (after production) contractor support of the equipment

Cost element symbol
(from Figure 10)

(Major cost category)

(Hierarchy of cost breakdown structure)

(Cost element of concern)

|  |  |
|---|---|
| Applicable cost model(s) identified, | ( ) Total |
| (if checked) | ( ) Differential |
| Cost element excluded from both models | ( ) Excluded |
| (if checked) |  |

NOTE: Both Total and Differential may be checked.

DESCRIPTION

Brief description of this cost element

RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

Reason for either including this cost element in the total and/or differential cost model(s) or excluding this cost element from either or both model(s). This section will substantiate the appropriateness of the box(es) checked above.

Standard Analysis Format.

Figure 3

or system. This does not apply to any future modifications or field changes which might require contractor engineering assistance.

(3) Maintenance required on coaxial cable is presently performed by Aviation Electricians and/or Aviation Electronic Technicians. The coax maintenance skill training is already an integral part of formal Navy schools and will not need to be expanded to support A-7 ALOFT coaxial system requirements.

(4) The initial maintenance training sessions for fiber optics will be conducted by the contractor. During the initial sessions, both Navy maintenance personnel and future Navy instructors will be trained. The future instructors would already be teaching in the appropriate Navy school(s) and, therefore, could be given temporary additional duty as students of fiber optic equipment or system maintenance.

(5) A throw-away vice repair policy is assumed for both fiber optic drivers and receivers, based on present discrete component costs and reliability, interface module development, and anticipated technological advances.

(6) The characteristics of fiber optic cable and components cause it to be more reliable and maintenance free than its coax cable counterpart. Reliability and maintainability data will be collected during the A-7 ALOFT program demonstration phase to test the validity of this assumption.

(7) System disposal cost equals zero. This cost is not relevant since both the current and the proposed systems have a physical life expectancy greater than the 10-year life cycle assumed.

(8) The basic technical factors and model assumptions outlined in NELC Technical Document 435 will apply. Specifically:

(a) The baseline configuration consists of signals listed in the A-7 ALOFT Signal List. (NELC TD 435, Appendix B.)

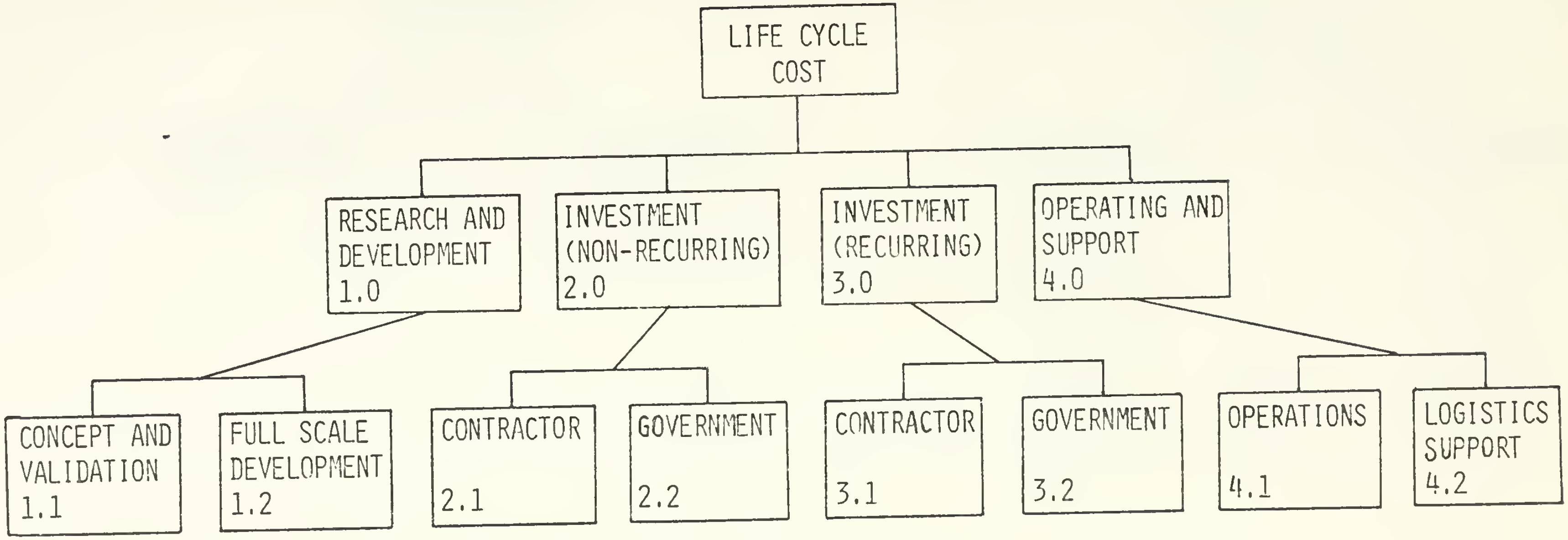
(b) The existence of the necessary multiplexing system for each alternative is assumed.

(c) Ten (10) year life cycle costs commencing in FY 1977 will be calculated.

## C. IDENTIFICATION AND DEVELOPMENT METHODOLOGY

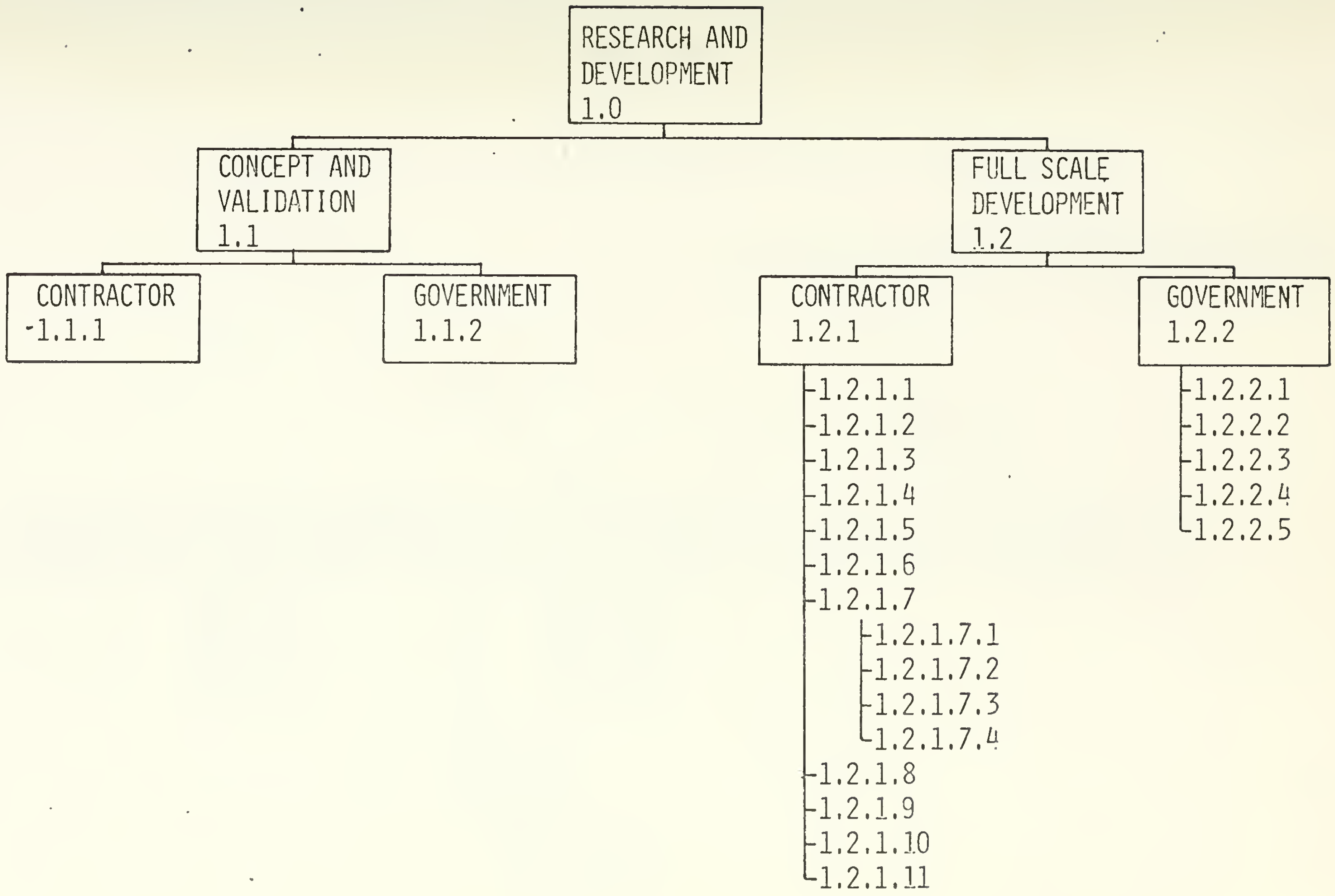
A convenient and thorough method to identify cost elements is to associate them with specific work elements which they represent. Normally this would be done with the use of a work breakdown structure(16), but aircraft wiring tasks are not broken down into that standard structure. Aircraft wiring tasks are primarily aggregated at the airframe level of a breakdown structure. Because there was no cost data available within the existing standard work breakdown structure the authors used the second level cost breakdown structure shown in Figure 4. This cost breakdown structure is further sub-divided into lower levels as shown in Figures 5, 6, 7, and 8.

The procedural flow of this cost model development is diagrammed in Figure 9 and is the primary structure for the remainder of this chapter. Phase three of the model development flow chart will be conducted as time permits, but a detailed examination of this phase will be reserved for a future project.



COST BREAKDOWN STRUCTURE

FIGURE 4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CONCEPT AND VALIDATION 1.1
FULL SCALE DEVELOPMENT 1.2
CONTRACTOR -1.1.1
GOVERNMENT 1.1.2
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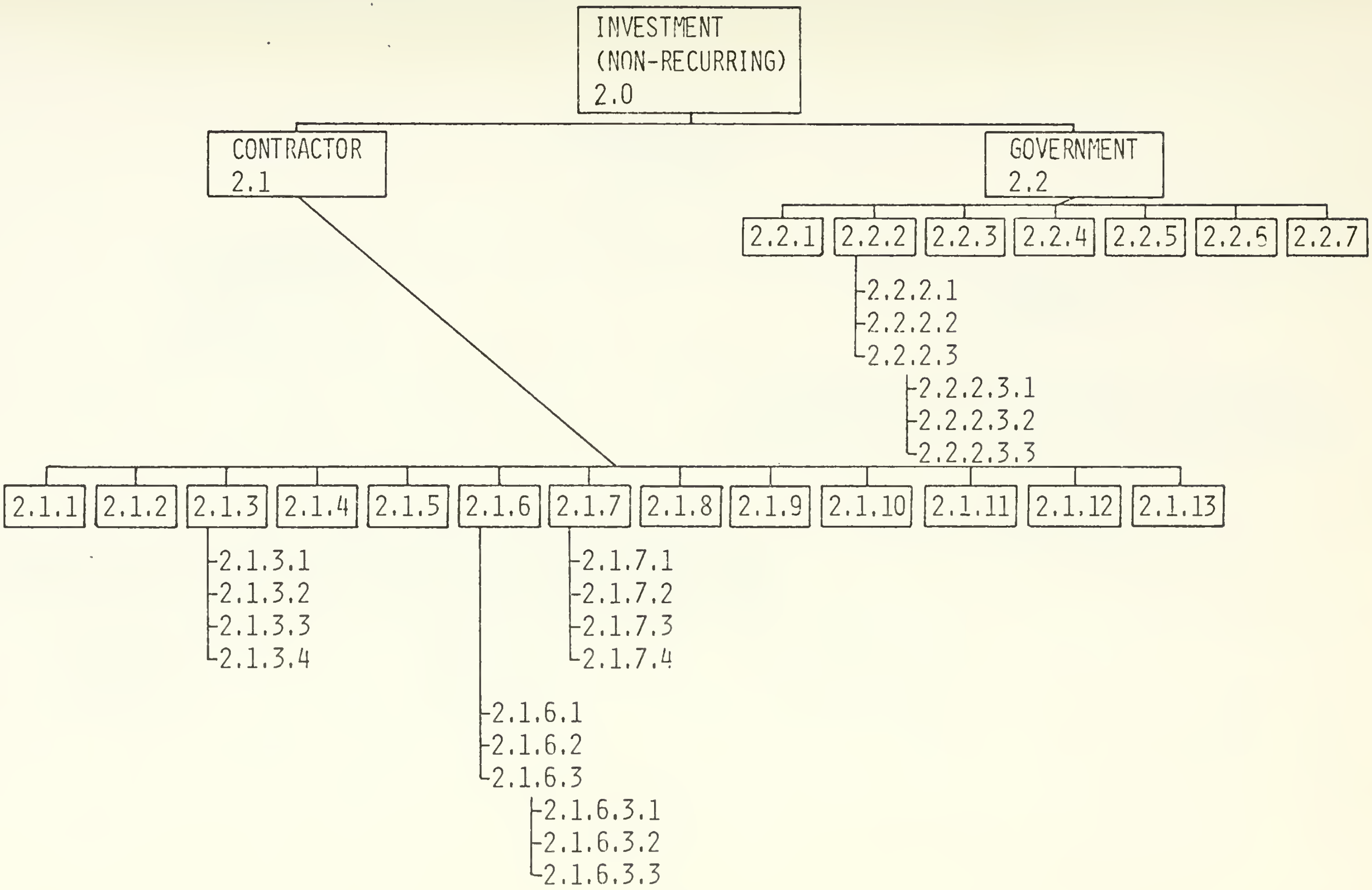
FIGURE 5


INVESTMENT
(NON-RECURRING)
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CONTRACTOR
2.1
GOVERNMENT
2.2
2.2.1
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2.2.2.1
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2.1.7.3
2.1.7.4
2.1.6.1
2.1.6.2
2.1.6.3
2.1.6.3.1
2.1.6.3.2
2.1.6.3.3

FIGURE 6

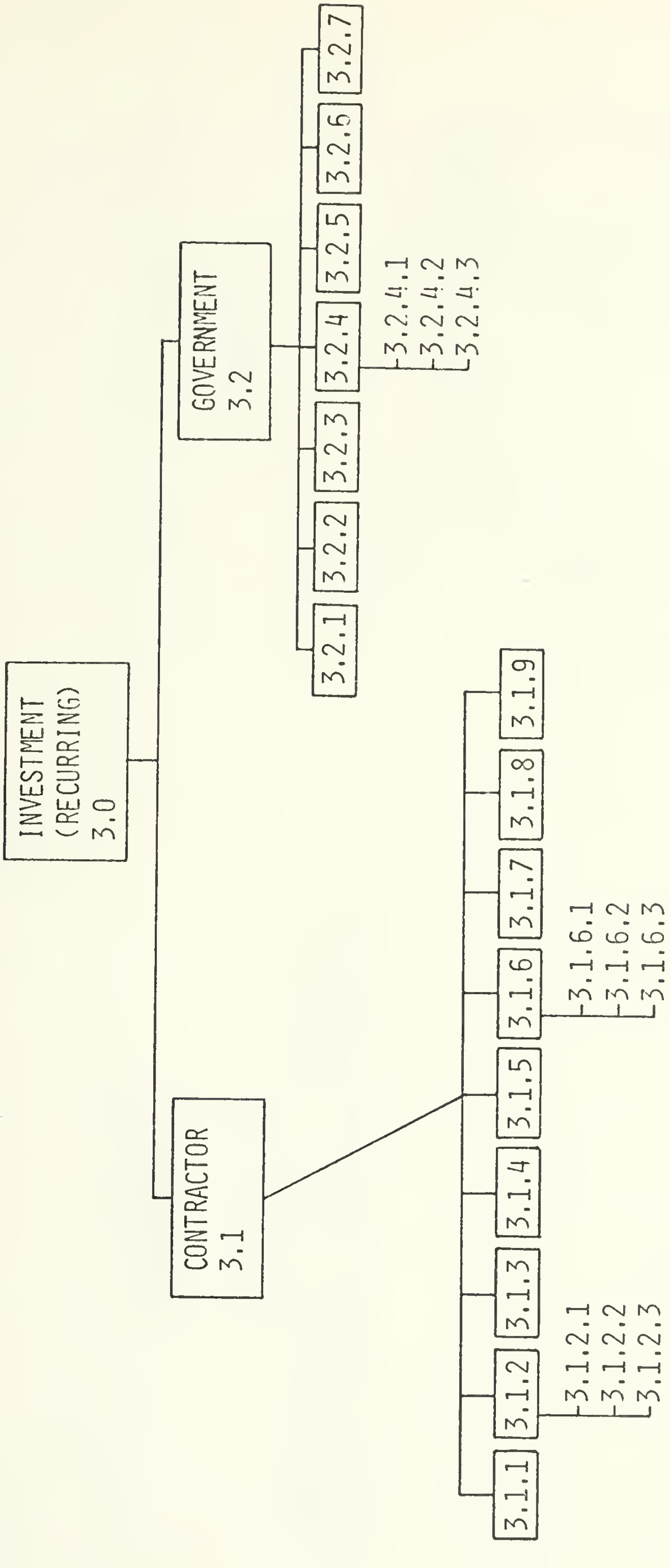

INVESTMENT
(RECURRING)
3.0
CONTRACTOR
3.1
GOVERNMENT
3.2
3.1.1
3.1.2
3.1.2.1
3.1.2.2
3.1.2.3
3.1.3
3.1.4
3.1.5
3.1.6
3.1.6.1
3.1.6.2
3.1.6.3
3.1.7
3.1.8
3.1.9
3.2.1
3.2.2
3.2.3
3.2.4
3.2.4.1
3.2.4.2
3.2.4.3
3.2.5
3.2.6
3.2.7

FIGURE 7

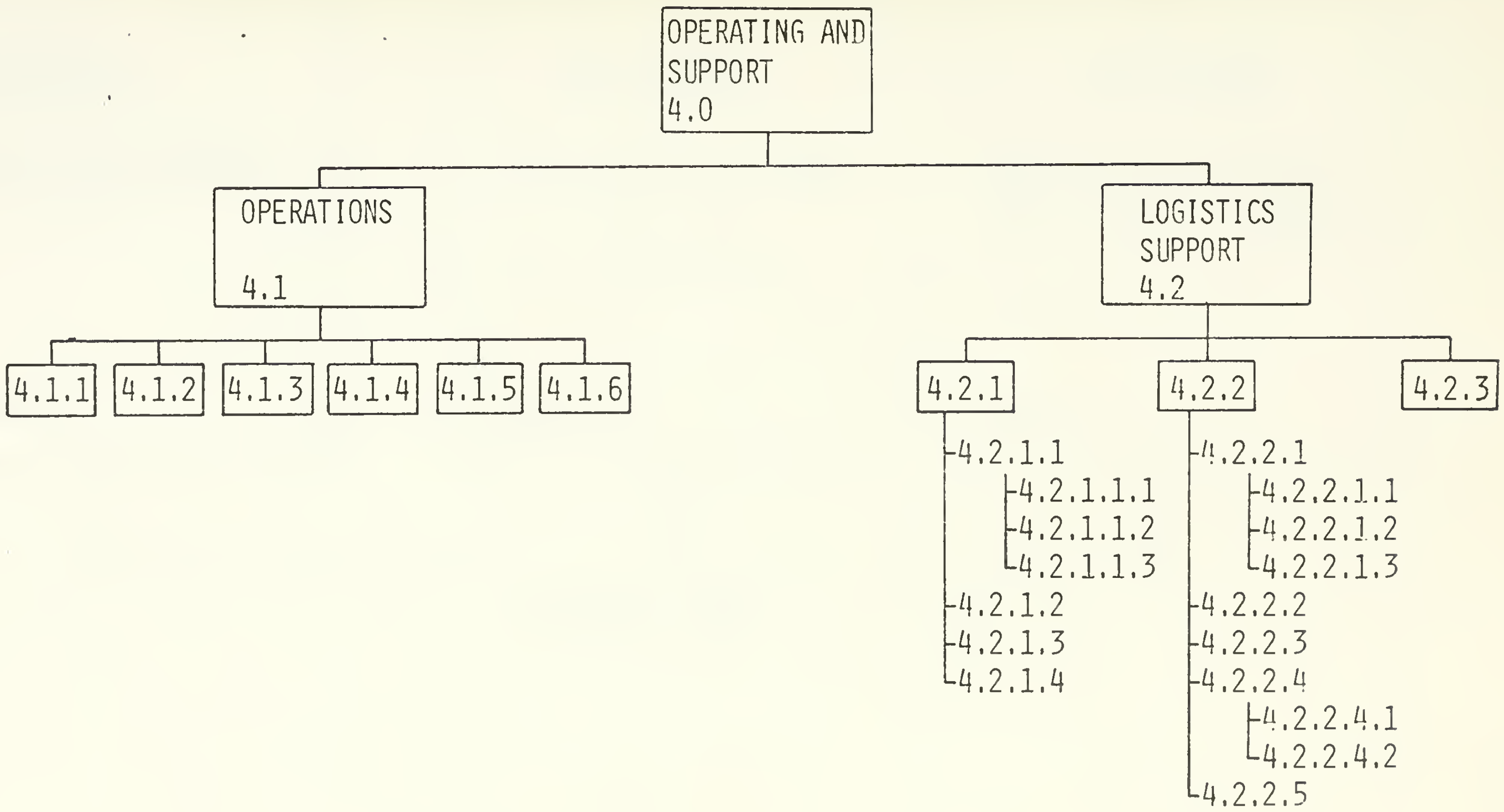
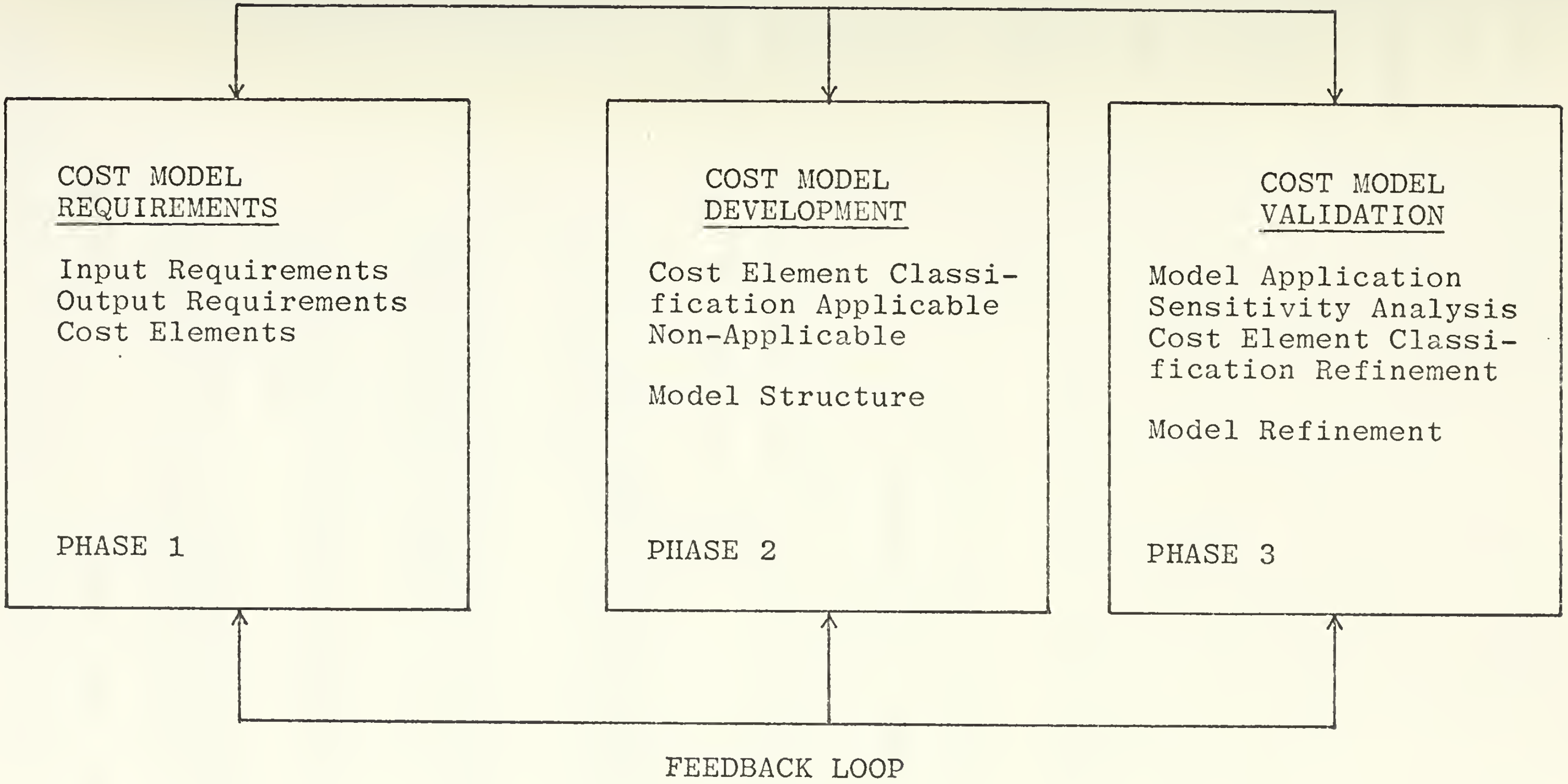

OPERATING AND SUPPORT 4.0
OPERATIONS 4.1
LOGISTICS SUPPORT 4.2
4.1.1
4.1.2
4.1.3
4.1.4
4.1.5
4.1.6
4.2.1
4.2.2
4.2.3
4.2.1.1
4.2.1.1.1
4.2.1.1.2
4.2.1.1.3
4.2.1.2
4.2.1.3
4.2.1.4
4.2.2.1
4.2.2.1.1
4.2.2.1.2
4.2.2.1.3
4.2.2.2
4.2.2.3
4.2.2.4
4.2.2.4.1
4.2.2.4.2
4.2.2.5

FIGURE 8



A-7 ALOFT Cost Model Development

Figure 9

### 1. Cost Model Input Structure

A cost model can be developed for any combination of several reasons; to aid in the decision process of a trade-off analysis, to help develop the guidelines for a program budget, to assist in the determination of the cost effectiveness of a proposed engineering change to an equipment or system, to list only a few. Because of the different reasons for which cost models are developed and the different aggregations of cost data available, cost models must be individually structured to best meet the purpose for which they are intended.

In order to structure the results of this anlaysis effort and ensure compatability with future needs of fiber optic cost analysis programs and data availability, the cost model was developed using four interrelated input components. The four input components are;

(1) descriptive information on assumptions setting forth such items as performance or physical characteristics, operational/maintenance concepts, and the like.

(2) an input structure containing well-defined categories identified within the "Cost Effectiveness Program Plan for Joint Tactical Communication."(33)

(3) Cost estimating relationships or estimating procedures for each element in the input structure.

(4) a systematic, sequential process to reduce all elements in the input structure to a minimal number of relevant elements.

Using the four structured input components, two cost models were developed and defined as:

Total Life Cycle Cost model which associates all applicable cost elements over the life time of an equipment or system. This model would, by necessity, be large and possibly difficult to evaluate. It is the sum of all applicable cost elements in the four major cost categories;

Research and development costs,
Investment (non-recurring) costs,
Investment (recurring) costs,
Operating and support costs.

Differential Life Cycle Cost model which compares the differential costs between two similar cost elements of two different equipments or systems. Since this model only operates with differential costs, it can be used when a detailed comparison between two equipments or systems is required. This model is the sum of differential costs identified with a small number of applicable cost elements in the four major cost categories listed above.

Within each cost model are four major cost categories which have been defined as:

> Research and Development costs refer to all costs associated with the research, development, test and evaluation of the system or equipment. This normally includes all costs during concept initiation, validation and full scale development.
>
> Investment (non-recurring) costs refer to those costs incurred beyond the program development phase, which are one time costs incurred during the program production phase. These costs can recur if there is a change in design, contractor or manufacturing process.
>
> Investment (recurring) costs include those production costs that recur with each unit produced. These costs tend to be subject to a learning curve concept in which the cost per unit decreases as quantity increases.

Operating and Support costs is normally the largest category. It includes the costs of personnel, material, facilities and other costs required to operate, maintain and support a system or equipment during its useful life time.

### 2. Cost Model Development

The total system life cycle cost structure is subdivided into lower level cost elements taken from the "Cost Effectiveness Program Plan for Joint Tactical Communications" (TRI-TAC)(33) and presented in Figure 10. After a detailed literature search, the TRI-TAC document was chosen as the source of cost elements because of its completeness and conformity with DoD Instruction 7041.3.(15) When specific cost elements are identified as applicable, they comprise the basis of the life cycle cost model. It is doubtful that all cost elements are applicable to any specific cost model, therefore each cost element must be systematically examined and its applicability to a specific cost model determined.

Each cost element listed in Figure 10 has been systematically examined by using the decision process outlined in Figure 11. The results of this detailed analysis is found in Appendix A in the form of the standard analysis format shown in Figure 3. If future analysis requirements dictate a change to the cost model, individual elements requiring change can be reevaluated without a full investigation of all cost elements. Figure 3 explains the various sections of the standard analysis format as used throughout this analysis.

Those cost elements classified as applicable to the TOTAL LIFE CYCLE COST model are structured in Figure 12 by

- 1.0 Research and Development
  - 1.1 Concept and Validation
    - 1.1.1 Contractor
    - 1.1.2 Government
  - 1.2 Full Scale Development (FSD)
    - 1.2.1 Contractor
      - 1.2.1.1 Program Management
      - 1.2.1.2 Engineering
      - 1.2.1.3 Fabication
      - 1.2.1.4 Contractor Development Tests (CDT)
      - 1.2.1.5 Test Support
      - 1.2.1.6 Producibility Engineering and Planning (PEP)
      - 1.2.1.7 Data
        - 1.2.1.7.1 Engineering Data
        - 1.2.1.7.2 Support Data
        - 1.2.1.7.3 Management Data
        - 1.2.1.7.4 Technical Orders and Manuals
      - 1.2.1.8 Peculiar Support and Test Equipment
      - 1.2.1.9 Other
      - 1.2.1.10 General and Administrative
      - 1.2.1.11 Fee
    - 1.2.2 Government
      - 1.2.2.1 Program Management
      - 1.2.2.2 Test Site Activation
      - 1.2.2.3 Government Tests (DTE/IOTE)
      - 1.2.2.4 Government Furnished Equipment (GFE)
      - 1.2.2.5 Other

COST ELEMENT STRUCTURE

Source: TRI-TAC

Figure 10

- 2.0 Investment (Non-Recurring)
  - 2.1 Contractor
    - 2.1.1 Program Management
    - 2.1.2 Producibility Engineering and Planning (PEP)
    - 2.1.3 Initial Production Facilities (IPF)
      - 2.1.3.1 Production Engineering
      - 2.1.3.2 Tooling
      - 2.1.3.3 Industrial Facilities
      - 2.1.3.4 Manufacturing Support Equipment
    - 2.1.4 Technical Support
    - 2.1.5 Initial Spares and Repair Parts
    - 2.1.6 Initial Training
      - 2.1.6.1 Training Facilities
      - 2.1.6.2 Training Devices and Equipment
      - 2.1.6.3 Initial Student Training
        - 2.1.6.3.1 Operator Training
        - 2.1.6.3.2 Maintenance Training
        - 2.1.6.3.3 Instructor Training
    - 2.1.7 Data
      - 2.1.7.1 Engineering Data
      - 2.1.7.2 Support Data
      - 2.1.7.3 Management Data
      - 2.1.7.4 Technical Orders and Manuals
    - 2.1.8 Leaseholds
    - 2.1.9 Common Support Equipment
    - 2.1.10 Peculiar Support and Test Equipment
    - 2.1.11 Other Non-Recurring Costs
    - 2.1.12 General and Administrative
    - 2.1.13 Fee or Profit

Figure 10 (continued)

- 2.2 Government (Non-Recurring)
  - 2.2.1 Program Management
  - 2.2.2 Initial Training
    - 2.2.2.1 Training Facilities
    - 2.2.2.2 Training Devices and Equipment
    - 2.2.2.3 Initial Student Training
      - 2.2.2.3.1 Operator Training
      - 2.2.2.3.2 Maintenance Training
      - 2.2.2.3.3 Instructor Training
  - 2.2.3 Production Acceptance Test and Evaluation (PATE)
  - 2.2.4 Operational Test and Evaluation (OTE)
  - 2.2.5 Test Site Activation
  - 2.2.6 Government Furnished Equipment (GFE)
  - 2.2.7 Other Non-Recurring Investment Costs

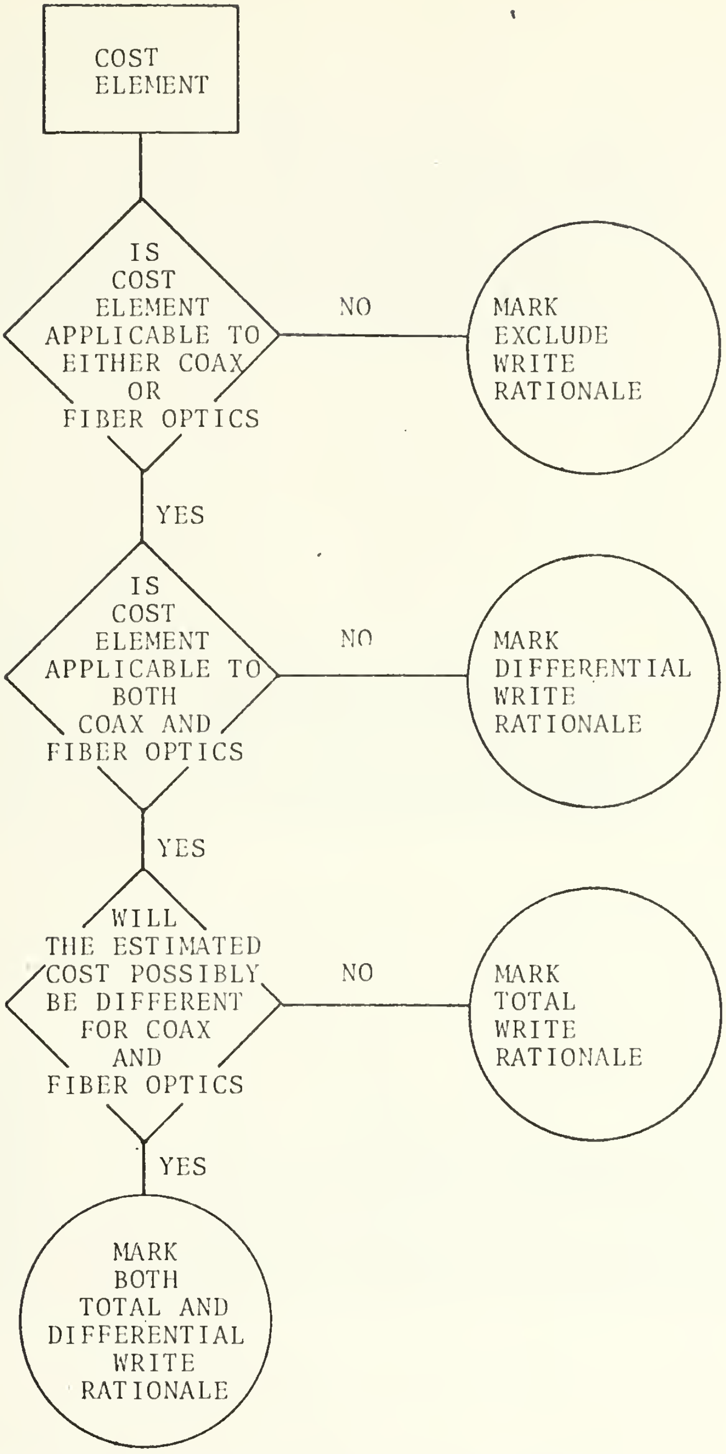
Figure 10 (continued)

- 3.0 Investment (Recurring)
  - 3.1 Contractor
    - 3.1.1 Manufacturing
    - 3.1.2 Production Material
      - 3.1.2.1 Purchased Equipment and Parts
      - 3.1.2.2 Subcontracted Items
      - 3.1.2.3 Other Material
    - 3.1.3 Sustaining Engineering
    - 3.1.4 Quality Control and Inspection
    - 3.1.5 Packaging and Transportation
    - 3.1.6 Operational/Site Activation
      - 3.1.6.1 Site Construction
      - 3.1.6.2 Site/Ship/Vehicle Conversion
      - 3.1.6.3 Assembly, Installation and Checkout
    - 3.1.7 Other Recurring Investment Costs
    - 3.1.8 General and Administrative Costs
    - 3.1.9 Fee or Profit
  - 3.2 Government (Recurring)
    - 3.2.1 Quality Control and Inspection
    - 3.2.2 Sustaining Engineering
    - 3.2.3 Transportation
    - 3.2.4 Operational/Site Activation
      - 3.2.4.1 Site Construction
      - 3.2.4.2 Site/Ship/Vehicle Conversion
      - 3.2.4.3 Assembly, Installation and Checkout
    - 3.2.5 Technical Orders and Manuals
    - 3.2.6 Government Furnished Material
    - 3.2.7 Other Recurring Cost

Figure 10 (continued)

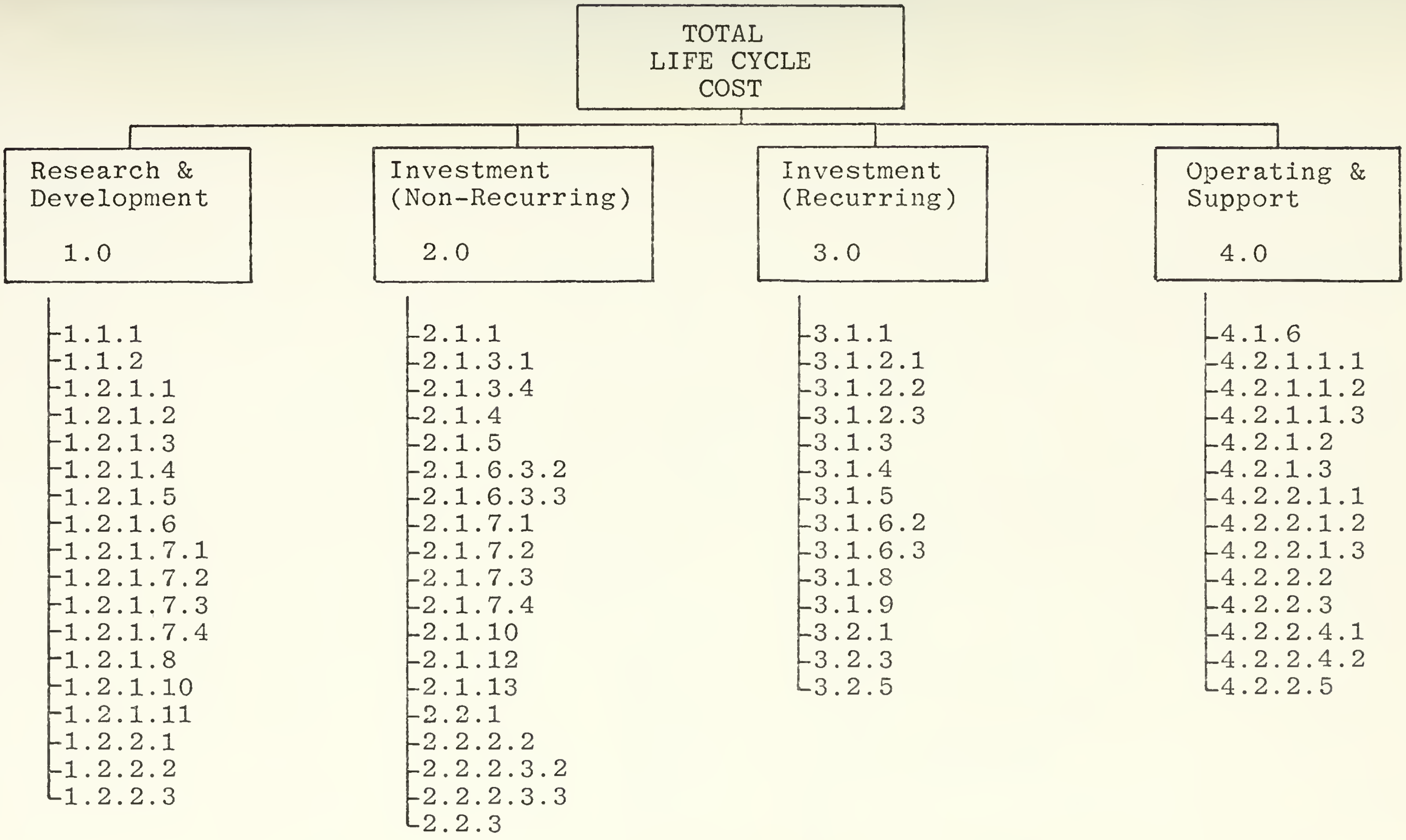
- 4.0 Operating and Support Costs (O&S)
  - 4.1 Operations
    - 4.1.1 Electrical Power
    - 4.1.2 Special Materials
    - 4.1.3 Operator Personnel
    - 4.1.4 Operational Facilities
    - 4.1.5 Equipment Leaseholds
    - 4.1.6 Other Operations Costs
  - 4.2 Logistic Support
    - 4.2.1 Maintenance
      - 4.2.1.1 Personnel
        - 4.2.1.1.1 Organizational Maintenance Personnel
        - 4.2.1.1.2 Intermediate Maintenance Personnel
        - 4.2.1.1.3 Depot Maintenance Personnel
      - 4.2.1.2 Maintenance Facilities
      - 4.2.1.3 Support Equipment Maintenance
      - 4.2.1.4 Contractor Services
    - 4.2.2 Supply
      - 4.2.2.1 Personnel
        - 4.2.2.1.1 Organizational Supply Personnel
        - 4.2.2.1.2 Intermediate Supply Personnel
        - 4.2.2.1.3 Depot Supply Personnel
      - 4.2.2.2 Supply Facilities
      - 4.2.2.3 Spare Parts and Repair Material
      - 4.2.2.4 Inventory Administration
        - 4.2.2.4.1 Inventory Management
        - 4.2.2.4.2 Inventory Holding
      - 4.2.2.5 Transportation and Packaging
    - 4.2.3 Other Logistic Support Costs

Figure 10 (continued)



COST ELEMENT SELECTION DECISION PROCESS

FIGURE 11



TOTAL LIFE CYCLE COST MODEL

Applicable Cost Elements Structured by Major Cost Category

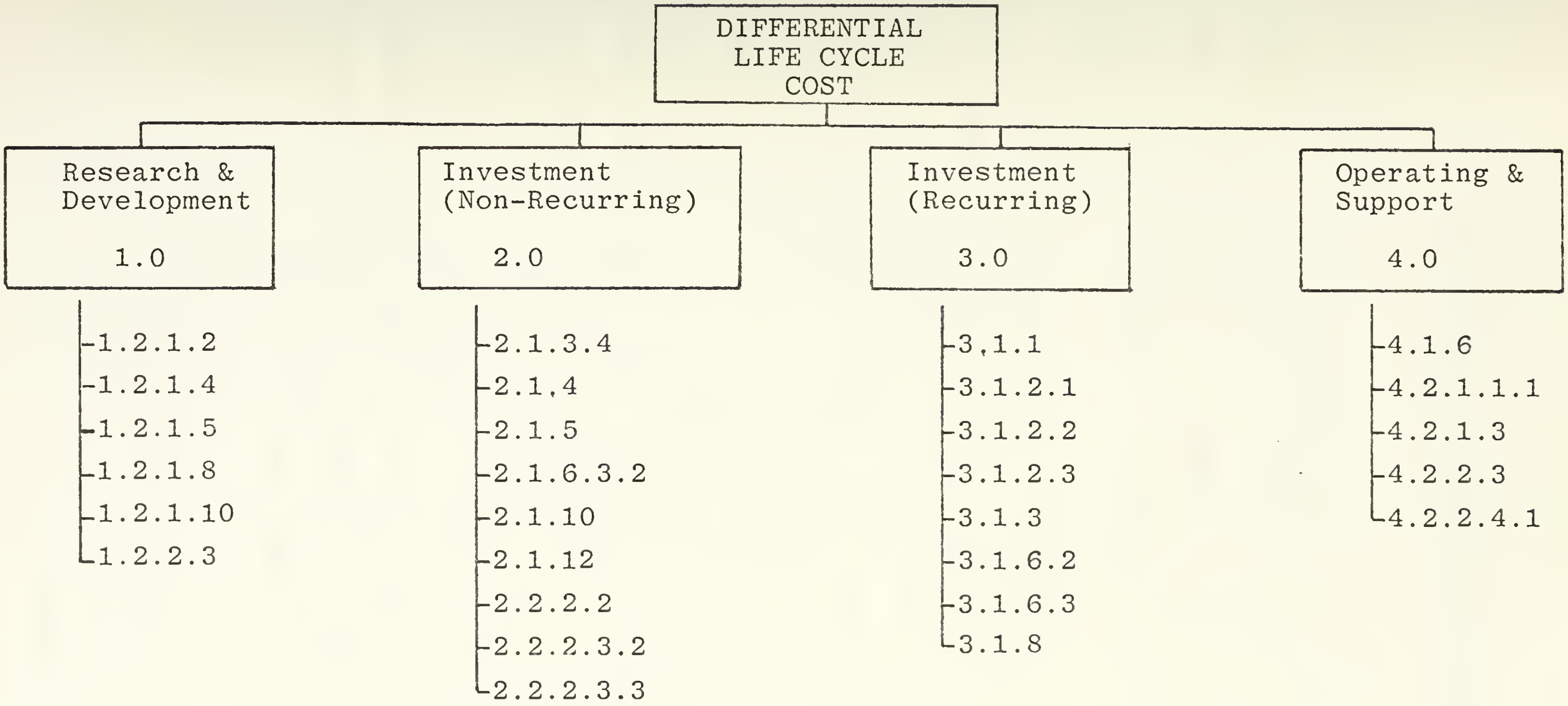
Figure 12

)

major cost category. The cost elements classified as applicable to the DIFFERENTIAL LIFE CYCLE COST model are structured in Figure 13, also by the four major cost categories; Research and Development, Investment (non-recurring), Investment (recurring), Operating and Support.

The TRI-TAC(33) system life cycle cost structure previously identified in Figure 10 contains 98 cost elements. Classifying those 98 cost elements as to their applicability to the TOTAL and/or DIFFERENTIAL LIFE CYCLE COST model(s) reduced the number within each model. The TOTAL LCC model retained 65 cost elements, a reduction of 35 percent while the cost elements applicable to the differential LCC model numbered only 28; a reduction from the total systems life cycle cost model of 70 percent.

The 70 percent reduction in cost elements which require cost data inputs will cause a significant reduction in the future data collection effort.



DIFFERENTIAL LIFE CYCLE COST MODEL

Applicable Cost Elements Structured by Major Cost Category

Figure 13

# III. FIBER OPTIC AND COAX COST ELEMENT COMPARISON

## A. PURPOSE

The purpose of Chapter III is to present a first approximation cost comparison between fiber optics and coaxial cable technology cost elements. Those cost elements previously identified and listed in Figure 13 were used for the cost comparison.

Comparing cost data for two different technologies, both performing the same function is a valid method of cost analysis. The authors have produced a cost comparison, on a cost element by element basis, between coax and fiber optic technologies. The basis for this comparison is the analogy method of cost estimating. The anology method relies upon persons knowledgeable in performing a task in one technology so that they can be questioned about the level of effort (in dollars, man-hours, etc.) required to perform the same task using a substitute technology.

This chapter presents a coax/fiber optic technology cost comparison based upon the authors best estimate or first approximation of cost estimates. Chapter IV expands upon this analogy cost estimating method with recommended procedures for cost data refinement.

Table I was developed as an aid to presenting the rationale for the author's first approximation of the costs presented in Table II. The performance characteristics of

| DIFFERENTIAL COST ELEMENTS / FIBER OPTIC CHARACTERISTICS | 1.2.1.2 | 1.2.1.4 | 1.2.1.5 | 1.2.1.8 | 1.2.1.10 | 1.2.2.3 | 2.1.3.4 | 2.1.4 | 2.1.5 | 2.1.6.3.2 | 2.1.10 | 2.1.12 | 2.2.2.2 | 2.2.2.3.2 | 2.2.2.3.3 | 3.1.1 | 3.1.2.1 | 3.1.2.2 | 3.1.2.3 | 3.1.3 | 3.1.6.2 | 3.1.6.3 | 3.1.8 | 4.1.6 | 4.2.1.1.1 | 4.2.1.3 | 4.2.2.3 | 4.2.2.4.1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HIGH TEMPERATURE TOLERANCE | X | | | | | | | | | | | | | | | | | | | X | X | | | X | X | | X | |
| VIBRATION TOLERANCE | X | | | | | | | | | | | | | | | | | | | X | X | | | X | X | | X | |
| NO CROSS TALK | X | X | X | | | X | | X | | | | | | | | | | | | X | X | | | | | | | |
| RFI/EMI/NOISE IMMUNITY | X | X | X | | | X | | X | | | | | | | | | | | | X | X | | | | | | | |
| TOTAL ELECTRICAL ISOLATION | X | | | | | | | | | | | | | | | | | | | X | X | | | | | | | |
| NO SPARK/FIRE HAZARD | X | | | | | | | | | | | | | | | | | | | X | X | | | X | X | | | |
| NO SHORT CIRCUIT LOADING | X | | | | | | | | | | | | | | | | | | | X | X | | | X | X | | | |
| EMP IMMUNITY | X | X | X | | | X | | X | | | | | | | | | | | | X | X | | | | | | | |
| NO CONTACT DISCONTINUITY | X | | | | | | | | | X | | | X | X | X | | | | | X | X | | | X | X | | | |
| WIDE SIGNAL BANDWIDTH | X | | | | | | | | | X | | | X | X | X | | | | | X | X | | | | | | | |
| CORROSION RESISTANT | X | | | | | | | | | | | | | | | | | | | X | X | | | X | X | | X | |
| HIGH SECURITY | X | X | X | | | X | | X | | | | | | | | | | | | X | X | | | | | | | |
| SMALL SIZE | X | | | | | | | | | | | | | | | X | | | | X | X | | | X | | | | |
| LIGHT WEIGHT | X | | | | | | | | | | | | | | | X | | | | X | X | | | X | | | | |
| REDUCED SAFETY HAZARD | X | | | | | | | | | | | | | | | | | | | X | X | | | X | X | | X | |
| REDUCED ELECTRICAL POWER REQUIREMENTS | X | | | | | | | | | | | | | | | | | | | X | X | | | X | | | | |

FIBER OPTIC PERFORMANCE CHARACTERISTICS

TABLE I

## RESEARCH AND DEVELOPMENT

| Cost Element | Fiber Optic Cost | | Remarks |
|---|---|---|---|
| | Minimum | Maximum | |
| 1.2.1.2<br>Full Scale Development Contractor Engineering | 1.0 | * | Since fiber optics is an infant technology there will undoubtly be a large effort expended to develop the potential use for fiber optics. The scope of this effort will be dependent upon both Government and industrial support or interest in the technology. |
| 1.2.1.4<br>Full Scale Development Contractor Development Test | 1.0 | * | In anticipation of maximum benefit from a fiber optic Research and Development program, the contractor must conduct an exhaustive test program. This type of effort, properly conducted, has a historically high cost. |
| 1.2.1.5<br>Full Scale Development Contractor Test Support | 1.0 | * | This cost will be highier for fiber optic for the same reasons as noted in cost element 1.2.1.4. Test support will be in conjunction with the effort identified in cost element 1.2.2.3. |

COST ELEMENT COMPARISON

Table II

Table II (continued)

## RESEARCH AND DEVELOPMENT

| Cost Element | Fiber Optic Cost |  | Remarks |
|---|---|---|---|
|  | Minimum | Maximum |  |
| 1.2.1.8<br>Full Scale Development Contractor Peculiar support and Test Equipment | 1.0 | 2.0 | Research and Development of peculiar support and test equipment is not expected to be a major effort. The anticipated requirements for support and test equipment that are unique or peculiar to the new fiber optic technology should be minimal. |
| 1.2.1.10<br>Full Scale Development Contractor General and Administrative | 1.0 | 1.8 | The level of effort of Research and Development in the fiber optic technology is expected to be larger than a coax technology program. There is existing a data base for coax technology but the data base for fiber optic technology is only being developed at this time. |
| 1.2.2.3<br>Full Scale Development Government Test | 1.0 | * | The culmination of an extensive Research and Development program are the purposeful tests. Expectations for future use of fiber optic technology dictates a major test and evaluation program. This effort will be much in excess of test programs for coax cable. |
|  |  | * | During the Research and Development phase of a new program the ceiling cost is primarily limited by the funding available. The present interest in fiber optic technology is quite strong and the program is expected to grow rapidly. |

Table II (continued)

## INVESTMENT (NON-RECURRING)

| Cost Element | Fiber Optic Cost<br>Minimum | <br>Maximum | Remarks |
|---|---|---|---|
| 2.1.3.4<br>Contractor Manufacturing Support Equipment | 1.2 | 1.8 | Manufacturing equipment for use with coax cable presently exists. To establish the capability of working with fiber optic cable, new support equipment will be required. This additional capability will cause an increase in the fiber optic support equipment cost. |
| 2.1.4<br>Contractor Technical Support | 0.6 | 1.0 | The replacement of coax cable with fiber optic cable will be contingent upon several factors. One primary consideration will be successful testing during the Research and Development phase of a program. If fiber optic cable is used in aircraft production it will only be after successful early testing and the assumption is then made that follow-on testing will be minimized or possibly eliminated. |
| 2.1.5<br>Contractor Initial Spare and Repair Parts | 0.8 | 1.6 | The advances in the fiber optic state-of-the-art and the ability of industry to economically mass produce cable, transmitter module and receives modules control this cost element range. |

Table II (continued)

INVESTMENT (NON-RECURRING)

| Cost Element | Fiber Optic Cost | | Remarks |
|---|---|---|---|
| | Minimum | Maximum | |
| 2.1.6.3.2<br>Contractor Initial Maintenance Training | 1.2 | 2.0 | Maintenance training for fiber optic equipment or systems will be in excess of the training presently conducted on systems using coax cable. The excess cost exists because a maintenance technician would be knowledgeable in coax cable maintenance but fiber optic technology is a new requirement in addition to this present ability. |
| 2.1.10<br>Contractor Peculiar Support and Test Equipment | 1.2 | 1.8 | Maintenance and support equipment unique or peculiar to an equipment or system using fiber optic cable will be required. This requirement is in addition to the existing requirement for coax cable maintenance and support equipment already in use. |
| 2.1.12<br>Contractor General and Administrative | 0.9 | 1.0 | Fiber optic technology should cause a production effort to be less than a simular coax system. Therefore, the General and Administrative costs would be slightly less for production using fiber optic technology. |

Table II (continued)

INVESTMENT (NON-RECURRING)

| Cost Element | Fiber Optic Cost |  | Remarks |
|---|---|---|---|
|  | Minimum | Maximum |  |
| 2.2.2.2<br>Government Training Devices and Equipment | 2.0 | 3.5 | The knowledge of coax cable technology exists within the appropriate Navy schools today. Adding fiber optic technology to the existing school curriculum will generate a cost that is in excess of any cost associated with coax cable training. |
| 2.2.2.3.2<br>Government Initial Maintenance Training | 1.1 | 1.8 | The Government cost to train both maintenance personnel (cost element 2.2.2.3.2) and instructor personnel (cost element 2.2.2.3.3) is directly related to the length of time required for the training. Fiber optic technology with require training in excess of that required presently by coax cable technology. |
| 2.2.2.3.3<br>Government Initial Instructor Training | 1.1 | 1.8 |  |

Table II (continued)

INVESTMENT (RECURRING)

| Cost Element | Fiber Optic Cost | | Remarks |
|---|---|---|---|
| | Minimum | Maximum | |
| 3.1.1<br>Contractor Manufacturing | 0.8 | 2.0 | As fiber optic technology advances and additional applications are discovered, the cost of material will probably decline. However, at this point in time the production base for fiber optics is limited, thereby keeping the cost of fiber optics above the cost of coax. |
| 3.1.2.1<br>Contractor Production Purchased Equipment and Parts | 0.8 | 2.0 | Large quantity usage and mass production is expected to reduce the cost of fiber optic components to a level below that of simular coax components. The present demand for fiber optics is limited, therefore the cost of components is higher than coax. |
| 3.1.2.2<br>Contractor Production Subcontracted Items | 0.8 | 2.0 | Increased applications of fiber optic technology coupled with a greater usage demand should reduce the cost of fiber optic components. At some point in future time, it is expected that fiber optic components will cost less than their coax counterparts but presently fiber optic component costs are generally higher than coax. |

Table II (continued)

INVESTMENT (RECURRING)

| Cost Element | Fiber Optic Cost | | Remarks |
|---|---|---|---|
| | Minimum | Maximum | |
| 3.1.2.3<br>Contractor Other Production Material | 0.8 | 2.0 | Raw material for the manufacture of fiber optic cable is readily available and mass production should decrease the cost of fiber optic components. Mass production can not begin until the demand for fiber optic increases. Copper is becoming a scarse commodity and therefore the cost of coax is expected to increase in the future. |
| 3.1.3<br>Contractor Sustaining Engineering | 0.7 | 0.9 | The engineering costs associated with future modification or field changes of a fiber optic equipment or system will be less than those costs associated with a coax system. The use of fiber optic technology would place fewer restriction on design engineers. |
| 3.1.6.2<br>Contractor Site/Ship/Vehicle Conversion | 0.7 | 1.0 | The physical characteristics of fiber optic cable allow its installation in places not accessible with coax cable. This attribute will allow design engineers to design fiber optic cable routes at a lower cost than coax cable. |

Table II (continued)

INVESTMENT (RECURRING)

| Cost Element | Fiber Optic Cost |  | Remarks |
|---|---|---|---|
|  | Minimum | Maximum |  |
| 3,1,6.3<br>Contractor Operational Assembly, Installation, Checkout | 0.85 | 1.0 | In conjunction with the reduced cable route design conplexity, checkout will be simplified for fiber optic cable systems. |
| 3.1.8<br>Contractor General and Administrative | 0.9 | 1.0 | Fiber optic technology should cause a production effort to be less than a simular coax system. Therefore, the General and Administrative costs would be slightly less for production using fiber optic technology. |

Table II (continued)

OPPERATING AND SUPPORT

| Cost Element | Fiber Optic Cost |  | Remarks |
|---|---|---|---|
|  | Minimum | Maximum |  |
| 4.1.6<br>Government Opportunity Cost | 1.0 | 1.0 | Reliability of a fiber optic cable system is expected to be higher than a simular coax system. If this assumption is valid, then the down time of an aircraft due to electrical problems will be less. However the daily or differential Opportunity cost of a down aircraft is the same regardless of the type cable system. The cost differential is identified where one system has fewer down days. |
| 4.2.1.1.1<br>Government Organizational Maintenance Personnel | 0.7 | 0.9 | The assumed reliability of fiber optic equipments or systems causes this cost to be less than a simular cost for a coax system. |
| 4.2.1.3<br>Government Support Equipment Maintenance | 1.0 | 1.5 | Support and test equipment presently in the inventory will remain even after the introduction of fiber optic cable. The additional cost will be recognized as that required to maintain the unique or peculiar support and test equipment which was developed under cost element 1.2.1.8. |

Table II (continued)

OPPERATING AND SUPPORT

| Cost Element | Fiber Optic Cost | | Remarks |
|---|---|---|---|
| | Minimum | Maximum | |
| 4.2.2.3<br>Government Spare Parts and Repair Material | 0.7 | 0.9 | The assumed reliability of fiber optic equipments or systems should reduce the cost of repair parts consumed during maintnenace. |
| 4.2.2.4.1<br>Government Supply Investory Management | 1.1 | 1.3 | Coax system components are already a part of the supply system. There will be a cost associated with introducing the new components of the fiber optic technology. |

fiber optic cable which enhance its use as a signal carrying conductor are listed in columnar form on the left side of the table. Across the top of the table are listed the differential cost elements previously identified. If a fiber optic performance characteristic could significantly impact upon a differential cost element, an (X) was placed in the tabular matrix. It should be noted that this matrix was used by the authors for the initial first approximation to each differential cost element and is subject to revision as fiber optic cost data becomes more readily available.

Coax cable does not inherantly posess the performance characteristic of fiber optic cable. A similar matrix presenting the lack of these performance characteristics inherant in coax cable would be a simple mirror image of Table I.

In order to standardize the meaning of each fiber optic performance characteristic listed in Table I, the authors have included a definition of each characteristic. The following definitions were compiled from various technical documents published by the fiber optic industry and NELC.

HIGH TEMPERATURE TOLERANCE - temperatures up to approximately 150°C can be tolerated by fiber optic cable.

VIBRATION TOLERANCE - fiber optic cable can tolerate vibrations without experiencing electrical problems such as internal cable short circuits or changing electrical conducting characteristics.

NO CROSS - TALK - adjacent cables within cable bundles or cable harnesses are not susceptible to stray signals induced due to their close proximity.

RFI/EMI/NOISE IMMUNITY - external electrical signals do not adversely affect the light signal within a fiber optic cable. There is no electrical signal to be either radiated or be susceptible to stray electrical signals.

TOTAL ELECTRICAL ISOLATION - there is no electrical current path within a fiber optic cable. This characteristic allows interconnected equipments to be electrically isolated from each other as well as isolated from the interconnecting cables.

NO SPARK/FIRE HAZARD - the total back of electric current within the fiber optic cable reduces the potential for spark generation to zero. This has a direct impact upon combustible ignition caused by sparks.

NO SHORT CIRCUIT LOADING - since fiber optic cables do not carry electric current, damage to a cable could not cause an electrical signal reflection back to an equipment, which could cause an equipment failure.

EMP IMMUNITY - similar to the RFI/EMI/NOISE IMMUNITY, nuclear radiation does not have a severe impact upon fiber optic cable.

NO CONTACT DISCONTINUITY - a light signal does not require a physical contact at signal connector interference, it can pass through an air gap.

WIDE SIGNAL BANDWIDTH - fiber optic cable has a wider bandwidth than either the present "twisted pair" cable or installed coax cable, however, the LED is the limiting factor for signal bandwidth.

CORROSION RESISTANT - common but severe environmental characteristics which affect electrical signal carrying cable have little or no affect upon the fiber optic cable signal quality.

HIGH SECURITY - fiber optic cable does not have the adverse characteristic which would allow it to radiate a signal that could be coupled and picked up in a non-secure environment.

SMALL SIZE - the diameter of present and the future fiber optic cable is equal to or less than that of a equivalent use coax cable.

LIGHT WEIGHT - fiber optic cable is lighter weight than an equivalent use coax cable.

REDUCED SAFETY HAZARD - the high temperature tolerance and no spark hazard characteristics coupled together allow fiber optic cable immunity to exclusion from location in a hazardous area.

REDUCED ELECTRICAL POWER REQUIREMENTS - fiber optic light transmitting and receiving modules have the potential to require less electrical power to operate than an equivalent coax cable system.

## B. COST ELEMENT COMPARISON DEVELOPMENT

Cost data is available for equipment or systems using coax cable. Similar cost data for equipment or systems using fiber optic cable is not necessarily available since fiber optics is an infant technology and only a limited cost data base has been collected. This lack of available cost data requires that many of the fiber optic costs be "best estimates." In order to facilitate a best estimate approach to determining costs, each fiber optic cost was formulated as a multiple of coax cost for the same cost element. This was done on an element-by-element basis using the substitution:

$$C^*_{fo} = A\ C_{cc} \text{ where } A = \frac{C^*_{fo}}{C_{cc}} \text{ and}$$

$C^*_{fo}$ is the cost of the fiber optic alternative of a specific cost element

$C_{cc}$ is the cost of the coax cable alternative of the <u>same</u> element,

A is the relative cost of the fiber optic alternative as a percentage of the known coax cable cost.

The source of actual cost data for coax cable equipment or systems is generally limited to aircraft manufacturers since they hold the expertise required to wire aircraft using present coax technology. With the use of known coax cost data for a specific task, a cost comparison for the <u>same</u> task can be determined in order to transition between two technologies. Because of the uncertainty associated with some costs, the fiber optic estimated cost is presented in the form of a cost range; a minimum value and a maximum

value. Uncertainty associated with any cost element is an indication of areas for future investigation. As the fiber optic technology advances, these first approximation costs will require refinement. It can be expected that over time, a future analysis effort will be required to revise both the minimum and maximum values of the estimated cost range. Chapter IV contains the authors' recommended procedures for future cost data collection.

Table II contains the authors' first approximation to the "best estimate" cost comparison between fiber optics and coax. As an example of the method used to develop a first approximation cost estimate, consider cost element 3.1.6.2 CONTRACTOR SITE/SHIP/VEHICLE CONVERSION during production. Table I indicates that all fiber optic performance characteristics could significantly impact (tend to reduce) this cost element. It is the authors' judgment that these superior fiber optic performance characterists would be considered and utilized during the development and design effort; to reduce the subsequent installation (conversion) effort and cost. Accordingly, the authors' maximum estimate for "A" in the equation:

$$A = \frac{C^*_{fo}}{C_{cc}} = \frac{\text{Cost contractor site/ship/vehicle conversion (fiber optic)}}{\text{Cost contractor site/ship/vehicle conversion (coaxial cable)}}$$

was established less than or equal to 1. In a similar manner the lower bound was estimated at 0.7.

$$0.7 \leq A \leq 1$$

In sum, the authors estimate that the cost of operforming the task identified by cost element 3.1.6.2 could range between the limits of:

(a) the task performed using fiber optics with a minimum cost of 70 percent of the same task performed using coax.

(b) the task performed using either fiber optics or coax would have a maximum cost equal to the cost of coax.

The significant of this result is that a general cost estimation process has been developed to permit cost estimation and direct comparison of two alternative technologies in the conceptual stage of development.

In the above example, the authors estimated that the fiber optic alternative offered superior cost advantages for element 3.1.6.2. The basis for this estimation was a combination of knowledge gathered during interviews, research, intuition, and judgment. All estimation concerns judgment. The purpose of this approach is to structure and direct the estimation process so that multiple expert judgments can be utilized and synthesized to a "statistically" significant "best estimate." This matter will be further discussed in Chapters IV and V. Table II contains the authors' "best estimate" of all cost comparisons relevant to the fiber optic development decision. As cost data is gathered as recommended in Chapter IV, the estimates shown in Table II will require revision to improve their accuracy.

# IV. METHODOLOGY TO DETERMINE COST ELEMENT VALUES

## A. PURPOSE

This chapter is dedicated to identifying the costing and data gathering methodology necessary for each differential cost element. Differential cost elements were selected as the most appropriate in order to facilitate the decision process addressed in Chapter I. The differential cost elements are those cost elements previously identified in Chapter II.

## B. SPECIFIC COST ELEMENT ANALYSIS

The Differential Life Cycle Cost model elements previously developed in Chapter II are the relevant LCC elements which must be determined. It was apparent that either a cost estimating relationship (CER) or alternative estimating procedure would be required for each element. An attempt was made to first identify a previously established CER. If a previously established CER was not available, alternative costing methodology was sought. Some of the cost estimating relationships were obvious and could be expressed in simple terms. For a variety of reasons, other relationships were not so obvious and many times there was no relationship in existence.

A direct method of estimating costs is with the use of a cost estimating relationship (CER). A CER is defined as

an analytic device that relates the value (in dollars or physical units) of various cost categories to the cost-generating or explanatory variables associated with the categories.(21)

The problem of estimating costs for cost elements that do not have a CER can be very complex. Since the fiber optic technology is in its infancy, only limited cost data is available. In order to avoid generating unnecessary work, a determination must be made as to whether adequate cost information is already available. The DoD Instruction 7041.3, "Economic Analysis and Program Evaluation for Resource Management,"(15) suggests the following categories of data sources:

(1) established reports
(2) opinion and judgments of experts
(3) observation and tabulation of steps in a work process
(4) outside organizations
(5) information centers

After an extensive search for fiber optic data transfer system technology cost data, the authors compiled the following list of data source categories:

(1) aircraft manufacturers
(2) fiber optic manufacturers/R&D activities
(3) historical files
(4) Chief of Naval Education and Training (CNET)
(5) Department of Defense (DoD) activities.

This is a general list of data source categories and is by

no means exhaustive. As the technology advances and greater uses are found for fiber optic data transfer systems this list of data sources will expand. Table III is a matrix presentation of all differential cost elements and the possible data sources. This was developed as a "quick-look" data source guide to enable the authors to rapidly determine which cost elements could be calculated using a CER and which elements would require some other data collection technique.

An expanded version of the quick-look data source guide is presented in Appendix B. Each differential cost element is again identified and the authors' recommended procedure for data collection is presented.

All differential cost elements were divided into one of three groups; those having: (a) cost estimating relationships, (b) a limited cost data base, (c) historical costs. Those cost elements for which no previously established cost estimating relationship was developed were further classified as:

Category I: Cost elements for which only limited published cost data is available. It contains the largest number of cost elements which are of the type:

(a) contractor engineering during R&D

(b) contractor development tests

(c) contractor manufacturing costs.

Category II: Which comprised the remaining cost elements; which by their nature have either a historical data base or

| DATA SOURCE / DIFFERENTIAL COST ELEMENT | COST ESTIMATING RELATIONSHIP | AIRCRAFT MANUFACTURERS | FIBER OPTICS MANUFACTURER | HISTORICAL FILES | TRI-TAC | CNET | DOD ORGANIZATION | CATEGORY I | CATEGORY II | QUESTIONNAIRE CROSS REFERENCE |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.2.1.2 |  | X |  |  |  |  |  | X |  | III-1 |
| 1.2.1.4 |  | X |  |  |  |  |  | X |  | III-2 |
| 1.2.1.5 |  | X |  |  |  |  |  | X |  | III-3 |
| 1.2.1.8 |  | X |  |  |  |  |  | X |  | III-4 |
| 1.2.1.10 |  | X |  | X |  |  |  |  | X | III-5 |
| 1.2.2.3 |  |  |  | X |  |  | X |  | X |  |
| 2.1.3.4 |  | X |  |  |  |  |  | X |  | IV-1 |
| 2.1.4 |  | X |  |  |  |  |  | X |  | IV-2 |
| 2.1.5 | X |  |  |  |  |  |  |  |  |  |
| 2.1.6.3.2 |  | X |  | X |  |  |  | X |  | IV-3 |
| 2.1.10 |  | X |  |  |  |  |  | X |  | IV-4 |
| 2.1.12 |  | X |  | X |  |  |  |  | X | IV-5 |
| 2.2.2.2 |  |  |  |  |  | X |  |  | X |  |
| 2.2.2.3.2 | X |  |  |  | X |  |  |  |  |  |
| 2.2.2.3.3 | X |  |  |  | X |  |  |  |  |  |
| 3.1.1 |  | X |  |  |  |  |  | X |  | V-1 |
| 3.1.2.1 |  |  | X |  |  |  |  | X |  | * |
| 3.1.2.2 |  |  | X |  |  |  |  | X |  | * |
| 3.1.2.3 |  |  | X |  |  |  |  | X |  | * |
| 3.1.3 |  | X |  |  |  |  |  | X |  | V-2 |
| 3.1.6.2 |  | X |  |  |  |  |  | X |  | V-3 |
| 3.1.6.3 |  | X |  |  |  |  |  | X |  | V-4 |
| 3.1.8 |  |  |  | X |  |  |  |  | X |  |
| 4.1.6 | X |  |  |  |  |  |  |  |  |  |
| 4.2.1.1.1 | X |  |  |  |  |  |  |  |  |  |
| 4.2.1.3 | X |  |  |  |  |  |  |  |  |  |
| 4.2.2.3 | X |  |  |  |  |  |  |  |  |  |
| 4.2.2.4.1 | X |  |  |  |  |  |  |  |  |  |

DATA SOURCES FOR DIFFERENTIAL COST ELEMENTS

TABLE III

there exists within DoD, activities which have the capability to determine the cost data in question. These cost elements are of the type;

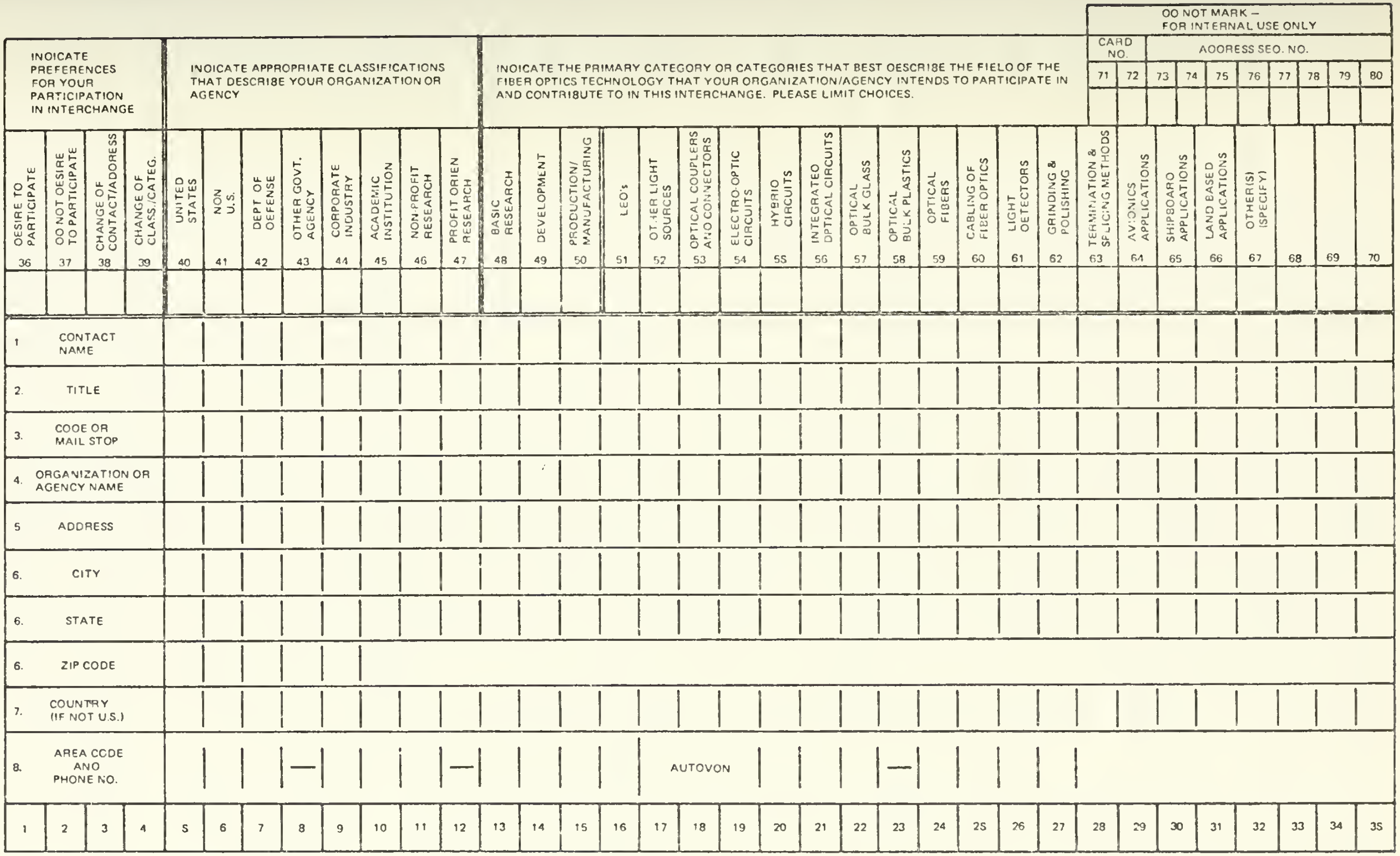
(a) contractor G&A costs

(b) Government test and evaluation (T&E)

(c) Government training devices and equipment.

The actual data collection will not be conducted by the authors. This will be a future effort by either a contractor or the Naval Postgraduate School.

Of the data source categories previously determined, there were two selected as primary sources for the required cost data; (1) aircraft manufacturers and (2) fiber optic manufacturers/R&D activities. Aircraft manufacturers are a rather small population and can be readily identified. To reduce the formidable task of identifying the many fiber optic manufacturers/R&D activities, the Naval Electronics Laboratory Center (NELC) was asked for assistance. NELC has established a dynamic set of composite distribution lists for use in exchanging data and reports with Government facilities and industry pertaining to the rapidly evolving fiber optics technology. NELC sorted and classified the data sources as to their particular interest and activities by the use of the data collection form shown in Figure 14. Constructing a list of actual data sources will be a part of the future data collection effort using aircraft manufacturing listings and the fiber optics composite distribution list at NELC. In order to facilitate future data collection for



| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| DO NOT MARK – FOR INTERNAL USE ONLY | | | | | | | | | |
| CARD NO. | | ADDRESS SEQ. NO. | | | | | | | |
| 71 | 72 | 73 | 74 | 75 | 76 | 77 | 78 | 79 | 80 |
| | | | | | | | | | |

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| INDICATE PREFERENCES FOR YOUR PARTICIPATION IN INTERCHANGE | | | | INDICATE APPROPRIATE CLASSIFICATIONS THAT DESCRIBE YOUR ORGANIZATION OR AGENCY | | | | | | | | INDICATE THE PRIMARY CATEGORY OR CATEGORIES THAT BEST DESCRIBE THE FIELD OF THE FIBER OPTICS TECHNOLOGY THAT YOUR ORGANIZATION/AGENCY INTENDS TO PARTICIPATE IN AND CONTRIBUTE TO IN THIS INTERCHANGE. PLEASE LIMIT CHOICES. | | | | | | | | | | | | | | | | | | | | | | |
| DESIRE TO PARTICIPATE | DO NOT DESIRE TO PARTICIPATE | CHANGE OF CONTACT/ADDRESS | CHANGE OF CLASS./CATEG. | UNITED STATES | NON U.S. | DEPT OF DEFENSE | OTHER GOVT. AGENCY | CORPORATE INDUSTRY | ACADEMIC INSTITUTION | NON-PROFIT RESEARCH | PROFIT ORIEN RESEARCH | BASIC RESEARCH | DEVELOPMENT | PRODUCTION/ MANUFACTURING | LED's | OTHER LIGHT SOURCES | OPTICAL COUPLERS AND CONNECTORS | ELECTRO-OPTIC CIRCUITS | HYBRID CIRCUITS | INTEGRATED OPTICAL CIRCUITS | OPTICAL BULK GLASS | OPTICAL BULK PLASTICS | OPTICAL FIBERS | CABLING OF FIBER OPTICS | LIGHT DETECTORS | GRINDING & POLISHING | TERMINATION & SPLICING METHODS | AVIONICS APPLICATIONS | SHIPBOARD APPLICATIONS | LAND BASED APPLICATIONS | OTHER(S) (SPECIFY) | | | |
| 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 | 60 | 61 | 62 | 63 | 64 | 65 | 66 | 67 | 68 | 69 | 70 |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. CONTACT NAME | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2. TITLE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3. CODE OR MAIL STOP | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 4. ORGANIZATION OR AGENCY NAME | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 5 ADDRESS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 6. CITY | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 6. STATE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 6. ZIP CODE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 7. COUNTRY (IF NOT U.S.) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 8. AREA CODE AND PHONE NO. | | | | | | | | — | | | | — | | | | | AUTOVON | | | | | | — | | | | | | | | | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 |

DATA COLLECTION FORM
FIGURE 14

those cost elements not having an established CER, the authors investigated the cost estimating techniques of engineering methods, analogy and Delphi. The result of this investigation was a composit cost estimating technique. It is the authors' contention that engineering estimates by experts in industry is an appropriate cost estimating method for this analysis. Engineering estimates in a new technology can be transformed into relative estimates by using an analogy of a similar engineering task in a known technology. An effective method to gather engineering estimates based upon an analogy is with the use of a Delphi Questionnaire.

Delphi is a method of technological forecasting which uses a questionnaire to poll experts who are actually attempting to accomplish a specific task addressed by the questionnaire. As with any method of technological forecast casting, the Delphi Questionnaire has both advantages and disadvantages. For an indepth study of the Delphi Technique the authors recommend references 26 and 35.

Two Delphi Questionnaires have been designed for future data collection. One for use by the aircraft industry and the second to be used by the fiber optic industry and are displayed in Appendices C and D.

The Delphi Questionnaire for use by the aircraft industry has been divided into five sections:

I. Respondent Identification
II. Fiber Optic Performance Characteristics
III. Research and Development Costs

IV. Non-Recurring Investment Costs

V. Recurring Investment Costs.

Each aircraft industry respondent would receive Sections I and II combined with one of the remaining three sections depending on the area of expertise being surveyed.

The Delphi Questionnaire for use by the fiber optic industry is a portion of the sample Delphi Questionnaire developed in the NPS thesis, "An Approach to the Estimation of Life Cycle Cost of a Fiber Optic Application in Military Aircraft,"(44) and consists of two sections:

I. Respondent Identification

II. Fiber Optics State-of-the-Art

The objective of the Delphi Questionnaire is to gather cost data from qualified personnel. To determine cost estimates for the required DIFFERENTIAL cost elements, two properly designed Delphi Questionnaires will conform to one or more of the following applicable requirements:

(1) be submitted to qualified technical/managerial representatives working in the field of fiber optics to determine future predicted costs, production rates, state-of-the-art breakthroughs.

(2) be submitted to qualified technical/managerial representatives working in the aircraft industry in order to determine relative engineering cost estimates of a representative coax cable task performed using fiber optics.

(3) be submitted to qualified personnel familiar with establishing training requirements and establishing schooling and training courses.

(4) be divided into sections which can be addressed by personnel of either (a) the fiber optic industry, (b) the aircraft industry, or (c) the field of military education and training.

(5) identify the qualifications of the person completing the questionnaire.

The Delphi Questionnaire for use within the aircraft industry, found in Appendix C, is designed to determine the major cost categories, Research and Development, Non-Recurring Investment and Recurring Investment. In an effort to minimize ambiguity and personal bias of the respondents, each section of the questionnaire establishes a baseline scenario. Each question within a section is then based upon the scenario for that specific section of the questionnaire and the list of Fiber Optic Performance Characteristics found in Section II of the questionnaire. The respondents are requested to estimate the relative cost of performing a specific task using fiber optic technology as a substitute technology for coax. The estimated relative cost of using fiber optics is expressed as a multiple of the cost of using coax.

The Delphi Questionnaire for use by the fiber optic industry relies mostly upon state-of-the-art advances and judgment. It is straightforward and requires no detailed explanation.

To determine which cost elements require the use of a Delphi Questionnaire as the data collection method, reference can be made to Table III. Each cost element has been

identified as being of the Category I or II type or having an established CER. Correlation between a specific cost element and a Delphi Questionnaire question is with the column labeled QUESTIONNAIRE CROSS REFERENCE. The numbers in the QUESTIONNAIRE CROSS REFERENCE column refer to the aircraft industry Delphi question numbers.

Only three cost elements require an input from the fiber optic industry and the application of the Delphi Questionnaire is explained in Appendix B under cost elements:

3.1.2.1 Contractor purchased parts and equipment for production

3.1.2.2 Contractor subcontracted production items

3.1.2.3 Contractor production material.

Table III column headed QUESTIONNAIRE CROSS REFERENCE is marked with an Asterisk (*) to indicate the use of the fiber optic industry Delphi Questionnaire found in Appendix D of this thesis.

The process of data collection through the use of a Delphi Questionnaire is iterative. Cost data collected from an initial survey is expected to be distributed within a cost range for each cost element surveyed. The numerical spread of this initial cost estimate is dependent upon the:

(a) qualifications of the questionnaire respondent,

(b) number of respondents,

(c) availability of data,

(d) ambiguity inherent within the questionnaire,

(e) respondents' individual bias and interpretation of each applicable question.

An iterative process will be required to modify the questionnaire(s) as problem areas, such as widely distributed cost estimates for a specific element, are discovered. As survey cost data is collected, it can be anticipated that specific cost areas will require further investigation.

Due to the time limitations of this study, the two Delphi Questionnaires presented in this chapter have not been validated and are presented as an initial point of departure for subsequent questionnaire design efforts. A thorough questionnaire review is recommended prior to using these two questionnaires for industry surveys.

# V. SUMMARY, CONSIDERATIONS, FINDINGS AND RECOMMENDATIONS

## A. SUMMARY

The purpose of this study was to develop an appropriate life cycle cost model for the A-7 ALOFT economic analysis to assist in determining whether further development of an airborne fiber optic data transfer system is warrented and can be justified. Because of the nature of the development decision, and the current conceptual phase of the A-7 ALOFT project, a comparative or differential cost model consisting of twenty-eight cost elements was defined (see Figure 13). The differential model was developed by a systematic element-by-element analysis, displayed within Appendix A, which preceded from the general TRI-TAC cost model of Figure 10. This analysis additionally identified a total fiber optic life cycle cost model as defined in Figure 12 for future budgetary purposed. In view of the planned iterative nature of the A-7 economic analysis, assumptions and considerations were specified in some detail throughout the analysis to ensure a systematic approach and traceability of results.

Estimating relationships for the differential cost model elements were next sought. While the nature and results of this search will be discussed in the next section, the unavailability of data and infant state of the fiber optic technology suggested that industrial surveys of some type would be required. To design such surveys and provide a

direct cost comparison of the two alternatives, the fiber optic life cycle cost model was structured in Chapter III to express fiber optic life cycle costs as a multiple of the identical coaxial cable life cycle cost elements. A first estimation of the relative cost coefficients was prepared by the authors, based on fiber optic characteristics and the probable impact of such characteristics on the associated cost element in Table II. The above scheme is quite simple, and general, yet provides the analysis, and the analyst, a means to directly compare identical functions in two different technologies. Uncertainty in assigning the multiple, alerts the analyst to those elements where uncertainty exists or additional information is needed. Last but not least, structuring the problem in this manner permits cost comparisons of a new technology based on costs developed in a known technology.

Twenty-eight differential cost elements for coaxial cable specified in Figure 13 are redefined in Table IV where:

a. $R_{it}$ = cost of the R&D elements,
$i=1 \ldots 6,\ t=1 \ldots 10$

b. $I_{jt}$ = non-recurring investment costs,
$j=1 \ldots 9,\ t=1 \ldots 10$

c. $D_{kt}$ = recurring investment costs,
$k=1 \ldots 8,\ t=1 \ldots 10$

and d. $O_{lt}$ = operational/support costs,
$l=1 \ldots 5,\ t=1 \ldots 10$

then the coaxial cable life cycle costs are:

## LCC ELEMENT SUBSTITUTION

Let: $R_{1t}$ = Coaxial cable cost of LCC element 1.2.1.1 in year t.

$R_{2t}$ = Coaxial cable cost of LCC element 1.2.1.4 in year t.

$R_{3t}$ = Coaxial cable cost of LCC element 1.2.1.5 in year t.

$R_{4t}$ = Coaxial cable cost of LCC element 1.2.1.8 in year t.

$R_{5t}$ = Coaxial cable cost of LCC element 1.2.1.10 in year t.

$R_{6t}$ = Coaxial cable cost of LCC element 1.2.2.3 in year t.

Let: $I_{1t}$ = Coaxial cable cost of LCC element 2.1.3.4 in year t.

$I_{2t}$ = Coaxial cable cost of LCC element 2.1.4 in year t.

$I_{3t}$ = Coaxial cable cost of LCC element 2.1.5 in year t.

$I_{4t}$ = Coaxial cable cost of LCC element 2.1.12 in year t.

$I_{5t}$ = Coaxial cable cost of LCC element 2.1.6.3.2 in year t.

$I_{6t}$ = Coaxial cable cost of LCC element 2.1.10 in year t.

$I_{7t}$ = Coaxial cable cost of LCC element 2.2.2.2 in year t.

$I_{8t}$ = Coaxial cable cost of LCC element 2.2.2.3.2 in year t.

$I_{9t}$ = Coaxial cable cost of LCC element 2.2.2.3.3 in year t.

Let: $D_{1t}$ = Coaxial cable cost of LCC element 3.1.1 in year t.

$D_{2t}$ = Coaxial cable cost of LCC element 3.1.2.1 in year t.

$D_{3t}$ = Coaxial cable cost of LCC element 3.1.2.2 in year t.

$D_{4t}$ = Coaxial cable cost of LCC element 3.1.2.3 in year t.

$D_{5t}$ = Coaxial cable cost of LCC element 3.1.3 in year t.

$D_{6t}$ = Coaxial cable cost of LCC element 3.1.6.2 in year t.

$D_{7t}$ = Coaxial cable cost of LCC element 3.1.6.3 in year t.

$D_{8t}$ = Coaxial cable cost of LCC element 3.1.8 in year t.

Table IV

Table IV (continued)

Let: $O_{1t}$ = Coaxial cable cost of LCC element 4.1.6 in year t.

$O_{2t}$ = Coaxial cable cost of LCC element 4.2.1.1.1 in year t.

$O_{3t}$ = Coaxial cable cost of LCC element 4.2.1.3 in year t.

$O_{4t}$ = Coaxial cable cost of LCC element 4.2.2.3 in year t.

$O_{5t}$ = Coaxial cable cost of LCC element 4.2.2.4.1 in year t.

$$C = \sum_{t=1}^{10} n_t \left( \sum_{i=1}^{6} R_{it} + \sum_{j=1}^{9} I_{jt} + \sum_{k=1}^{8} D_{kt} + \sum_{l=1}^{5} O_{lt} \right)$$

where $n_t$ = the discount factor for year t, t = 1 ... 10.

If the substitution, $R^*_{it} = A_{it} R_{it}$ $i=1 \ldots 6,\ t=1 \ldots 10$

represents the Research and Development cost elements for fiber optics expressed as a multiple of the identical coaxial cable cost element

where $$A_{it} = \frac{R^*_{it}}{R_{it}}$$

and similar substitutions are made for the recurring, non-recurring and operational support categories, then the differential fiber optic life cycle cost can be specified as:

$$C^* = \sum_{t=1}^{10} n_t \left( \sum_{i=1}^{6} A_{it} R_{it} + \sum_{j=1}^{9} A_{jt} I_{jt} + \sum_{k=1}^{8} A_{kt} D_{kt} + \right.$$

$$\left. + \sum_{l=1}^{5} A_{lt} O_{lt} \right)$$

where $n_t$ is the discount factor for year t. Differential costs as utilized herein are costs which differ between the alternatives as defined in Chapter I; and should not be confused with incremental costs or the difference between the life cycle costs of the alternatives used by some authors.

The $R_{it}$, $I_{jt}$, $D_{kt}$, and $O_{lt}$ represent differential cost element coaxial cable life cycle costs which will be calculated by a contractor for the A-7 ALOFT Economic

Analysis. Calculation of differential fiber optic life cycle costs will, therefore, depend on developing reliable estimates of the appropriate $A_{it}$, $A_{jt}$, and $A_{kt}$ relative cost coefficients. The $A_{lt}$ relative cost coefficients need not be estimated since explicit cost estimating relationships (CER) are available for the $O_{lt}$ costs. Chapter IV contains the development of explicit CER's for these operating and support cost categories and for their non-recurring investment costs, $I_{3t}$, $I_{8t}$, and $I_{9t}$. With these exceptions, and for reasons specified under Considerations, the remaining cost categories and the relative cost coefficients will require an industrial survey. Delphi Surveys, structured to identify the required $A_{it}$, $A_{jt}$, and $A_{kt}$ relative cost coefficients, are developed in Appendices C and D for use in a follow-on study.

## B. CONSIDERATIONS

### 1. Data Availability

Information and cost data needed to develop aircraft data transfer system and fiber optic cable and component costs is currently unavailable. Reference 44 outlined the fiber optic costing problem and recommended an industrial experience curve approach for projecting possible fiber optic material costs. This study placed major emphasis on the development of an A-7 ALOFT LCC model, the identification of relevant costs, and how to estimate them. Despite an extensive literature search and library review, little

published information was found. Discussions with knowledgeable government and non-government personnel in the electrical interconnect field revealed that cost is not a primary consideration on developing electrical systems, and that aircraft manufacturers are the primary source of any information which exists.

There are two major reasons for this situation. First, the aircraft manufacturers have a virtual monopoly on aircraft electrical engineering knowledge and technology because they are the sole practitioners. This has resulted, possibly for proprietary reasons, in little published data concerning the field in general (only two text books were located (59) and (62) both English and both dated) and aircraft systems in particular. Second, aircraft manufacturers have historically not aggregated costs at the electrical interconnect subsystem level.

Aircraft electrical system costs have primarily been aggregated within airframe costs, and airframe costs have historically been aggregated in functional categories such as Engineering, Manufacturing, Tooling, etc.(38) The lack of published electrical interconnect system cost-data, precludes either an analysis of interconnect system cost relationships, or the development of cost estimating relationships for fiber optic systems based on them. This lack of historical data also requires a reliance on analagous cost estimating methods to develop comparative fiber optic costs. The extremely limited published information on the

subject of aircraft electrical engineering practice supports this thesis. "The electrical design engineer often finds himself with requirements to electrically interconnect numerous avionic systems and associated equipment panels and boxes often structural design is firm, armament designated, hydraulic routing completed and cooling and heating installed."(56) "It must be emphasized that system selection is not, or is ever likely to be, a precise science. It cannot be determined by mathematical methods alone, since final selection is controlled by many aspects both technical and practical. Intuition and experience are the most valuable tools of the designer (electrical systems), and are never more useful than in assessing the best system arrange-for a particular aircraft."(59)

In summary, there is very little published information on how electrical systems are developed, their historical costs, how such costs are established or the retrievability of such costs. This information apparently exists only within the corporate memories of airframe manufacturing firms. For example, a value engineering estimate for an A-7E type electrical interconnect syste, (Figure 15) was provided the authors. Although the basis and accuracy of this estimate is unknown, the relative size of the various cost categories is of interst and the ability of LTV to develop such estimates demonstrates the feasibility of an industrial survey approach.

## A-7E Type Electrical System

(Value Engineering Estimate Only)

| | |
|---|---|
| Non-Recurring Costs | |
| Engineering Development, etc. | 3.2 M |
| Non-Recurring Costs | |
| Tooling and Manufacturing, etc. | 3.0 M |
| Recurring Costs | |
| Material | 50.0 K |
| Labor and other | 109.0 K |
| Total | 6.359 M |

Source: LTV Aircraft Company Personnel

Figure 15

### 2. Model Development

For the above reasons, the emphasis of this study has been to structure a cost model to support an industrial survey approach using analogous type cost estimating techniques.

*Military Equipment Cost Analysis* by the Rand Corporation indicates: "Because a private concern generally has information only on its own products, much of the estimating in industry is based on anology, particularily when a firm is venturing into a new area."(52) Figure 16 displays the A-7 ALOFT differential cost model as developed in this study, including relative cost coefficients estimated by the authors in Chapter III. The relative cost coefficients were estimated by the authors on the basis of fiber optic characteristics, program assumptions, the state of the A-7 ALOFT development, etc., and the anticipated affect of such factors on the particular cost element. Note that a range of values were established for each relative cost coefficient displayed and that the relative cost coefficient is considered in this display as a constant in respect to time.

That is: $A_i = A_{it}$, $A_j = A_{jt}$, $A_k = A_{kt}$

for all t, $t = 1 \ldots 10$.

The formulation of the model in this manner is to facilitate the relative comparison of costs at the level of aggregation desired in order to simplify industrial survey techniques needed to develop comparitive costs during the

FIBER OPTIC LIFE CYCLE COST =
TEN-YEAR DISCOUNTED SUM OF THE FOLLOWING COST ELEMENTS:

*NOTE: parenthesis before the $R_{it}$, $I_{jt}$, and $D_{kt}$ repre represent the range of the $A_{it}$, $A_{jt}$, and $A_{kt}$ estimated in Table II.

+ (1.0 - ?) $R_{1t}$
+ (1.0 - ?) $R_{2t}$
+ (1.0 - ?) $R_{3t}$
+ (1.0 - 2.0) $R_{4t}$ (Research & Development Costs)
+ (1.0 - 1.8) $R_{5t}$
+ (1.0 - 1.8) $R_{6t}$

\+

+ (1.2 - 1.8) $I_{1t}$
+ (0.6 - 1.0) $I_{2t}$
+ $I_{3t}$
+ (0.9 - 1.0) $I_{4t}$
+ (1.2 - 2.0) $I_{5t}$ (Non-Recurring Investment Costs)
+ (1.2 - 1.8) $I_{6t}$
+ (2.0 - 3.5) $I_{7t}$
+ $I_{8t}$
+ $I_{9t}$

\+

Figure 16

Figure 16 (continued)

$+ (\ .8 - 2,0)\ D_{1t}$

$+ (\ .8 - 2.0)\ D_{2t}$

$+ (\ .8 - 2.0)\ D_{3t}$

$+ (\ .8 - 2.0)\ D_{4t}$ (Recurring Investment Costs)

$+ (0.7 - 0.9)\ D_{5t}$

$+ (0.7 - 1.0)\ D_{6t}$

$+ (0.85 - 1.0)\ D_{7t}$

$+ (0.9 - 1.0)\ D_{8t}$

$+$

$O_1 + O_2 + O_3 + O_4 + O_5$ (Operational/Support Costs)

program's conceptual phase. For example, it seems more practical and reasonable to ask an expert in tooling to compare and assess differences in total tooling costs of the fiber optic/coaxial cable alternatives, rather than the annual estimates of such costs. While it is conceptually more appealing to treat the relative value coefficients as a variable with time, because of the time phasing of the costs, the resultant benefits of such a procedure must be weighed against the more complicated estimation process which will result. In addition, the relative value coefficients may indeed be constants, or essentially so, for the period under consideration; and industrial estimating practice may suggest that annual estimates are feasible and desired. In either case, the cost model should be structured to facilitate the survey techniques by utilizing methods of aggregation, which best suit the industrial estimation process and the model's purpose.

The purpose of this model is to compare relevant fiber optic/coaxial cable life cycle costs. Because the knowledge, information, and historical data needed to develop such cost estimates resides in the aircraft and fiber optic industries, the model was structured to support analogous estimates utilizing industrial surveys. The nature of this problem is identical to many state-of-the-art costing problems during the conceptual stage of development. That is parametric methods are not available, engineering design approaches are time consuming, costly, and potentially biased; and industrial

analogous estimating approaches are too often unreliable due to the limited data bases upon which they are developed.

The A-7 ALOFT LCC model was structured to take advantage of: industrial familiarity with analogous estimating techniques, expert opinion, estimation, and comparison at well defined levels of aggregation; and survey methods to develop statistically significant sample sizes. The use of relative cost coefficients allow the problem to be disaggregated into various levels of expertise and direct functional/material comparisons so that a final estimate can be synthesized from a number of independantly provided industrial/government estimates. Delphi surveys to develop the required $A_i$, $A_j$, and $A_k$ relative cost coefficients for the A-7 ALOFT model are developed in Appendices C and D. An initial survey of all aircraft manufacturers and firms interested in the aircraft data transfer application is envisioned, with subsequent surveys based on initial results and statistical analysis. This iterative survey approach will provide the means to limit and identify areas of costing uncertainty, and should provide a more reliable fiber optic data transfer system cost estimate based on a multiple firm industrial sample.

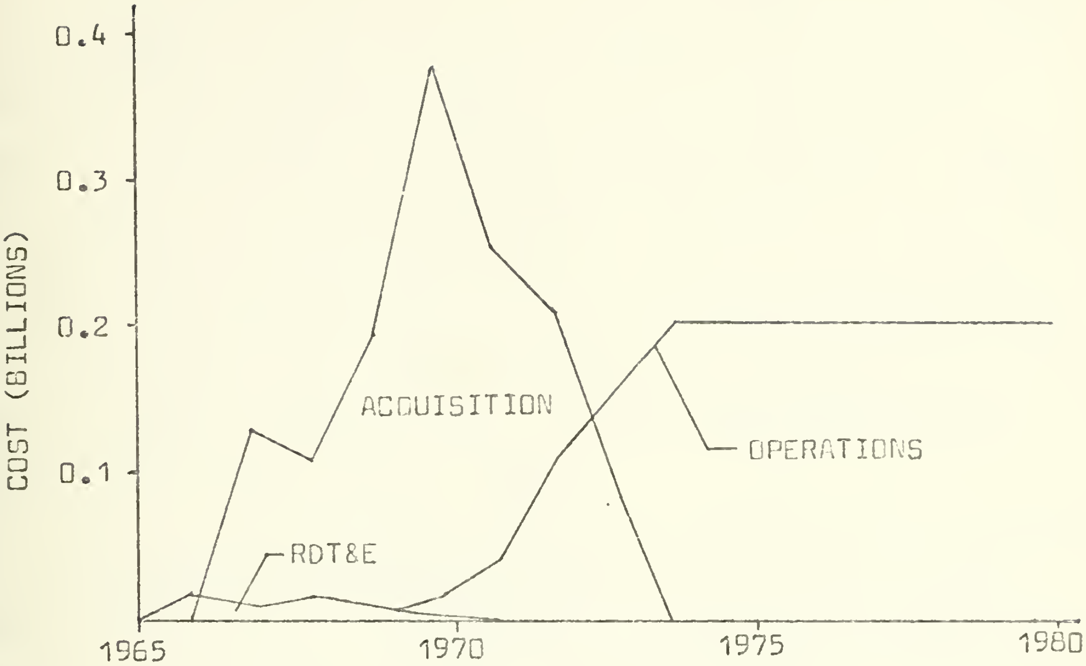
### 3. An A Priori Cost Estimate

While the actual cost quantification of the A-7 ALOFT fiber optic date transfer system will be developed by a follow-on effort, it is pertinent to consider what can be summarized at this stage of the economic analysis.

If one views the fiber optic life cycle cost model (see Figure 16) in broad perspective, and considers the relative cost coefficients, a direct comparison between fiber optic and coaxial cable cost elements is displayed within the four cost categories. In addition, Figure 17 displays the ten year life cycle cost curves for the A-7D to illustrate the distribution and timing of a major systems cost.

a. Research and Development Costs: Historically, development costs have represented a small percentage of total life cycle costs at least for major systems like the A-7D. Because of the state of fiber optic development, and the state of fiber optic experience within the airframe industry, a greater development cost for fiber optics can be anticipated for the A-7 ALOFT application. However, because of less restrictive design characteristics and reductions in testing which can be anticipated as fiber optic experience grows, future development costs for this application or development costs of a full vice subsystem application would be expected to be greatly reduced. In any respect, the authors' uncertainty in projecting relative cost coefficients for these cost elements points to the need for greater investigation in this area and expert opinion.

b. Non-Recurring Investment Costs: Historically, investment or acquisition costs have been the decisive factor in making system decisions. Acquisition costs for major systems have represented approximately 45 to 47 percent of the LCC



A-7D LIFE CYCLE COSTS

SOURCES: RDT&E - Senate Hearings 1966-1973
ACQUISITION - Senate Hearings 1966-1973
OPERATIONS - AFM 173-10 1973

Cumulative LCC After 10 Years of Operations

| | Billions | Percent |
|---|---|---|
| RDT&E | $0.584 | 2.0 |
| ACQUISITION | 1.332 | 45.6 |
| OPERATIONS | 1.528 | 52.4 |
| | $3.444 | 100.0 |

Figure 17

after 10 years of operations. As can be seen from Figure 16, neither candidate system clearly dominates the non-recurring investment cost category and costs vary from element to element. Intuitively the coaxial cable alternative should have lower non-recurring investment costs due to the state of that technology and the fact that introduction of fiber optic technology will require additional investment in areas such as training, spares, etc., where equivalent coaxial cable capabilities already exists.

c. Recurring Investment Costs: Historically, the major recurring investment or acquisition costs for electrical interconnect systems have been labor intensive. In the A-7E value estimate the ratio of labor/overhead costs: direct material costs were 105K:50K. The ratio for an F-4N is estimated to be 65K:35K. The alternative fiber optic or coaxial cable systems will significantly reduce future labor related production costs because of the order of magnitude reductions in the number of cables to be installed. Tables V and VI display the comparitive costs of the present A-7 ALOFT wire interconnect system and its fiber optic replacement, which are about equal if multiplexing/demultiplexing costs are ignored. In sum, fiber optic/coaxial cable systems will cost more than present wire systems, at least initially, and these costs will be more material than labor related.

Emphasis has been placed on developing projections of future fiber optic costs. Although the need to develop such estimates is not underestimated, the significance of

## A-7 ALOFT FIBER OPTIC CABLES AND CONNECTORS

| COMPONENT | TYPE | R'QRD QNTY | $COST/UNIT | TOTAL COST | UNIT WT | TOTAL |
|---|---|---|---|---|---|---|
| Fiber Optic Cable | Valtec |  |  |  |  |  |
|  | (IBM P/N L20-262-1) | 224 ft | $2.50/ft | 560.00 | 1.3 lbs/100 ft | 2.91 |
|  | *Valtec (P/N L20-262-2) | 224 ft | 2.00/ft | 448.00 | .68 lbs/100 ft | 1.52 |
| Single Channel Bulkhead Connectors | IBM (P/N L20-242) | 13 ea | 2.50 ea | 32.50 | .0297 lbs ea | 0.38 |
| Single Channel Pressure Bulkhead Connectors | NELC (P/N 6507) | 5 ea | 3.50 ea | 17.50 | .0499 lbs ea | 0.25 |
| Multi-Channel Bulkhead (rack-panel) Connector | ITT Cannon (P/N DBK-4B) | 1 ea | ***294.05 | 294.05 | .559 lbs ea | 0.55 |
| Cost of Terminating, Polishing & Testing Final Harness | Labor | 12 hrs | 20.00 hr | 240.00 |  |  |
| Cost/Weight Totals |  |  |  | $1,592.05 |  | 5.61 |

NOTES: * The first listed fiber optic cable was the cable selected by IBM for their delivery of the ALOFT system. The second listed cable is the alternative set of cables being procured by NELC in time for the Flight Test. The new cable has the same optical properties, but utilizes a new lightweight, non-conductive hytrel (c) jacket in lieu of the PVC jacketed, steel Monocoil (c) for protective packaging.

** Total reflect weight and cost of newer Valtec cable.

*** $500.00 set-up.

Table V

A-7 ALOFT DISPLACED WIRES AND CONNECTORS*

| COMPONENT | TYPE | R'QRD QNTY | $COST/UNIT | TOTAL COST | UNIT WT | TOTAL WT |
|---|---|---|---|---|---|---|
| Coaxial Cable | RG-179B/V | 222 ft | $ .1045/ft | 23.20 | .0170 lbs/ft | 3.77 lbs |
| Wire, Unshielded | M22754/16-22 | 222 ft | .0228/ft | 5.06 | .00368 lbs/ft | 0.82 lbs |
| Wire, Shielded | M17500A22/TE1T14 | 456 ft | .0882/ft | 40.22 | .0088 lbs/ft | 4.01 lbs |
| 2 Wires, Shielded | M27500A22/TE2T14 | 192 ft | .1405/ft | 26.98 | .0169 lbs/ft | 3.24 lbs |
| 3 Wires, Shielded | M27500A22/TE3T14 | 24ft | .1700/ft | 4.08 | .0206 lbs/ft | .49 lbs |
| Wire, 2 Shields | M27500A22/TE1V14 | 543 ft | .1285/ft | 69.74 | .0188 lbs/ft | 10.21 lbs |
| 2 Wires, 2 Shields | M27500A22/TE2V14 | 231 ft | .2314/ft | 53.44 | .0319 lbs/ft | 7.37 lbs |
| Connector, Receptacle (212 Contacts) | CVC6092 - IN | 2 ea* | 30.79 ea | 61.58 | .72 lbs ea | 1.44 lbs |
| Connector, Receptacle (212 Contacts) | CVC6093 - IN | 2 ea* | 32.81 ea | 65.62 | .64 lbs ea | 1.28 lbs |
| Cost of Terminating Above and Testing Final Harness | Labor | 42 hrs | 20.00/hr | 840.00 |  | 2.00 lbs** |
| Cost/Weight Totals |  |  |  | $1,189.92 |  | 34.63 lbs |

NOTES: * These connectors are not actually replaced by the ALOFT components, but an approximately equal no. of contacts (424) are idle in the subsystems involved after ALOFT modification. In actuality these 424 signal contacts are normally distributed over 9 of these types of connectors along with power wires in the original computer interface configuration.

** This additional approximate weight is generated by the termination, potting and harnessing materials.

Table VI

material costs on both production costs and life cycle costs should also be understood. For example, cost comparisons of coaxial cable/fiber optic systems for the A-7 Aloft analysis prepared in NELC TD435 suggest that coaxial cable systems that perform equal functions are cheaper, lighter, and require less power. This may be. However, it should be recognized that these systems also represent different capabilities in terms of weight, volume, maintainability, reliability and supportability, all of which affect LCC and cost-benefit tradeoffs. A most important consideration is that present fiber optic material costs probably represent an upper bound which can be expected to decrease with time. However, on a relative comparison basis, the coaxial cable alternative will probably be cost advantageous from a production standpoint for some time into the future.

d. Operational and Support Costs: Historically, operational and support costs represent a major percentage of total life cycle costs. Operational and support costs are highly dependent on the reliability and maintainability of a system:

Maintainability: From an interconnect viewpoint, both alternatives will enhance maintainability since fewer cables are involved when compared with today's typical wire system. This reduced "look factor" is of major importance in corrective maintenance actions and the fiber optic alternative which has essentially a go/no go built in test capability should provide significant fault isolation

advantages over coaxial cable. Since the multiplexing equipment added, will affect both alternatives in a like manner, the maintainability of the system will largely depend on the fault isolation capability and the interconnect system reliability.

Reliability: Reliability measures the system's ability to perform without failure. Since all the advantages of a fiber optic data transfer system are shortcomings of coaxial cable systems, enhanced reliability is probable, despite the addition of additional components to the system such as LEDs and photo diodes. Coaxial cable system problems such as shorts, connector pin problems, cold flow, and parallel path resistance changes are eliminated in the fiber optic alternative.

Although reliability studies and tests are needed to evaluate fiber optic data system reliability, and unforeseen problems are certain to occur, the fiber optic alternative would appear simpler, more maintainable and reliable a system; and thus offer operational and support cost advantages.

In summary, the above rather intuitive but structured a priori cost analysis would suggest that the coaxial cable alternative will be developed and produced at lesser cost than an identical function fiber optic system during the FY 77-80 timeperiod, but that subsequent fiber optic operations and support costs will be less. This consideration emphasizes the need to closely evaluate the reliability

and maintainability of the fiber optic system during the A-7 ALOFT demonstration. It also suggests that analysis results may be biased by the limited size of the systems under consideration, because of the following considerations.

### 4. System Size Assumptions

The limited data transfer system assumed for this analysis may unrealistically bias results against the fiber optic alternative for several reasons. First, maintenance people will need to be trained in fiber optics; and fiber optic related support established at numerous locations regardless of the size of the system developed. However, the size of the system installed has important operational implications on the survivability, maintainability and weight/volume, payload/range benefits. The size of the system installed also has important design implications in that x pounds of equipment weight can translate into 4x to 7x pounds of aircraft weight.(62) It is also interesting to consider the implication on the demand for fiber optic cable and components.

The authors have asked: How much of an aircraft's installed electrical system could be replaced by fiber optics? The answers have varied between 50 - 90 percent, which appear reasonable when the distribution of designed current carrying capacity is considered. An F-4 aircraft has approximately 12 miles of installed wire, a Vickers Viscount approximately 17 miles,(59) and the Supersonic Concorde 150 miles.(47)

If 50 percent of an F-4's wiring is replaced (35,000 ft.) and 7 foot cable size assumed, 500 cables will be replaced. If the same A-7 ALOFT ratio of wire length to: fiber optic length is assumed, (1890:224) 4,147 feet of fiber optic cable will be required. For a fleet of 4200 F-4 aircraft, this would represent a fiber optic production requirement of approximately 17.5 million feet. Although this simple demand analysis was presented to emphasize the implications of a subsystem assumption, an extended analysis based on additional data could do much to scope potential aircraft demand. Such an analysis, combined with the experience curve techniques of reference 44, could provide a reasonable range of fiber optic aircraft system costs.

### 5. Risk and Uncertainty

Last, but not a least consideration is the question of risk and uncertainty. Table VII illustrates the cost estimating problem and the uncertainty found in early cost estimates as developed by the Electronics X Study. To offset costing uncertainty, the model developed by the authors was structured to develop a simple comparative estimating technique to direct consideration to the essential cost elements, maximize the reliability of expert and analogous estimates; and by industrial survey techniques, develop statistically significant results. Program risk is a second major area that has potentially significant cost growth programs. Table VIII also selected from the Electronics X Study,(24 and 25) is a series of questions

COST-ESTIMATING "KNOWNS" AND "UNKNOWNS" AT VARIOUS STAGES IN THE ACQUISITION PROCESS, ESTIMATING TECHNIQUES, AND PROBABLE ACCURACY.

| | ESTIMATING "KNOWNS" | ESTIMATING "UNKNOWNS" | ESTIMATING TECHNIQUES | PROBABLE ACCURACY OF ESTIMATE |
|---|---|---|---|---|
| Cost estimating at program initiation | 1. Conceptual configuration<br>2. Analog description of system<br>3. General approach to concept verification | 1. Ultimate program or product description<br>2. Ultimate performance<br>3. Ultimate technological problem areas (unknown "unknowns")<br>4. Ultimate producibility<br>5. Development program plan<br>6. Production quantities or rate<br>7. Reliability or maintainability<br>8. Future economic condition,<br>9. Future business conditions | 1. Analog estimates<br>2. Parametric estimate<br>3. Expert opinion | 1. Expected underestimate of 100 percent with a standard deviation of 150 percent |
| Cost estimating at DSARC II | 1. Prototype configuration<br>2. Specified performance "envelope"<br>3. Specified development schedule<br>4. Areas of anticipated risk (known "unknowns")<br>5. Estimated development program plan | 1. Performance deviations technical, reliability, maintainability<br>2. Test success<br>3. Technology growth rate<br>4. Engineering changes<br>5. Economic changes<br>6. Business base changes<br>7. Schedule changes<br>8. Producibility<br>9. Unknown "unknowns" | 1. Engineering estimates<br>2. Analogy estimates<br>3. Parametric estimates<br>4. Expert opinion | 1. Expected underestimate of 80% with a standard deviation of 100 percent |
| Cost estimating at DSARC III | 1. System configuration<br>2. Production process<br>3. Production prototype reliability and maintainability | 1. Economic changes<br>2. Business base changes<br>3. Product configuration changes<br>4. Future production rate<br>5. Producibility in high rate production<br>6. Operational reliability and maintainability<br>7. True cost of operations | 1. Engineering estimates<br>2. Analogy estimates<br>3. CER's and LCC models<br>4. Expert opinion | 1. Expected underestimate of 50 percent with a standard deviation of 35 percent<br>2. Operating and maintenance cost |
| Cost estimating at reprocurement | 1. Equipment/system configuration<br>2. Production process<br>3. Procurement cost of previous buy<br>4. Reported reliability and maintainability | 1. Economic changes (direct and indirect costs)<br>2. Business base changes (indirect costs)<br>3. Ability of competitors to produce an acceptable product<br>4. Production rate and quantity changes<br>5. True cost of operations (equipment and personnel)<br>6. Support changes | 1. Engineering estimates (production)<br>2. Analogy estimates (production and operation)<br>3. Expert opinion (business and economic forecasting) | 1. Production cost -- expected underestimate of 25 percent with a standard deviation of 7 percent<br>2. Operating and maintenance cost |

Table VII

# QUESTIONS TO BE ANSWERED ABOUT FIBER OPTIC SYSTEMS AND SUBSYSTEMS DURING MANAGMENT REVIEW

| | Optical Data Bus (High Risk) | A-7 ALOFT (Low Risk) |
|---|---|---|
| * What components exists? | Most | All |
| * What components need new development? | Optical Couplers | None |
| * What is the development/test status of existing components? | Laboratory | Developed, Produced & Tested |
| * Are new technologies involved? If so, which and what is their status? | Yes<br>Experimental | No |
| * Have the components previously been integrated into a subsystem? | Yes | Yes |
| * If so, has it been operated outside the laboratory? | No | Yes |
| * Has there been subsystem OT&E? | No | A-7 ALOFT Demonstration |
| * How do results compare with requirements? | - | " |
| * What are the specific interface problems with other subsystems? | Multiple | Interface Module Milspec. Qualification |
| * What are the cost, performance, and schedule implications of of resolving those problems in this new development? | R&D Implications Only | Minor if full scale development is undertaken |
| * What are the opions if there is excess cost growth? | | |
| a) Alternative components/subsystems? | Yes | Coax/Wire |
| b) Let cost grow? | Yes | Yes |
| c) Reduce performance requirement? | - | No |
| d) Reduce force? | - | - |
| e) Find another way to do the job? | Yes | Yes |

Table VIII

designed to develop in an uncomplicated straight-forward manner the degree of risk involved in a proposed development. Although the questions were designed to synthesize and reflect requirement and uncertainty problems of major electronics subsystems, their application to this analysis is evident. If successful accomplishment of the A-7 ALOFT demonstration is assumed, the point-to-point data transfer system represented by the ALOFT Project can be considered Low-Risk while a fiber optic Data Bus System would be High-Risk. The above techniques, and the development and use of structured scenarios outlined in reference 44, are the major methods recommended to assess and evaluate risk in the A-7 ALOFT economic analysis.

## C. FINDINGS AND RECOMMENDATIONS.

### 1. Findings

#### a. Life Cycle Costs

The development of reliable life cycle cost estimates by which to compare alternative systems in the early stages of a program, is a major cost estimating problem of today. Unfortunately, despite analytical interest and effort, few new tools, techniques, or concepts have evolved.

#### b. Data Availability

The aircraft and fiber optic industries represent the primary source of information and expertise needed to develop reliable life cycle costs for the A-7 economic analysis; due to the unavailability of parametric techniques or industrial cost data and information.

c. Cost Estimating Uncertainty

Due to the unavailability of historical cost data, the conceptual phase of the A-7 ALOFT project, and the required reliance on industrial analogous estimating techniques; the costing uncertainty is potentially high. (Reference Table VII.)

e. Model Assumptions and Results

The assumption of only a N/WDS application as defined for the A-7 Aloft LCC effort may unfavorably bias the cost benefit analysis against the fiber optic alternative by: limiting design, operational, support, and economies of scale advantages; while requiring essentially full training and support costs for a subsystem operation. See discussion in CONSIDERATIONS.

f. Projected Fiber Optic Material Costs

Time did not permit this study an extensive analysis of potential demand for fiber optic components and cable by the aircraft industry. The possibility of applying simple analogous estimating techniques to scope such a demand is discussed under CONSIDERATIONS. Such an effort combined with the experience curve techniques suggested in reference 44 could provide reasonable projections of the range of fiber optic costs.

g. A-7 ALOFT Life Cycle Cost Model

The A-7 ALOFT differential LCC model developed within this study was designed to utilize available data and estimating techniques, to identify and minimize costing

uncertainty, while providing side-by-side cost comparisons of the alternatives at levels of aggregation selected/ designed to facilitate industrial estimation. Assuming adequate survey response and reasonable survey, results, reliable cost estimates should result.

h. Opportunity Costs

Most life cycle cost models do not explicitly address opportunity costs. In view of the conceptual development decision to be made, and the equal function but unequal reliability alternative specified; an opportunity cost element is required. (Reference Appendix B cost element 4.1.6.)

2. Recommendations

Findings a, b, c and d above suggested that new methods and means should be sought to develop an appropriate LCC model. The step-by-step analytical process developed to identify, classify and quantify the A-7 ALOFT model is completely general and can be applied to any program. In addition, the relative value scheme developed, in conjunction with Delphi Survey Techniques, can provide statistically significant industrial samples upon which to base cost estimates and identify major problem areas and uncertainties. In view of these findings, and the continuing nature of the A-7 ALOFT economic analysis, the following is recommended:

a. In conjunction with selected industrial sources, refine and initiate the initial Delphi survey, and collect the data necessary to scope fiber optic component demand.

b. Develop and maintain a government best estimate of the relative fiber optic/coax cable costs to support continuing economic analysis efforts and decisionmaking.

c. Develop reliability/maintainability estimates for each alternative system at the earliest practical time, in order to better assess the nature of operational and support costs for each.

d. Prior to the cost benefit analysis, specify a development, production, and operations profile for the A-7 ALOFT program based on current fleet operations and practice, with which to scope and develop total force life cycle cost estimates for the A-7 ALOFT configuration.

This study has addressed a cost model structured to meet the peculiar circumstances and nature of the A-7 ALOFT cost problem. However, the process by which it was developed can provide a straight forward simple means to address future cost problems of a similarly complex nature. For this reason, both the cost and accuracy of this approach should be evaluated throughout the economic analysis to determine its cost effectiveness.

# APPENDIX A: COST ELEMENT IDENTITY

1.1.1

1.0 Research and Development
  1.1 Concept and Validation
    1.1.1 Contractor

(X) Total
( ) Differential
( ) Excluded

## DESCRIPTION

The cost of any Concept Initiation and Validation work that may be performed under the contract.

## RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

Application of a new technology would necessarily require concept studies and validation. The determining factor for total inclusion of this cost element was the extent and depth of present data available from either contractor efforts or Government research. (See also cost element 1.1.2) (Assumption 1).

1.0 Research and Development
  1.1 Concept and Validation
    1.1.2 Government

(X) Total
( ) Differential
( ) Excluded

DESCRIPTION

The cost of any Concept Initiation and Validation work that may be performed by the Government.

RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

Application of a new technology would necessarily require concept studies and validation. The work level addressed by this cost element would possibly be affected by the contractor work convered by cost element 1.1.1. However, the level of effort applied to either fiber optics or coax would be similar. (Assumption 1.)

1.0 Research and Development
  1.2 Full Scale Development
    1.2.1 Contractor
      1.2.1.1 Program management

(X) Total
( ) Differential
( ) Excluded

DESCRIPTION

This element refers to the technical and administrative planning, organizing, directing, coordinating, controlling, and approval actions designed to accomplish overall program objectives during the R&D phase of the equipment life cycle. Examples of these activities are configuration management, cost/schedule management, data management, contract management, liaison, value engineering, quality assurance and integrated logistic support management.

RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

This element will be included in the total life cycle cost model only, because proper management of any program is essential. Depending upon the type of work, size of the contractor and the type of contract, this cost may just be included in the general category of overhead, regardless of the contractors effort, fiber optics or coax technology, this is a cost element applicable to both technologies.

1.0 Research and Development
  1.2 Full Scale Development
    1.2.1 Contractor
      1.2.1.2 Engineering

(X) Total
(X) Differential
( ) Excluded

DESCRIPTION

This element refers to all engineering efforts associated with the system/equipment design and development. Specifically, this includes the cost of systems engineering and integration, design engineering (electrical, mechanical, drafting, etc.), design support (reliability, maintainability, human factors engineering and safety, value engineering, microelectronics), and the redesign or formulation of engineering changes. It includes the cost of direct labor, materials, overhead and other direct costs which must be incurred during the engineering process. The development of computer software is included herein as well as the cost of computer time. The engineering effort associated with peculiar support and test equipment is contained in 1.2.1.8.

RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

Engineering during a Research and Development program is of primary importance to the final product. The development and application of a new technology is predominantly an engineering effort. It is anticipated that engineering costs

associated with fiber optic cable will be less than that engineering cost associated with copper cable. This is expected because of the predominately fewer restrictions placed on the allowable locations of fiber optic cables within an aircraft. This theory cannot be tested until a thorough Research and Development program has been executed.

1.0 Research and Development
  1.2 Full Scale Development
    1.2.1 Contractor
      1.2.1.3 Fabrication

(X) Total
( ) Differential
( ) Excluded

## DESCRIPTION

This element refers to the fabrication and assembly of full scale development models in support of the engineering design activity. Specifically, this includes the cost of direct labor, materials and overhead associated with material procurement and handling, tooling and test equipment in support of manufacturing, fabrication, assembly, system integration and checkout.

## RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

Fabrication of prototype units is a prerequisite to effective test and evaluation. The integration of fiber optic cable into present copper cable signal carrying systems is dependent upon successful testing of prototype units. This effort would be required of both fiber optic and copper cable systems, and would therefore be a total life cycle cost element.

1.0 Research and Development
  1.2 Full Scale Development
    1.2.1 Contractor
      1.2.1.4 Contractor Development Tests (CDT)

(X) Total
(X) Differential
( ) Excluded

## DESCRIPTION

These tests are generally conducted on one or more prototype full scale development models at the contractor's facility to demonstrate that design specifications related to performance, control, maintenance, safety, maintainability, reliability, and human factors are satisfied. This cost element includes the cost of direct labor, materials, overhead and other direct charges required to perform CDT.

## RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

In anticipation of reducing future fiber optic technology testing, specifically operational test and evaluation prior to final production, the fiber optic cable development tests will be extensive in scope.* This cost element coupled with cost element 1.2.1.5 will identify the associated costs. The Government will also actively participate in the Research and Development phase test. (See cost element 1.2.2.3.)

* The rationale is that once proven, fiber optic cable installation would not require any additional testing for RFI/EMI/NOISE immunity and other electrical cable problems.

1.0 Research and Development
  1.2 Full Scale Development
    1.2.1 Contractor
      1.2.1.5 Test Support

(X) Total
(X) Differential
( ) Excluded

## DESCRIPTION

This element includes those costs which are incurred in support of Government testing (DTE/IOTE). It may include the cost of site activation, consulting services, training, spare parts, maintenance, testing and/or the transportation of equipment and contractor testing personnel to the test site.

## RATIONALE FOR INCLUSION/EXCLUSION IN MODEL

This cost element is required to include the contractor incurred costs associated with the Research and Development test program. (See cost elements 1.2.1.4 and 1.2.2.3.) The cost associated with fiber optic cable testing is expected to be a larger percentage of copper cable testing due to the extended scope of fiber optic testing conducted during the initial Research and Development test.

1.0 Research and Development
  1.2 Full Scale Development
    1.2.1 Contractor
      1.2.1.1 Producibility Engineering and Planning (PEP)

(X) Total
( ) Differential
( ) Excluded

DESCRIPTION

PEP cosists of those planning and engineering tasks undertaken during the development phase to insure the timely and economic producibility of a component/item prior to release for production. PEP tasks consist of the following type activities: develop technical data packages, design special purpose production equipment and tooling, computer modeling/ simulation, engineering drawings, engineering, manufacturing and quality support information, dimensional and tolerance data, manufacture assembly sequences, wiring diagrams, material and finishing information, inspection, test and evaluation requirements, calibration information and quality control data.

RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

This cost element is mandatory to insure a smooth transition from the Research and Development phase to production. This effort will be monitored by the Government through the Production Acceptance and Evaluation program. Regardless of the technology incorporated, fiber optics or coax, there is

a certain cost identified during the transition period from Research and Development to Production. (See cost element 2.2.3.)

1.0 Research and Development
  1.2 Full Scale Development
    1.2.1 Contractor
      1.2.1.7 Data
        1.2.1.7.1 Engineering Data

(X) Total
( ) Differential
( ) Excluded

## DESCRIPTION

The engineering data element refers to those engineering drawings, associated lists, specifications, and other documentation required by the Government. This element includes all plans, procedures, reports and documentation pertaining to systems, subsystems, component engineering, and testing.

## RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

This cost element is required in order to obtain all necessary engineering data. Any engineering data that is developed after the Research and Development phase will be included in cost element 2.1.7.1. The cost of data collection and documentation would be independent of the technology being investigated.

1.0 Research and Development
  1.2 Full Scale Development
    1.2.1 Contractor
      1.2.1.7 Data
        1.2.1.7.2 Support Data

(X) Total
( ) Differential
( ) Excluded

## DESCRIPTION

The support data element refers to those data items required by the Government to develop and acquire the Support System. This included maintenance data, provisioning data and lists, support and test equipment data and lists, logistic support plans and progress reports, technical publications requirements data, training planning data and transportation and handling data, etc.

## RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

This cost element is required in order to obtain all necessary support data. Any support data that is developed after the Research and Development phase will be included in cost element 2.1.7.2. The cost associated with data collection identified within this cost element would be similar for both fiber optic and coax technology.

1.0 Research and Development
  1.2 Full Scale Development
    1.2.1 Contractor
      1.2.1.7 Data
        1.2.1.7.3 Management data

(X) Total
( ) Differential
( ) Excluded

## DESCRIPTION

The management data element refers to those data items necessary for configuration management, cost, schedule, contractual data mangement, programs management, etc., required by the Government.

## RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

This cost element is required in order to obtain all necessary management data. Any management data that is developed after the Research and Development phase will be included in cost element 2.1.7.3. Fiber optic and coax technology would both have similar costs associated with them.

1.0 Research and Development
  1.2 Full Scale Development
    1.2.1 Contractor
      1.2.1.7 Data
        1.2.1.7.4 Technical Orders and Manuals

(X) Total
( ) Differential
( ) Excluded

DESCRIPTION

This element refers to those handbooks, technical manuals, technical orders, technical data sheets, etc. required by the Government.

RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

This cost element is required in order to obtain all necessary technical orders and manuals. Any system or equipment changes that occur after the Research and Development phase will be incorporated in technical orders and manuals covered under cost element 2.1.7.4. Even though fiber optics is a newer technology than coax, the costs associated with technical manuals would be the same.

1.0 Research and Development
  1.2 Full Scale Development
    1.2.1 Contractor
      1.2.1.8 Peculiar Support and Test Equipment

(X) Total
(X) Differential
( ) Excluded

DESCRIPTION

Peculiar support equipment is that equipment, including tools, required to maintain and care for the system or portions of the system while not directly engage in the performance of its mission, and which have application peculiar to a given defense material item. It includes, for example, vehicles, equipment and tools used to service, transport and hoist, repair, overhaul, assemble, disassemble, test, inspect, or otherwise maintain the mission equipment. This cost element includes the cost of direct labor, materials, overhead and other direct charges required in the design development and test of the peculiar support equipment.

RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

Fiber optic cable, once installed, will not require any special maintenance other than routine PMS checks. This does not eliminate the need for development of peculiar support and test equipment. There will be equipment developed that is compatible with the other fiber optic technology. (See cost elements 2.1.3.4 and 2.1.10.)

1.0 Research and Development
  1.2 Full Scale Development
    1.2.1 Contractor
      1.2.1.9 Other

( ) Total
( ) Differential
(X) Excluded

DESCRIPTION

This element includes all costs incurred by the contractor during full scale development not included in the previously listed elements.

RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

The Research and Development costs associated with both fiber optic and copper cable technology should be quantifiable and directly assessable to a specific cost element. Neither technology in so complex nor filled with unknowns that additional Research and Development cost elements would be identified.

1.0 Research and Development
  1.2 Full Scale Development
    1.2.1 Contractor
      1.2.1.10 General and Administrative (G&A)

(X) Total
(X) Differential
( ) Excluded

## DESCRIPTION

G&A includes the expenses of a contractor's general and executive offices, the cost of staff services such as legal, accounting, public relations, financial, and similar expenses and other miscellaneous expenses related to the overall business. Included are directors' and executive committee members' fees, bonuses and incentive awards, employee stock portions, and employee fringe benefits.

## RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

General and Administrative (G&A) costs are associated with every contractor. This is another portion of the contractors overhead expense but would be different for both fiber optic and coax research. Overhead is normally a fixed percentage of a contractors direct costs and a fiber optic Research and Development program would probably be more costly than a simular effort involving coax technology.

1.0 Research and Development
  1.2 Full Scale Development
    1.2.1 Contractor
      1.2.1.11 Fee

(X) Total
( ) Differential
( ) Excluded

DESCRIPTION

Fee is that portion of the total contract price which is allowed a contractor over and above the cost to produce or perform.

RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

With the exception of a non-profit organization or educational institution, the contractor is expected to earn a fee. That fee would be the same regardless of the technology being researched. Since the fee earned would be quite similar for both technologies it would be improper to include it is the differential cost model. (Assumption 1.)

1.0 Research and Development
  1.2 Full Scale Development
    1.2.2 Government
      1.2.2.1 Program Management

(X) Total
( ) Differential
( ) Excluded

DESCRIPTION

This element refers to the technical and administrative planning, organizing, directing, coordinating, controlling, and approval actions designed to accomplish overall program objectives during the R&D phase of the equipment life cycle. Examples of these activities are configuration managment, cost/schedule management, data management, contract management, liaison, value engineering, quality assurance and integrated logistic support management.

RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

Successful Government programs require a dedicated program management effort. This effort will be in addition to the contractor's program management includes as cost element 1.2.1.1. The Government cost to manage either a fiber optic or coax technology Research and Development program would be simular.

1.0 Research and Development
  1.2 Full Scale Development
    1.2.2 Government
      1.2.2.2 Test Site Activation

(X) Total
( ) Differential
( ) Excluded

DESCRIPTION

This element refers to the costs incurred to prepare a test site for Government Testing. It includes the cost of transportation of equipment and testing personnel to the test site. The cost of direct labor, material, overhead and other direct charges is also included.

RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

This cost element must be included so that all Government costs associated with the Research and Development test program are identified. This cost element should be simular for both the fiber optic tests and for copper cable tests.

1.0 Research and Development
  1.2 Full Scale Development
    1.2.2 Government
      1.2.2.3 Government Tests (DTE/IOTE)

(X) Total
(X) Differential
( ) Excluded

DESCRIPTION

The Development Test and Evaluation (DTE) is designed to determine and/or verify technical performance and safety characteristics of an item, associated tools, and test equipment. It is conducted to: demonstrate that the engineering design and development process is complete; demonstrate that the design risks have been minimized; demonstrate that the system will meet specifications; and estimate the system's utility when introduced. Initial Operational Test and Evaluation (IOTE) is that portion of Operational Test and Evaluation performed during the FSD Phase prior to a production decision. The objectives are to provide information at the production decision point as to the system/equipment military use, expected operational effectiveness and operational suitability. This cost element includes the cost of direct labor, materials, overhead and other direct charges incurred in the conduct of DTE/IOTE. It also includes any Government costs in preparing test requirements, plans and procedures.

## RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

Test and Evaluation of fiber optic technology will be emphasized during the Research and Development phase. It is expected that thorough testing at this time will reduce or totally eliminate the need for operational test and evaluation prior to the final production phase. (See cost elements 1.2.1.4 and 1.2.1.5.)

1.0 Research and Development
  1.2 Full Scale Development
    1.2.2 Government
      1.2.2.4 Government Furnished Equipment (GFE)

( ) Total
( ) Differential
(X) Excluded

## DESCRIPTION

This is the effective cost to the Government of GFE supplied to the contractor during the full scale development phase of the equipment life cycle. Equipment loaned to a contractor and later returned to the Government in good condition may result in zero cost for this element if the cost of lost utility for the loaned equipment can be considered negligible.

## RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

The only anticipated Government Furnished Equipment will be included in cost element 2.2.2.2, training devices and equipment. A contractor would be expected to either develop or sub-contract for all necessary equipment.

1.0 Research and Development
  1.2 Full Scale Development
    1.2.2 Government
      1.2.2.5 Other

( ) Total
( ) Differential
(X) Excluded

DESCRIPTION

This element includes any cost incurred by the Government during full scale development which is not included in the previous elements.

RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

The costs associated with both fiber optic and copper cable technology should be quantifiable and directly assessable to a specific cost element. Since the Governments involvement with the Research and Development would be predominately managerial, all cost elements would have been previously identified.

2.0 Investment (Non-Recurring)
  2.1 Contractor
    2.1.1 Program Management

(X) Total
( ) Differential
( ) Excluded

DESCRIPTION

This element refers to the technical and administrative planning, organizing, directing, coordinating, controlling, and approval actions designed to accomplish overall program objectives during the investment phase of the equipment life cycle. Examples of these activities are configuration management, cost/schedule management, data management, contract management, liaison, value engineering, quality assurance and integrated logistic support management.

RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

Proper management is an essential ingredient in a successful program. This cost will normally be included as a portion of contractor overhead. A parallel management effort may be on-going within the Government. (See cost element 2.2.1.)

2.0 Investment (Non-Recurring)
  2.1 Contractor
    2.1.2 Producibility Engineering and Planning (PEP)

( ) Total
( ) Differential
(X) Excluded

DESCRIPTION

If PEP is not accounted for during the development phase (1.2.1.6) it shall be accounted for here. PEP consists of those planning and engineering tasks undertaken to insure the timely and economic producibility of a component/item prior to release for production. PEP tasks consist of the following type activities: develop technical data packages, design special purpose production equipment and tooling, computer modeling/simulation, engineering drawings, engineering, manufacturing and quality support information, dimensional and tolerance data, manufacture assembly sequences, wiring diagrams, material and finishing information, inspection, test and evaluation requirements, calibration information and quality control data.

RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

Producibility Engineering and Planning (PEP) was identified and accounted for under the major category of Research and Development, cost element 1.2.1.6. The assumption was made that the Research and Development contractor would follow-on into the Production phase.

2.0 Investment (Non-Recurring)
  2.1 Contractor
    2.1.3 Initial Production Facilities
      2.1.3.1 Production Engineering

(X) Total
( ) Differential
( ) Excluded

DESCRIPTION

This cost element includes that engineering necessary to translate the technical data package into a production line and also minor changes or fixes to the technical data package.

RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

Production Engineering is the activity which helps insure a smooth transition from the development phase into final production. A required activity in order to finalize the programs production decision. Both fiber optic technology and coax technology would require a similar level of effort for the transition.

2.0 Investment (Non-Recurring)
  2.1 Contractor
    2.1.3 Initial Production Facilities
      2.1.3.2 Tooling

( ) Total
( ) Differential
(X) Excluded

## DESCRIPTION

This element includes the costs incurred for the fabrication, assembly, installation, modification, and rework of all tools required for equipment assembly. It further includes the costs of dies, jigs, fixtures, gauges, handling equipment, and work platforms.

## RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

It is anticipated that because of the physical simularities between fiber optic cable and copper cable there will be no special tooling required for installation or handling.

2.0 Investment (Non-Recurring)
  2.1 Contractor
    2.1.3 Initial Production Facilities
      2.1.3.3 Industrial Facilities

( ) Total
( ) Differential
(X) Excluded

DESCRIPTION

The industrial facilities element refers to the construction, conversion, or expansion of facilities for production. This includes real property acquisition or modernization where applicable. The cost of direct labor, material, overhead and other direct charges incurred in the actual set up of the final production line is also included here.

RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

The installation of fiber optic cable in place of copper would not require a contractor to convert or expand his facilities. Those physical characteristics of fiber optic cable which would require production planning are similar to the physical characteristics of copper cable.

2.0 Investment (Non-Recurring)
  2.1 Contractor
    2.1.3 Initial Production Facilities
      2.1.3.4 Manufacturing Support Equipment

(X) Total
(X) Differential
( ) Excluded

## DESCRIPTION

Manufacturing support equipment is that required in the manufacture and testing of the equipment being produced. Any special test devices, circuit checkout equipment, automatic machines, test assemblies, etc. are accounted for under this element. This element includes not only the cost of material, but the cost of the labor required to produce the support equipment.

## RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

The present methods of checking for cable continuity will not be applicable to fiber optic cable. A new procedure will be required to send and receive a light signal in place of the conventional electrical signal continuity checks.

2.0 Investment (Non-Recurring)
  2.1 Contractor
    2.1.4 Technical Support

(X) Total
(X) Differential
( ) Excluded

DESCRIPTION

This element includes the cost of any contractor technical support required by the Government during the investment phase of the equipment life cycle. An example would be contractor support during Government conducted Production Acceptance Test and Evaluation (PATE) and Operational Test and Evaluation (OTE).

RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

Fiber optic cable does not possess the troublesome electrical properties inherent in copper cable, e.g., electro-magnetic interference (EMI), electrical ground problems, signal cross-talk. It is anticipated that no further testing will be required after testing is successfully completed during the Research and Development phase. (See cost element 1.2.1.4 and 1.2.1.5.)

2.0 Investment (Non-Recurring)
  2.1 Contractor
    2.1.5 Initial Spares and Repair Parts

(X) Total
(X) Differential
( ) Excluded

## DESCRIPTION

The initial spares and repair parts element refers to the modules, spare components, and assemblies used for replacement purposes in major end items of equipment which are a part of the initial procurement. These initial spares and repair parts are separately costed, and are in addition to parts procured annually to replace initial spares or repair parts used for maintaining the equipment (4.2.2.3).

## RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

During the period of time the standard supply system is building its inventory of either fiber optic or copper cable components, initial spares will be required to support any new system. However, the fiber optic equipments or systems would require support peculiar to itself. Peculiar items would be fiber optic transmitting and receiving modules, connectors and the fiber optic cable itself.

2.0 Investment (Non-Recurring)
  2.1 Contractor
    2.1.6 Initial Training
      2.1.6.1 Training Facilities

( ) Total
( ) Differential
(X) Excluded

## DESCRIPTION

This element includes the cost incurred in construction and general provisioning of special facilities for training. It accounts for only those facilities required by the system/ equipment under consideration.

## RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

The similarities between copper signal carriers and fiber optic cable preclude the necessity for special training facilities. Since Navy school facilities presently exist, any training unique to fiber optic technology would be directly incorporated into the existing facilities. (See cost element 2.2.2.1.)

2.0 Investment (Non-Recurring)
  2.1 Contractor
    2.1.6 Initial Training
      2.1.6.2 Training Devices and Equipment

( ) Total
( ) Differential
(X) Excluded

## DESCRIPTION

This is the cost of any special training devices and equipment. This cost is a one time cost for the special equipment required in the training of operators and maintenance personnel. The cost of vugraphs, charts, test papers, and supplies is included under this element. Mission equipment used for training is covered as a recurring cost.

## RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

It is anticipated that training devices required for initial operator and maintenance training will be furnished by the Government and included in cost element 2.2.2.2.

2.0 Investment (Non-Recurring)
  2.1 Contractor
    2.1.6 Initial Training
      2.1.6.3 Initial Student Training
        2.1.6.3.1 Operator Training

( ) Total
( ) Differential
(X) Excluded

DESCRIPTION

This element represents the cost of training operators for the equipment.

RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

There will be no requirements for contractor supported operator training. Fiber optic cable used in place of copper cable will not cause any need to train operators. An operator is not primarily concerned with the method of signal transmission beyond that which can be learned through a short self study course. (See cost element 2.2.2.2.)

2.0 Investment (Non-Recurring)
  2.1 Contractor
    2.1.6 Initial Training
      2.1.6.3 Initial Student Training
        2.1.6.3.2 Maintenance Training

(X) Total
(X) Differential
( ) Excluded

DESCRIPTION

This element represents the cost of training maintenance personnel for the equipment.

RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

Initial training of selected Navy maintenance personnel, both military and civilian, would be required to insure a smooth transition from contractor system or equipment support to full Navy support. The depth of training would be dependent upon the technology being taught. Fiber optic technology would require more instruction time than coax technology.

2.0 Investment (Non-Recurring)
  2.1 Contractor
    2.1.6 Initial Training
      2.1.6.3 Initial Student Training
        2.1.6.3.3 Instructor Training

(X) Total
( ) Differential
( ) Excluded

DESCRIPTION

This element represents the cost of training instructor personnel.

RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

The initial maintenance personnel training conducted by the contractor will utilize contractors' experienced personnel to augment the specially trained contractor instructors. (Assumption 3.)

2.0 Investment (Non-Recurring)
  2.1 Contractor
    2.1.7 Data
      2.1.7.1 Engineering Data

(X) Total
( ) Differential
( ) Excluded

DESCRIPTION

The engineering data element refers to those engineering drawings, associated lists, specifications, and other documentation required by the Government. This element includes all plans, procedures, reports and documentation pertaining to systems, subsystems, and components engineering and testing.

RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

This cost element is required to obtain all engineering data not obtained during the Research and Development phase under cost element 1.2.1.7.1.

2.0 Investment (Non-Recurring)
  2.1 Contractor
    2.1.7 Data
      2.1.7.2 Support Data

(X) Total
( ) Differential
( ) Excluded

DESCRIPTION

The support data element refers to those data items required by the Government to develop and acquire the Support System. This includes maintenance data, provisioning data and lists, support and test equipment data and lists, logistic support plans and progress reports, technical publications requirements data, training planning data and transportation and handling data, etc.

RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

This cost element is required to obtain all support data not obtained during the Research and Development phase under cost element 1.2.1.7.2.

2.0 Investment (Non-Recurring)
  2.1 Contractor
    2.1.7 Data
      2.1.7.3 Management Data

(X) Total
( ) Differential
( ) Excluded

## DESCRIPTION

The management data element refers to those data items necessary for configuration management, cost, schedule, contractual data management, programs management, etc., required by the Government.

## RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

This cost element is required to obtain all management data not obtained during the Research and Development phase under cost element 1.2.1.7.3.

2.0 Investment (Non-Recurring)
  2.1 Contractor
    2.1.7 Data
      2.1.7.4 Technical Orders and Manuals

(X) Total
( ) Differential
( ) Excluded

## DESCRIPTION

This element refers to those handbooks, technical manuals, technical orders, technical data sheets, etc. required by the Government.

## RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

This cost element is required to obtain technical orders and manuals not obtained during the Research and Development phase under cost element 1.2.1.7.4.

2.0 Investment (Non-Recurring)
  2.1 Contractor
    2.1.8 Leaseholds

( ) Total
( ) Differential
(X) Excluded

## DESCRIPTION

This element includes the costs for leasing special or peculiar equipment, devices, communications circuits, or material to be used during the production of the equipment.

## RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

Since there is nothing unique or peculiar about the physical characteristics of fiber optic cable, there would be no requirements for special equipment during the production phase.

2.0 Investment (Non-Recurring)
  2.1 Contractor
    2.1.9 Common Support Equipment

( ) Total
( ) Differential
(X) Excluded

## DESCRIPTION

The common support equipment element refers to the equipment, including tools, required to maintain and care for the system or portions of the system while not directly engaged in the performance of its mission, and which are presently in the DoD inventroy for support of other systems. This element includes all effort required to assure availability of this equipment for support of the particular defense material item. It also includes the acquisition of additional quantities of these equipments if caused by the introduction of the defense material item into operational service.

## RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

Fiber optic cable, once installed, will not require any special maintenance other than routine PMS checks. Contractor equipment required for routine checks was identified under cost element 2.1.10.

2.0 Investment (Non-Recurring)
  2.1 Contractor
    2.1.10 Peculiar Support and Test Equipment

(X) Total
(X) Differential
( ) Excluded

DESCRIPTION

Peculiar support equipment is that equipment, including tools, required to maintain and care for the system or portions of the system while not directly engaged in the performance of its mission, and which have application peculiar to a given defense material item. It includes, for example, vehicles, equipment, and tools used to service, transport and hoist, repair, overhaul, assemble, disassemble, test, inspect, or otherwise maintain the mission equipment. This cost element includes the cost of direct labor, materials, overhead and other direct charges required in the production of the peculiar support and test equipment.

RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

Fiber optic cable, once installed, will not require any special maintenance other than routine PMS checks. The PMS checks and routine maintenance will require special equipment. This support equipment was developed under cost element 1.2.1.8.

2.0 Investment (Non-Recurring)
  2.1 Contractor
    2.1.11 Other

( ) Total
( ) Differential
(X) Excluded

DESCRIPTION

This element includes any contractor incurred non-recurring investment costs not contained in the previous cost elements.

RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

The costs associated with both fiber optic and copper cable technology should be quantifiable and directly assessable to a specific cost element.

2.0 Investment (Non-Recurring)
  2.1 Contractor
    2.1.12 General and Administrative (G&A)

(X) Total
(X) Differential
( ) Excluded

## DESCRIPTION

G&A includes the expenses of a contractor's general and executive offices, the cost of staff services such as legal, accounting, public relations, financial, and similar expenses and other miscellaneous expenses related to the overall business. Included are directors' and executive committee member's fees, bonuses and incentive awards, employee stock options, and employee fringe benefits.

## RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

General and Administrative (G&A) costs are associated with every contractor. This is another portion of the contractor's overhead expense but would be different for both fiber optic and coax efforts since overhead is normally a fixed percentage of a contractor's direct costs. An anticipated savings in the use of fiber optic technology would be reflected in this cost element.

2.0 Investment (Non-Recurring)
  2.1 Contractor
    2.1.13 Fee or Profit

(X) Total
( ) Differential
( ) Excluded

DESCRIPTION

Fee is that portion of the total contract price which is allowed a contractor over and above the cost to produce or perform.

RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

With the exception of a non-profit organization or education institution, the contractor is expected to earn a fee or make a profit. That fee or profit would be the same regardless of the technology being researched. Since the fee earned would be quite similar for both technologies it would be improper to include it in the differential model. (Assumption 1.)

2.0 Investment (Non-Recurring)
  2.2 Government
    2.2.1 Program Management

(X) Total
( ) Differential
( ) Excluded

## DESCRIPTION

This element refers to the technical and administrative planning, organizing, directing, coordinating, controlling, and approval actions designed to accomplish overall program objectives during the investment phase of the equipment life cycle. Examples of these activities are configuration management, cost/schedule management, data management, contract management, liaison, value engineering, quality assurance and itegrated logistic support management.

## RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

Successful Government programs require a dedicated program management effort. This effort will be in addition to the contractor's program management included in cost element 2.1.1.

2.0 Investment (Non-Recurring)
  2.2 Government
    2.2.2 Initial Training
      2.2.2.1 Training Facilities

( ) Total
( ) Differential
(X) Excluded

## DESCRIPTION

This element incudes the cost incurred in construction and general provisioning of special facilities for training. It accounts for only those facilities required by the system/equipments under consideration.

## RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

It is anticipated that all training required to introduce the fiber optic technology into the fleet would be conducted at presently existing Navy Training facilities. Any cost incurred to phase-in this fiber optic training will be included in cost elements 2.2.2.2 and 2.2.2.3.3. (See cost element 2.1.6.1.)

2.0 Investment (Non-Recurring)
  2.2 Government
    2.2.2 Initial Training
      2.2.2.2 Training Devices and Equipment

(X) Total
(X) Differential
( ) Excluded

## DESCRIPTION

This is the cost of any special training devices and equipment. This cost is a one time cost for the special equipment required in the training of operators and maintenance personnel. The cost of vugraphs, charts, test papers, and supplies are included under this element. Mission equipment used for training is covered as a recurring cost.

## RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

This cost element will include the cost of modifying present Navy class A/B/C school courses as applicable to include the new fiber optic technology. Development of a self-teaching guide to introduce fiber optics to operator personnel will be included here. (See cost element 2.1.6.3.1.)

2.0 Investment (Non-Recurring)
  2.2 Government
    2.2.2 Initial Training
      2.2.2.3 Initial Student Training
        2.2.2.3.1 Operator Training

( ) Total
( ) Differential
(X) Excluded

DESCRIPTION

This element represents the cost of training operators for the equipment.

RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

The replacement of copper cable with fiber optic cable will not introduce a need for operator training. A basic overview of the use of fiber optics can be accomplished by the use of operator self-teaching guides developed under cost element 2.2.2.2.

2.0 Investment (Non-Recurring)
  2.2 Government
    2.2.2 Initial Training
      2.2.2.3 Initial Student Training
        2.2.2.3.2 Maintenance Training

(X) Total
(X) Differential
( ) Excluded

## DESCRIPTION

This element represents the cost of training maintenance personnel for the equipment.

## RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

The contractor will be tasked to train an initial group of selected Navy maintenance personnel under cost element 2.1.6.3.2. The level of required training will vary for both fiber optic and coax technology. Fiber optic technology would be introduced as a new technology, while coax technology would build upon a Navy technicians' present knowledge of coax. (Assumption 3 and 4.)

2.0 Investment (Non-Recurring)
  2.2 Government
    2.2.2 Initial Training
      2.2.2.3 Initial Student Training
        2.2.2.3.3 Instructor Training

(X) Total
(X) Differential
( ) Excluded

DESCRIPTION

This element represents the cost of training instructor personnel.

RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

During the training by the contractor under cost element 2.1.6.3.2, a few select Navy school instructors will also attend the classes. This will allow the new fiber optic technology to be incorporated into existing formal Navy school training. The training of Navy instructors in fiber optic technology would require more time than a similar task associated with coax technology. (Assumption 4.)

2.0 Investment (Non-Recurring)
  2.2 Government
    2.2.3 Production Acceptance Test and Evaluation (PATE)

(X) Total
( ) Differential
( ) Excluded

DESCRIPTION

The production acceptance tests are conducted on production items produced early in the production run (generally identified as the "initial production run"). The tests are designed to insure that the production systems and equipment conform to design specifications and performance requirements when manufactured in accordance with production specifications and quantity production processes. This cost element includes the cost of direct labor, materials, overhead and other direct charges incurred in the conduct of PATE.

RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

Production Acceptance Test and Evaluation (PATE) is required to insure a smooth transition from the Development phase to the Production phase. PATE is the Governments method of verifying the contractor's accuracy and completeness of his Producibility Engineering and Planning. This cost would be similar for either fiber optic or coax technology. (See cost element 1.2.1.6.)

2.0 Investment (Non-Recurring)
  2.2 Government
    2.2.4 Operational Test and Evaluation (OTE)

( ) Total
( ) Differential
(X) Excluded

DESCRIPTION

User Operational Tests and Evaluation (OTE) are tests generally conducted by user personnel (military unit(s)) under conditions of operational tactical environments. They are conducted to estimate the prospective system's military utility, operational effectiveness, and operational suitability (including compatibility, interoperability, reliability, maintainability, and logistic and training requirements), and need for any modifications. In addition, OTE provides information on organization, personnel requirements, doctrine, and tactics. Also it may provide data to support or verify material in operating instructions, publications, and handbooks. This element includes the cost of labor, material, overhead and other direct charges incurred in the conduct of OTE.

RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

Replacement of copper cable with fiber optic cable will not require additional operational test and evaluation beyond the testing accomplished during the Research and Development (R&D) phase. Testing accomplished during R&D will be the

determining factor when considering fiber optics for production use. Without sufficiently good results from the Research and Development tests, fiber optic technology would not be considered for production. (See cost element 1.2.2.3.)

2.0 Investment (Non-Recurring)
  2.2 Government
    2.2.5 Test Site Activation

( ) Total
( ) Differential
(X) Excluded

## DESCRIPTION

This element refers to the costs required to prepare test sites for OTE. This includes construction, conversion, expansion, modification, modernization and installation as required. The costs of direct labor, material, overhead and other direct charges are included.

## RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

The lack of a requirement for operational test and evaluation after the Research and Development phase (see cost element 2.2.4) precludes the need for a test site.

2.0 Investment (Non-Recurring)
  2.2 Government
    2.2.6 Government Furnished Equipment (GFE)

( ) Total
( ) Differential
(X) Excluded

## DESCRIPTION

This is the effective cost to the Government of GFE supplied to the contractor during the investment phase of the equipment life cycle. Equipment loaned to a contractor and later returned to the Government in good condition may result in zero cost for this element if the cost of lost utility for the loaned equipment can be considered negligible.

## RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

The only anticipated Government Furnished Equipment will be included in cost element 2.2.2.2, training devices and equipment.

2.0 Investment (Non-Recurring)
  2.2 Government
    2.2.7 Other

( ) Total
( ) Differential
(X) Excluded

DESCRIPTION

This element includes any Government incurred non-recurring investment cost not contained in the previous cost elements.

RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

The costs associated with both fiber optic and copper cable technology should be quantifiable and directly assessable to a specific cost element. There should be no areas of cost not previously identified as a cost element.

3.0 Investment (Recurring)
  3.1 Contractor
    3.1.1 Manufacturing

(X) Total
(X) Differential
( ) Excluded

DESCRIPTION

Manufacturing includes the direct labor, overhead and other direct charges incurred during the fabrication, processing, subassembly, final assembly, reworking, modification and installation of parts and equipment to an end item of equipment.

RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

This cost elements includes a large portion of the fiber optic or coax equipment costs. In addition to the costs identified in this cost element, the costs associated with elements 3.1.2.1, 3.1.2.2 and 3.1.2.3 form another large portion of the equipment cost.

3.0 Investment (Recurring)
  3.1 Contractor
    3.1.2 Production Material
      3.1.2.1 Purchased Equipment and Parts

(X) Total
(X) Differential
( ) Excluded

DESCRIPTION

This element includes the cost of manufactured and assembled items, usually procured from outside sources by the contractor. Purchased equipment usually costs in excess of $100 per unit and exhibits a wide range of complexity. It is usually termed off-the-shelf equipment and consists of, for example, batteries, motors, generators, air conditioning equipment, hydraulic pumps and instruments. Purchased parts are distinguished from purchased equipment by cost and complexity. Usually purchased parts cost under $100 per unit and are essentially standard, off-the-shelf hardware items.

RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

This cost element is included in order to identify all off-the-shelf items which are consumed in the production of the prime equipments or systems.

3.0 Investment (Recurring)
  3.1 Contractor
    3.1.2 Production Material
      3.1.2.2 Subcontractor Items

(X) Total
(X) Differential
( ) Excluded

DESCRIPTION

This element includes the cost of parts, components and assemblies produced by manufacturers other than the prime contractor in accordance with the prime contractor's designs, specifications or directions. It does not include equipment bought off-the-shelf. It does include the cost of transportation or shipment if itemized by the subcontractor.

RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

This cost element is included in order to identify all subcontractor produced items which are consumed in the production of the prime equipments or systems.

3.0 Investment (Recurring)
  3.1 Contractor
    3.1.2 Production Material
      3.1.2.3 Other Material

(X) Total
(X) Differential
( ) Excluded

## DESCRIPTION

This element includes all the raw and semifabricated material, intercompany transfers and other material used in the production of the equipment.

## RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

This cost element is included in order to identify all other materials produced or purchased for consumption in the production of the prime equipments or systems. Nearly all costs would have been identified and associated with a particular cost element. However, to ensure completeness this cost element is included.

3.0 Investment (Recurring)
  3.1. Contractor
    3.1.3 Sustaining Engineering

(X) Total
(X) Differential
( ) Excluded

## DESCRIPTION

All Engineering performed after quantity production starts is included in this element. This will include such items as maintainability-reliability engineering, maintnenace engineering, value engineering, and production engineering. It also includes redesign, evaluation, and other sustaining efforts of the engineering function.

## RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

Unless specifically rejected by a contractual agreement, sustaining engineering will be included as a portion the equipment or system life cycle cost. This is applicable to both fiber optic and copper cable systems. However, the anticipated benefits gained through the use of fiber optic cable in lieu of coax will probably reduce the cost of activities such as air craft modifications or field changes.

3.0 Investment (recurring)
  3.1 Contractor
    3.1.4 Quality Control and Inspection

(X) Total
( ) Differential
( ) Excluded

## DESCRIPTION

This includes such tasks as receiving inspection, in-process and final inspection of tools, parts, subassemblies and complete assemblies. Quality Control is that function of management relative to all procedures, inspections, examinations, and tests requied during procurement, production, receipt, storage, and issue that are necessary to provide the user with an item of the required quality.

## RATIONAL FOR INCLUSION/EXCLUSION IN COST MODEL

Quality control is an ever-continuing requirement to maximize the system or equipment quality. There would be little difference between fiber optic and coax technology quality control. The Government monitors this quality control and inspection effort continually. (See cost element 3.2.1.)

3.0 Investment (Recurring)
  3.1 Contractor
    3.1.5 Packaging and Transportation

(X) Total
( ) Differential
( ) Excluded

DESCRIPTION

This includes the costs associated with packing the article for shipment and transportation from the point of procurement production or testing to the first destination under contract.

RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

This cost element is included as a regular input to the total life cycle cost. At a minimum, the contractor will be required to provide packaging for equipment spare parts prior to shipment to the Navy for inclusion into the supply system.

3.0 Investment (Recurring)
  3.1 Contractor
    3.1.6 Operational/Site Activation
      3.1.6.1 Site Construction

( ) Total
( ) Differential
(X) Excluded

## DESCRIPTION

The site construction element refers to the real estate, site preparations, construction, and other special-purpose facilities necessary to achieve system operational status. This element also includes the construction of utilities, roads, and interconnecting cabling.

## RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

The use of fiber optic cable in lieu of copper cable will not generate a requirement for special-purpose facilities construction. Use of fiber optic technology would require working conditions very similar to those required by the use of coax technology.

3.0 Investment (Recurring)
3.1 Contractor
3.1.6 Operational/Site Activation
3.1.6.2 Site/Ship/Vehicle Conversion

(X) Total
(X) Differential
( ) Excluded

## DESCRIPTION

The site/ship/vehicle conversion element refers to all materials and services required to provide for the conversion/ modification of existing site/ship/vehicle to accomodate the mission equipment and selected support equipment directly related to the specific system.

## RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

If fiber optic cable is to be used in place of existing copper cable then there will be a conversion cost identified. Since the applications of fiber optic technology are few in number, any use of fiber optics, in the near future, would generate some level of conversion requirement and associated cost. Conversion to coax technology would have a cost associated with it but the fewer installation restrictions placed on fiber optic cable would make the conversion to fiber optic technology less costly.

3.0 Investment (Recurring)
  3.1 Contractor
    3.1.6 Operational/Site Activation
      3.1.6.3 Assembly, Installation and Checkout

(X) Total
(X) Differential
( ) Excluded

DESCRIPTION

This element refers to the materials and services involved in the assembly of mission and support equipment at the site. It includes the complete system checkout or shakedown to insure achievement of operational status.

RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

In conjunction with cost element 3.1.6.2, the contractor will be required to verify the system or equipment after his conversion work. It is anticipated that the fewer restrictions associated with fiber optic technology would make the cost less than a similar effort using coax technology.

3.0 Investment (Recurring)
  3.1 Contractor
    3.1.7 Other

( ) Total
( ) Differential
(X) Excluded

## DESCRIPTION

This cost element includes any contractor incurred recurring investment costs not contained in the previous cost elements.

## RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

The costs associated with both fiber optic and copper cable technology should be quantifiable and directly assessable to a specific cost element.

3.0 Investment (Recurring)
  3.1 Contractor
    3.1.8 General and Administrative (G&A)

(X) Total
(X) Differential
( ) Excluded

## DESCRIPTION

G&A includes the expenses of a contractor's general and executive offices, the cost of staff services such as legal, accounting, public relations, financial, and similar expenses and other miscellaneous expenses related to the overall business. Included are chairman's and executive committee members' fees, bonuses and incentive awards, employee stock options, and employee fringe benefits.

## RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

General and Administrative (G&A) costs are associated with every contractor. This is another portion of the contractor's overhead expense but would be different for both fiber optic and coax efforts since overhead is normally a fixed percentage of his direct costs. It is assumed that the direct costs of a task requiring fiber optic technology would be less than similar costs for coax technology.

3.0 Investment (Recurring)
  3.1 Contractor
    3.1.9 Fee or Profit

(X) Total
( ) Differential
( ) Excluded

DESCRIPTION

Fee is that portion of the total contract price which is allowed a contractor over and above the cost to produce or perform.

RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

With the exception of a non-profit organization or educational institution, the contractor is expected to earn a fee or make a profit. That fee or profit would be the same regardless of the technology being researched. Since the fee earned would be similar for both technologies it would be improper to include it in the differential model. (Assumption 1.)

3.0 Investment (Recurring)
  3.2 Government
    3.2.1 Quality Control and Inspection

(X) Total
( ) Differential
( ) Excluded

## DESCRIPTION

This element includes all Government quality control and inspection activities at the contractor's plant or at first destination.

## RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

The Government has an on-going program to monitor the contractor's quality control program (see Cost Element 3.1.4). This quality control is incorporated into all major contractual agreements and would be similar in scope for either fiber optic or coax technology.

3.0 Investment (Recurring)
  3.2 Government
    3.2.2 Sustaining Engineering

( ) Total
( ) Differential
(X) Excluded

## DESCRIPTION

All Government engineering performed after quantity production starts is included in this element. This will include such items as maintainability-reliability engineering, maintenance engineering, value engineering, and production engineering. It also includes the preparation, at depot level, for assuming the engineering function during the operating and support phase of the equipment life cycle.

## RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

The contractor is tasked under cost element 3.1.3 to perform sustaining engineering. The Government will follow the contractors efforts and be the recipient of the data obtained.

3.0 Investment (Recurring)
  3.2 Government
    3.2.3 Transportation

(X) Total
( ) Differential
( ) Excluded

## DESCRIPTION

This element includes all transportation, storage and handling costs of the prime mission equipment from the point of procurement, production or testing to the user.

## RATIONAL FOR INCLUSION/EXCLUSION IN COST MODEL

The contractor will provide handling and transportation to a predetermined position. If additional packing, transportation and storage is required than the Government will fund the additional cost through cost element 3.1.5.

3.0 Investment (Recurring)
  3.2 Government
    3.2.4 Operational/Site Activation
      3.2.4.1 Site Construction

( ) Total
( ) Differential
(X) Excluded

DESCRIPTION

The site construction element refers to the real estate, site preparation, construction, and other special-purpose facilities necessary to achieve system operational status. This element also includes the construction of utilities, road, and interconnecting cabling.

RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

The use of fiber optic cable in lieu of copper cable will not gererate a requirement for special-purpose facilities construction.

3.0 Investment (Recurring)
  3.2 Government
    3.2.4 Operational/Site Activation
      3.2.4.2 Site/Ship/Vehicle Conversion

( ) Total
( ) Differential
(X) Excluded

## DESCRIPTION

The site/ship/vehicle conversion element refers to all materials and services required to provide for the conversion/ modification of existing site/ship/vehicle to accomodate the mission equipment and selected support equipment directly related to the specific system.

## RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

Any conversion work will be a contractor effort and there will be no direct Government involvement. Government involvement would be in the form of management. (See cost element 3.1.6.2.)

3.0 Investment (Recurring)
  3.2 Government
    3.2.4 Operational/Site Activation
      3.2.4.3 Assembly, installation and Checkout

( ) Total
( ) Differential
(X) Excluded

## DESCRIPTION

This cost element refers to the materials and services involved in the assembly of mission and support equipment at the site. It includes complete system checkout or shakedown to insure achievement of operational status.

## RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

Since the Government will not be directly involved in conversion work, there will be no cause for direct involvement in system or equipment checkouts. (See cost element 3.1.6.3.)

3.0 Investment (Recurring)
  3.2 Government
    3.2.5 Technical Orders and Manuals

(X) Total
( ) Differential
( ) Excluded

DESCRIPTION

This element covers the cost of assembling and publishing technical manuals/orders and other documents shipped with the equipment.

RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

This cost will be required to finalize the technical orders and manuals received from the contractor during both the Research and Development phase and the Production phase under cost elements 1.2.1.7.4 and 2.1.7.4. There would be no difference in the cost of assembling and publishing either fiber optic or coax technology manuals.

3.0 Investment (Recurring)
  3.2 Government
    3.2.6 Government Furnished Material

( ) Total
( ) Differential
(X) Excluded

DESCRIPTION

This element includes the cost for any materials provided to a contractor for incorporation in the end article being procured. An example of such material misht be microcircuit chips for COMSEC equipment.

RATIONAL FOR INCLUSION/EXCLUSION IN COST MODEL

The only anticipated Government Furnished Material will be included in cost element 2.2.2.2, training devices and equipment.

3.0 Investment (Recurring)
  3.2 Government
    3.2.7 Other

( ) Total
( ) Differential
(X) Excluded

DESCRIPTION

This includes any Government recurring investment costs not included in the elements listed previously.

RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

The costs associated both fiber optic and copper cable technology should be quantifiable and directly assessable to a specific cost element. No costs other than those already identified can be anticipated at this time.

4.0 Operating and Support
  4.1 Operations
    4.1.1 Electrical Power

( ) Total
( ) Differential
(X) Excluded

## DESCRIPTION

The cost of electrical power is the cost of battery, generator, or commercially supplied power required for the operation of the equipment.

## RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

This cost is not applicable since power will be supplied to the equipments which will be interconnected by the fiber optic cables. There are no electrical power requirements for the fiber optic cable. Initial equipment or system design would account for any reduction in actual operating power requirements.

4.0 Operating and Support
  4.1 Operations
    4.1.2 Special Materials

( ) Total
( ) Differential
(X) Excluded

DESCRIPTION

This element covers the cost of materials consumed in the operation of the equipment. Examples of some typical items and materials are POL (petroleum, oil and lubricants), facsimile paper and paper rolls and paper tapes used with teletypewriter equipment.

RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

Fiber optic cables require no consumable material during their normal life time. This cost element is not included in the cost model since the only "consumable" materials are maintenance spare parts. Spare parts are included in cost element 4.2.2.3

4.0 Operating and Support
  4.1 Operations
    4.1.3 Operator Personnel

( ) Total
( ) Differential
(X) Excluded

DESCRIPTION

This cost element is the manpower cost, direct and indirect, this is incurred in operating the equipment. Included within the determination of manpower cost is not only the cost of the operator's pay and allowances, but also the miscellaneous expenses, support costs, incentive and special pay, and replacement training costs.

RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

Fiber optic cable requires no direct operator procedures. It is only a signal carrying medium between equipments and is totally a passive device.

4.0 Operating and Support
4.1 Operations
4.1.4 Operational Facilities

( ) Total
( ) Differential
(X) Excluded

DESCRIPTION

This element refers to the annual maintenance of facilities used to house prime mission equipment. This includes maintenance of real property where applicable. All direct labor, material, overhead and other direct charges are included.

RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

The fiber optic cables become an integral part of the structure which encloses and supports the basic equipment being interconnected. There can be no maintenance cost attributable to the fiber optic cable installed within.

4.0 Operating and Support
  4.1 Operations
    4.1.5 Equipment Leaseholds

( ) Total
( ) Differential
(X) Excluded

## DESCRIPTION

This element includes costs for leasing special or peculiar equipment, devices, communication circuits, or material during the operating life cycle phase of the equipment/system.

## RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

Since there is nothing unique or peculiar about the physical characteristics of fiber optic or coax cable, there would be no requirement for special equipment during the operating phase of equipments or systems.

4.0 Operating and Support
  4.1 Operations
    4.1.6 Other

(X) Total
(X) Differential
( ) Excluded

## DESCRIPTION

This element includes other operations costs not included previously. The following are examples of these possible costs:

- Operating Costs related to equipment shelters (i.e., heating and air conditioning);
- The cost of transportation of special material from Central Supply locations/depots to the user if not included in the cost of the special material;
- Transportation costs of the prime mission equipment for purpose of operation (i.e., training exercises, deployments, etc.). For mobile tactical equipment, this basically involves POL for transporting vehicles.
- Opportunity cost of a non-available (down) aircraft due to electrical cable problems.

## RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

Fibers optic technology is expected to increase equipment or system reliability. Therefore a constant cost per day (C) can be established as the opportunity cost of a down aircraft. This is the cost of not having the aircraft due to wiring problems and must be evaluated as both a total cost and a differential cost to determine the cost of unreliability.

4.0 Operating and Support
  4.2 Logistic Support
    4.2.1 Maintenance
      4.2.1.1 Personnel
        4.2.1.1.1 Organizational Maintenance Personnel

(X) Total
(X) Differential
( ) Excluded

## DESCRIPTION

This element includes that portion of the maintenance personnel costs associated with the organizational level of maintenance to include corrective and preventive maintenance. Organizational maintenance is that maintenance which is the responsibility of and performed by a using organization on its assigned equipment. Its phases normally consist of inspecting, servicing, lubricating, adjusting, and the replacement of parts, minor assemblies and sub-assemblies.

## RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

This cost element is included because it includes the routine PMS performed on the equipment or system and the system or equipment corrective maintenance. Maintenance must be performed regardless of whether the aircraft has fiber optic cable, copper cable or both, but it is anticipated that fewer maintenance actions would be required on fiber optic cable. (Assumption 6.)

4.0 Operating and Support
  4.2 Logistic Support
    4.2.1 Maintenance
      4.2.1.1 Personnel
        4.2.1.1.2 Intermediate Maintenance Personnel

(X) Total
( ) Differential
( ) Excluded

## DESCRIPTION

This element includes that portion of maintenance personnel costs associated with the intermediate level of maintenance. Intermediate maintenance is that maintenance which is the responsibility of and performed by designated maintenance activities for support of using organizations. Its phases normally consist of calibration, repair or replacement of damaged or unserviceable parts, components or assemblies; the manufacture of critical non-available parts; and providing technical assistance to using organizations. Intermediate maintenance is normally accomplished in fixed or mobile shops, tenders, or shore based repair facilities, or by mobile teams.

## RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

Fiber optic technology will proceed to the degree of module replacement. This type maintenance will be performed by organizational level personnel and intermediate level personnel will not be required. The requirement for intermdediate level maintenance personnel would exist for major rework due to aircraft modification or on an as required basis only. (Assumption 5.)

4.0 Operating and Support
  4.2 Logistic Support
    4.2.1 Maintenance
      4.2.1.1 Personnel
        4.2.1.1.3 Depot Maintenance Personnel

(X) Total
( ) Differential
( ) Excluded

DESCRIPTION

This element includes that portion of maintenance personnel costs associated with the depot level of maintenance. To simplify life cycle cost calculations, this element also includes the cost of material, depot overhead and other direct charges required to overhaul or repair the equipment. Depot maintenance is that maintenance which is the responsibility of and performed by designated maintenance activities, to augment stocks of serviceable material, and to support Organizational maintenance and Intermediate maintenance activities by the use of more extensive shop facilities, equipment and personnel of higher technical skill than are available at the lower levels of maintenance. Its phases normally consist of inspection, test, repair, modification, alteration, modernization, conversion, overhaul, reclamation, or rebuild of parts, assemblies, sub-assemblies, components, equipment and items, and weapon systems; the manufacture of critical non-available parts; and providing technical assistance to intermediate maintenance organizations, using and other activities. Depot maintenance is normally accomplished

in fixed shops, shipyards and other shore based facilites, or by depot field teams.

## RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

The state-of-the-act advancements will cause the modular replacement concept to proceed to throw away modules. Depot maintenance will not be required to service fiber optic components, but could be called upon to assist intermediate maintenance personnel for extensive corrective maintenance. (Assumption 5.)

4.0 Operating and Support
  4.2 Logistic Support
    4.2.1 Maintenance
      4.2.1.2 Maintenance Facilities

(X) Total
( ) Differential
( ) Excluded

## DESCRIPTION

This element refers to the annual upkeep of facilities for maintenance. This includes upkeep of real property where applicable. All direct labor, material overhead and other direct charges are included.

## RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

Maintenance facilities at the organizational level exist presently and the replacement of copper cable with fiber optic cable would cause no cost changes. Intermediate and depot level facilities would be selectively required and therefore there could be a cost associated with them. (See cost elements 4.2.1.1.2 and 4.2.1.1.3.)

4.0 Operating and Support
  4.2 Logistic Support
    4.2.1 Maintenance
      4.2.1.3 Support Equipment Maintenance

(X) Total
(X) Differential
( ) Excluded

DESCRIPTION

This cost element includes the cost of maintenance and calibration of the common and peculiar support equipment.

RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

This cost element must be included in order to include the maintenance and calibration of support equipment peculiar to the fiber optic technology. There already exists equipment capable of support of coax technology.

4.0 Operating and Support
  4.2 Logistic Support
    4.2.1 Maintenance
      4.2.1.4 Contractor Services

( ) Total
( ) Differential
(X) Excluded

## DESCRIPTION

This element includes contractor costs for engineering and technical services and maintenance of the system/equipment. Contractor engineering and technical services include those services provided by commercial or industrial companies for advice, instruction and training to DoD personnel in the installation, operation and maintenance of the equipment/ system. Contract maintenance includes the cost incurred for maintenance of the equipment by commercial organizations on a one-time or continuing basis, without distinction as to the level of maintenance accomplished. All direct labor, material, overhead and other direct charges are included.

## RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

Fiber optic technology is expected to advance the state-of-the-art to the point where all maintenance will be performed by organizational level maintenance personnel. Historical data indicated that contractor services required in the present electrical systems have been minimal. (See cost element 4.2.1.1.1.)

4.0 Operating and Support
  4.2 Logistic Support
    4.2.2 Supply
      4.2.2.1 Personnel
        4.2.2.1.1 Organizational Supply Personnel

(X) Total
( ) Differential
( ) Excluded

## DESCRIPTION

This element includes that portion of the supply personnel costs associated with the organizational level of supply. Material control personnel under the control of the Maintenance Department are included herein.

## RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

These organizational supply personnel must be included in order to accumulate the total life cycle cost, even though the differential cost between copper cable and fiber optic is negligible. Actual organizational supply processing of either fiber ptic or coax components would be quite similar.

4.0 Operating and Support
  4.2 Logistic Support
    4.2.2 Supply
      4.2.2.1 Personnel
        4.2.2.1.2 Intermediate Supply Personnel

(X) Total
( ) Differential
( ) Excluded

## DESCRIPTION

This element includes that portion of supply personnel costs associated with the intermediate level of supply. Base Supply personnel on a military Base are included herein.

## RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

These supply organization personnel must be included in order to accumulate the total life cycle cost, even though the differential cost between copper cable and fiber optic cable is negligible.

4.0 Operating and Support
  4.2 Logistic Support
    4.2.2 Supply
      4.2.2.1 Personnel
        4.2.2.1.3 Depot Supply Personnel

(X) Total
( ) Differential
( ) Excluded

## DESCRIPTION

This element includes that portion of the supply personnel costs associated with the depot level of supply if not included in 4.2.2.4.2.

## RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

These supply organization personnel must be included in order to accumulate the total life cycle cost, even though the differential cost between copper cable and fiber optic cable is negligible.

4.0 Operating and Support
  4.2 Logistic Support
    4.2.2 Supply
      4.2.2.2 Supply Facilities

(X) Total
( ) Differential
( ) Excluded

DESCRIPTION

This element refers to the maintenance of facilities for supply. It includes maintenance of real property where applicable. All direct labor, material, overhead and other direct charges are included. General storage costs are included in Inventory Holding Costs (4.2.2.4.2).

RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

The supply facilities maintenance must be included in order to accumulate the total life cycle cost, even though the differential cost between copper cable and fiber optic cable is negligible.

4.0 Operating and Support
  4.2 Logistic Support
    4.2.2 Supply
      4.2.2.3 Spare Parts and Repair Material

(X) Total
(X) Differential
( ) Excluded

## DESCRIPTION

This cost element represents the cost of the repair parts, assemblies, consumables and other materials consumed in the maintenance process. Initial spares and repair parts purchased during the production are considered an expended cost, and therefore are not included in this cost element. Material required during depot overhaul is covered in Depot Maintenance Personnel (4.2.1.1.3).

## RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

This cost element is considered a routine element in a cost model. Neither fiber optics nor coax require consumable parts support, but both technologies require replacement parts. The reliability of fiber optic technology is expected to be greater than that of coax. Therefore the fiber optic repair part cost should be less than coax parts cost.

4.0 Operating and Support
  4.2 Logistic Support
    4.2.2 Supply
      4.2.2.4 Inventory Administration
        4.2.2.4.1 Inventory Management

(X) Total
(X) Differential
( ) Excluded

## DESCRIPTION

This cost element refers to the management costs for entering and maintaining an item in inventory. The costs include identification, description, sumission to and screening and editing by Data Documents Center, inclusion in maintenance and supply catalogs, establishing by supply management of inventory and replacement rates, provisioning, requisitioning, rebuild directions, and procurement directives.

## RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

This cost element must be included in order to accumulate the total life cycle cost. The differential costs between copper technology and fiber optic technology are expected to be the transmitting and receiving modules, connectors and the fiber optic cable itself. Many coax technology components exist within the supply system at this time.

4.0 Operating and Support
  4.2 Logistic Support
    4.2.2 Supply
      4.2.2.4 Inventory Administration
        4.2.2.4.2 Inventory Holding

(X) Total
( ) Differential
( ) Excluded

DESCRIPTION

Inventory holding is the cost of physically holding inventory in the supply system for one year. The factors included are: general storage cost, deterioration in storage, obsolescence, and losses in storage.

RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

This supply cost element must be included in order to accumulate the total life cycle cost, even though the differential cost between copper cable and fiber optic cable is negligible.

4.0 Operating and Support
  4.2 Logistic Support
    4.2.2 Supply
      4.2.2.5 Transportation and Packaging

(X) Total
( ) Differential
( ) Excluded

## DESCRIPTION

This cost element includes packaging, handling and transportation of spares, repair parts and other material between organizational, intermediate, depot and supply points (overseas and CONUS) in support of maintenance operations. Also included is the transportation of the end item to the depot and return for the purpose of depot overhaul.

## RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

This cost element must be included in order to accumulate the total life cycle cost, even though the differential cost between copper cable and fiber optic cable is negligible.

4.0 Operating and Supply
  4.2 Logistic Support
    4.2.3 Other

( ) Total
( ) Differential
(X) Excluded

DESCRIPTION

This element includes any logistic support costs not specifically included in the previously listed elements. Maintenance and logistic support of shelters, vehicles, ECU's, power generators and other ancillary equipment may be included herein as appropriate.

RATIONALE FOR INCLUSION/EXCLUSION IN COST MODEL

The costs associated with both fiber optic and copper cable technology should be quantifiable and directly assessable to a specific cost element.

# APPENDIX B; DATA SOURCE GUIDE

1.2.1.2

## ENGINEERING

This is a Category I cost element which will use the Delphi Questionnaire technique to obtain cost data. The source for this cost data would be aircraft manufacturers experienced in aircraft electrical signal interconnect design.

Delphi Questionnaire sections I, II and III are applicable to this cost element and would be forwarded to the aircraft manufacturers. Question III-1 will produce the required cost data.

## CONTRACTOR DEVELOPMENT TESTS

This is a Category I cost element which will use the Delphi Questionnaire technique to obtain cost data. The source for the cost data would be aircraft manufacturers experienced in development test procedures.

Delphi Questionnaire sections I, II and III are applicable to this cost element and would be forwarded to the aircraft manufacturers. Question III-2 will produce the required cost data.

## TEST SUPPORT

Assuming that the fiber optic performance characteristics successfully pass the Research and Development contractor development tests, it is anticipated that the Government will conduct an extensive Development Test and Evaluation program as a final assurance of operational quality.

Collection of cost data for the cost element will be a two step process. The analyst must first determine the magnitude of testing to be conducted under cost element 1.2.2.3. Secondly the information received as a response to the Delphi Questionnaire must be combined with that information to determine the final cost data.

Delphi Questionnaire sections I, II and III are applicable to this cost element and would be forwarded to the aircraft manufacturers. Question III-3 will produce the required cost data.

## PECULIAR SUPPORT AND TEST EQUIPMENT

This is a Category I cost element which will use the Delphi Questionnaire technique to obtain cost data. The source for this cost data will be aircraft manufacturers experienced in the development of aircraft support equipment.

Delphi Questionnaire sections I, II and III are applicable to the cost element and would be forwarded to the aircraft manufactuers. Question III-4 will produce the required cost data.

## GENERAL AND ADMINISTRATIVE

This is a Category II cost element for which cost data can be collected from an aircraft manufacturer's historical files. The required information could be obtained without the use of a Delphi Questionnaire but this question was included in order to consolidate all data.

Delphi Questionnaire sections I, II and III are applicable to this cost element and would be forwarded to the aircraft manufacturers. Question III-5 will produce the required cost data.

## GOVERNMENT TESTS (DTE/IOTE)

This is a unique cost element in that there is no industry counterpart to a Government testing agency. To obtain cost data for this element, the analyst will be required to search files on previously conducted tests and contact the known Government testing agencies.

A recommended data source is the office of the Operational Test and Evaluation Forces (OPTEVFOR).

## MANUFACTURING SUPPORT EQUIPMENT

This is a Category I cost element which will use the Delphi Questionnaire technique to obtain cost data. The source for this cost data would be aircraft manufacturers experienced in establishing production equipment requirements.

Delphi Questionnaire sections I, II and IV are applicable to this cost element and would be forwarded to the aircraft manufacturer. Question IV-1 will produce the required cost data.

## TECHNICAL SUPPORT

This is a Category I cost element which will use the Delphi Questionnaire technique to obtain cost data. The cost data predicted for this cost element is subject to a wide variance due to its subjective nature. The source for the cost data would be aircraft manufacturers familiar with the technical support requirements of Government Test Programs.

Delphi Questionnaire sections I, II and IV are applicable to this cost element and would be forwarded to the aircraft manufacturer. Question IV-2 will produce the required cost data.

## INITIAL SPARES AND REPAIR PARTS

These spare and repair parts are a one-time procurement and the quantity is dependent upon the output of a level of repair (LOR) analysis. Cost data for individual components can be obtained directly from the fiber optic component manufacturers or the purchase records of an aircraft manufacturer.

## COST FORMULA

$$\begin{bmatrix}\text{Initial Spares}\\ \text{and}\\ \text{Repair Parts}\end{bmatrix} = \sum_{i=1}^{N} \begin{bmatrix}\text{Quantity}\\ \text{of Repair}\\ \text{Part } i\end{bmatrix} \text{X} \begin{bmatrix}\text{Price}\\ \text{of Repair}\\ \text{Part } i\end{bmatrix}$$

| COST FACTORS | UNITS |
|---|---|
| QUANTITY OF REPAIR PART i | EA. |
| PRICE OF REPAIR PART i | $/EA. |

## COMMENT

N is the total number of unique spare parts procured

i identifies each unique spare part.

## MAINTENANCE TRAINING

An experienced aircraft manufacturer will have a historical file of costs associated with previous training programs that were conducted by the firm. Since the establishment of a training program is a routine procedure, the available historical cost can be a data base used to extrapolate new cost data.

Delphi Questionnaire sections I, II and IV are applicable to this cost element and would be forwarded to the aircraft manufacturers. Question IV-3 will produce the required cost data.

## PECULIAR SUPPORT AND TEST EQUIPMENT

This is a Category I cost element which will use the Delphi Questionnaire Technique to obtain cost data. The source for this cost data would be aircraft manufacturers experienced in the development and production of aircraft support equipment.

Delphi Questionnaire sections I, II and IV are applicable to this cost element and would be forwarded to the aircraft manufacturers. Question IV-4 will produce the required cost data.

## GENERAL AND ADMINISTRATIVE

This is a Category II cost element for which cost data can be collected directly from an aircraft manufacturer historical files. The required information could be obtained without the use of a Delphi Questionnaire but this question was included in order to consolidate all data.

Delphi Questionnaire sections I, II and IV are applicable to this cost element and would be forwarded to the aircraft manufacturers. Question IV-5 will produce the required cost data.

2.2.2.2

## TRAINING DEVICES AND EQUIPMENT

The costs associated with the development of existing training devices and equipment and their implementation into Navy schools are available through the office of CNET. There are no major training device requirements anticipated, therefore this effort should be within the present state-of-the-art.

The Delphi Questionnaire would serve no purpose where obtaining cost data for this element. Direct contact with the appropriate CNET offices would be the most effective method of data collection.

## MAINTENANCE TRAINING

The economic cost of military personnel includes the following cost elements:

(1) basic pay and allowances

(2) PCS travel

(3) Retirement

(4) Support costs

(5) Replacement training

Referring to the tables in reference 33 the annual cost of training a maintenance man in a new technology is:

## COST FORMULA

$$\begin{bmatrix}\text{Maintenance}\\ \text{Training}\\ \text{Cost}\end{bmatrix} = \begin{bmatrix}\text{Basic Pay}\\ \text{and}\\ \text{Allowance}\end{bmatrix} + \begin{bmatrix}\text{PCS}\\ \text{Travel}\\ \end{bmatrix} + \begin{bmatrix}\text{Retire-}\\ \text{ment}\end{bmatrix} + \begin{bmatrix}\text{Support}\\ \text{Costs}\\ \end{bmatrix} + \begin{bmatrix}\text{Replacement}\\ \text{Training}\\ \end{bmatrix}$$

| COST FACTORS | UNITS |
|---|---|
| Basic Pay and Allowances | $/yr. |
| PCS Travel | $/yr. |
| Retirement | $/yr. |
| Support Costs | $/yr. |
| Replacement Training* | $/yr. |

* DCA Circular 600-60-1 can be used where no specific training course yet exists.

To determine the daily training cost

divide $\begin{bmatrix}\text{Maintenance}\\ \text{Training}\\ \text{Cost}\end{bmatrix}$ by the number of anticipated

work days per year.

2.2.2.3.3

## INSTRUCTOR TRAINING

The assumption was previously made that Navy instructors would be trained during the same time period as maintenance personnel. Therefore the same cost relationship as used to calculate costs for maintenance training (cost element 2.2.2.3.2) can be used for this element.

Referrring to the tables in reference 33 the annual cost of training an instructor in a new technology is:

## COST FORMULA

$$\begin{bmatrix}\text{Instructor}\\\text{Training}\\\text{Cost}\end{bmatrix} = \begin{bmatrix}\text{Basic Pay}\\\text{and}\\\text{Allowance}\end{bmatrix} + \begin{bmatrix}\text{PCS}\\\text{Trav-}\\\text{el}\end{bmatrix} + \begin{bmatrix}\text{Retire-}\\\text{ment}\\\ \end{bmatrix} + \begin{bmatrix}\text{Support}\\\text{Costs}\\\ \end{bmatrix} + \begin{bmatrix}\text{Replace-}\\\text{ment}\\\text{Training}\end{bmatrix}$$

| COST FACTORS | UNITS |
|---|---|
| Basic Pay and Allowances | \$/yr. |
| PCS Travel | \$/yr. |
| Retirement | \$/yr. |
| Support Costs | \$/yr. |
| Replacement Training* | \$/yr. |

* DCA Circular 600-60-1 can be used where no specific training course yet exists.

To determine the daily training cost

divide $\begin{bmatrix}\text{Instructor}\\\text{Training}\\\text{Cost}\end{bmatrix}$ by the number of anticipated work days per year.

## MANUFACTURING

This is a Category I cost element which will use the Delphi Questionnaire Technique to obtain cost data. The sources for the cost data would be aircraft manufacturers experienced in aircraft production.

Delphi Questionnaire sections I, II and V are applicable to this cost element and would be forwarded to the aircraft manufacturer. Question V-1 will produce the required cost data.

## PURCHASED EQUIPMENT AND PARTS

A somewhat different approach must be taken to gather data for this cost element and cost elements 3.1.2.2 and 3.1.2.3. The analyst must obtain a list of the fiber optic component requirements for a specific task from a aircraft manufacturer. This fiber optic component list can then be priced wtih, the use of the cost data received from the fiber optic industry via the Delphi Questionnaire in Appendix D or actual catalog prices.

The Delphi Questionnaire in Appendix D would be forwarded to the fiber optic manufacturer/R&D activities found in the NELC composite distribution list.

## SUBCONTRACTED ITEMS

A somewhat different approach must be taken to gather data for this cost element and cost elements 3.1.2.1 and 3.1.2.3. The analyst must obtain a list of the fiber optic component requirements for a specific task from an aircraft manufacturer. This fiber optic component list can then be priced with the use of the cost data received from the fiber optic industry via the Delphi Questionnaire in Appendix D or actual catalog prices.

The Delphi Questionnaire in Appendix D would be forwarded to the fiber optic manufacturer/R&D activities found in the NELC composite distribution list.

## OTHER MATERIAL

A somewhat different approach must be taken to gather data for this cost element and cost elements 3.1.2.1 and 3.1.2.2. The analyst must obtain a list of the fiber optic component requirements for a specific task from an aircraft manufacturer. This fiber optic component list can then be priced with the use of the cost data received from the fiber optic industry via the Delphi Questionnaire in Appendix D or actual catalog prices.

The Delphi Questionnaire in Appendix D would be forwarded to the fiber optic manufacturers/R&D activities found in the NELC composite distribution list.

## SUSTAINING ENGINEERING

This is a Category I cost element which will use the Delphi Questionnaire technique to obtain cost data. The source for this cost data would be aircraft manufacturer familiar with the engineering requirements of modifications and field changes.

Delphi Questionnaire sections I, II and V are applicable to this cost element and would be forwarded to the aircraft manufacturers. Question V-2 will produce the required cost data.

## SITE/SHIP/VEHICLE CONVERSION

This is a Category I cost element which will use the Delphi Questionnaire technique to obtain cost data. The source for this cost data would be aircraft manufacturers familiar with aircraft conversion to update to a new technology.

Delphi Questionnaire sections I, II and V are applicable to this cost element and would be forwarded to the aircraft manufacturers. Question V-3 will produce the required cost data.

## ASSEMBLY, INSTALLATION AND CHECKOUT

This is a Category I cost element which will use the Delphi Questionnaire technique to obtain cost data. The source for this cost data would be aircraft manufacturers familiar with aircraft conversion to update to a new technology.

Delphi Questionnaire sections I, II and V are applicable to this cost element and would be forwarded to the aircraft manufacturers. Question V-4 will produce the required cost data.

3.1.8

## GENERAL AND ADMINISTRATIVE

The data required for this cost element will be the same as the cost data obtained for cost element 2.1.12. The analyst can use the cost data produced by Delphi Questionnaire section IV, question IV-5 to fulfill the requirements of this cost element.

## OTHER OPERATIONS COSTS

This element represents the annual opportunity cost associated with either alternative when the A-7 weapons system becomes inoperable due to the N/WDS interconnect system. Opportunity costs attempt to measure the opportunity which is lost or sacrificed when a choice of action precludes another. For example, there are several costs associated with an inoperable aircraft. First, there are the direct/ indirect support costs to repair and restore the aircraft to an operable condition. Second, there are those costs associated with the missions not flown or the training not received, during the period the aircraft is inoperable. Most life cycle cost models recognize and account for the direct costs associated with aircraft downtime; but neglect the opportunity costs involved. This could be due to the difficulties associated with quantification of opportunity costs or the structure of the cost-benefit model.

Opportunity costs are difficult to measure becasuse they may indeed represent different costs to different decision makers. For example, the cost of missing a training mission would intuitively be less than the cost of missing a scheduled wartime strike mission. Force level planners often recognize lost mission opportunity costs by increasing the number of forces to ensure the desired mission results. The A-7 ALOFT coax/fiber optic alternative systems are

systems are specified as functional equivalents, and will probably have different mission reliabilities associated with them. Because of this, the life cycle costs are not directly comparable because one system will operate more frequently then the other. In addition, since a cost decision model whould provide the decision maker with all relevant costs which impact the decision (such as the affect of reliability on total life cycle costs) as opportunity cost element, computed in an identical manner for each alternative, is required.

Several methods to quantify opportunity costs were considered. The following method suggested by Professor C. R. Jones of the Naval Postgraduate School was selected:

It is assumed that at the time of the procurement decision, that the net present value of the weapon system's effectiveness is equal or greater than the procurement costs. In formula terms this is:

$$C \leq \int_{o}^{T} E(t)\, e^{-it} dt \qquad (1)$$

where: $E(t)$ = the weapon systems effectiveness timestream from time zero to time T, its planned service life.

$C$ = A-7 weapon system unit procurement cost

$i$ = interest rate.

Now, if the weapon system is assumed to have an equal average annual effectiveness, denoted by $\overline{E}$, then,

$$C \leq \bar{E} \int_{o}^{T} e^{-it} dt = \frac{\bar{E}}{i}(1-e^{-it})$$

or

$$\frac{iC}{(1-e^{-iT})} \leq \bar{E} \qquad (2)$$

Therefore, at the time of the procurement decision, the average annual weapon system effectiveness is at least worth,

$$\bar{E} = \frac{iC}{1-C^{-iT}}$$

Accordingly, $\bar{E}$ can also be used as a measure of the cost of not having the capability. Cost element 4.1.6 is, therefore, defined for either alternative as:

$$O_{1t} = N_t \bar{E}$$

$$= \frac{N_t \; i \; C}{1-e^{-iT}}$$

where: $N_t$ = aircraft years of downtime due N/WDS system in year t, for the alternative

$t = 1 \ldots 10$

C = A-7 unit procurement cost

T = A-7's expected service life

and i = discount or interest rate.

## ORGANIZATIONAL MAINTENANCE PERSONNEL

The TRI-TAC office has developed the following cost formula to calculate the cost of this element. Since the hourly cost of organizational maintenance personnel can and will vary, it is recommended that the latest personnel costs ber verified with the office of the Chief of Naval Personnel.

COST FORMULA

$$\left[\begin{array}{l}\text{ORGANIZATIONAL}\\ \text{MAINTENANCE}\\ \text{PERSONNEL}\\ \text{COST}\end{array}\right] = \left[\left[\begin{array}{l}\text{PREVENTATIVE}\\ \text{MAINTENANCE}\\ \text{TIME}\end{array}\right] + \left[\begin{array}{l}\text{CORRECTIVE}\\ \text{MAINTENANCE}\\ \text{TIME}\end{array}\right]\right] \times \left[\begin{array}{l}\text{COST OF}\\ \text{ORGANIZATIONAL}\\ \text{MAINTENANCE}\\ \text{PERSONNEL}\\ \text{PER/HOUR}\end{array}\right] \times \left[\begin{array}{l}\text{QUANTITY OF}\\ \text{OPERATIONAL}\\ \text{EQUIPMENT}\end{array}\right]$$

WHERE:

$$\left[\begin{array}{l}\text{CORRECTIVE}\\ \text{MAINTENANCE}\\ \text{TIME}\end{array}\right] = \left[\begin{array}{l}\text{NUMBER OF}\\ \text{OPERATING HOURS}\\ \text{PER YEAR}\end{array}\right] \times \frac{\left[\begin{array}{l}\text{MEAN TIME}\\ \text{TO REPAIR}\end{array}\right]}{\left[\begin{array}{l}\text{MEAN TIME}\\ \text{BETWEEN FAILURES}\end{array}\right]}$$

| COST FACTORS | UNITS |
|---|---|
| PREVENTATIVE MAINTENANCE TIME** | HOURS/YR. |
| CORRECTIVE MAINTENANCE TIME** | HOURS/YR. |
| NUMBER OF OPERATING HOURS PER YEAR | HOURS/YR. |
| MEAN TIME TO REPAIR | HOURS |
| MEAN TIME BETWEEN FAILURES | HOURS |
| COST OF ORGANIZATIONAL MAINTENANCE PERSONNEL PER HOUR | $/HOUR |
| QUANTITY OF OPERATIONAL EQUIPMENT | UNITS |

**MAINTENANCE TIME SHOULD BE ADJUSTED TO INCLUDE TIME REQUIRED FOR DOCUMENTATION SUCH AS MAINTENANCE RECORDS AND SUPPLY TRANSACTION RECORDS.

## SUPPORT EQUIPMENT MAINTENANCE

Historical data analysis has shown that the cost of support equipment maintenance can be approximated by a factor of 10 percent of the equipment cost. The TRI-TAC office has developed the following cost formula to calculate the cost of this element.

COST FORMULA

$$\begin{bmatrix}\text{SUPPORT}\\ \text{EQUIPMENT}\\ \text{MAINTENANCE}\\ \text{COST}\end{bmatrix} = \begin{bmatrix}\text{SUPPORT}\\ \text{EQUIPMENT}\\ \text{MAINTENANCE}\\ \text{FACTOR}\end{bmatrix} \times \begin{bmatrix}\text{COST OF COMMON AND}\\ \text{PECULIAR SUPPORT}\\ \text{EQUIPMENT}\end{bmatrix}$$

| COST FACTORS | VALUE | UNITS |
|---|---|---|
| SUPPORT EQUIPMENT MAINTENANCE FACTOR | 10% | PERCENT |
| COST OF COMMON AND PECULIAR SUPPORT EQUIPMENT | | $ |

4.2.2.3

## SPARE PARTS AND REPAIR MATERIAL

Based upon a 5 percent estimator the following cost formula was developed by the TRI-TAC office.

COST FORMULA

$$\left[\begin{array}{l}\text{SPARE PARTS}\\ \text{AND}\\ \text{REPAIR MATERIAL}\end{array}\right] = \left[\begin{array}{l}\text{INVENTORY}\\ \text{REPLENISHMENT}\\ \text{COST FACTOR}\end{array}\right] \times \left[\begin{array}{l}\text{EQUIPMENT}\\ \text{UNIT}\\ \text{PRODUCTION}\\ \text{COST}\end{array}\right] \times \left[\begin{array}{l}\text{QUANTITY OF}\\ \text{OPERATIONAL}\\ \text{EQUIPMENT}\end{array}\right]$$

| COST FACTORS | VALUE | UNITS |
|---|---|---|
| INVENTORY REPLENISHMENT COST FACTOR | 5% | PERCENT/YR |
| EQUIPMENT UNIT PRODUCTION COST | | $/UNIT |
| QUANTITY OF OPERATIONAL EQUIPMENT | | UNITS |

## INVENTORY MANAGEMENT

The cost of item inventory management is not directly dependent upon the type of item or the associated technology. Inventory management cost is indirectly dependent upon the item and associated technology through the item cost and the number of new items entered into the inventory.

The TRI-TAC office has developed the following cost formula to calculate the cost of this element.

COST FORMULA

$$\begin{bmatrix}\text{INVENTORY}\\ \text{MANAGEMENT}\\ \text{COST}\end{bmatrix} = \begin{bmatrix}\text{NUMBER OF}\\ \text{NEW FSN}\\ \text{ITEMS}\end{bmatrix} \times \frac{\begin{bmatrix}\text{FSN ITEM}\\ \text{1ST YEAR}\\ \text{COST}\end{bmatrix} + \begin{bmatrix}\text{FSN ITEM}\\ \text{RECURRING}\\ \text{COST}\end{bmatrix} \times \begin{bmatrix}\text{NUMBER OF}\\ \text{YEARS PER} - 1\\ \text{LIFE CYCLE}\end{bmatrix}}{\begin{bmatrix}\text{NUMBER OF}\\ \text{YEARS PER}\\ \text{LIFE CYCLE}\end{bmatrix}}$$

| COST FACTORS | VALUE | UNITS |
|---|---|---|
| NUMBER OF NEW FSN ITEMS | | ITEMS |
| FSN ITEM 1ST YEAR COST | FROM CHART BELOW | $/ITEM |
| FSN ITEM RECURRING COST | FROM CHART BELOW | $/ITEM/YEAR |
| NUMBER OF YEARS PER LIFE CYCLE | | YEARS |

INVENTORY LINE ITEM MANAGEMENT COSTS

| FSN DOLLAR VALUE | INTRODUCTION COSTS | FIRST YEAR COST * | ANNUAL RECURRING COSTS |
|---|---|---|---|
| $25,000 – OVER | $680 | $1070 | $720 |
| $10,000 – $24,999 | 530 | 770 | 420 |
| $ 2,500 – $ 9,999 | 450 | 580 | 130 |
| UNDER – $ 2,500 | 430 | 460 | 110 |
| WEIGHTED AVERAGE | 480 | 510 | 160 |

*INCLUDES INTRODUCTION COST

# APPENDIX C: AIRCRAFT INDUSTRY DELPHI QUESTIONNAIRE

## SECTION I RESPONDENT IDENTIFICATION

Organization or Firm Name ______________________________

Respondent* Name ______________________ Position Title ______________

Business Address ______________________
______________________ Phone No. ______________

Years in Present Position __________ Years in Present Occupation __________ Years in the Industry __________

Would you be willing to discuss the questionnaire with an interviewer? ( ) Yes ( ) No

* If additional personnel assist in completing this questionnaire enter their name(s) by the applicable question(s).

## SECTION II

## FIBER OPTICS PERFORMANCE CHARACTERISTICS

This section lists the general Fiber Optics Performance Characteristics which fiber optics cable posses but are lacking in equivalent coax cable designed to perform a simular task.

### HIGH TEMPERATURE TOLERANCE

Temperatures up to approximately 150$^0$C can be tolerated by fiber optic cable.

### VIBRATION TOLERANCE

Fiber optic cable can tolerate vibration without experiencing electrical problems, such as internal cable short circuits or changing electrical conducting characteristics.

### NO CROSS TALK

Adjacent cables within a cable bundle or cable harness are not susceptible to stray signals induced do to their close proximity.

### RFI/EMI/NOISE IMMUNITY

External electrical signals do not adversely affect the light signal within a fiber optic cable. There is no electrical signal to be either radiated or be susceptible to stray electrical signals.

## TOTAL ELECTRICAL ISOLATION

There is no electrical current path within a fiber optic cable. This characteristic allows interconnected equipments to be electrically isolated from each as well as isolated from the interconnecting cables.

## NO SPARK/FIRE HAZARD

The total lack of electric current within the fiber optic cable reduces the potential for spark generation to zero. This has a direct impact upon combustible ignition caused by sparks.

## NO SHORT CIRCUIT LOADING

Since fiber optic cables do not carry electric current, damage to a cable could not cause an electrical signal reflection back to an equipment, which could cause an equipment failure.

## EMP IMMUNITY

Similar to the RFI/EMI/NOISE immunity, nuclear radiation does not have a severe impact upon fiber optic cable.

## NO CONTACT DISCONTINUITY

A light signal does not require a physical contact at signal connector interfaces, it can pass through an air gap.

## WIDE SIGNAL BANDWIDTH

Fiber optic cable has a wider bandwidth than either the present twisted pair cable or installed coax cable, however the LED is the limiting factor for signal bandwidth.

## CORROSION RESISTANT

Common but severe environmental characteristics which affect electrical signal carrying cable have little or no affect upon the fiber optic cable signal quality.

## HIGH SECURITY

Fiber optic cable does not have the adverse characteristic which would allow it to radiate a signal that could be coupled and picked up in a non-secure environment.

## SMALL SIZE

The diameter of present and the future fiber optic cable is equal to or less than that of an equivalent use coax cables.

## LIGHT WEIGHT

Fiber optic cable is lighter weight than an equivalent use coax cable.

## REDUCED SAFETY HAZARD

The high temperature tolerance and no spark hazard characteristics coupled together allow fiber optic cable immunity to exclusion from location in a hazardous area.

## REDUCED ELECTRICAL POWER REQUIREMENTS

Fiber optic light transmitting and receiving modules have the potential to require less electrical power to operate than an equivalent coax cable system.

## SECTION III

## RESEARCH AND DEVELOPMENT COSTS

Research and Development costs refer to all costs associated with the research, development test and evaluation of the system or equipment. This includes all costs during concept initiation, validation and full scale development.

## SCENARDIO

Your firm has contracted with the Government for a twofold Research and Development effort involving;

(1) design of a new Navy fighter aircraft with the stipulation that all electrical signal carrying wiring will be eliminated and fiber optic cable will be substituted.

(2) redesign of an existing Navy fighter aircraft electrical signal interconnect cable system. All existing electrical signal carrying wiring will be replaced with fiber optic cable.

The new fiber optic cable will no longer be a point-to-point connection. In both of the above situations, the fiber optic cable will carry a multiplexed light signal.

In order to standardize all questionnaire responses assume that if fiber optic cable was not available, each of the above efforts would be completed using coaxial cable. Knowing the anticipated advantages of fiber optic cable over coaxial cable listed in section II, answer the following questions and indicate your qualifications to answer each question.

## SECTION III-1

Given the potentially fiwer restrictions of fiber optic cable compared to coax, would the electrical cabling design engineering effort using fiber optic cable be GREATER THAN, LESS THAN or EQUAL TO the design engineering required if using coax? If either GREATER or LESS, BY what fraction?

( ) GREATER THAN

( ) LESS THAN

( ) EQUAL TO

____________________
Fractional Difference

What are your qualifications to answer this question?

(1) HIGHLY QUALIFIED TO (5) POORLY QUALIFIED ( )

Respondent Name ____________________

COMMENTS:

## SECTION III-2

With the operationally unproven fiber optic performance characteristics would your development test effort on a prototype model using fiber optic cable be GREATER THAN, LESS THAN or EQUAL TO the development test effort if using coax? If either GREATER or LESS, by what fraction?

( ) GREATER THAN

( ) LESS THAN

( ) EQUAL TO

______________________
Fractional Difference

What are your qualifications to answer the question?

(1) HIGHLY QUALIFIED TO (5) POORLY QUALIFIED ( )

Respondent Name ______________________

COMMENTS:

## SECTION III-3

Based upon your previous experience with Government Development Test and Evaluation (DTE) programs conducted during Research and Development and the fiber optics performance characteristics, would your support of Government DTE using fiber optic cable be GREATER THAN, LESS THAN or EQUAL TO the support required if using coax? If either GREATER or LESS, by what fraction?

( ) GREATER THAN

( ) LESS THAN ______________________ Fractional Difference

( ) EQUAL TO

What are your qualifications to answer this question?

(1) HIGHLY QUALIFIED TO (5) POORLY QUALIFIED ( )

Respondent Name ______________________

COMMENTS:

## SECTION III-4

Assume that fiber optic cable is installed in aircraft as signal carrying conductors in place of coax cable. Would the design engineering effort to develop peculiar support equipment for a fiber optic installation be GREATER THAN, LESS THAN or EQUAL TO the design engineering required to develop similiar equipment for a coax cable installation? If GREATER or LESS, by what fraction?

( ) GREATER THAN

( ) LESS THAN

( ) EQUAL TO

______________________
Fractional Difference

What are your qualifications to answer this question?

(1) HIGHLY QUALIFIED TO (5) POORLY QUALIFIED ( )

Respondent Name ____________________________

COMMENTS:

## SECTION III-5

What is the rate used to apply the cost of General and Administrative (G&A) expenses to Government Research and Development contracts of the type noted in the section III scenario? To which costs is this rate applied?

G&A RATE: ______________

G&A APPLIED TO: ______________________________

What are your qualifications to answer this question?

(1) HIGHLY QUALIFIED TO (5) POORLY QUALIFIED ( )

Respondent Name ___________________________

COMMENTS:

## SECTION IV

## NON-RECURRING INVESTMENT COSTS

Non-recurring investment costs refer to those costs incurred beyond the program development phase, which are one time costs incurred during a program production phase.

## SCENARIO

Your firm has contracted with the Government for a two phase production effort involving:

(1) modification of an existing Navy fighter aircraft by replacing all electrical signal interconnect cable with fiber optic cable.

(2) production of a new Navy figher aircraft using fiber optic cable as the signal interconnect medium for all signal carrying cables.

The fiber optic cable will not be a point-to-point connection. In both of the above situations, the fiber optic cables will carry a multiplexed light signal.

In order to standardize all questionnaire responses assume that if fiber optic cable was not available, each of the above efforts would be completed using coaxial cable. Knowing the anticipated advantages of fiber optic cable over coaxial cable listed in section II, answer the following questions and indicate your qualifications to answer each question.

SECTION IV-1

Knowing the performance characteristics of fiber optics listed in section II, would the one time investment in manufacturing support equipment required for a production effort using fiber optic cable be GREATER THAN, LESS THAN or EQUAL TO the investment in similar equipment if using coax cable? If either GREATER or LESS, by what fraction?

( ) GREATER THAN

( ) LESS THAN

( ) EQUAL TO

______________________
Fractional Difference

What are your qualifications to answer this question?
(1) HIGHLY QUALIFIED TO (5) POORLY QUALIFIED ( )

Respondent Name ______________________

COMMENTS:

## SECTION IV-2

Assume that the Government does not conduct an Operational Test and Evaluation (OTE) program to further verify the performance characteristics of fiber optics. Based on your previous experience with Government OTE programs what FRACTION of OTE technical support costs would be saved by using fiber optics in place of coax cable?

FRACTION OF COST SAVED ______________________________

What are your qualifications to answer this question?

(1) HIGHLY QUALIFIED TO (5) POORLY QUALIFIED ( )

Respondent Name ______________________________

COMMENTS:

## SECTION IV-3

Knowing the fiber optic performance characteristics listed in section II and the fact that the appropriate Navy maintenance personnel have a basic knowledge of coax cable systems, would a fiber optics maintenance program effort be GREATER THAN, LESS THAN or EQUAL TO a similar program if teaching coax cable maintenance procedures? If GREATER or LESS, by what fraction?

( ) GREATER THAN

( ) LESS THAN

( ) EQUAL TO

________________________
Fractional Difference

What are your qualifications to answer this question?

(1) HIGHLY QUALIFIED TO (5) POORLY QUALIFIED ( )

Respondent Name ________________________

COMMENTS:

## SECTION IV-4

Assume that fiber optic cable is installed in aircraft as signal carrying conductors in place of coax cable. Would the production cost of peculiar support and test equipment for a fiber optic installation be GREATER THAN, LESS THAN or EQUAL TO the production cost for similar equipment for a coax cable installation? If GREATER or LESS, by what fraction?

( ) GREATER THAN

( ) LESS THAN

( ) EQUAL TO

____________________________
Fractional Difference

What are your qualifications to answer this question?

(1) HIGHLY QUALIFIED TO (5) POORLY QUALIFIED ( )

Respondent Name ______________________________

COMMENTS:

## SECTION IV-5

What is the rate used to apply the cost of General and Administrative (G&A) expense to Government production contracts of the type noted in the section IV scenario? To what costs is the rate applied?

G&A RATE: ____________

G&A APPLIED TO: ______________________________

What are your qualifications to answer this question?

(1) HIGHLY QUALIFIED TO (5) POORLY QUALIFIED ( )

Respondent Name ____________________________

COMMENTS:

## SECTION V

## RECURRING INVESTMENT COSTS

Recurring investment costs include those production costs that recur with each unit produced. These costs tend to be subject to a learning curve concept in which the cost per unit decreases as quantity increases.

### SCENARIO

Your firm has contracted with the Government for a two phase production effort involving:

(1) modification of existing Navy fighter aircraft by replacing all electrical signal interconnect cable with fiber optic cable,

(2) production of a new Navy fighter aircraft using fiber optic cable as the signal interconnect medium for all signal carrying cables.

The fiber optic cable will not be a point-to-point connection. In both of the above situations, the fiber optic cables will carry a multiplexed light signal.

In order to standardize all questionnaire responses assume that if fiber optic cable was not available, each of the above efforts would be completed using coaxial cable. Knowing the anticipated advantages of fiber optic cables over coaxial cable listed in section II, answer the following questions and indicate your qualifications to answer each question.

## SECTION V-1

Being experienced in aircraft production, and knowing the fiber optics performance characteristics listed in section II, would manufacturing costs using fiber optic cable be GREATER THAN, LESS THAN or EQUAL TO the manufacturing costs if using coax cable? If GREATER or LESS, by what fraction?

( ) GREATER THAN

( ) LESS THAN ______________________ Fractional Difference

( ) EQUAL TO

What are your qualifications to answer this question?

(1) HIGHLY QUALIFIED TO (5) POORLY QUALIFIED ( )

Respondent Name ______________________

COMMENTS:

SECTION V-2

Given the performance characteristics of fiber optic cable, would the engineering effort applied to future aircraft modifications and field changes if using fiber optic cable be GREATER THAN, LESS THAN or EQUAL TO the engineering effort required if using coax cable? If GREATER or LESS, by what fraction?

( ) GREATER THAN

( ) LESS THAN

( ) EQUAL TO

____________________
Fractional Difference

What are your qualifications to answer this question?

(1) HIGHLY QUALIFIED TO (5) POORLY QUALIFIED ( )

Respondent Name ____________________________

COMMENTS:

## SECTION V-3

Using any Navy fighter aircraft with which you are familiar and knowing the fiber optic performance characteristics, would the cost to convert the actual aircraft to accomodate fiber optic cable be, GREATER THAN, LESS THAN or EQUAL TO the cost of a similar conversion if using coax cable? If GREATER or LESS, by what fraction?

( ) GREATER THAN

( ) LESS THAN

( ) EQUAL TO

______________________
Fractional Difference

What are your qualifications to answer this question?

(1) HIGHLY QUALIFIED TO (5) POORLY QUALIFIED ( )

Respondent Name ______________________

COMMENTS:

## SECTION V-4

After completing the conversion addressed in the previous question (V-3) would the cost of systems checkout using fiber optic cable be GREATER THAN, LESS THAN or EQUAL TO the cost of a similar effor if using coax cable? If GREATER or LESS, by what fraction?

( ) GREATER THAN

( ) LESS THAN

( ) EQUAL TO

____________________________
Fractional Difference

What are your qualifications to answer this question?
(1) HIGHLY QUALIFIED TO (5) POORLY QUALIFIED ( )

Respondent Name ________________________________

COMMENTS:

## APPENDIX D: FIBER OPTIC INDUSTRY DELPHI QUESTIONNAIRE

### PARTICIPANT IDENTIFICATION

Organization or Firm Name ______________________________

Participant Name ____________________ Position Title ____________

Business ____________________

Address ____________________ Phone No. ______________

Years in Present Position __________ Years in Present Occupation ________ Years in the Industry ____

Would you be willing to discuss the questionnaire with an interviewer? ( ) Yes ( ) No

PARTICIPANT
SELF-RATING ON
QUALIFICATIONS
TO ANSWER IN AREAS
OF INTEREST
(1), HIGHLY QUALIFIED TO (5), POORLY
QUALIFIED

| | | | User desirability | | | | | | Producer feasibility | | | | | | Probable timing | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | Enter the year by which you feel the probability is $P$ that the named event will have occured | | |
| | # | BASIC EVENTS (including assumptions) | Necessary - definitely needed now | Will be necessary soon | Desirable now, but not necessary | Will be desirable soon | Undesirable now, possibly desired later | Cannot forsee any desirability in future | Highly feasible - could produce now | Feasible - could produce in future | Likely to be produced very soon | Likely to be produced in future | Unlikely, but possible to be produced | Cannot forsee possibility of production | $P=.20$ | $P=.50$ | $P=.90$ |
| (3) | A | (EXAMPLE: AVIONICS COMPUTERS IN MILITARY AIRCRAFT ARE MINIATURIZED TO 1/4 THEIR PRESENT SIZE). | | | X | | | | | | | X | | | 1985 | 1992 | 2000 |
| | | ------FIBER OPTICS TECHNOLOGY--------- | | | | | | | | | | | | | | | |
| ( ) | 1 | Modular drivers/receivers, utilizing LED & PIN type diodes, etc., are in production and considered as off-the-shelf items. More than two companies are in competition for contracts. No monopolies. ........... | | | | | | | | | | | | | | | |
| ( ) | 2 | Monolithic integrated optical circuit drivers & receivers are off-the-shelf available. (etc., as in above question). ................. | | | | | | | | | | | | | | | |
| ( ) | 3 | MULTI-CHANNEL "STAR", etc., type connectors are off-the-shelf available. (etc., as in event 1). ...... | | | | | | | | | | | | | | | |
| ( ) | 4 | SINGLE CHANNEL TRUNK, "T", CONNECTORS are in production as off-the-shelf items. (etc., as in event 1). ..... | | | | | | | | | | | | | | | |

| PARTICIPANT SELF-RATING ON QUALIFICATIONS TO ANSWER IN AREAS OF INTEREST (1), HIGHLY QUALIFIED TO (5), POORLY QUALIFIED | # | EVENT | User desirability | | | | | | Producer feasibility | | | | | | Probable timing<br>Enter the year by which you feel the probability is $P$ that the named event will have occured | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Necessary - definitely needed now | Will be necessary soon | Desirable now, but not necessary | Will be desirable soon | Undesirable now, possibly desired later | Cannot forsee any desirability in future | Highly feasible - could produce now | Feasible - could produce in future | Likely to be produced very soon | Likely to be produced in future | Unlikely, but possible to be produced | Cannot forsee possibility of production | $P$=.20 | $P$=.50 | $P$=.90 |
| | | ------FIBER OPTICS PRICE TO USER------ | | | | | | | | | | | | | | | |
| ( ) | 5 | Multimode fiber-optic cable, low-loss (<50dB/km), designed to meet cable performance requirements, purchased in 10,000 foot lots, will cost: (Assume full production mode, several competing manufacturers, etc.)<br>A. 40-50¢/ft (constant 1975 $'s)...<br>B. 30-40¢/ft (constant 1975 $'s)...<br>C. 20-30¢/ft (constant 1975 $'s)...<br>D. 10-20¢/ft (constant 1975 $'s)...<br>E. Other ........................... | | | | | | | | | | | | | | | |

| PARTICIPANT SELF-RATING ON QUALIFICATIONS TO ANSWER IN AREAS OF INTEREST (1), HIGHLY QUALIFIED TO (5), POORLY QUALIFIED | # | EVENT | User desirability | | | | | | Producer feasibility | | | | | | Probable timing<br>Enter the year by which you feel the probability is $P$ that the named event will have occured | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Necessary - definitely needed now | Will be necessary soon | Desirable now, but not necessary | Will be desirable soon | Undesirable now, possibly desired later | Cannot forsee any desirability in future | Highly feasible - could produce now | Feasible - could produce in future | Likely to be produced very soon | Likely to be produced in future | Unlikely, but possible to be produced | Cannot forsee possibility of production | $P$=.20 | $P$=.50 | $P$=.90 |
| | | ---FIBER OPTICS PRODUCTION (DEMAND)--- | | | | | | | | | | | | | | | |
| ( ) | 6 | Total U.S. production of low-loss (<50dB/km) single mode fiber optic cable will be: | | | | | | | | | | | | | | | |
| | | A. 1,000,000 feet ................. | | | | | | | | | | | | | | | |
| | | B. 10,000,000 feet ................ | | | | | | | | | | | | | | | |
| | | C. 100,000,000 feet ............... | | | | | | | | | | | | | | | |
| | | D. other .......................... | | | | | | | | | | | | | | | |
| ( ) | 7 | Total U.S. production of multimode (>200 fibers) medium loss (100-500dB/km) cable will be: | | | | | | | | | | | | | | | |
| | | A. 1,000,000 feet ................. | | | | | | | | | | | | | | | |
| | | B. 10,000,000 feet ................ | | | | | | | | | | | | | | | |
| | | C. 100,000,000 feet ............... | | | | | | | | | | | | | | | |
| | | D. other .......................... | | | | | | | | | | | | | | | |

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| 5. | CDR R. L. Johnson<br>Office of the Chief of Naval Operations (CNA-OSG)<br>Naval Department<br>Washington, D.C. 20350 | 1 |
| 6. | Dean of Research Administration, Code 023<br>Naval Postgraduate School<br>Monterey, California 93940 | 1 |
| 7. | Professor C. R. Jones, Code 55JS<br>Naval Postgraduate School<br>Monterey, California 93940 | 7 |
| 8. | LCDR E. Zabrycki, Code 55 Zx<br>Naval Postgraduate School<br>Monterey, California 93940 | 1 |
| 9. | CDR D. Forsgren<br>CNO (OP-982E2)<br>Washington, D.C. 20350 | 1 |
| 10. | Chief of Naval Material<br>NMAT-03422<br>Washington, D.C. 20360 | 1 |

11. A. D. Klein 2
Naval Air Systems Command
AIR-360G
Washington, D.C. 20361

12. CAPT R. N. Winkel 1
Naval Air Systems Command
AIR-533
Washington, D.C. 20361

13. Andrew S. Glista 2
Naval Air Systems Command
AIR-52022
Washington, D.C. 20361

14. N. Butler 1
Naval Electronic Systems Command
ELEX-304
Washington, D.C. 20360

15. K. C. Trumble 1
Air Force Avionics Laboratory
AAM
Wright-Patterson AFB, Ohio 45433

16. J. Ramage/Gene James 1
AFFDL/FGA
Wright-Patterson AFB, Ohio 45433

17. CWO R. Parent, USA 1
U. S. Army ECOM
Avionics Lab., AMSEL-VL-A
Ft. Monmouth, New Jersey 07703

18 T. R. Coleman 1
LTV Vought Systems Division
Code 2-14000
P. O. Box 5907
Dallas, Texas 75222

19. R. Betts 1
IBM Federal Systems Division
Owega, New York 13827

20. Commander
Naval Electronics Laboratory Center
271 Catalina Blvd.
San Diego, California 92152

Attn:
Code 1640 (J. Ellis) 2
Code 235 (R. Greenwell) 5
Code 4400 (L. Kinkel) 1

21. D. Dreyfus 1
Rand Corporation
Santa Montica, California 90406