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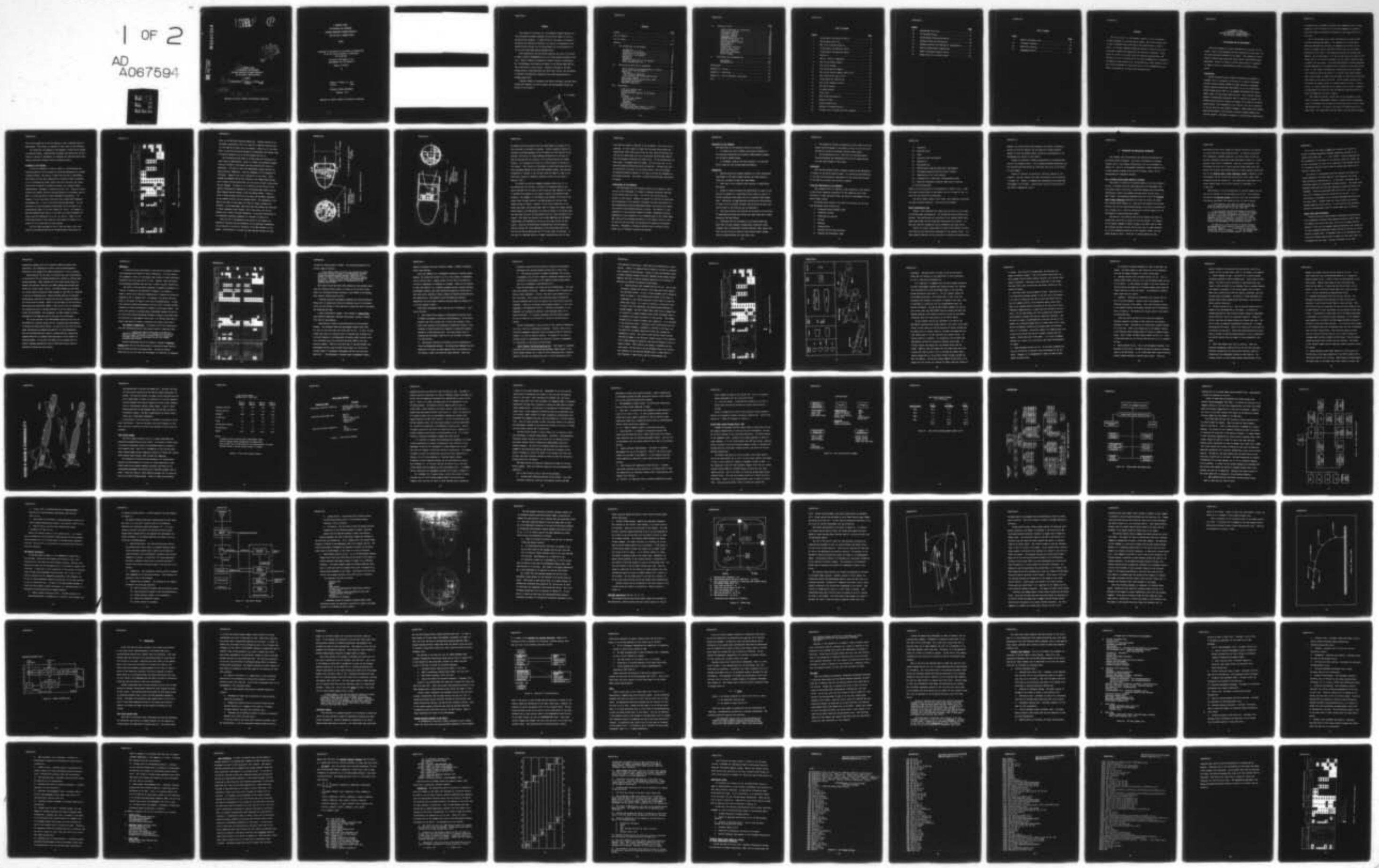

A TRADEOFF STUDY
TO DETERMINE THE PREFERRED
DISTANCE MEASURING GUIDANCE MODULE(S)
FOR THE GBU-15 WEAPON SYSTEM

THESIS

AFIT/GSM/SM/74D-3

Francis C. Gideon, Jr
Captain USAF

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A TRADEOFF STUDY

TO DETERMINE THE PREFERRED

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FOR THE GBU-15 WEAPON SYSTEM

THESIS

Presented to the Faculty of the School of Engineering
of the Air Force Institute of Technology
Air University
in Partial Fulfillment of the
Requirements for the Degree of
Master of Science

by

Francis C. Gideon, Jr., B.S.
Captain USAF

Graduate Systems Management

December 1974

Preface

This thesis is the report of a cost-benefit tradeoff analysis of four alternative guidance packages for the GBU-15 family of air-to-ground tactical weapons. A large portion of the report is devoted to historical and descriptive material, not only as a background to the analysis which follows, but for my personal use in anticipation of a job at the Guided Bombs System Program Office.

Both quantitative and qualitative analyses were done in an effort to make a logical recommendation as to the best guidance package of the four. Special thanks are extended to Colonel William J. McClelland, Mr. Jim McCormack, and Captain Bob Karner at the Guided Bombs SPO for their assistance in this project. Captain Al Lindsey of the PLSS Program Office, Wright-Patterson Air Force Base, and Mr. Bob Eisiminger of Rockwell International Corporation also contributed greatly in helping gather data.

A special thanks is extended to my faculty advisors, Capt Bob Tripp and Maj Bill Letzkus, for their support and encouragement during the course of this project.

F. C. Gideon

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Abstract

This is a report of a cost-benefit analysis of four alternative guidance packages for a guided weapon system. Life Cycle Costing (LCC) is used to analyse those inputs which were quantifiable in terms of costs. An original computer program was devised to sum the life cycle costs and to handle the computations for sensitivity analysis. Those inputs not found to be quantifiable are discussed qualitatively, and the basis for their contribution to the final recommendation is explained. As expected, close similarity of the alternatives in most respects led to very little difference in life cycle costs, so the recommendations are heavily influenced by the qualitative considerations.

A TRADEOFF STUDY TO DETERMINE THE PREFERRED DISTANCE MEASURING GUIDANCE MODULE(S) FOR THE GBU-15 WEAPON SYSTEM

I. The Problem and Its Environment

This first chapter is a brief introduction to the topic of the thesis. Many of the statements are left undetailed at this point, but are fully explained elsewhere in the report. The problem is a cost/benefit tradeoff study using Life Cycle Costing (LCC) methods where applicable. Benefit is found to be much more difficult to quantify in terms of costs, so other methods are used to evaluate benefit inputs.

Introduction

Missile Systems Division, Rockwell International Corporation, Columbus, Ohio, is currently in the midst of a product improvement contract (Letter Contract F08635-74-C-0046, modified by Amendment P00001, hereafter abbreviated 0046-P00001) let by the Guided Bombs System Program Office (SPO) at the Armament Development Test Center (ADTC), Eglin Air Force Base (AFB), Florida. This contract charters Rockwell International Corporation (RIC) to explore the concepts and hardware associated with a family of weapons to be known as the GBU-15 Weapon System. This designation is not official yet, but is reserved by the Air Force for this family of weapons. These weapons are modular, guided glide bombs to be delivered by tactical fighter-bombers onto tactical targets. The bombs are modular in that different combinations of guidance units, warheads, wings and other components may be joined together, at the discretion of the tactical commander, to provide a particular weapon configuration optimized for the target which is to be struck.

One of the guidance units under consideration is known as DME (Distance Measuring Equipment). The components of this Distance Measuring Equipment may naturally be packaged in a variety of ways within the weapon, and the tradeoffs involved lead to the problem addressed by this thesis. RIC presently envisions two possible DME modules. One is configured to fit like a nose cone on the front of the weapon, and is to be used for guidance from the time of weapon release to impact with the target. The second configuration involves packaging the DME components in the adapter section between the nose and the warhead. In this weapon configuration, the DME would guide the weapon only during the mid-course phase of its flight--from weapon release until visual contact is made with the target through an electro-optical (EO) device in the nose of the bomb. The EO guidance section would then guide the weapon through its terminal phase of flight. Alternatively, if visual conditions did not permit use of the EO in terminal, the DME module could function like the DME nose described above and guide the weapon all the way to impact.

With these two options in mind, part of the Statement of Work (SOW) of Contract 0046-P00001 requires a tradeoff study be performed by RIC to determine the desirability of procuring one or both of these DME guidance units. In effect, this thesis is doing precisely the same thing. The Guided Bombs SPO must make a decision before November

1974 on the proper mix of all the modules to buy, including these two DME modules. This thesis is intended to be an input to that decision.

The reader may find Appendix A and Appendix B useful while reading the material herein. Abbreviations, acronyms, and definitions are provided as a source of information to eliminate the confusion which often results from their different uses by different people.

Statement of the Problem

It will be necessary to refer to Figure 1, "Guided Weapon Configuration Matrix," while reading the following explanation of the DME tradeoff problem. This matrix is taken from the SOW of 0046-P00001 (Ref 28:87), and has been changed only to correctly label the modules as CI's (configuration items) rather than CEI's (contract end items). Notice that the matrix is divided vertically into columns labeled "Applications," "Warheads," "Guidance Section," etc. These are further divided into subsets which are actually modules of the weapon, each of which is titled and given a coded alphanumeric designation. For example, CI K_3 is the United States Air Force (USAF) MK-84 Expanded Wing Adapter Kit. CI M_1 is the Field Installed DME Module. By combining one of each type module horizontally across the matrix, the configurations shown in the left column will result. For example, a DME-only expanded wing version of the bomb with a MK-84 warhead will result from the combination of W_1, G_2, C_1, and K_3. There is a detailed description of every module in this matrix in Chapter II, so space will not be used here for that purpose.

With the above knowledge of how to read the matrix, note that there are two DME modules--one is the DME Guidance Section G_2; the

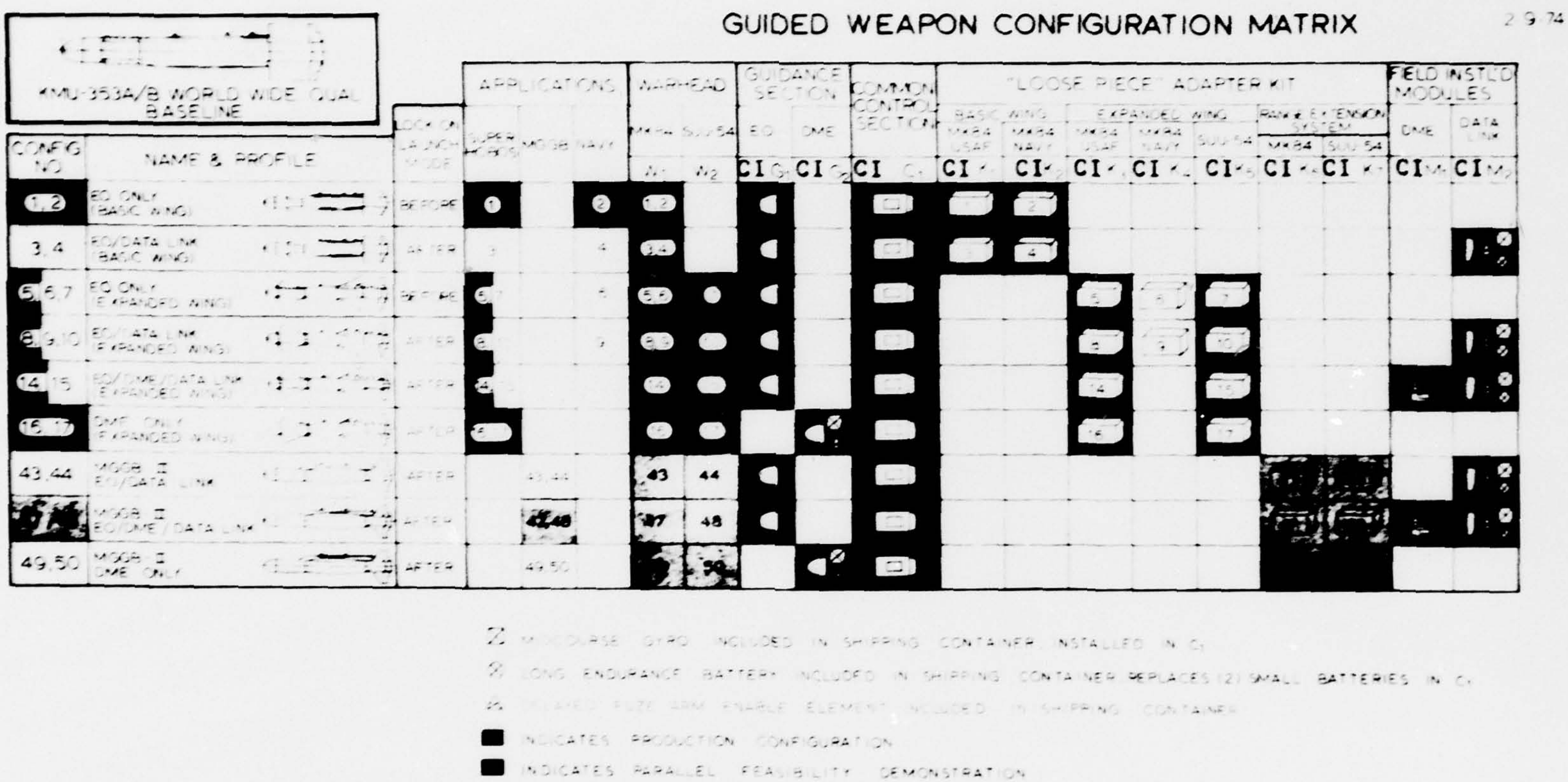


Figure 1. Guided Weapon Configuration Matrix

other is the DME Field Installed Module M_1. Guidance Section G_2 is the module envisioned by RIC to be used for a DME-only mission (that is, only DME and no other type of guidance). Module M_1, on the other hand, is used for mid-course guidance in combination with another form of terminal guidance such as the EO Guidance Section, G_1.

One interesting point needs to be made about the similarity between these two DME modules. After it is made, the perceptive reader would be inclined to ask himself the same question this thesis is addressing. The point is that both DME modules contain exactly the same electronic components. Only the packaging of the components is different. Figures 2 and 3 are illustrative of this fact. These figures are adapted from an RIC briefing to the Guided Bombs SPO and are no longer accurate depictions, but they serve to make a point which has not changed. In Figure 2, G_2 is shown as a nose section of the weapon, containing the components of the on-board DME system, with an empty adapter section between it and the warhead behind. Figure 3 shows a second guidance section in the nose, the M_1 Module installed in the adapter section, and the warhead behind. The components of the DME are the same in both cases, but they are simply arranged differently. As was mentioned, there have been some changes and additions to these components since Figures 2 and 3 were drawn, but the two modules still contain the same components. An accurate description of the presently-conceived components is contained in Chapter II.

With this bit of background on the nature of the weapon, the modularity involved, and the similarity of the electronic components, we turn briefly to the use or functions of the DME equipment in the weapon. One function is to guide the bomb sometime between the time

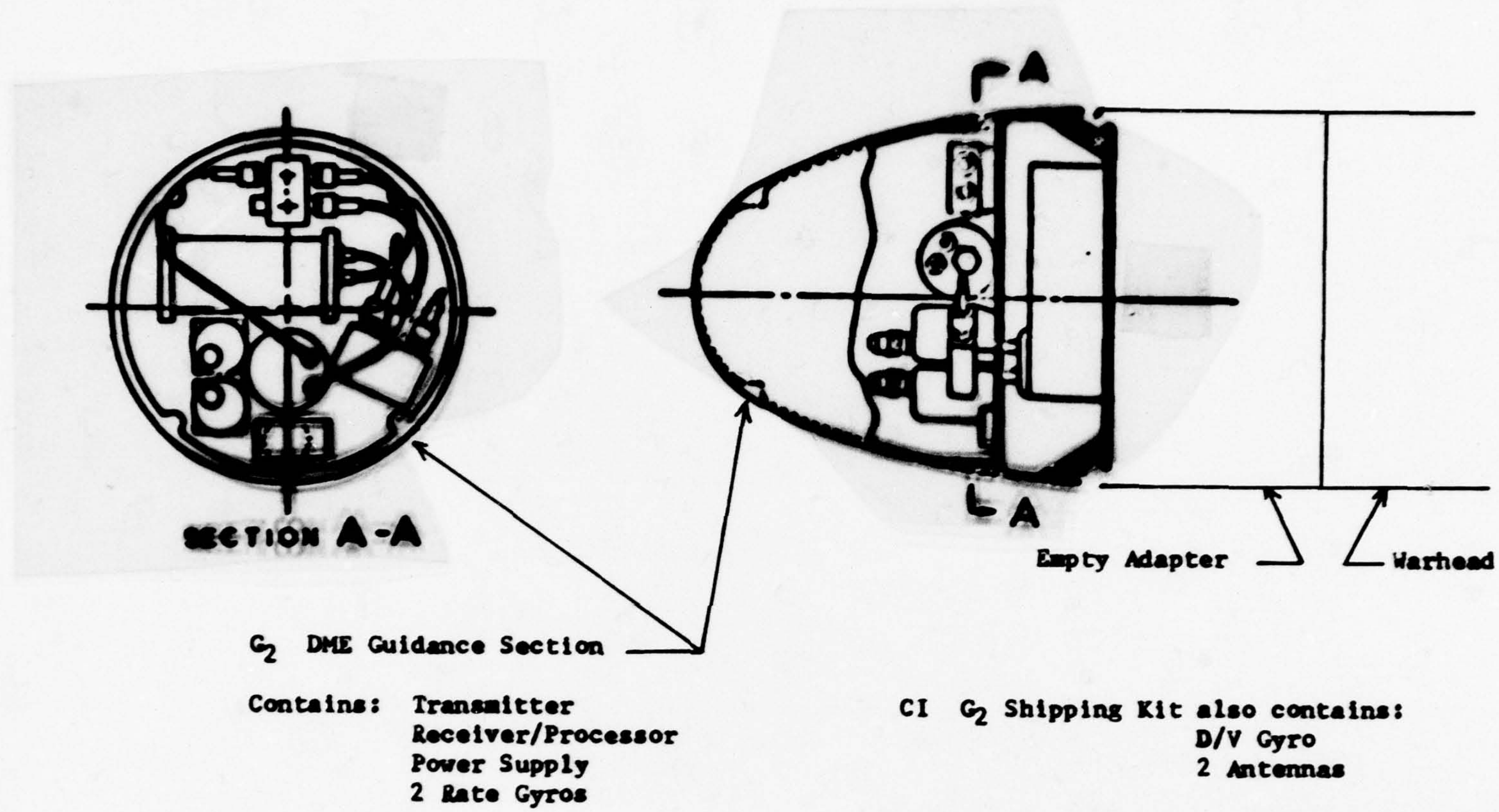


Figure 2. DME Guidance Section G_2

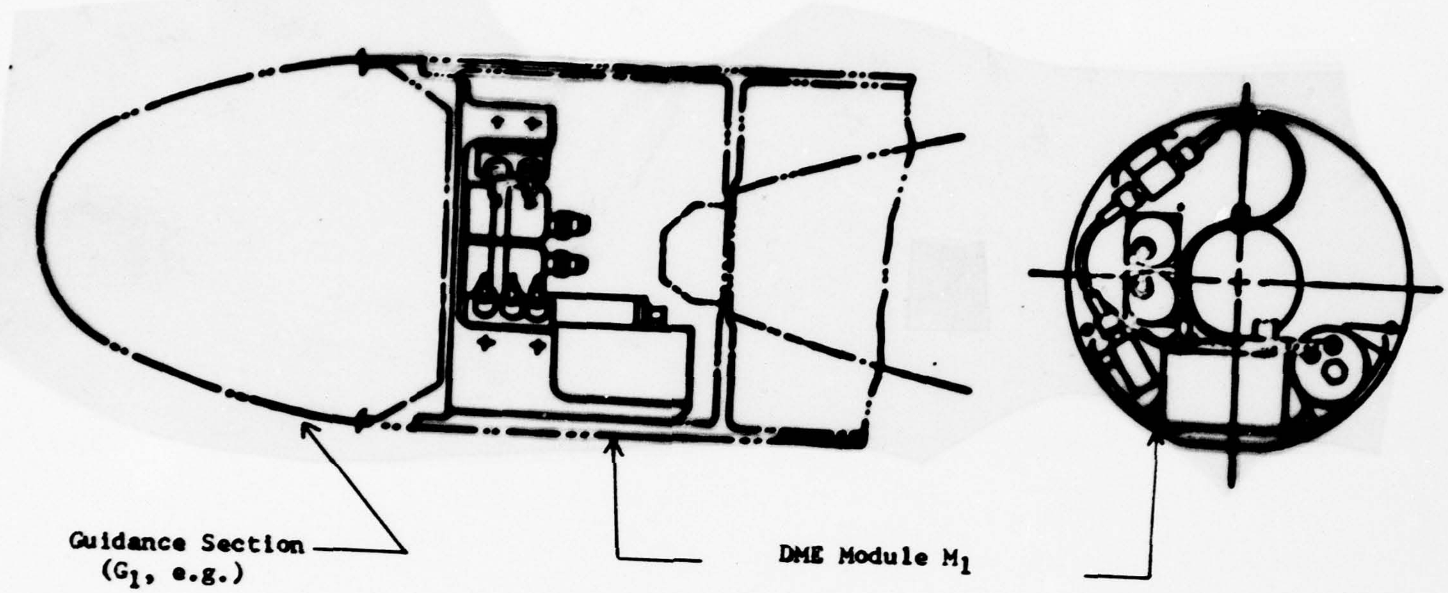


Figure 3. DME Field Installed Module M_1

of release from the aircraft until the bomb impacts the ground or the fuze functions to detonate the warhead. Another important function is provided by the DME equipment while the weapon is still captive on the aircraft, and that is to relay steering information to the pilot so that he may position his aircraft to the optimum location for weapon release. The information is shown on a video display (TV screen) in the cockpit. This location is determined by associated ground and airborne equipment making up the total DME guidance system. The steering information is relayed to the aircraft from the weapon by some of the additional electronic components alluded to above but not shown in Figures 2 and 3.

To provide the tactical commander maximum flexibility, it is envisioned that he will have a variety of the modules shown in the matrix available at his base so that he may put them together in a mix to optimize his weapons for the target, weather, and expected enemy defenses. For example, if the weather were forecast to be poor in the target area, he might decide to use DME guidance all the way from weapon release to impact. However, if the visual conditions at the target were good, the aircrew might elect to release the weapon outside enemy defenses, use DME guidance to steer the weapon to the target area, and then take over with the EO guidance unit for a more accurate hit on target. With these two possible uses of DME (DME-only and the DME/EO combination), RIC proposes use of G_2 for the former and M_1 for the latter. There are obviously many considerations, but the question asked by several Air Force employees at the Guided Bombs SPO is why not buy only the M_1 Module and use it for both types of missions. In the case of a DME-only profile, a dummy, ballasted nose cone of some kind would be needed in addition to the M_1 Module. This nose will be coded M_5. At first glance it seems that the same effectiveness and capabilities result from using the M_1 for both types of missions, and that the Air Force saves the cost of procuring the additional module with the attendant logistics and supply costs. So the alternatives are then clear: (1) M_1/M_5 versus (2) M_1/G_2. As of 24 July 1974, an Air Force/RIC meeting produced two more alternatives. Although they were not originally to be part of this thesis effort, they are included. The meeting produced proposals of two ways to divide the components of M_1 between M_1 and M_5. The result is three different M_1/M_5 combinations and M_1/G_2.

Significance of the Research

The significance of this research effort lies in making a contribution to the development of a family of weapons considered important to the United States Air Force. The writer will be acting as an analyst in this thesis. Normally an analyst will define the objectives and alternatives of the analysis, determine the costs and benefits of the alternatives, devise an appropriate model, and describe the output that results from applying different criteria. The analysis is then presented to a user (decision maker) who makes a management decision. Regardless of the acceptance of the recommendations by the Guided Bombs SPO, there will be thorough discussion of the relevant facts, so that the SPO will have available the background for making an intelligent decision. Presumably, a different decision from the writer's would result only if different criteria were applied.

Objectives of the Research

The objectives of this research effort are as follows:

- to analyze the cost, schedule, and quality tradeoffs of procuring and deploying four alternative DME guidance packages for the GBU-15 Weapon System,
- to recommend, based on the above analysis, the preferred choice among the four proposed DME procurements.

Assumptions

1. DME mid-course and terminal guidance is a valid operational requirement of the GBU-15 Weapon System, and either M_1/M_5 or G_2/M_1 will be bought to meet this requirement.
2. Each input to the tradeoff study consists of identifiable attributes.
3. Enough of these attributes are quantifiable in terms of cost and can be combined in a functional form or model to point to a clearly preferred choice among the four alternative DME package buys. (Obviously, not all important attributes are quantifiable, so these will be discussed in detail and the basis for their subjective input to the decision will be explained.)
4. Life Cycle Costing (LCC) methods can be applied to the choice of subsystems even after most design has taken place and a single contractor has been chosen.
5. Sufficient data are attainable at the Guided Bombs SPO, Eglin AFB, Florida, Rockwell International Corporation (RIC), Columbus, Ohio, International Business Machines (IBM), Owego, New York, and the Precision Location Strike System (PLSS) Program Office, Wright-Patterson Air Force Base, Ohio.

6. The modulatiry concept as applied by the Air Force to air-to-ground tactical weapons is the method by which the Air Force will provide for future air-to-ground tactical weapon needs.

7. The established (as of 1 June 1974) Air Force/contractor interrelationships and responsibilities will not change during the time frame spanned by this study.

Hypothesis

Only one DME guidance module, presently called the M_1 DME Module, is needed for the GBU-15 Weapon System. In conjunction with Module M_5 it can meet the DME guidance requirements for all envisioned missions of the GBU-15 at optimal cost effective tradeoff.

Scope and Limitations of the Research

This research effort is limited by time constraints (four months) on the writer, budgetary constraints on TDY (temporary duty) funds available to travel and gather data, and security requirements on the GBU-15 Weapon System.

The system being studied is the GBU-15 Life Cycle, and its relevant subsystems under scrutiny are:

1. Aerospace Ground Equipment (AGE)
2. Production process
3. Production engineering
4. Storage
5. Handling
6. Transportation
7. Training for Air Force personnel
8. Research and Development (R&D)

9. Warranties

10. Operating Costs

11. Tests

12. Contractor data requirements

13. Reliability

14. Maintainability

15. Effectiveness (meeting operational requirements)

16. Performance (meeting technical specifications)

17. Compatibility with future modules

18. Vulnerability to electronic countermeasures (ECM)

19. Munitions Maintenance Squadron (MMS) ease of handling at the operating base.

Items 1-12 are envisioned to be quantifiable in terms of cost. Items 13-19 may be quantifiable in some sense, but not in terms of cost, so they will bear subjective evaluations.

The GBU-15 Weapon System is also under total budgetary constraints and under schedule pressures. These will be considered.

Thesis Presentation Plan

Chapter I has acquainted the reader with the nature of the trade-off problem under consideration. The problem has been introduced and defined. The significance and objectives of the research effort have been stated along with the scope and limitations of the effort. In addition, specific assumptions and an hypothesis have been stated.

Chapter II covers a broad range of topics while probing in detail the historical and descriptive background of the research effort. For those readers familiar with the evolution of guided air-to-ground glide weapons, the current Pave Strike program, the concept of modularity applied to tactical weapons, and the operation of DME equipment, Chapter II could be skipped without losing any understanding of the methodology and results of this thesis.

Chapter III contains a complete presentation of the methodology used in this research effort. The originally-proposed methodology and the actually-used methodology are described along with the rationale for any changes.

Chapter IV presents the analysis of data and findings of the research. The last chapter then draws conclusions from the material in Chapter IV. Finally, recommendations addressing the proposed DME procurements will be made. Abbreviations, notation and definitions are found in Appendices A and B.

II. Historical and Descriptive Background

This chapter sets the historical and descriptive background of the GBU-15 family of weapons. This type of information is grouped together here so that lengthy descriptions will not be necessary in Chapter IV. Since it is background information, readers familiar with the DME tradeoff problems could omit this chapter without loss of understanding of subsequent chapters.

Use of Guided Air-to-Ground Weapons in Warfare

"The advent of guided air-to-ground weapons in the late stages of the war in Southeast Asia and improvements and new development work since have caused a revolution in munitions systems that necessitated establishing a deputy for armament systems during the past year, ..." (Ref 73:265). The preceding quotation from the 15 July 1974 *Aviation Week & Space Technology* highlights how brief the history of guided air-to-ground glide weapons is. There have been guided air-to-ground missiles such as the rocket-powered Bullpup in the active inventory for over a decade, but it took the Vietnam War to provide impetus for the development of large guided glide bombs.

The need for this sophisticated tactical weaponry has been expressed most succinctly in terms of lives and dollars. For example, in the bombing campaign of North Vietnam in pre-1968, tons of bombs were dropped and many aircraft and men were lost to enemy defenses--all in the attempted destruction of one important target, the Paul Doumer Bridge in Hanoi. World War II vintage bombs were used, prescribing tactics which caused the tactical aircraft to be exposed to a very effective target defense system. In contrast, during the 1972 Linebacker I bombing operations, the first flight of four F-4 aircraft targeted on this same bridge destroyed one span of it within minutes without loss to themselves. What was the difference? The difference was their use of electro-optical guided bombs which permitted high accuracy and minimum exposure to enemy defenses (Ref 86:16). Most of the Aviation Week & Space Technology (AW&ST) references in the Bibliography contain pictures and descriptions of the "smart bomb" successes during the Vietnam War. The large scale operational use of guided weapons began with the first mission of Linebacker I on 11 May 1972.

Effectiveness of this new generation of tactical weapons was not lost on the Israelis in the Yom Kippur War of 1973. The following quotations from National Defense illustrate this fact and emphasize the growing requirement for weapons such as the GBU-15 family.

> In the Israelis' case, again for example, they had stand-off weapons--Maverick, Walleye, Hobo (homing bomb)--which over-all were about 90 per cent effective . . . .
>
> It has galvanized the American Defense Establishment into action--Congress willing, as it considers the requests now before it--on the replenishment and expansion of war reserves to meet needs of both U. S. forces and allies, expansion of airlift capability, production of a waiting array of defensive and offensive precision munitions, and research and development of next-generation weapons . . . .
>
> Dr. Malcolm R. Currie, Director of Defense Research and Engineering, told Congress in testimony on the fiscal 1975 budget requests: . . . "technology has significantly changed the nature of weaponry . . . with the biggest impact in the area of precision-guided weapons" (Ref 21:506).

The 15 July 1974 issue of AW&ST also stressed the "need for a variety of defense suppression weapons, graphically defined in the October Arab-Israeli War, . . ." (Ref 73:265). Security measures prevent assessment in this thesis of the specific results of Israeli use of this type weapon, but that is not important to the research effort. It is enough to note the brief history of guided glide weapon use in warfare - 1968 to 1973.

As a matter of unconfirmed historical interest, the author has found reference to TV-guided bombs on a wall plaque at the Guided Bombs SPO dating from World War II. It describes a TV-guided, gyro-stabilized weapon with aerodynamic surfaces attached. The Wright Field Equipment Laboratory and 1942 were mentioned as place and time of development. There were supposedly 1000 units built, a few of which were used in Germany during the latter part of the war. It is interesting to contemplate why no further development was done until the early 1960's. Perhaps there was little interest in pinpoint bombing capability in the 1950's. It could also be that available Research and Development funds for guided bombs were too limited.

Guided Glide Bomb Development

Electro-optical and Laser guidance technologies received their first Department of Defense (DOD) emphasis during the early 1960's. For example, the first crude Lasers were built by Hughes Aircraft Company in 1960, and the Armament Research Laboratory (now called the Air Force Armament Laboratory) became involved by setting up a Laser Division in March 1962. By September 1963, it was determined that there was a weapons application for Lasers but that power level requirements were very high. Advances continued, but by 1968, engineering problems were still unsolved though the physics were understood. The technology was found to have seeker/designator application even though direct Laser destruction is still a problem.

Electro-optics (TV) has been in existence for over three decades, so the specific use for weapons guidance was a matter of solving engineering problems. These problems are still being solved today, but weapons like Walleye, Maverick, and HOBOS (Homing Bomb System) have proven the concept beyond a doubt. The HOBOS Program was initiated as a quick reaction capability (QRC) program in late 1967 as a reaction to the war in Southeast Asia. Missile Systems Division of Rockwell International received the contract and had pilot production models in the field within 16 months. HOBOS is the RIC name for the Air Force's Electro-optical Guided Bomb (EOGB). When the kit, that is everything but warhead and fuse, is shipped from RIC to the Air Force, it is termed the KMU-353A/B. Once assembled, the EOGB becomes the GBU-8. Deployment of the EOGB has been to tactical units world-wide.

RIC is now involved in the 0046-P000001 Contract which uses the KMU-353A/B as a baseline weapon and will integrate many improvements to develop the whole GBU-15 family. As late as 22 July 1974, the proposed terminology was changed from AGM-112 to a GBU designation. AGM (air-to-ground missile) implies a powered missile, whereas GBU (guided bomb unit) is slightly more descriptive of this family of unpowered bombs. In any case, the family has now become part of a greater "defense suppression" effort called Pave Strike, which is described following the next section.

Modularity

It should be clear from Chapter I that one of the primary concepts which generated this thesis is that of modularity. At first glance, the arguments in favor of the concept seem to make it highly desirable, especially from the user's point of view. However, there are design and performance problems that may tend to offset tactical flexibility.

The result of the modularity approach to weapons procurement is a "family" of weapons as was explained in Chapter I for Figure 1. Figure 4 shows the 54 possible configurations of modules as originally proposed by RIC in January 1974. By February, this matrix had been pared to the matrix of Figure 1 with only 20 configurations. In part, this reduction reflected awareness by the Air Force of design problems created by a large proliferation of modules in one weapon family. The writer has observed at several design conferences between RIC and the Air Force that frustrating design problems of making a new module meet the form and fit requirements forced upon it by limited space make it almost seem easier to design a completely new weapon from scratch.

The Concept of Modularity. In contrast to the last observation, note the following quotation from General Gerald K. Hendricks (USA):

> . . . science and industry have given us so many new capability combinations that it is becoming obvious that the nation no longer can afford to develop and buy a completely new weapon for each new performance option that becomes available (Ref 43:300).

Another interesting article by Timothy D. Desmond in National Defense makes note of the large extent of duplication among tactical air-to-surface missiles and guided bombs. He does not address modularity per se, but calls for development of "families" of armaments

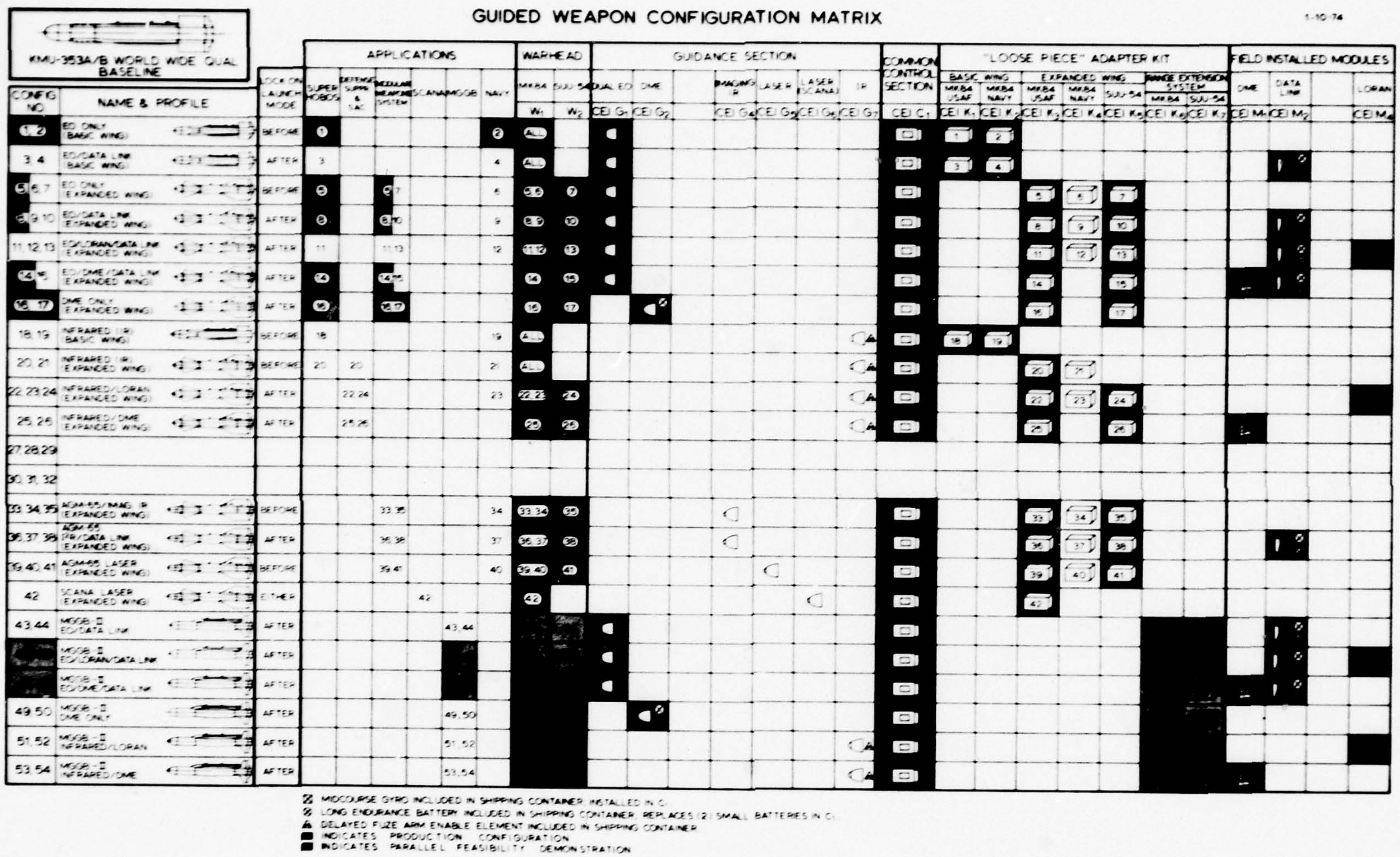


Figure 4. Guided Weapon Configuration Matrix

to meet the varying needs of combat. The closing paragraph of his article reads as follows:

> Until missile state of the art can provide the strike pilot with a choice in flight of interchangeable guidance systems and multiple warhead designs, there must be a variety of similar "smart" munitions--families of weapons, as it were. The art is still young, and proliferation of designs is a necessary adjunct of experimentation and learning (Ref 29:531).

Both these writers and most other students of the problem recognize the conditions which prevail to create it in the first place. These are illucidated by Major William A. Rose (USAF) in his management study as follows (Ref 74:1-10):

--national security requirements competing for scarce resources. Rising cost of weapons and inflation ultimately lead to two options--either buy few systems or find some way to reduce the cost of acquiring and operating new ones.

--rapid technological change. Alvin Toffler in Future Shock (Ref 82:25-29) emphasizes technical obsolescence causing a reduced life cycle of new products.

--duplication of effort and proliferation of air-to-surface weapons. The reference above and Development Concept Paper (DCP) No. 128, 31 July 1973, make this point (Ref 22:1-3). In fact, the DCP claims that there are currently about 30 unguided and 13 guided air-to-surface weapons in the Department of Defense (DOD) tactical inventory, excluding guns, anti-radiation missiles (ARM's), and Army peculiar weapons. There are also more than 11 ongoing Research and Development efforts, each of which could result in a new air-to-surface weapon if independent development efforts were continued (Ref 22:1). The Department of Defense needs a management concept capable of dealing with rapid technical change - capable of adapting rather than reacting.

Given this emphasis for a management technique to acquire needed weapons, the modularity concept is in its first stages of implementation by the Air Force. Simply stated, the Air Force will acquire a variety of components (or modules) of a weapon. There will be several of each type module--i.e., warhead, guidance section, control section, aerodynamic surfaces, and other special-use modules--of which one of each type can be combined to make a weapon of required characteristics and capabilities. Each module will be developed and produced separately, but with proper interface controls among the modules of a particular weapons "family."

Three major advantages result from the use of modularity. They are as follows:

1. The concept shows promise of substantially reducing costs of RDT&E, procurement, operations and maintenance. An Air Force analysis (Ref 22:5) showed that a 30 per cent savings in Life Cycle Costs resulted from applying the modularity concept to the purchase of 100,000 missiles as opposed to buying four separate systems of 25,000 missiles each. The large savings were in research and development (R&D) due to the avoidance of duplicative R&D efforts.

2. Operational flexibility increases with the development of field interchangeable modules. The operational commander has the capability of quickly building weapons which are optimized for the weather, target, and expected enemy defenses. Long term

flexibility results from the ability to absorb new technology subsystems into existing weapons quickly and at lower cost.

3. "The modular approach to weapons development will provide a management tool by which competing technology programs can be evaluated in relationship to the complete weapon system rather than as an independent function"(Ref 22:5).

There are advantages, but there are also disadvantages. The first deals with modular interfaces. Modular components must interface with several other components. As such, they may be more expensive on a unit cost basis. This results from interface design problems and limited packaging space within the weapon for a particular functional component. These are the design type problems alluded to in the first paragraph of the Modularity section. Similarly, performance of the component will probably be inferior to one designed *solely for a* specific mission. It is highly improbable that the modular weapon will be as effective in all cases as a series of special-purpose weapons.

Another disadvantage is the possibility that required standardization will stifle new technological advances. Finally, there is the difficult management transition from the present method of acquiring weapons to a strictly modular approach. An example of the type of problem created by implementing the modularity concept of management is illustrated in the section on Pave Strike.

GBU-15 Modules (Excluding M_1/M_5 and G_2). This thesis is concerned primarily with the Distance Measuring Equipment (DME) modules of the GBU-15 Weapon System, but in order to fully understand what a complete weapon is and what its capabilities are, a brief description of the other modules is given here. M_1/M_5 and G_2 are described in a later section. Figure 1 is repeated here as Figure 5 for ease of reference while reading the descriptions. Figure 6, taken from Rockwell International's Missile Systems Division's "Modular Guided Weapon System" pamphlet (Ref 58) is another excellent depiction of the concept of modularity as applied to Rockwell's Super-Hobos.

1. Electro-optical (EO) Guidance Section (CI G_1). This is the 150-pound, rounded nose section of the bomb about which mention has been made before. It has a 15-inch diameter and is shaped as shown in Figure 6. The extreme front portion of the shell is transparent to the visible spectrum to allow light to reach the camera lens inside. As a point of interest, a protective cover is placed over the transparent nose during ground handling to prevent damage. The lens (seeker head) along with a preamplifier is attached to a gimbal assembly which allows the seeker head to be slewed by the weapon controller in the aircraft. This gimbal assembly has a circular 29 degree slew capability. It is attached to the protective shell. Electronic circuit cards mount just aft of the gimbal assembly, a bulkhead is attached to the rear, and the whole unit is gasket sealed and filled with nitrogen for atmospheric control. The circuit cards provide visual pictures from the EO seeker to the aircrews' display screen in the aircraft. This is done through an umbilical cord when the weapon is still in captive flight. While captive, the weapon is operating on aircraft power. On the rear of the aft bulkhead there is an electrical connector for the required 28±4VDC power, a purge valve, a test connector, a mode switch, and two potentiometers for

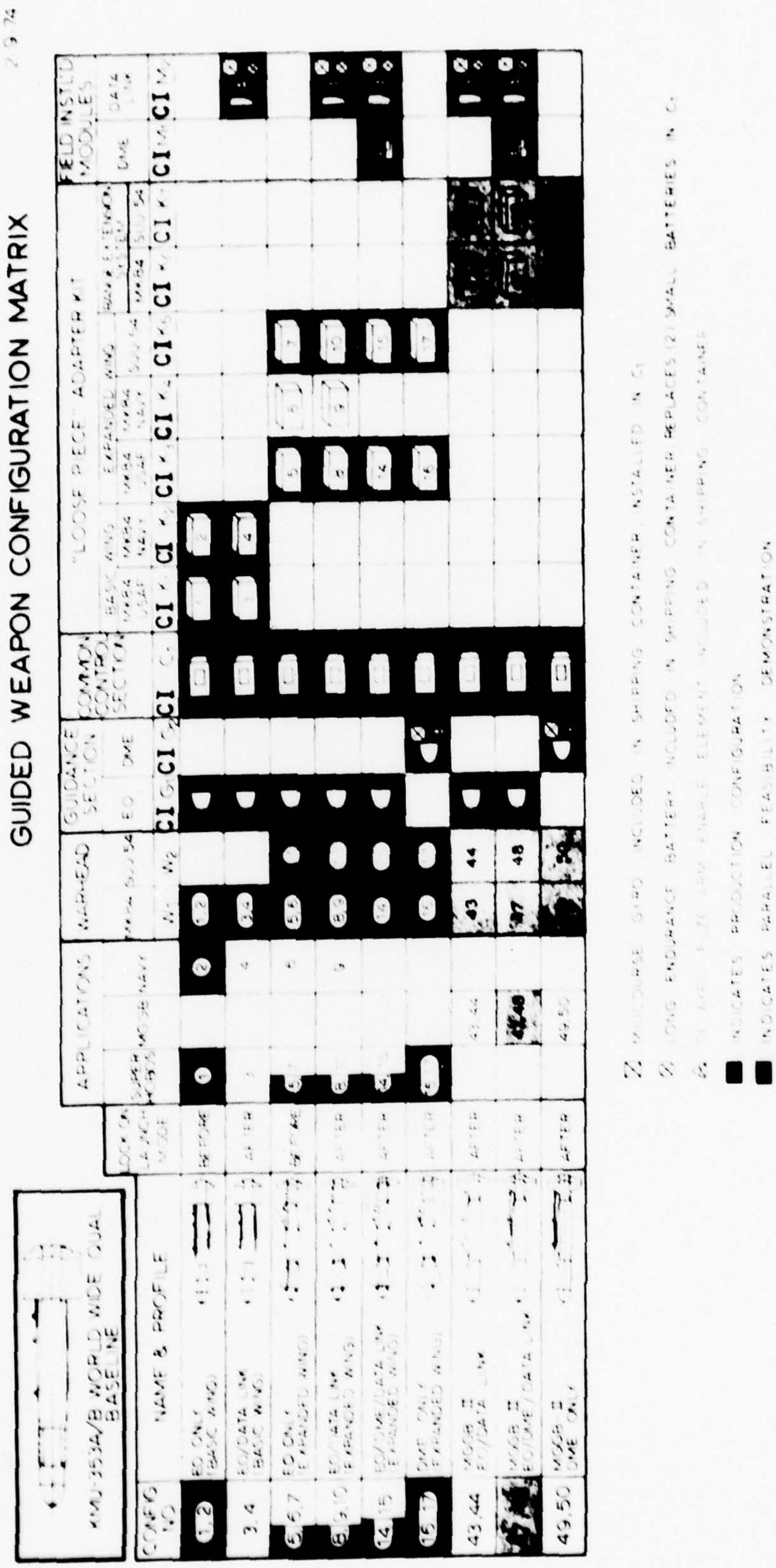


Figure 5. Guided Weapon Configuration Matrix

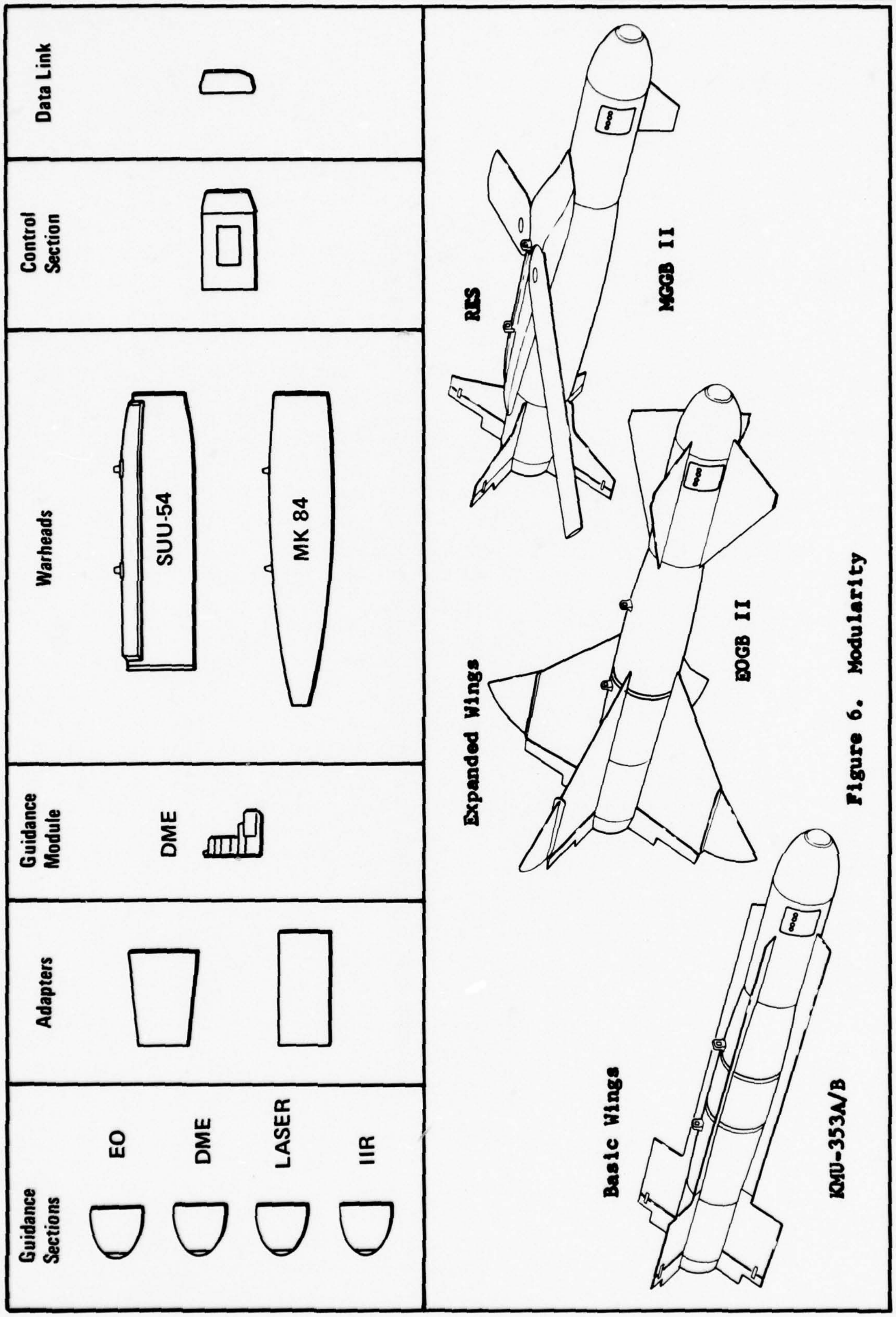


Figure 6. Modularity

adjustment. The mode switch is preset by the aircrew before flight and its function is not significant to this discussion, nor has it been fully determined yet.

It is important to remember that the GBU-15 weapon program is a product improvement program which equates closely to a combination validation/full scale development phase of the classical system acquisition cycle (Ref 1). For this reason, almost all the hardware described in this thesis and, in fact, even the techniques and concepts, are subject to change at any time. This is mentioned in connection with the potentiometers here, but applies throughout. The EO and DME Guidance Modules (G_1 and G_2) are covered under the 0046-P00001 Contract whereas the Laser and Imaging Infrared (IIR) Guidance Sections (G_4 and G_5) are simply conceptual ideas for future growth of the GBU-15 family.

The EO Guidance Section was conceived to be used on the KMU-353A/B electro-optical guided weapon in the direct attack mode. "Direct attack" means the aircrew acquires the target through the EO seeker prior to launch, locks on, releases the weapon and can then forget about it so that they may take evasive action. No further control is possible. In conjunction with the Data Link (DL) Module, the EO will provide an indirect attack mode. In indirect attack, the weapon will be released miles from the target. DME will take the weapon into the target area where the aircrew will then be able to find it through the seeker head's inputs relayed back to the aircraft display screens through the Data Link Module. The DL also relays command instructions to the weapon from the aircrew for slewing the seeker head and locking on to target. Once lock-on is accomplished, the EO guides the weapon as before to impact. The two available launch modes are often termed "lock-on before launch" (direct), and "lock-on after launch" (indirect). Obviously visual conditions in the target area must allow time for acquiring the target, locking on, and arming the weapon.

2. Data Link Field Installed Module (CI M_2). Basically, this is an electronics package secured to the tail end of the weapon. It is used in conjunction with EO (G_1) and the Control Section (C_1) for command control of the EO-guided weapon after launch. There is an antenna mounted externally at the back for RF (radio frequency) communications to a Data Link pod carried by the aircraft. The aft DME antenna will also be physically attached to the DL Module, although they have no electrical interface. The DL cover is shaped to aerodynamically close off the end of the weapon, so a similarly-shaped cover is needed when no DL is used. The aft aerodynamic surfaces are nestled around the DL Module after it is installed. Electrical signals for communicating with G_1 and C_1 are routed fore and aft through a conduit and wire bundle. The DL also uses 28 VDC power. It is built by Hughes Aircraft Co., Culver City, California, and weighs approximately 20 pounds.

3. Laser Guidance Section (CI G_5). No new Laser guidance section for the GBU-15 is presently under development by the Air Force. Instead, it is contemplated to adapt the AGM-65 Laser seeker for GBU-15 use.

An airborne or ground designator is used to spotlight the target. The Laser seeker is then locked on to the designated spot and the weapon launched in a direct attack mode.

4. Imaging Infrared (IIR) Guidance Section (CI G_7). This is another seeker which, like G_5, is in the conceptual phase for use in the GBU-15. It will present an image to the pilot similar to the EO picture, but makes use of infrared energy rather than the visible spectrum to find the target. An increased all weather/ night capability will result.

5. Adapters. Confusion of terminology could result with the use of the word adapter. Figures 5 and 6 use adapters for different portions of the weapon. This brief discussion refers to the adapter between the guidance sections and the warheads as shown in Figure 6. The adapter kits (K_1-K_7) shown in the matrix are discussed later.

Since the SUU-54 and MK-84 are of different diameters, different adapters are needed to mate them with the guidance sections in front. The adapters are simply metal shells designed to do that job. There is an access port in the adapter leading to the interior which contains about 10 inches of usable fore-aft space. This is where the DME Guidance Module M_1 will fit. Space is also sufficient for the SUU-54's FMU-110 fuze if it is selected for use.

6. MK-84 Warhead (CI W_1). One of two designated warheads to be delivered by the GBU-15, the MK-84 has been successfully used many times on the KMU-353A/B. It is a 2000-pound (1927 pounds actually) unitary warhead designed to destroy hard targets. Fuzes are

usually located in the nose and tail and are set to go off on contact or with a slight delay (.025 or .01 seconds, for example).

7. SUU-54 Warhead (CI W_2). The SUU-54 is a cluster warhead containing hundreds of BLU-63 submunitions. Total weight is 2060 pounds. The fuze is set to function at some height above the target so that the BLU-63's are dispersed over an optimum diameter. The warhead is designed to kill softer targets than the MK-84. Radar vans, surface-to-air missiles (SAM's), personnel, and anti-aircraft guns are examples. The SUU-54 is being developed as a separate Pave Strike program called Pave Storm. (See the Pave Strike section following.)

8. Control Section (CI C_1). This is the only module which is common to all configurations of the weapon. It houses the pneumatic/mechanical flap actuator system, powered by compressed helium (7000 psi) stored in a spherical reservoir. Autopilot circuit logic and the weapon battery are located here also. The unit is built by Rockwell International Corporation. It weighs approximately 200 pounds. There is an access port on the side of the Control Section shell. Mid-course directional/vertical gyroscope is needed for DME and EO/DL missions, so this is mounted in the Control Section when the weapon is being assembled in the field.

9. Basic Wing Adapter Kits (CI's K_1 and K_2). These are identical aerodynamic surface kits for the Air Force and Navy. Different designations are used because different fuzes are shipped with the aerodynamic surfaces to each Service. The surfaces consist of four strakes mounted longitudinally on the

weapon, with larger fins and control flaps at the tail. It is these flaps which are controlled and moved by C_1 to guide the weapon through the air. Figure 6 shows the configuration of the basic wings. Clearly these wings do very little more than stabilize the bomb as it drops away from the aircraft, so the weapon is used in the direct attack mode with a very low glide ratio. Kits K_1 through K_5 are manufactured by RIC.

10. Expanded Wing Adapter Kits (CI's K_3, K_4, and K_5). The expanded wing planform was developed to allow the aircrew to stand-off in the "direct attack" mode at lower altitude. This could only be done by increasing the wing area and therefore lift. An added benefit to this requirement was the indirect attack capability. Coincidentally, operational use of the HOBOS highlighted a requirement for an indirect attack capability, so the expanded wing planform of the EOGB II and RES (Range Extension System) of the MGGB II were both found suitable. It is obvious from a glance at the expanded wings that considerably more lift can be developed than the basic wing provides. The cruciform wings are hinged about one third of the way from the tips to allow folding for carriage under tactical fighter aircraft wings. They are spring loaded and extend after release from the aircraft. The weight of the forward strakes and aft wings and control surfaces is about 270 pounds.

11. Range Extension System (RES) Adapter Kit (CI's K_6 and K_7). The RES adds a long range capability to the GBU-15 family with a relatively high-lift set of wings. These wings are stowed against the upper spine of the weapon until after launch, at which time

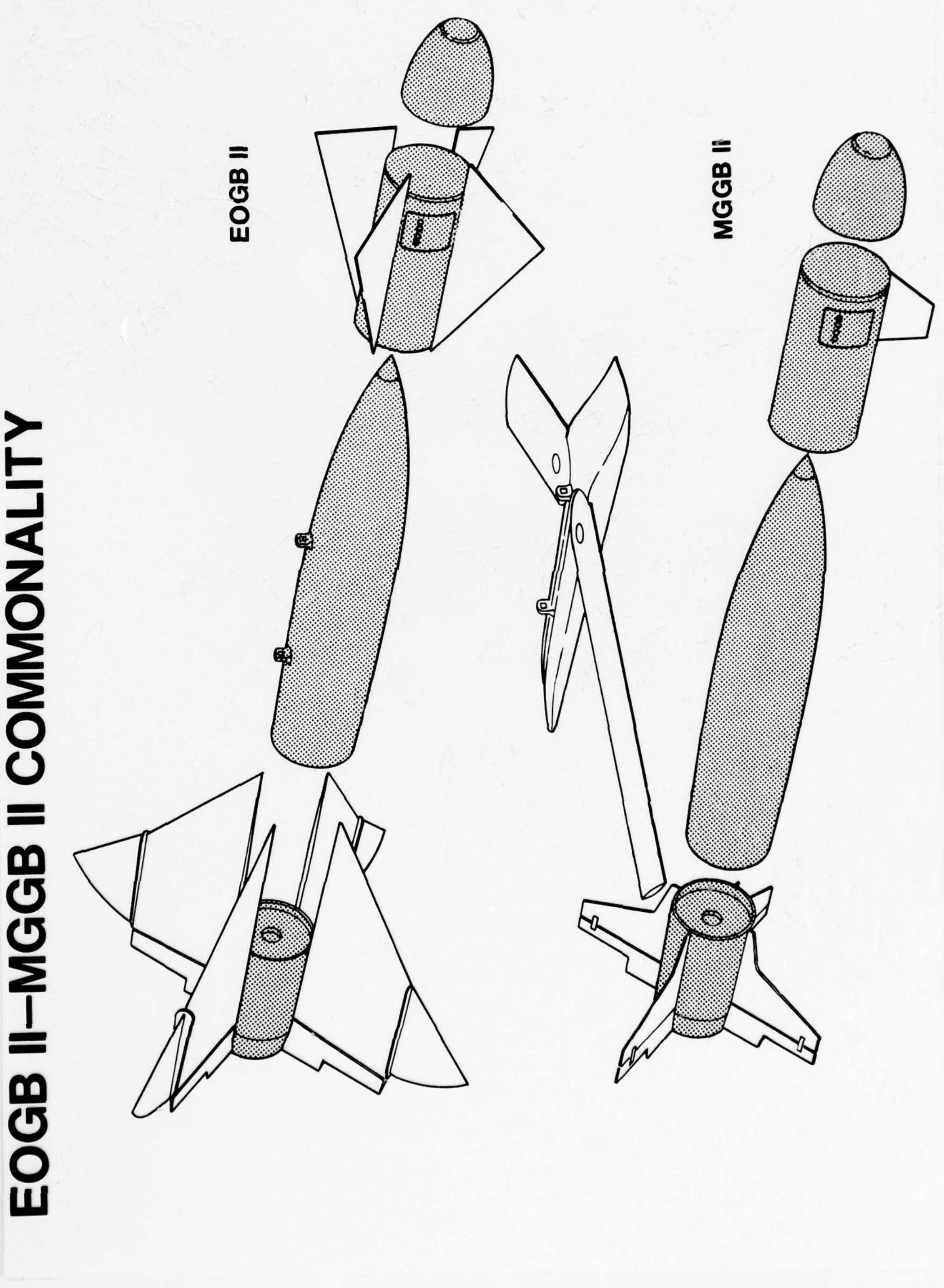


Figure 7. EOGB II - MGGB II Commonality

they spring open to provide the needed lift. The RES, cruciform tail and control surfaces and the ventral strake weigh about 315 pounds. For security reasons, no range figures are given here for any of these types of wings, but suffice it to say that capabilities are present from close-in range with direct attack configuration to considerable indirect attack ranges. Figure 7 gives another depiction of the expanded wings and the RES, as well as the modular concept. The RES is manufactured by Celesco Industries, Inc., Costa Mesa, California.

An indication of the total size of the EOGB II and MGGB II can be seen from Figure 8. They are obviously quite hefty weapons, so only one or two can be carried on the tactical fighters for which they are designed.

Pave Strike Program

The GBU-15 Weapon System is part of a larger development and acquisition program known as Pave Strike. A discussion of Pave Strike is therefore considered relevant as background material relating to this tradeoff study. Much of the information in this section comes from a Senate Armed Services Committee hearing on 20 March 1974, during which Colonel James Lindsay, USAF, briefed the committee.

The objective of the Pave Strike Program is "to significantly improve the effectiveness of tactical air forces operating in high threat areas during adverse weather, day/night conditions by the accelerated development and acquisition of selected systems" (Ref 78: 4448). There are eleven of these selected systems, four of which are parts of the GBU-15 Weapon System. Figure 9 shows the individual

PAVE STRIKE WEAPONS
WEIGHTS AS OF 1 JUNE 1974[4]

	EOGB II MK 84	EOGB II SUU 54	MGGB II MK 84	MGGB II SUU 54
Guidance Section[1]	186	198	158	158
Control Section	177	177	212	212
Warhead[2]	1900	2060	1900	2060
Strong Back	---	---	257	257
Wings	270	270	240	240
Tail/Control Surface	---	---	75	75
Miscellaneous	14	14	---	---
TOTAL[3]	2547	2719	2842	3002

Notes:

[1]Guidance Section includes EOGB strakes/MGGB canard.

[2]SUU-54 Warhead weight assumes BLU-63 submunitions.

[3]For EO data link or DME capability add approximately 20 pounds.

[4]Weights based on current design subject to change.

Figure 8. Pave Strike Weapon Weights

PAVE STRIKE PROGRAM

Capability Need	Programs
Detection, Location, Targeting	Tactical ALSS, PLSS Photogrammetric Target System Pave Tack
Precision Attack Munitions	EOGB II MGGB II SUU-54 (Pave Storm) Laser Maverick Imaging IR
Electronic Warfare Capability	RPV EF-111 F-4E/Wild Weasel

Figure 9. Pave Strike Program

programs opposite the particular need fulfilled by each. The EOGB II (Electro-optical Guided Bomb II), MGGB II (Modular Guided Glide Bomb II), SUU-54, and the Imaging IR (infrared) are combinations or parts of the GBU-15. EOGB II is simply the name given to the combination of the following modules: EO guidance section, adapter section with or without DME, a MK-84 warhead, the control section, data link and expanded wing aerodynamic surfaces (see Figure 6). MGGB II is similar in all respects except that the aerodynamic surfaces are called a RES (Range Extension System) (see Figure 6). SUU-54 is nothing more than another warhead, which, with the proper adapter, could be substituted for the MK-84 as explained in the Modularity section above. The development program for the SUU-54 is called Pave Storm. Imaging IR is another guidance section which is substitutable for EO. It is designated as a separate development program under Pave Strike.

It is possible to suggest from reviewing the breakdown of the Pave Strike program and the concept of modularity, that evolution of the management structure for development of these weapons has not kept pace with the changes in scope and concepts of modularity. For example, the EOGB II, which is nothing more than a particular combination of modules, is still being managed as a complete weapon system. Originally it was a separate system, but now the modularity concept has overtaken it. In contrast, DME and the SUU-54 (e.g.) are individual modules and are managed as such (see pages 43,45). A recommendation concerning this management problem will be made in Chapter V.

On 2 November 1973, General Brown, the Air Force Chief of Staff, directed the Air Force Systems Command (AFSC), the Tactical Air Command (TAC), and the Air Staff to study problems which surfaced as a result of the recent Mideast War. Enhancement of our own tactical capabilities by addressing the conduct of that war was the expected result of the study. After addressing the Mideast War, the inter-command study group led by the Assistant (to Commander AFSC) for Defense Suppression switched their interests to Europe and NATO (North Atlantic Treaty Organization). Projections of a European war include massive enemy forces, a more competent professional military, unfavorable aviation weather, enemy offensive air power capability, diffuse NATO force deployment and command structure, and the presence of a civilian population. With all these problems in mind, the group looked at 112 Research and Development programs in existence and selected 11 as shown to become the Pave Strike program (Ref 78:4449-4450).

The Pave Strike concept is fairly simple, but it requires a sizeable investment in advanced technologies. Basically, a photogrammetric targeting system covering the whole world will be combined with an electronic emitter location system and a DME guidance system for selected weapons. The Pave Strike program would then allow photogrammetric and electronic detection and location of targets, a wide choice of weapons to strike the target in all weather and visual conditions, and three different systems as shown to fight the electronics warfare portion of the battle.

DME helps provide two important capabilities sought by the Pave Strike program. These are stand-off capability and all-weather/night capability.

Let us look briefly at the 11 Pave Strike programs.

1. Tactical ALSS (Advanced Location Strike System) - the total electronic detection, location, and guidance system using DME

techniques by ground and airborne stations. ALSS is essentially a development program and PLSS (precision location strike system) will be the production/operational program.

2. Photogrammetric Target System - the basic grid system upon which the Pave Strike targeting is based.

3. Pave Tack - an acquisition and designator system carried in a pod on the F-4E or F-111. It uses forward-looking infrared (FLIR) and a Laser ranger designator to enhance daytime target acquisition capability in smoke and haze as well as night/marginal weather target acquisition capability.

4, 5, 6. EOGB II, MGGB II, SUU-54 - described previously.

7. Laser Maverick - a program to develop and procure 5000 rocket-powered Mavericks using a Laser seeker which will enhance night operations and low contrast/unbounded targets. This will be an improvement over the current Maverick which uses an EO guidance section.

8. Imaging Infrared (IIR) Modules - IIR seeker in advanced development for use on the Maverick. Later it will also be integrated into the EOGB II and MGGB II. It will enhance day-night strike capability, especially during smoke and haze during the daytime.

9. Multi-mission RPV (Remotely-Piloted Vehicle) - a ground-controlled pilotless aircraft making use of modular noses to have the capabilities for Electronic Warfare (EW), reconnaissance, and weapons drop (strike).

10. EF-111A - an improved F-111A to provide standoff and strike

escort jamming by means of the ALQ-99 pod. This is an urgently needed replacement for the tiring EB-66 fleet.

11. F-4E Wild Weasel - a modification program on 116 F-4E's to allow search and destroy missions on hostile radar-directed systems.

Figure 10 summarizes the Pave Strike Program, showing hardware, portion of the mission covered, and weather capabilities. Pave Strike funding as of March 1974 appears in Figure 11.

Guided Bombs System Program Office (SPO)

Armament Development and Test Center (ADTC) at Eglin AFB, Florida has primary responsibility in the Air Force for development, testing, and initial purchase of all non-nuclear munitions. The Center reports to the Commander, AFSC. Because of the recent emphasis on sophisticated weaponry, it is not inconceivable that ADTC may become a separate product division of Air Force Systems Command, similar to Aeronautical Systems Division, Electronic Systems Division, and Space and Missile Systems Organization.

The recent high-level Air Force interest, given added impetus during the Arab-Israeli War of 1973, in non-nuclear weapons development is seen in the creation of a Deputy of Armament Systems at ADTC. It was organized in late 1973 and presently (August 1974) has five system program offices (SPO's), a Systems Support Directorate, and three smaller offices. One of the SPO's is called the Guided Bombs System Program Office. The first and present director is Colonel William J. McClelland. Figure 12 is an organisational chart of ADTC as of April 1974. Going one step further, Figure 13 shows the typical SPO

STRIKE MISSION

DETECTION RECOGNITION ACQUISITION

*Photogrammetric
√ALSS, PLSS
♦Pave Tack
♦√RPV-RECCE Module

DELIVERY

Direct Attacks
♦Maverick Options
♦√EOGB II Options
♦√Pave Storm Options
♦*Free Fall

Stand Off
*♦√MGGB II Options
*♦RPV-Strike Module

GUIDANCE

√DME
♦Laser
*EO
♦IIR
♦√Combinations
♦*Free Fall

STRIKE FORCE PROTECTION

√EF-111 Jammer
√Wild Weasel
√RPV-EW Module

TARGET DESTRUCTION

♦√Large Unitary
♦√Large Cluster
♦Small Missile
♦*Free Fall Munitions

* Day
♦ Day/Night
√All/Adverse WX

Figure 10. Pave Strike Mission Summary

PAVE STRIKE FUNDING SUMMARY
($ in Millions)

Appropriation	FY 74 Budget	FY 74 Supplement	FY 75 Budget
3600	38.2	17.7	132.6
3010	23.3	4.5	13.9
3020	---	---	---
3080	5.5	36.6	62.3
	67.0	58.8	125.8

Figure 11. Pave Strike Funding Summary (March 1974)

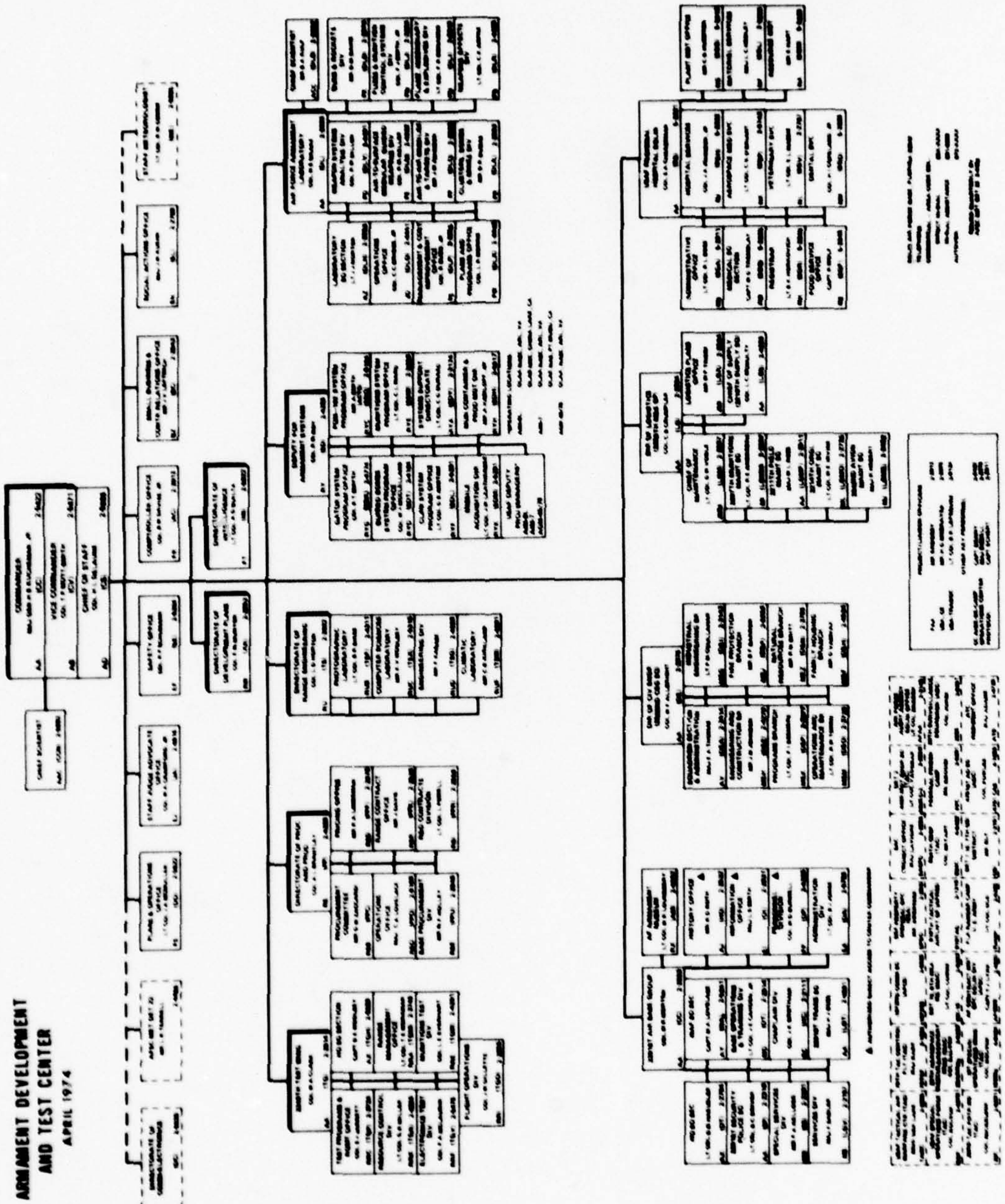


Figure 12. ADTC Organization (April 1974)

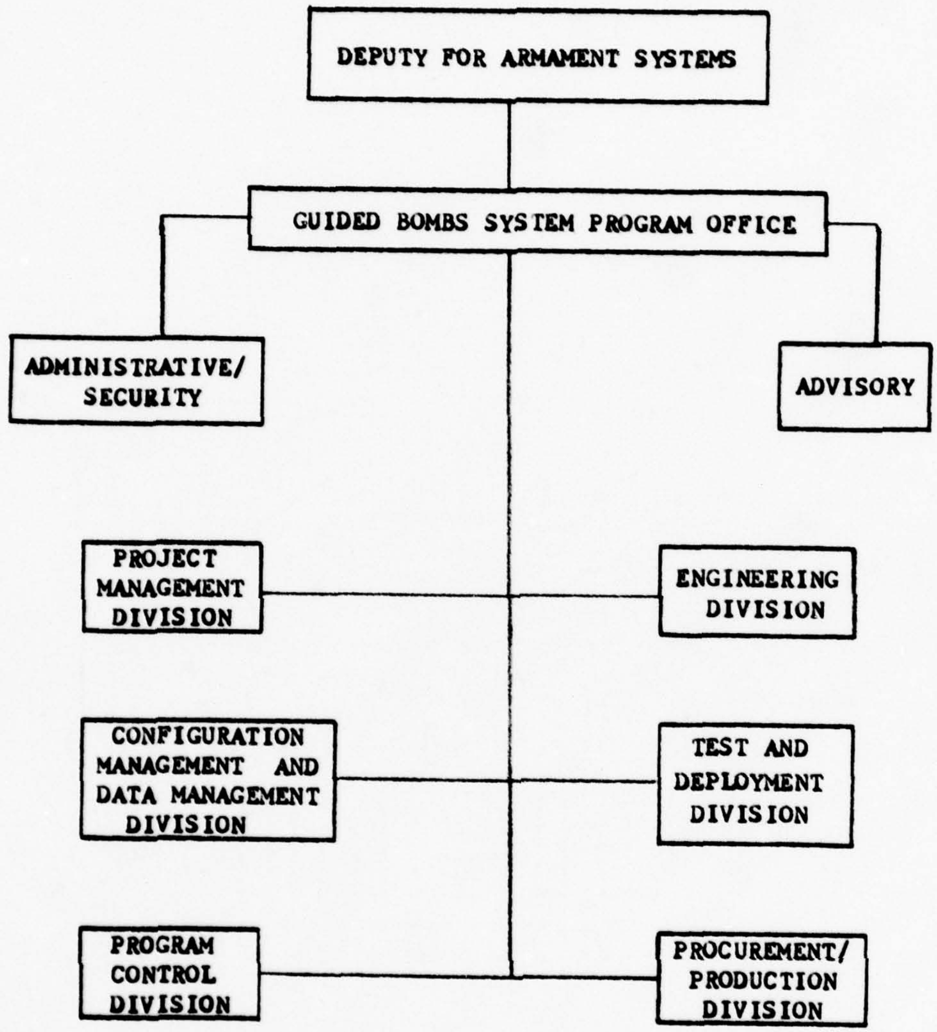


Figure 13. Guided Bombs SPO Organization

organization of the Guided Bombs System Program Office. Approximately 75 people are employed by the SPO.

Figure 14 comes from the proposed Pave Strike Guided Glide Weapons Program Management Plan (PMP). It depicts the portions of the command structure of the Air Force organizations with which the Guided Bombs SPO normally communicates to carry out its programs. Added by the writer is the PLSS Program Office under the Aeronautical Systems Division (ASD)--the lead member of the DME team.

The Guided Bombs SPO has five projects in being associated with the GBU-15 family of weapons. These are DME, DL, Laser Seekers, MGGB II, and EOGB II. Each of these projects is managed by a project manager. The reason for this somewhat confusing division of projects is primarily the evolution of the family of weapons. It seems strange to have one person responsible for whole series of modules which, when joined, become the EOGB II or MGGB II, and at the same time have another person responsible for only one module (e.g., Data Link or DME). This occurs because the concept of modularity came after the EOGB was named and configured with a specific combination of what are now called modules. The DME, DL, and Laser Seeker were conceived later to give additional capabilities to the EOGB. The MGGB accompanied the concept of modularity as its name implies, but it too is a specific combination of modules. In truth, all the project managers are concerned with and actively help manage one another's programs because their final products all have to be compatible. Authority for these projects in the Guided Bombs SPO is contained in the following documents:

1. PMD R-P2081(4)/27241F, PE 27241F, Electro-Optical Guided Bomb II, AFSC Form 56, 213B 13-74-29.

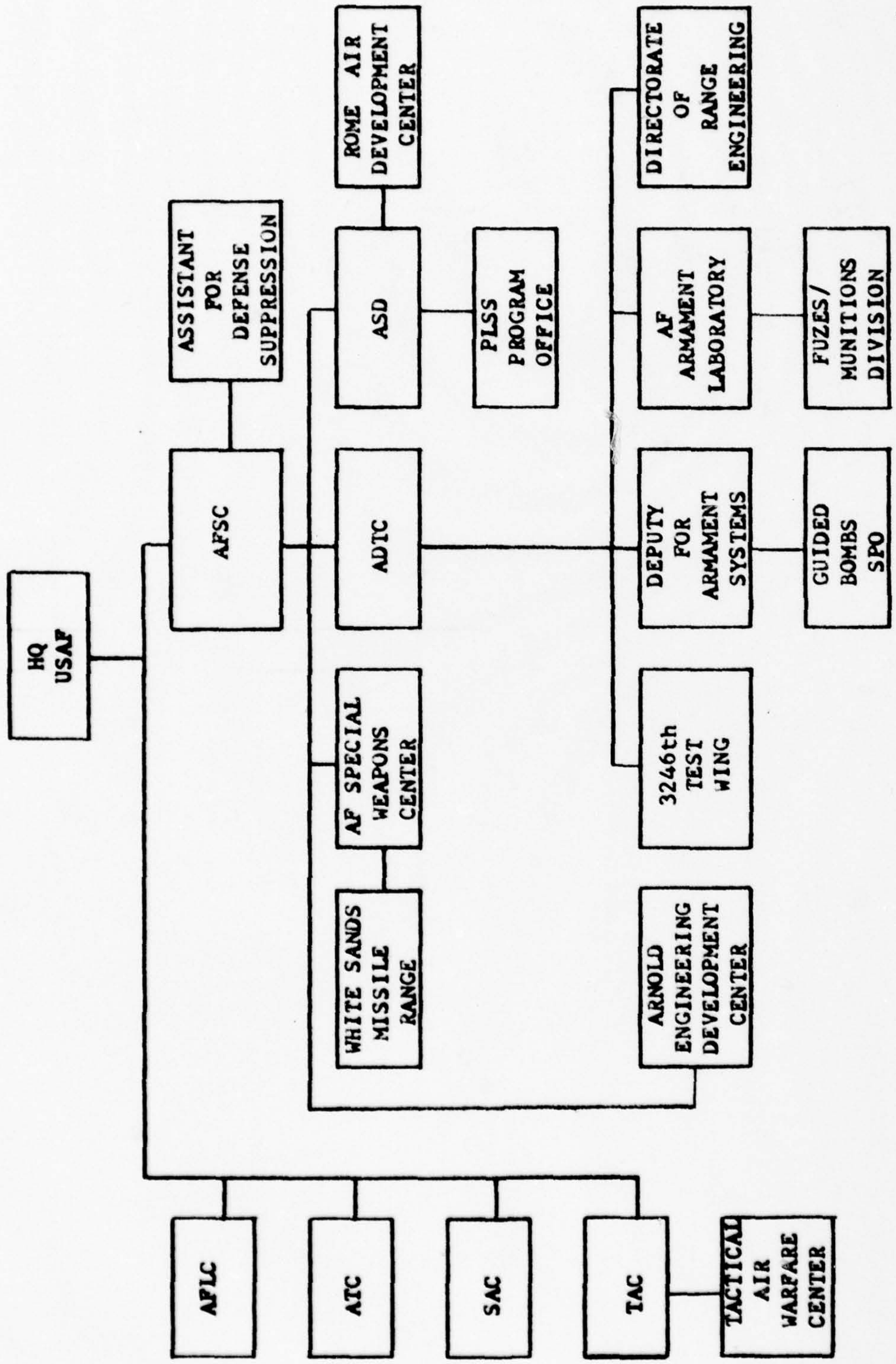


Figure 14. Pave Strike Command Structure

2. Project 2076 of R-P3048(1)/64733F, Program Management Directive for Surface Defense Suppression, AFSC Form 56, 2076-1-74-37.

3. PMD R-P3047(1)/63741F/1901, Program Management Directive for Surface Defense Suppression Projects, AFSC Form 56, 1902-5-74-40.

4. AFSC/CC letter, Tactical Force Capabilities, dated 6 December 1973 (Ref 41:1-4).

DME is the obvious concern of this thesis effort. It is hoped that a condensation of the relevant considerations about the proposed DME procurement will be a helpful input to the DME Project Manager's decision. Now we turn to a description of the modules about which we are most concerned.

DME Modules Description

As was mentioned in Chapter 1, the components of M_1/M_5 and G_2 are the same. There have been changes since Figures 2 and 3 were offered by RIC, and there are still changes occurring. However, this section will describe the configuration as it is presently (August 1974) conceived. A large part of the information of this section is extracted from the Prime Item Development Specifications, Part I (Ref 59, 60). Since G_2 contains all the components applicable to DME guidance, but the mix of these components between M_1 and M_5 has not yet been decided, G_2 will be described first. The heart of the DME guidance package is called the WGSS (Weapon Guidance Subsystem), so a paragraph about it is appropriate before describing the complete modules.

1. Weapon Guidance Subsystem (WGSS). The WGSS consists of a receiver/processor, a transmitter, a circulator, two antennas, and

an antenna switching device. A block diagram of the WGSS appears in Figure 15.

The Weapon Guidance Subsystem is manufactured by IBM, Owego, New York, at a unit cost of about $9,300 in the 100/month, 1000/year unit production range (see Chapter IV). It is purchased on contract from IBM by the Precision Location Strike System (PLSS) Program Office, and supplied GFE (government furnished equipment) to the Guided Bombs SPO and thence to RIC for inclusion in the DME modules.

a. Receiver/processor. The receiver/processor receives and decodes serial input data in a standard message format. After processing, analog output signals are provided for weapon guidance, rate stabilization, telemetry, and discrete commands as required. In addition, the receiver/processor provides a composite signal which is further processed to furnish video display steering signals to the aircrew in the cockpit.

b. Transmitter. The transmitter provides pulsed RF signals when commanded by the receiver/processor. These signals are provided to one of the antennas.

c. Antennas and RF elements. The antennas and RF elements accomplish the following functions:

(1) receive radiated RF signals from an external source,

(2) route received RF energy to the receiver/processor,

(3) provide control signals to the transmitter,

(4) radiate RF transmitter energy,

(5) select between two antennas.

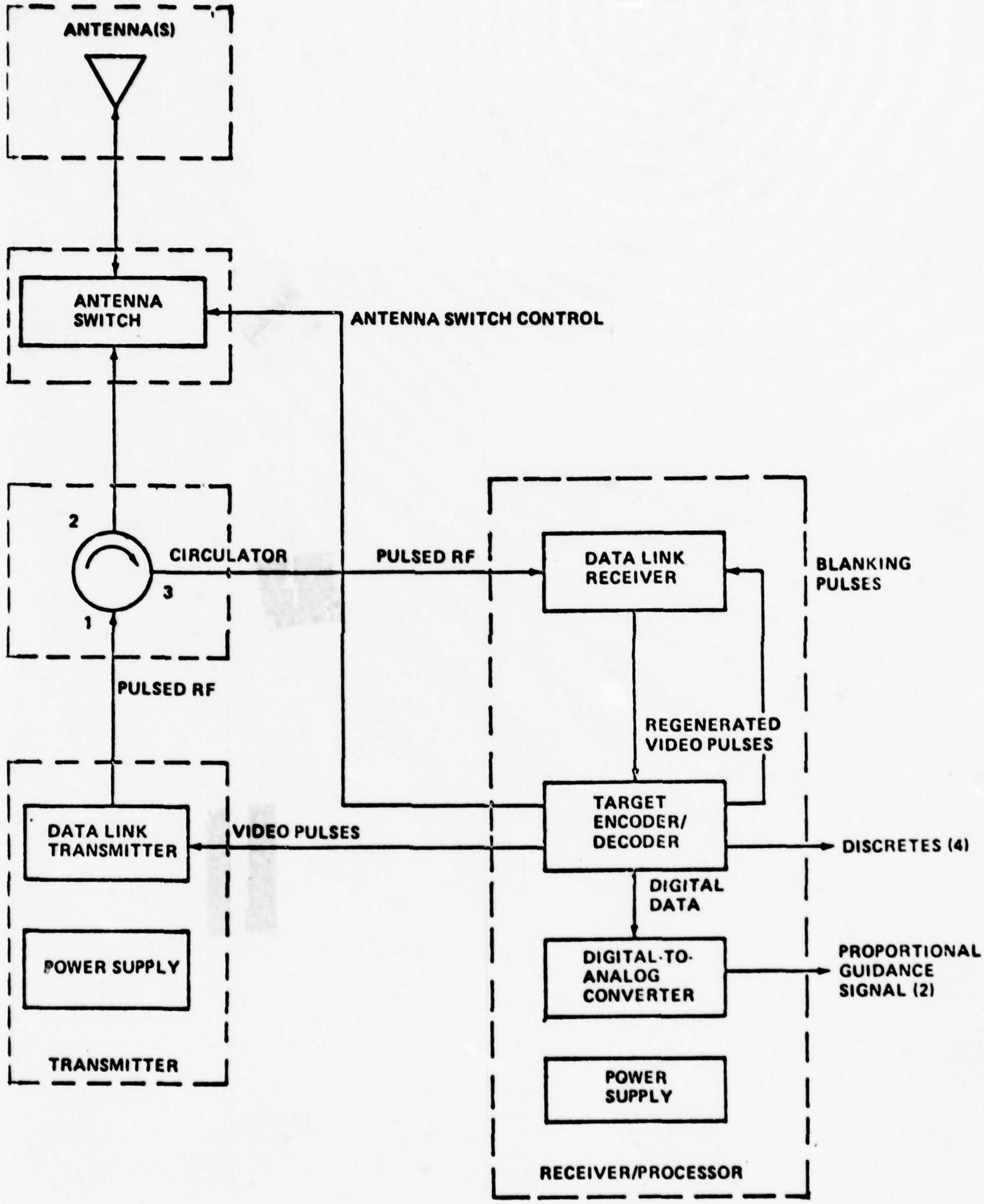


Figure 15. WGSS Block Diagram

d. Antenna Switch. The antenna switch connects either the mid-course antenna (aft) or the terminal antenna (forward) to the circulator.

e. Circulator. The circulator directs RF energy from the transmitter to the selected antenna or allows a received signal from the selected antenna to enter the receiver.

Antenna placement has been a continuing integration problem for the Air Force and contractors. As of 1 August 1974, the forward blade antenna is located on the underneath side of the adapter section. The slotted wave-guide ("birdbeak") aft antenna is located on the underneath side of the DL Module, or aft cover if no DL is installed.

2. DME Guidance Section (CI G_2). G_2 is the DME Guidance Module, shaped like a nose cone, which fits on the front of the weapon to provide guidance from weapon release to impact (i.e., DME-only guidance). The other element needed for complete DME-only guidance is a D/V gyro which is shipped with G_2 but is mounted in C_1 during weapon assembly in the field. Technically, this D/V gyro and the two antennas are part of the total G_2 kit as shipped.

The contents of G_2 are as follows:

- external shell
- ballast
- WGSS
- power control
- telemetry and message-good conditioning circuitry
- two rate gyros
- synthetic video, video cue generation and video synchronization circuitry
- D/V gyro
- forward and aft antennas

A component called the Guidance Interface Module (GIM) physically houses the electronic circuitry not found in the WGSS. Figure 16 is a drawing of the G_2 layout.

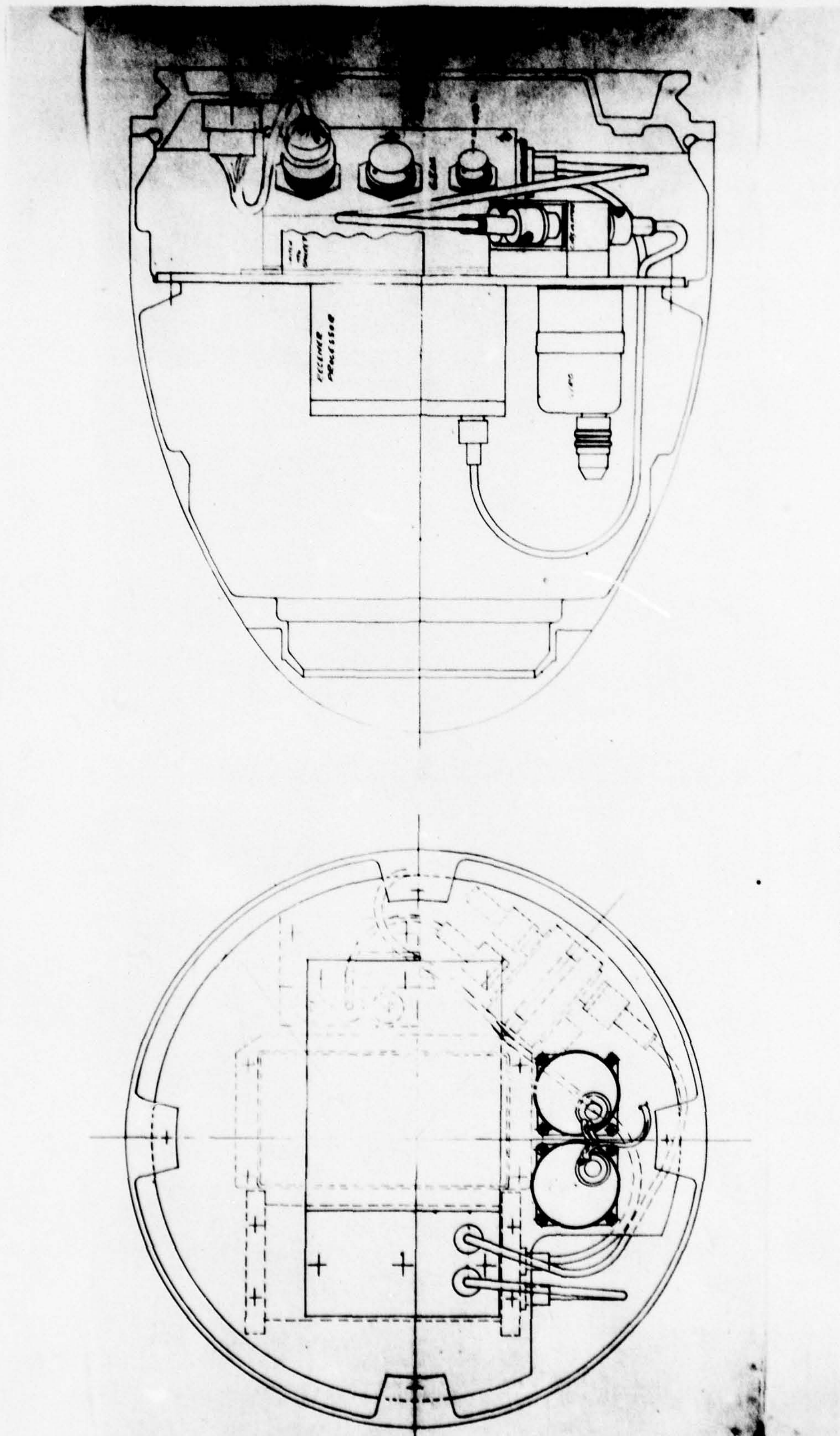


Figure 16. G_2 Layout Drawing

"The DME Guidance Section G_2 provides guidance signals for the Advanced Location and Strike System (ALSS), stabilization signals for the autopilot, and a delayed fuze arm signal"(Ref 59:6).

3. DME Field Installed Module (CI M_1) and Dummy Nose (CI M_5). M_1 is the DME module conceived to be used for mid-course guidance in conjunction with another terminal guidance nose section such as G_1. It is to contain exactly the same components as shown above for G_2 with exceptions as follows:

a. There is no shell or ballast since the unit is mounted within the adapter section.

b. No directional/vertical (D/V) gyro is shipped in the M_1 kit since there is one shipped with the data link (DL) kit for indirect attack missions, which is the only time DME will be used. Functionally, M_1 is identical to G_2.

If a decision is made not to purchase G_2, it will be necessary to provide a nose cone for aerodynamic shaping when a DME-only mission is to be flown. This leads to the M_1/M_5 combination. M_5 is the terminology to be applied to the nose (Ref 28:24).

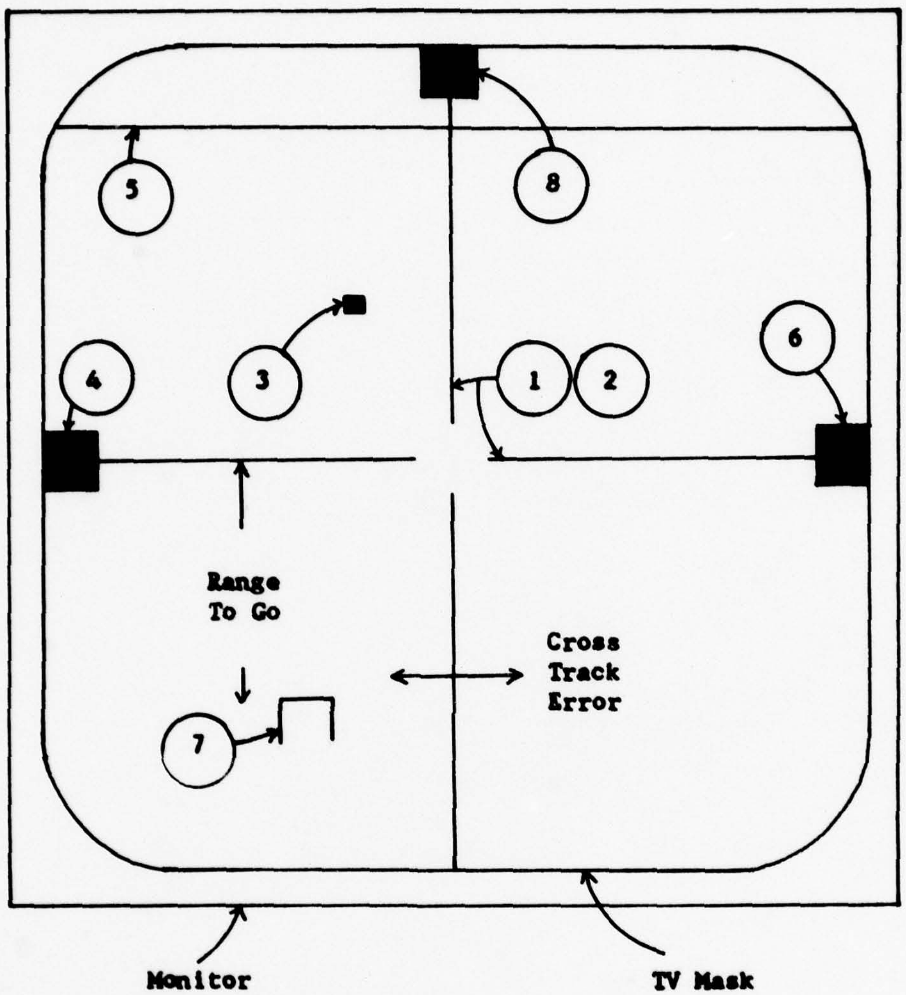
At a 23-24 July 1974 meeting between RIC and Air Force personnel, three options for the contents of M_1 and M_5 were proposed. Since there is much unused space in an empty (except for ballast) M_5, proposals were submitted for various ways in which to distribute the components of M_1 between M_1 and M_5. This is an involved problem and will be discussed in Chapter IV. At this point it should be noted that the referenced meeting actually increased the number of alternatives originally addressed by this thesis from two (M_1/M_5 and M_1/G_2) to four (three different M_1/M_5 options and M_1/G_2).

4. Aircraft Video Display. Mention has been made throughout this chapter of the aircraft video display, so a section about it is indicated. There are two functions of the display. In a DME mission, steering signals generated by M_1 or G_2 are displayed on the screen to get the aircraft into the proper position in space for a weapon release. The steering marker doubles as a weapon release command. The second function is to display the picture seen by the EO seeker head G_1 on an EO mission. If the target is visible before weapon release, the weapon can be locked on and will guide itself to impact. If an indirect mission is flown, the weapon is guided by DME to the target area. Meanwhile, the Weapon System Operator in the release aircraft is searching for the target in the video display as seen by the EO seeker head. He has slew control of the EO Seeker through data link. When the target is identified on the display, he takes guidance away from the DME and begins to guide the weapon himself with a control in the aircraft. He can either guide it all the way to impact, or at any time he may lock-on and let the weapon guide automatically.

Several visual cues are presented on the video display to the aircrew during the course of the mission. These are shown in Figure 17.

<u>ALSS/PLSS</u> <u>Description</u> (Ref 69, 70, 71, 72)

The Advanced Location and Strike System (ALSS) was developed by IBM Corporation, Federal Systems Division, under contract to the Air



1 Tracking Gate Crosshairs - G_1

*2 DME Reference Marks (No gap in DME Only) - G_2 or M_1

3 Nose Index Marker (Blanked out inside gate and removed during EO terminal track only) - G_1

*4 Cage Condition Marker - G_1

*5 Transition Enable Marker (-25°) - G_1

*6 Data Link Message Good - G_1

7 DME Steering Marker - G_2 or M_1

*8 DME Message Good - G_2 or M_1

*Indicates Fixed Location on TV Monitor

Figure 17. Visual Cues

Force. Design and development took place between March and November 1972. Flight testing was performed at White Sands Missile Range (WSMR), New Mexico until May 1973. At that time the system was delivered to the Air Force for Initial Development Test and Evaluation.

The system configuration is as shown in Figure 18. It consists of a Ground Control Station (GCS), two Ground Relay Beacon Stations (GRBS's), three Airborne Relay Stations (ARS's), a strike aircraft, and the DME guided weapon.

The GCS is the control center for ALSS missions, providing all computational equipment as well as status displays and manual inputs for use by the system operators. There are two operators sitting side by side at the Navigation and Location Consoles. The operator at the Navigation Console positions and guides the weapon to a predesignated target. The Location operator is concerned with collecting information on the location of hostile targets. The proximity of the operators allows them to exchange data verbally to immediately counter a new threat.

The Airborne Relay Stations are tracked by measuring the distance to surveyed ground stations. Weapons, captive or after launch, are tracked and guided from measurements made by using the ARS triad as a reference platform. Distances are computed from transit time of radio signals initiated by one station and transponded by the second. When a pulse is transmitted at point A, a clock timer is started. This transmitted pulse goes to point B and is returned to point A, causing the timer to be stopped. The pulse travel time between two points is one-half the time it takes the pulse to make the round trip, with

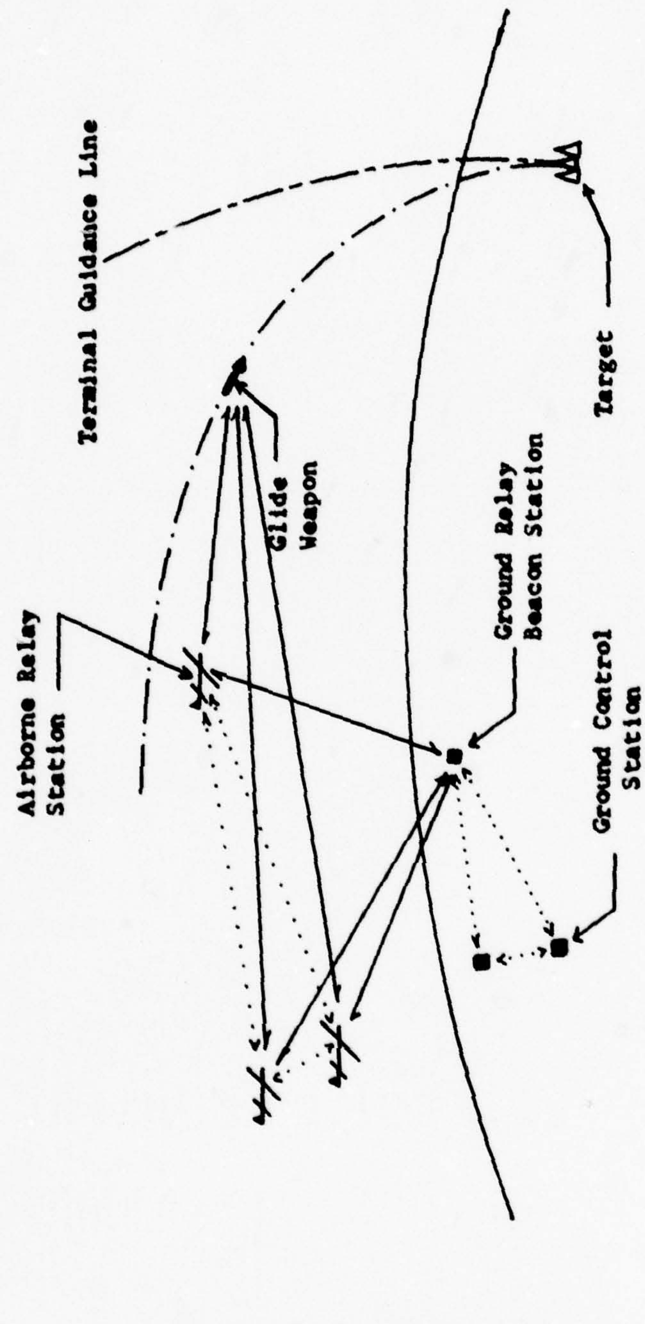


Figure 18. ALSS System Configuration

allowance made for equipment delay and atmospheric effects on propagation velocity. This whole process is known as the DME technique or principle.

During captive flight (before weapon launch) the steering information received by the weapon is displayed to the pilot on his ADI (Attitude Direction Indicator) display via signal wires through the weapon pylon. The horizontal needle on the ADI is positioned at a distance from the center and moves towards the center, to indicate range to go before launch. The vertical needle on the ADI indicates right or left of course to the target. At the launch point, the horizontal needle is deflected fully downward as a signal to the pilot to launch the weapon. The Advanced Location and Strike System (ALSS) makes use of the Attitude Direction Indicator, but the Precision Location Strike System (PLSS) now under development will provide the same information on a video display as previously described. For readers who may be questioning the acronym PLSS, as of 1 August 1974, PLSS became the official designation of what was formerly called PELSS (Precision Emitter Location Strike System). After launch, pitch and yaw steering signals are transmitted to the weapon by the Ground Control Station. These signals are scaled in the Ground Control Station and are proportional to the magnitude of the weapon position error along the nominal trajectory. The weapon has three flight phases.

Initially, the weapon begins a glide flight through the mid-course phase. The pitch attitude (and thus the glide angle) is controlled by a "g-bias" within the weapon and a command from the Ground Control Station which increases as the launch attitude decreases. The total command is a constant DC voltage which offsets the null on the autopilot pitch rate channel input causing a constant up body command to generate a positive angle-of-attack and thus positive lift. Weapon body pitch rate and yaw rate stability loops are utilized throughout the entire flight as is roll attitude control. Cross range steering signals from the Ground Control Station control the right and left movement of the weapon along the flight path to the target.

Upon Ground Control Station command the vehicle enters the pitch-over phase. The weapon "g" bias is disabled and a GCS pitch steering command is transmitted to direct a pitch down command. The magnitude of this command is a function of weapon velocity and launch altitude. However, it is modified proportionally to the vehicle position with respect to a nominal pitchover trajectory. At some point through pitch-over, a GCS command is provided to switch from the aft antenna to the forward antenna to maintain a useful antenna pattern and polarity for terminal guidance. As the weapon proceeds through pitchover, the forward antenna pattern becomes less favorable so an automatic feature is built into the WGSS to cycle antennas looking for the strongest signal if the signal deteriorates to the point that data are lost. This feature is disabled when the antenna switch command is received. The weapon continues pitchover toward a near vertical flight path to intersect the "guidance line" which extends to the target.

After the pitchover maneuver is completed, the terminal phase begins. Range-to-go and right-left steering signal continue to be provided to the weapon to yield, respectively, pitch and yaw guidance commands. Pitch and yaw steering drives the down range and cross range errors, respectively, to zero with respect to the guidance line. The weapon is thus guided vertically along the "guidance line" to impact on the target. Figure 19 shows the three phases of flight and Figure 20 is a schematic of the weapon guidance loop.

PLSS is currently in the conceptual phase of the weapon acquisition cycle. Its growth will be managed by the PLSS Program Office, Aeronautical Systems Division, Wright-Patterson AFB, Ohio. ALSS may be considered a prototype of PLSS.

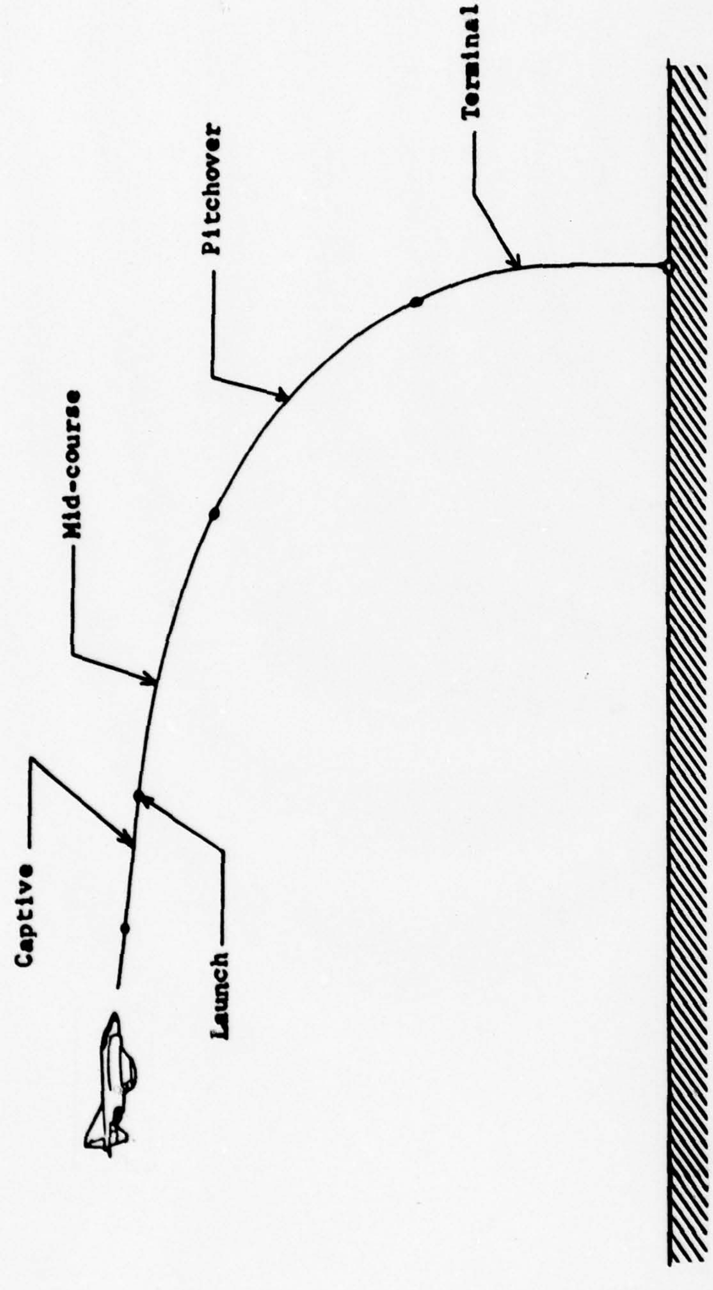


Figure 19. Phases of Flight

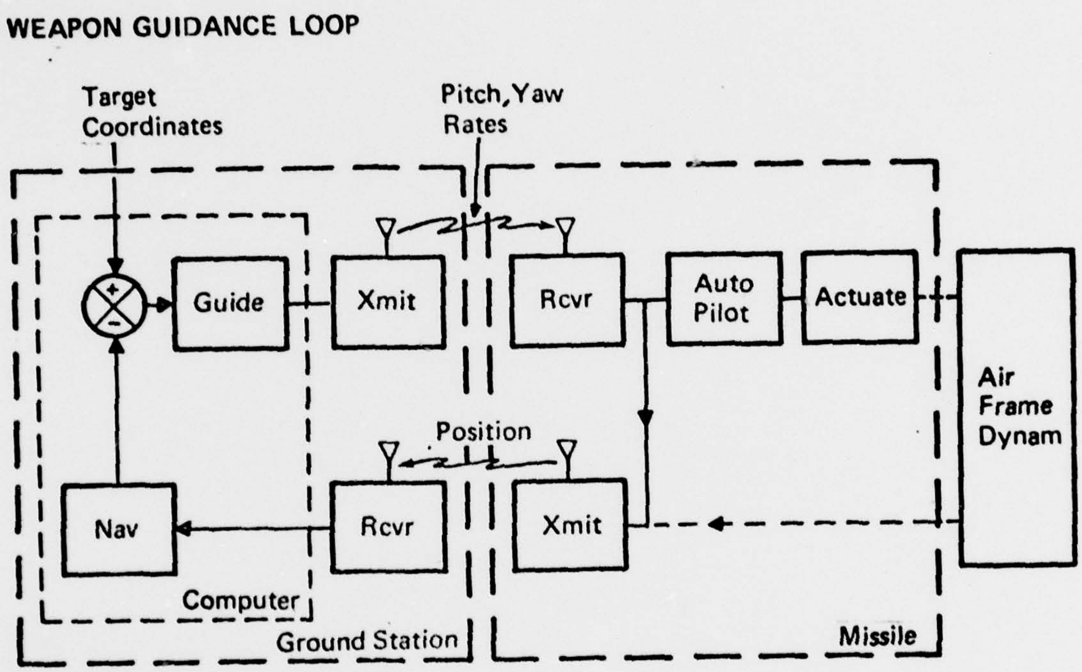


Figure 20. Weapon Guidance Loop

III. Methodology

In May 1974 when the basic problem of this thesis was presented to the writer by Mr. James McCormack of the Guided Bombs SPO, a straightforward benefit/cost tradeoff study was indicated. Life Cycle Costing (LCC) was selected as the appropriate method of analyzing the cost portion of the study. Realizing that most inputs to the benefit half of the study would be difficult to quantify in terms of cost (which would have allowed a simple summation of all costs in order to arrive at the least-cost solution), the writer proposed to discuss these inputs in a qualitative manner and weigh them against the costs. For this reason, the recommendations are heavily colored by qualitative inputs and are not clear-cut least-cost alternatives.

Another interesting event occurred during the 23-24 July 1974 DME meeting at Rockwell International Corporation which changed the scope of this thesis. That meeting effectively added two more M_1/M_5 options by proposing different ways to split the DME components between M_1 and M_5. The number of alternatives then jumped from two to four at a point in time when changing the scope of the thesis was difficult. However, the change was made, and data analysis includes all four options.

Life Cycle Costing (LCC)

DODI 7041.3, 26 February 1969, establishes policies and procedures for consistent application of economic analysis for the acquisition process within the Department of Defense (Ref 31). The stated intent is to help the decision maker compare relative merits of various alternatives as an aid in selecting the best. DODI 7041.3 specifically states that a benefit/cost analysis will be done. In order to comply with the intent of this instruction, part of the 14 March 1974 Statement of Work (SOW) to 0046-P00001 requires an unspecified type of tradeoff study of DME guidance CI G_2 versus CI M_1/M_5 (Ref 28:24). This study, performed by the contractor, becomes an input to the DME guidance decision by the Guided Bombs SPO. The study was presented at the 8-12 July 1974 EOGB II Preliminary Design Review at Rockwell International Corporation. No economic analysis was done, however, so this thesis is attempting to add that input to the decision via Life Cycle Costing.

As a matter of interest, E. S. Quade gives a very interesting discussion of the limitations of quantitative analysis in a short article by that title (Ref 68). It will not be discussed here, but is recommended to the interested reader.

There are three possible objectives of economic analysis as follows:

A. Determine the least cost alternative of several equally effective alternatives.

B. Compare the relative costs of various alternatives and relative benefits so a judgment can be made as to whether increased benefits are worth the increased costs.

C. Determine the alternative expected to produce the greatest benefits for a given cost (Ref 31:2).

It was not clear at the outset which objective between A and B was being pursued. C was not applicable because neither the total budget for the GBU-15 family nor the portion allotted to DME was fixed. It was thought that objective A was the more likely goal since effectiveness (defined as "meeting operational requirements") was probably the same for both alternatives. This applies as well for the expanded four-alternative analysis. Since there are other "benefits" besides effectiveness, objective B seemed almost as likely.

Life Cycle Costing is an attempt to estimate the total cost of a new item or system over its full economic life (Ref 8:1). LCC is one of the methods by which DOD is attempting to carry out the economic analysis required by its own DODI 7041.3. The main guidelines for specific application of Life Cycle Costing are found in LCC Procurement Guides, LCC-1 and LCC-2 (Ref 27, 25). Estimates attribute more than half of a weapon system's total life cycle costs to operation, training and support costs (Ref 63:v). For this reason alone it seems imperative to consider more than initial investment costs in a benefit/cost analysis - hence, LCC. The 15 July 1974 AW&ST has this to say about the Air Force Systems Command policy on LCC:

> A large danger in the past has been the tendency to design to initial acquisition cost or to prototype costs only, according to Major General Robert T. Marsh, Systems Command Deputy Chief of Staff for Systems. In the future, close attention will be paid to the lifetime maintenance and operating costs, which can account for 60-70 per cent of total system cost over that span (Ref 19:21).

Literature Search

After deciding on a general approach to the research as described above, the next step was a search of applicable literature and background information. Specific background information on the GBU-15 Weapon System came from two sources - the Guided Bombs SPO, Eglin AFB, and the PLSS Program Office, Wright-Patterson AFB, Ohio. In order to keep abreast of current weapon developments throughout the summer of 1974, one visit was made to International Business Machines (IBM), Federal Systems Division, Owego, New York, and several trips were made to Rockwell International Corporation (RIC), Missile Systems Division, Columbus, Ohio.

The occasion of the IBM visit was the "EOGB-II/MGGB-II DME Guidance Integration" Preliminary Design Review, held 1-2 August 1974. It was required by Data Item A006, Contract No. F33657-74C-0454. Visits to RIC were to attend the following meetings:

1. Interface Control Working Group (ICWG), 2 July 1974.
2. EOGB II Preliminary Design Review (PDR), 8-12 July 1974.
3. DME tradeoff meeting, 23-24 July 1974.
4. Talks with design and contract personnel, 5 September 1974.

Visits to the Guided Bombs SPO, Eglin AFB, occurred 22-23 May 1974 and 22-30 June 1974. There were several data-gathering sessions at the PLSS Program Office, Wright-Patterson AFB, during the summer of 1974.

Besides verbal information and documents received from the above sources, considerable time was spent during June and July 1974 in searching the many sources available through the AFIT Library, AFIT Master Publications Library, and ASD Military Standards Library. Most of the useful current literature came from the National Technical Information Service Microfiche files at the AFIT Library. Many of these references are listed in the Bibliography.

Systems Analysis Approach to the Thesis

In attempting to structure a logical approach to this tradeoff study, the writer chose the system analysis approach as most suitable.

E. S. Quade, in his Analysis for Military Decisions, suggests the following iterative procedure for attacking a systems analysis problem, and this is the procedure used (Ref 67:158).

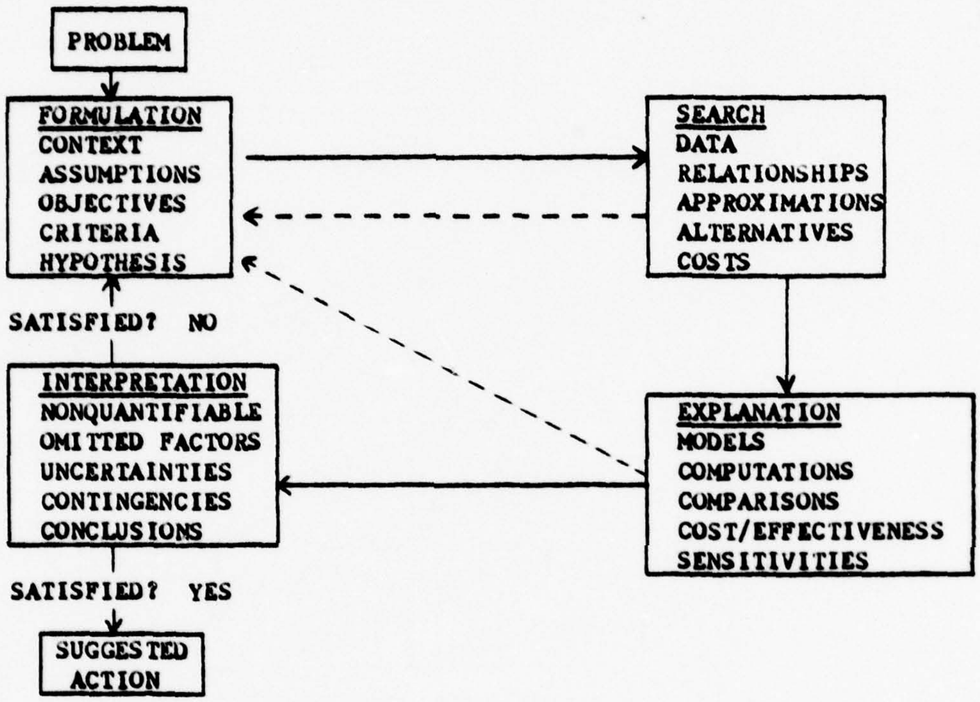


Figure 21. Approach to Systems Analysis

Each of the topics in this systems analysis approach is covered in the thesis, though not necessarily in the exact order shown. However, the chapters do follow the general order of the procedure above. The one excursion taken by the writer from the strict application of the above procedure was to move directly back to the FORMULATION block from any of the other blocks, not just the INTERPRETATION block. Thus, when obvious changes were needed, the total loop was short cut to save time (dotted lines). The characteristics of system analysis (called "cost-utility analysis" by Gene H. Fisher) which led the writer to choose it as the best approach to this thesis are as follows:

1. It is a systematic examination and comparison of alternative courses of action over a period of time.

2. The main considerations of each alternative are: assessment of cost, utility (benefits or gains).

3. The time context is the future; e.g., 5, 10 years.

4. Uncertainty is involved because of the future time period.

5. Purely quantitative work is heavily supplemented by qualitative (Ref 36:66-7).

Fisher also says the purpose of cost-utility analysis is to sharpen the intuition of the decision-maker (Ref 36:67). This is precisely what the writer hopes to do with this thesis for the Guided Bombs System Program Office.

Costs

Since a great deal of this thesis deals with "costs," it is appropriate to comment upon this difficult subject. As any accounting textbook will tell you, there is no such thing as "the" cost of something. The appropriate definition depends upon the purpose for which the cost is to be used. Though this may seem to be an obvious statement, it is worth mentioning here to avoid misuse or misinterpretation of what are being called costs in this thesis. The cost of something is the resource drain on the economy or the opportunity lost by gaining that something instead of something else which could have been gotten instead. In analytical work, dollar cost is often used as a measure of the resource cost. It provides a way to represent the sum of many dissimilar items; i.e., a common denominator.

Since price level changes (inflation or deflation) would affect any of the alternatives in essentially the same way, FY 76 constant dollars are assumed. In addition, there are other unknown future influences on the system under consideration (decisions on operational use, for example) which stand to have a much greater impact on differences among the alternatives than inflation or deflation. We are looking for meaningful comparisons, not accuracy in monetary figures. For this reason also, constant dollars are used.

Although future price levels may be unimportant, there is a time value to money. Since expenditures will be time phased, this time value must be considered. Originally, the writer intended to do so by forming the present value of the estimated stream of expenses for each alternative. The Department of Defense has established a 10 per cent discount rate to be used in economic analyses of proposed investments (Ref 31:Encl 3). The formula used to discount future alternative costs to present value is:

$$P.V. = x \frac{1}{(1+i)^n}$$

where x = the dollars received (or paid) at the end of n years.

i = the applicable interest rate

n = the number of years from FY 76.

Since the time streams of expenditure for the alternatives are identical, a determination was made not to consider discounting. The following quotation supports this decision:

> The important thing to note is that discounting will change the relative present value of alternative systems only if the time streams of expenditure (or outputs) associated with these systems differ. Where these time streams

have identical shape, application of discounts will leave the relative positions of the alternatives unchanged (Ref 23:2).

Likewise, it was decided not to attempt to apply an annual reduction in price/unit from the contractor as a result of learning on the production line, although this effect will undoubtedly be present in actuality. Actual price estimates beyond the first year were unavailable, so the assumption of identical learning curves for all alternatives appeared reasonable. For this reason, the learning effect has no influence on relative standing of the alternatives. Therefore, price/unit was assumed constant for each year that purchases are made.

LCC Model

Once the problem was formulated, background information collected, a literature search made, and the general approach selected, the next step was to identify and list all possible inputs which might bear on the problem. Another way to consider this step is that of putting bounds on the system under consideration (differential life cycle costs). By the way, note that this system for the LCC model is a subsystem of the one mentioned on page 11 as the total system being studied in this thesis. Once the list of inputs was analyzed and substantially reduced (as explained in the next section), the remaining quantifiable inputs were shaped into an LCC model. Rather than attempt to use an existing LCC model, the writer found it much simpler to design his own model using only the applicable costs. Most existing models are very general and require input data which was unavailable within the time constraints of this research.

Several LCC models were researched in order to compile a list of possible data elements. "Elements" is defined as those parts of the cost that will be considered. LCC-1 (Ref 27:2) states that lack of data may limit use of some elements, but that it is preferable to include some elements rather than none. Obviously, it is the analyst's choice as to which to include or exclude. In the case of this thesis, rationale for the choice will be given for each of the possible data elements.

Most of the prior LCC modeling done by others has been for total weapon systems and not just for a single subsystem such as DME guidance for the GBU-15. For this reason none of the existing LCC models found during the literature search was directly applicable to this problem. Therefore, they were used to compile a list of possible data elements, but were not used directly to compute Life Cycle Costs. Another reason is that only differential costs among the alternatives are relevant. All the models researched profess to find the total Life Cycle Costs of the systems, and those values are not needed for this tradeoff study. This view is supported by the following quotation from a 1971 Rand report:

> The use of Logistics Life Cycle Cost (LCC(L)) when design parameters have not yet been fixed should enable the design engineer to make decisions based more upon support cost considerations than has been done in the past. In comparing the relative LCC(L) of the two alternative item designs, it is necessary to include only those costs that vary between designs. We assume that a designer will use such a model when he is considering two or more alternative designs, both of which meet performance specifications (Ref 63:31).
>
> For these kinds of decisions, cost accuracy is not outstandingly important, as long as the cost precision is adequate. In other words, a comparison is being made; therefore, as long as all costs are treated relatively the same, the absolute accuracy of the cost prediction is unimportant (Ref 63:32).

One other point about relevant costs has occurred to the writer. That is, if the differential costs among alternatives are a very small percentage of the total expected GBU-15 expenses, then in truth all the costs become irrelevant and a decision should be based upon expected benefits only.

Possible Cost Elements. The list of possible cost elements for inclusion in the LCC model is quite lengthy. Figure 22 is the originally formulated list for the DME guidance models of the GBU-15. Each one of these elements will be mentioned in turn with the assumptions for its inclusion or exclusion given.

A. Initial Investment Costs:

1. Purchase price (unit cost) - included; it was expected that the unit cost of the alternatives would be a significant input in a cost model. They will be higher during the first year as the production line gears up to maximum rate and before a learning experience reduces cost.

2. Delivery to wholesale storage - excluded; storage is assumed to be at RIC, so there is zero delivery cost.

3. Delivery to base - excluded; in order to be consistent, this will be included under recurring costs for all units.

4. Acceptance testing costs - excluded; assumed to be the same for each alternative.

5. Initial Aerospace Ground Equipment (AGE) - included; M_1/M_5 interface tests should add cost and complexity to AGE for some alternatives.

6. Rehabilitation of buildings, fittings, non-recurring

ORIGINAL LIST OF POSSIBLE LCC DATA ELEMENTS

A. Initial Investment Costs
- Purchase price
- Delivery to: stateside/overseas
- Acceptance testing cost
- ATE purchase
- Rehabilitation of: buildings/fittings/services at base/depot
- Item management costs: inventory management system/ basic technical data
- Training at: base/depot
- Initial AGE
- Personal maintenance equipment
- Travel costs
- Value of existing usable facilities replaced
- Research and development
- System test and evaluation
- Reusable shipping containers

B. Operating Costs (Recurring)
- Warranty
- Consumable: materials/supplies
- Utilities and other services
- Training replacement personnel: base/depot
- Maintenance (excluding labor):
    - Preventive maintenance: test equipment/material
    - Corrective maintenance: test equipment/material
    - ATE and software
- Base personnel, pay, allowances, overhead: military/civilian
- Delivery, wholesale storage to base: overseas/stateside
- AGE operating cost: maintenance/POL
- Downtime costs
- Item management cost: inventory management costs/ recurring technical data purchase
- Contractor support equipment
- Contractor storage costs
- Base supply item management costs
- Throw-away shipping container cost
- Failed module shipping cost

C. Final Costs
- Salvage (residual) value after life
- Salvage value of failed module
- Disposal costs

D. Other Data
- weights, operational numbers, expected usage, standard rates, total purchase, etc., etc.

Figure 22. LCC Data Element List

services at base or depot (RIC) - excluded; none of this is necessary or applicable for this small bit of DME equipment.

7. Initial item management costs - included; consists of:

a. initial inventory management system - differences between alternatives will occur because of different numbers of Federal Stock Numbers (FSN).

b. basic technical data - different numbers of technical order pages account for different costs among alternatives.

8. Initial training at base or depot - excluded; should be same for all alternatives. Any differences would be minimal.

9. Automatic Test Equipment (ATE) - included; these cost differences are included in the AGE costs.

10. Personal maintenance equipment - excluded; no significant differences exist among alternatives.

11. Travel cost - excluded; no differences between alternatives.

12. Value of existing usable facilities replaced - excluded; not applicable to the DME guidance units.

13. Reusable shipping containers - included; differences exist in types and numbers of containers among alternatives.

B. Final Costs:

1. Salvage (residual) value after life - included; like purchase price, differences are expected; will be entered into the model opposite in sign from costs.

2. Disposal costs - included; weight and number of units should create differences among alternatives.

C. Operating (Recurring) Costs:

1. Warranty - excluded; not to be written into the production contract.

2. Consumables: materials and supplies - excluded; there are none for DME guidance units.

3. Utilities and other services - excluded; not applicable for DME guidance units.

4. Training replacement personnel, base or depot - excluded; same for all alternatives.

5. Preventive maintenance: test equipment, material - excluded; none is required by the system specifications (paragraph 3.2.4.1 of Spec. VJ50011 and VJ50014)(Ref 59,60).

6. Corrective maintenance: test equipment, material - excluded; very little corrective maintenance will be done at base level. Defective modules will be removed and replaced, and sent back to RIC for possible repair. Since all alternatives are designed to identical specifications as regards reliability and maintainability, it is logical to assume that their maintenance and maintenance costs would be substantially the same. This maintenance concept is one of the areas which is least certain about the whole GBU-15 system.

7. Automatic test equipment and software - excluded; recurring costs of this nature should be minimal and essentially the same for all alternatives.

8. Base personnel: pay, allowances - excluded; no differences in manpower are anticipated for the different alternatives.

9. Delivery costs - included; number of containers and weights thereof will create differences among the alternatives. Stateside and overseas costs will be different.

10. AGE operating costs - excluded; recurring costs should be identical for all alternatives.

11. Downtime costs (use of alternate equipment) - excluded; identical for all alternatives.

12. Recurring item management costs - included; same as initial item management costs, except that there is no recurring basic technical data cost.

13. Contractor support equipment - excluded; same for all alternatives.

14. Storage costs (at RIC) - included; weight, size and numbers of storage containers will make differences among alternatives. Although this cost is included in the model, it was discovered that the RIC facility at Columbus, Ohio is government-owned, and storage costs are accounted for only in the overhead costs of running the plant. Therefore, the assumption above for including the cost is erroneous, and the cost is entered at zero value since there is no difference among alternatives.

15. Shipping cost of failed module(s) - included; although personnel and maintenance costs are excluded, failed units are shipped back to RIC for possible repair (one-half of

these is assumed to be repaired; the other half is assumed salvaged immediately.) See comments in 6. above. Stateside and overseas costs will be different.

16. Salvage value of unrepairable module(s) - included; as with residual salvage value, differences in income among alternatives for disposal of unrepairable modules should occur. This income is included under operating costs rather than final costs because the income will accrue throughout the life cycle of the GBU-15.

17. Base supply item management cost - included; different alternatives have different numbers of items which must be maintained at the base. Since it is unknown whether they will be stored in the base supply system or at the bomb dump or in the Munitions Maintenance Squadron (MMS), the Air Force standard base supply item management cost will be used.

18. Contractor data requirements - excluded; no significant differences among alternatives is expected.

In summary, included costs for the cost model are as follows:

A. <u>Initial Costs</u>
   Unit Cost (price/DME module(s))
   Aerospace Ground Equipment
   Item Management Costs
   Reusable Shipping Containers

B. <u>Recurring Costs</u> (operating costs)
   Delivery, Storage to Base
   Item Management Costs
   Storage (at RIC) Costs
   Base Supply Item Management Costs
   Shipping Costs, Failed Modules
   Salvage Value, Unrepairable Modules

C. <u>Final Costs</u>
   Salvage Value, After Expected Life
   Disposal Costs.

Data Collection. In order to properly apply the LCC method of economic analysis, the required data elements are made contractual requirements or parts of the contractor's cost proposal. The analyst then has sufficient data to combine with certain standard values and known operational requirements of the weapon system. In the case of the GBU-15, very few of the costs identified above were historically available for DME guidance modules, so the original lengthy list was formulated by the writer who then interviewed personnel at the Guided Bombs SPO, RIC, IBM, and the PLSS Program Office. Many costs were excluded as explained above on the basis of these interviews. The estimates of those costs which were included are frought with uncertainty. For example, pricing personnel at RIC cannot possibly estimate the price/unit of a G_2 in FY 78 when they do not know what the precise configuration of a G_2 would be, and when they do not know how many units would be ordered by the Air Force in FY 78. This is a type of uncertainty concerning the state of the world in the future. There is another distinguishable type identified as statistical uncertainty. As explained by Gene H. Fisher, "This type of uncertainty stems from chance elements in the real world having a more or less objective or calculable probability of occurrence. It would exist even if there were no uncertainties of the first type" (Ref 35:12). Three techniques often used to deal with both types of uncertainty are sensitivity analysis, contingency analysis, and a fortiori analysis. These are all used in this thesis in Chapter IV. Much has been written about them, so space will not be taken here to paraphrase those writings. Interested readers may refer to Fisher (Ref 35:11-13), Massey (Ref 52:21-24), the <u>Economic Analysis Handbook</u> (Ref 26:18-20), E. S. Quade (Ref 67:15-17, 232-236, 288-293), or Jones (Ref 46:117-129).

<u>The Model</u>. Once the included costs had been determined, the Life Cycle Costing model became a summation of these costs, year by year, throughout the expected life of the DME guidance modules. That model is presented here. The assumptions which led to it are found in the next section.

$$
\begin{aligned}
LCC = & \sum_{K=1}^{15} \sum_{L=1}^{2} \sum_{M=1}^{2} \left[D(L,M) \times NS(L,M,K) + FMSC(L,M) \times NF(L,M,K)\right] \\
& + \sum_{K=1}^{15} \left[BSIMC \times NBS(K) + S(1) \times NMST(1,K) + S(2) \times NMST(2,K)\right. \\
& - SVU(1) \times NMFU(1,K) - SVU(2) \times NMFU(2,K) - SVR(1) \times NMR(1,K) \\
& - SVR(2) \times NMR(2,K) + DPL \times ND(K) + PU(1,K) \times NM(1,K) \\
& \left. + PU(2,K) \times NM(2,K)\right] + \left[AGE + IMCIINV \times NFS + IMCIBTD \times IPG\right. \\
& + RSC(1) \times NRSC(1) + RSC(2) \times NRSC(2) + TSC \times NTSCM \\
& \left. + 15 \times IMCRINV \times NFS\right]
\end{aligned}
$$

where:

LCC = life cycle cost
K = year (1-15) index
L = location (overseas, stateside) index
M = module (M_1, G_2 or M_5) index
D = delivery cost
NS = number shipped
FMSC = failed module shipping cost
NF = number failed
BSIMC = base supply item management cost
NBS = number of items in base supply
S = storage cost
NMST = number of modules in storage
SVU = salvage value of failed module
NMFU = number of failed modules salvaged
SVR = salvage value after 10-year life
NMR = number of modules salvaged after life
DPL = disposal cost
ND = number of modules disposed of

PU = price/module (purchase cost)
NM = number of modules bought
AGE = AGE cost
IMCIINV = inventory item management cost
NFS = number of Federal Stock Numbers
IMCIBTD = basic tech data item management cost
IPG = number of pages in tech orders
RSC = reusable shipping container cost
NRSC = number RSC's
TSC = throw-away shipping container cost
NTSCM = number of TSC's
IMCRINV = recurring inventory item management costs.

Note the entry of salvage values with negative signs, since income may be considered a negative expense.

Assumptions. The assumptions made for inclusion or exclusion of each cost element in the model were explained in a previous section. In order to use the model, however, several assumptions are necessary about the operational situation during the life cycle of the GBU-15. The situation must be assumed because it is unknown to the writer and, he feels, unknown to anyone else. Even if some numbers have been definitized by higher headquarters planners, they are almost as uncertain as the writer's assumptions, so in order to keep this thesis unclassified, his assumptions will be used. Figure 23 gives a pictorial view of the assumed life cycle of the DME guidance modules purchased for the GBU-15. The assumptions are as follows:

1. The total life cycle of a DME guidance module is 10 years, at which time it will be salvaged. (Based upon system specifications for a 10-year minimum shelf life.)

2. Production of DME guidance modules by RIC will begin in October 1975, the first month of FY 76 if proposed legislation to that effect is passed by Congress. Production output will be a variable input to the LCC model. (Based upon RIC planning schedule released on 11 July 1974.)

3. Regardless of the actual size of the production run, the ratio of modules purchased will remain constant as follows:

a. $M_1/G_2 = 1/1$ b. $M_1/M_5 = 2/1$.

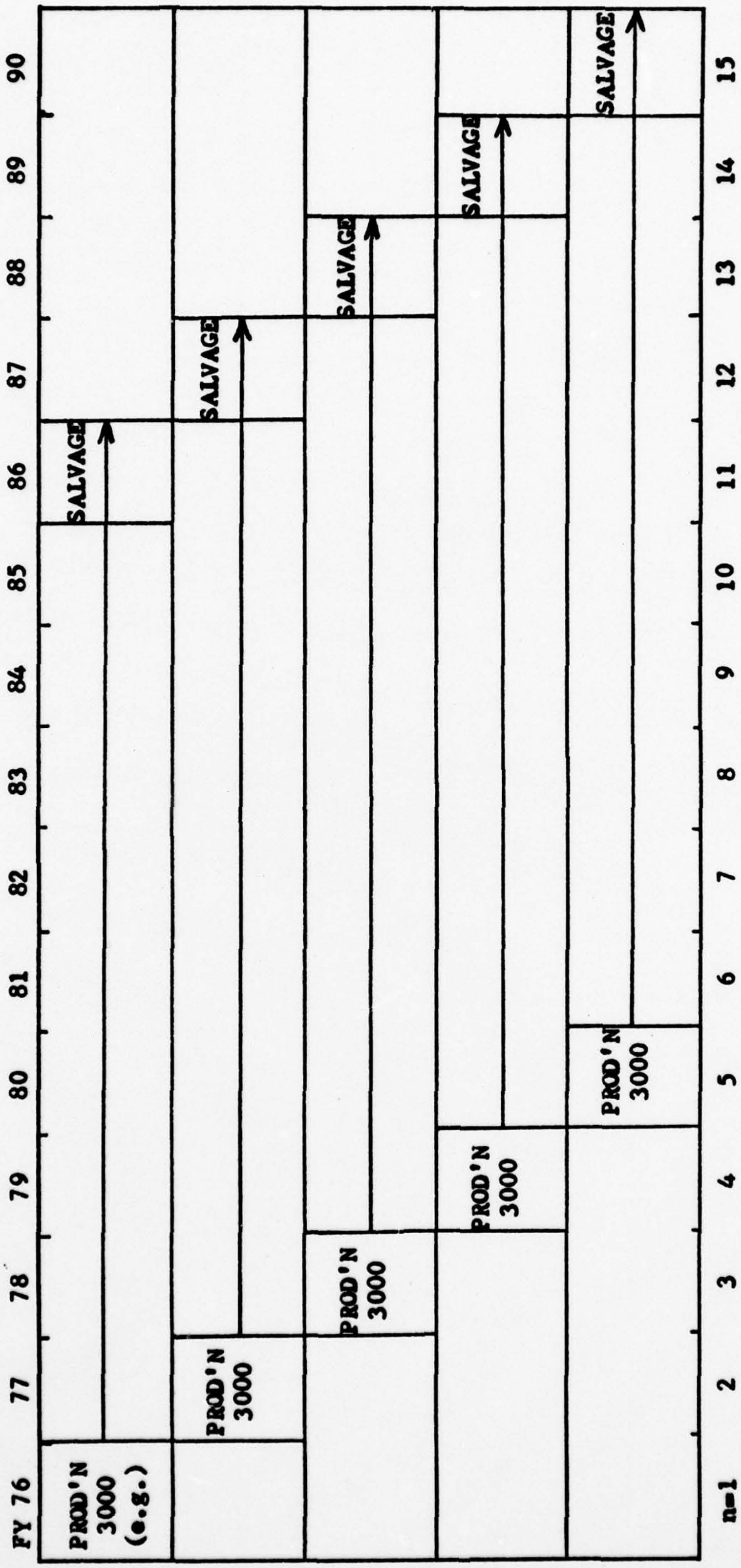


Figure 23. Assumed DME Life Cycle

In addition, the number of G_2's or M_5's purchased will be one-fourth the number of warheads dedicated to the GBU-15 Weapon System. (Based upon Senate Armed Services Committee testimony.) (Ref 78:4458-9).

4. Total warhead procurement will be a variable input ranging from 2000 to 6000 per year. (Based upon a 4-year total KMU-353 buy of over 3900; a 5-year production run will be assumed as a ballpark figure for a valid comparison.)

5. There will be no wars requiring use of the GBU-15 from FY 76 to FY 90. (Training use assumptions should give a trend toward large-scale use. Also, further qualitative discussion will be made on this point.)

6. Inflation and discounting will not be considered for reasons stated previously.

7. All costs are accrued at the end of each fiscal year.

8. The assumption is made that there will be 10 operating bases using the GBU-15 for its full life cycle. Three training bases will be in the U. S., and seven will be overseas (five in Europe, two in the Pacific area). (Based upon actual HOBOS deployment and the current world situation, i.e., no Vietnam War.)

9. The number of DME guidance units will be distributed equally among the bases. The number per base will be addressed parametrically.

10. Training use assumes the oldest in inventory are used first. Those in the year group being salvaged may be used for training.

11. Iterative computation of the numbers in the LCC model are done in the following order:

a. manufacture (purchase)
b. store
c. ship
d. fail (salvage one-half and repair one-half)
e. use
f. salvage (after life)

12. Numerous checks prevent the model from trying to ship more than are stored, use more than are at the base, etc.

13. The costs dependent on year, module, and base location are computed first. Next, those dependent on module and year are figured. Third, the constant costs dependent only on the alternative are figured. Finally, all the costs are summed.

14. The arithmetic operations which require division or decimal multiplication truncate the fractional portion of the quotient or product.

The following four pages contain a listing of the LCC model written in FORTRAN for time-sharing (TSS) on the General Electric/ Honeywell 600 Series computer system. Some of the constant values shown were varied, and some of the input variables shown became constant during analysis in Chapter IV. These four pages become Figure 24.

Qualitative Inputs

In reviewing the original list of non-quantifiable inputs on page 12, maintainability, effectiveness, performance, and vulnerability have been previously discussed. No significant differences among alternatives was found. As for reliability, it is partially treated in the LCC model with the "failed module" assumptions. Other mention will be made in Chapter IV. Compatibility with future modules and MMS ease of handling will also be discussed in Chapter IV.

In addition, the following considerations will be given individual treatment in order to provide further inputs to the decision maker:

1. Further discussion of M_1/M_5 options.

2. Impact of expected versus actual use of the DME guidance modules.

3. Creation of additional FSN's. This is also partially treated via the LCC model inputs.

4. Schedule impact on RIC.

5. Electrical interference, one module with another.

6. Special packaging requirements of the different alternatives.

Possible Thesis Scope Change as a Result of Higher Headquarters Directive

During the week of 22 July 1974, telephone conversations between the Assistant for Defense Suppression, AFSC, and the Guided Bombs SPO

```
LIST

10 DIMENSION NM(2,15),NZ(2,2,15),NRSC(2),NTSC(2,2),NST(2,2,15)
20 DIMENSION NB(2,2,15), NS(2,2,15), NF(2,2,15), NU(2,2,15)
30 DIMENSION NFU(2,2,15), NR(2,2,15), NT(2,15),NMST(2,15), NMFU(2,15)
40 DIMENSION NMR(2,15), ND(15), NBS(15), PU(2,15), NWH(15), NRQ(2)
50 DIMENSION S(2), SVU(2), SVR(2), NMU(2), FMSC(2,2), D(2,2)
60 DIMENSION RSC(2)
70 PRINT:"                    DIFFERENTIAL LCC CALCULATION"
80 PRINT:"                         FOR DME OPTIONS"
90 10 READ: J,NUSE,NQ,NWHK,PUONE,PUTWO,R
100 N=15
110 F=1.0-R
120 DO 5 K=1,5
130 5 NWH(K)=NWHK
140 DO 6 K=1,5
150 PU(1,K)=PUONE
160 6 PU(2,K)=PUTWO
170 DO 20 M=1,2
180 DO 20 K=6,N
190 20 PU(M,K)=0.0
200 DO 25 K=6,N
210 25 NWH(K)=0
220 IF (J.EQ.5) STOP
230 IF (J-2) 30,40,50
240 30 SVR(2)=274.
250 SVU(2)=2.38
260 S(2)=0.
270 FMSC(1,2)=39.
280 FMSC(2,2)=73.50
290 D(1,2)=39.
300 D(2,2)=73.50
310 NFS=19
320 IPG=145
330 DO 35 K=1,N
340 NBS(K)=9
350 35 NM(1,K)=NWH(K)/4
360 NRQ(1)=NQ/4
370 NMU(1)=NUSE/4
380 GO TO 90
390 40 SVR(2)=137.
400 SVU(2)=2.38
410 S(2)=0
420 FMSC(1,2)=39.
430 FMSC(2,2)=73.50
440 D(1,2)=39.
450 D(2,2)=73.50
460 NFS=15
```

Figure 24. LCC Program Listing

```
470 IPG=130
480 DO 45 K=1,N
490 45 NBS(K)=7
500 GO TO 80
510 50 IF (J-3) 99,60,70
520 60 SVR(2)=144.
530 SVU(2)=2.38
540 S(2)=0
550 FMSC(1,2)=39.
560 FMSC(2,2)=73.50
570 D(1,2)=39.
580 D(2,2)=73.50
590 NFS=15
600 IPG=130
610 DO 65 K=1,N
620 65 NBS(K)=7
630 GO TO 80
640 70 SVR(2)=144
650 SVU(2)=2.38
660 S(2)=0
670 FMSC(1,2)=41.60
680 FMSC(2,2)=78.40
690 D(1,2)=41.60
700 D(2,2)=78.40
710 NFS=16
720 IPG=135
730 DO 75 K=1,N
740 75 NBS(K)=8
750 80 DO 85 K=1,N
760 85 NM(1,K)=NWH(K)/2
770 NRQ(1)=NQ/2
780 NMU(1)=NUSE/2
790 90 DO 95 K=1,N
800 NZ(1,1,K)=.3*NM(1,K)
810 NZ(2,1,K)=.7*NM(1,K)
820 NM(2,K)=NWH(K)/4
830 NZ(1,2,K)=.3*NM(2,K)
840 95 NZ(2,2,K)=.7*NM(2,K)
850 NMU(2)=NUSE/4
860 NRQ(2)=NQ/4
870 S(1)=0
880 SVU(1)=.60
890 SVR(1)=141.
900 FMSC(1,1)=26.
910 FMSC(2,1)=49.
920 IMCIINV=663
930 IMCIBTD=160
940 IMCRINV=663
950 TSC=50.
960 D(1,1)=26.
970 D(2,1)=49.
980 RSC(1)=400.
990 RSC(2)=500.
1000 DPL=149.
```

```
1010 JRSC=0
1020 BSIMC=12.
1030 AGE=0.
1040 DO 100 L=1,2
1050 DO 100 M=1,2
1060 ISUM=0
1070 JSUM=0
1080 KSUM=0
1090 LSUM=0
1100 MSUM=0
1110 NNSUM=0
1120 MMSUM=0
1130 DO 100 K=1,N
1140 ISUM=ISUM+NZ(L,M,K)
1150 NST(L,M,K)=ISUM-JSUM-MMSUM+MSUM
1160 NB(L,M,K)=JSUM-KSUM-LSUM-NNSUM
1170 IF ((NB(L,M,K)).LT.0) GO TO 99
1180 NSC=NRQ(M)-NB(L,M,K)
1190 IF (NSC.LT.0) GO TO 99
1200 IF (((NST(L,M,K))-NSC).LT.0) GO TO 110
1210 NS(L,M,K)=NSC
1220 GO TO 120
1230 110 NS(L,M,K)=NST(L,M,K)
1240 120 JSUM=JSUM+NS(L,M,K)
1250 NST(L,M,K)=ISUM-JSUM-MMSUM+MSUM
1260 NB(L,M,K)=JSUM-KSUM-LSUM-NNSUM
1270 NF(L,M,K)=NB(L,M,K)*F
1280 IF((NF(L,M,K)).GT.(NB(L,M,K))) NF(L,M,K)=NB(L,M,K)
1290 LSUM=LSUM+NF(L,M,K)
1300 NB(L,M,K)=JSUM-KSUM-LSUM-NNSUM
1310 IF((NMU(M)-NB(L,M,K)).GT.0) GO TO 140
1320 NU(L,M,K)=NMU(M)
1330 GO TO 150
1340 140 NU(L,M,K)=NB(L,M,K)
1350 150 KSUM=KSUM+NU(L,M,K)
1360 NB(L,M,K)=JSUM-KSUM-LSUM-NNSUM
1370 NFU(L,M,K)=NF(L,M,K)/2
1380 MSUM=MSUM+NFU(L,M,K)
1390 NST(L,M,K)=ISUM-JSUM-MMSUM+MSUM
1400 IF ((K-10).GT.0) GO TO 170
1410 NR(L,M,K)=0
1420 GO TO 180
1430 170 KK=K-9
1440 NSUM=0
1450 DO 175 I=KK,K
1460 175 NSUM=NSUM+NZ(L,M,I)
1470 IF((NB(L,M,K)+NST(L,M,K)-NSUM).LT.0) GO TO 176
1480 NR(L,M,K)=NB(L,M,K)+NST(L,M,K)-NSUM
1490 IF(NR(L,M,K)-NB(L,M,K)) 177,177,178
1500 177 NNSUM=NNSUM+NR(L,M,K)
1510 NB(L,M,K)=JSUM-KSUM-LSUM-NNSUM
1520 GO TO 180
1530 178 NNSUM=NNSUM+NB(L,M,K)
1540 MMM=NR(L,M,K)-NB(L,M,K)
```

```
IF((MMM).GT.(NST(L,M,K))) MMM=NST(L,M,K)
MMSUM=MMSUM+MMM
NST(L,M,K)=ISUM-JSUM-MMSUM+MSUM
NB(L,M,K)=JSUM-KSUM-LSUM-NNSUM
GO TO 180
176 NR(L,M,K)=0
180 IF (M-1) 99,100,185
185 NTSC(L,2)=ISUM
100 CONTINUE
LCCR=0.
DO 300 K=1,N
IF (J.EQ.2) GO TO 200
IF (J.EQ.1) GO TO 190
IF (J.EQ.3) GO TO 200
NBS(K)=4*(NS(1,1,K)+NS(1,2,K)+NS(2,1,K)+NS(2,2,K))
GO TO 210
190 NBS(K)=4*(NS(1,1,K)+NS(2,1,K))+5*(NS(1,2,K)+NS(2,2,K))
GO TO 210
200 NBS(K)=4*(NS(1,1,K)+NS(2,1,K))+3*(NS(1,2,K)+NS(2,2,K))
210 NT(1,K)=NB(1,1,K)+NB(2,1,K)
NT(2,K)=NB(1,2,K)+NB(2,2,K)
NMST(1,K)=NST(1,1,K)+NST(2,1,K)
NMST(2,K)=NST(1,2,K)+NST(2,2,K)
NMFU(1,K)=NFU(1,1,K)+NFU(2,1,K)
NMFU(2,K)=NFU(1,2,K)+NFU(2,2,K)
NMR(1,K)=NR(1,1,K)+NR(2,1,K)
NMR(2,K)=NR(1,2,K)+NR(2,2,K)
ND(K)=NMFU(1,K)+NMFU(2,K)+NMR(1,K)+NMR(2,K)
LCCS=0
DO 220 L=1,2
DO 220 M=1,2
220 LCCS=D(L,M)*(NS(L,M,K))+FMSC(L,M)*(NF(L,M,K))
300 LCCR=LCCR+LCCS+BSIMC*NBS(K)+S(1)*NMST(1,K)+S(2)*NMST(2,K)
&-SVU(1)*NMFU(1,K)-SVU(2)*NMFU(2,K)-SVR(1)*NMR(1,K)
&-SVR(2)*NMR(2,K)+DPL*ND(K)+PU(1,K)*NM(1,K)+PU(2,K)*NM(2,K)
IF (J-2) 230,240,225
225 IF (J-3) 240,230,240
230 NRSC(2)=NT(2,5)+NMST(2,5)-JRSC
NTSCM=0
GO TO 250
240 NRSC(2)=0
NTSCM=NTSC(1,2)+NTSC(2,2)
250 NRSC(1)=NT(1,5)+NMST(1,5)
LCC=LCCR+AGE+IMCIINV*NFS+IMCIBTD*IPG+RSC(1)*NRSC(1)
&+RSC(2)*NRSC(2)+TSC*NTSCM+15*IMCRINV*NFS
260 FORMAT(1H0,5X,13HFOR OPTION   ,I1,25H   LIFE CYCLE COST
&EQUALS,I15)
PRINT 260,J,LCC
GO TO 10
99 PRINT:"BOMBED"
GO TO 10
END
```

indicated that the Air Force had decided not to purchase any G_2 modules. Therefore, one of the alternatives of this thesis was effectively removed from contention. On the belief that very few decisions are final, the writer continued this study as if that decision had not been made. The results will thus serve to support or refute the decision, but will not be an input. RIC immediately published a new Weapon Configuration Matrix as shown in Figure 25 to reflect the new decision.

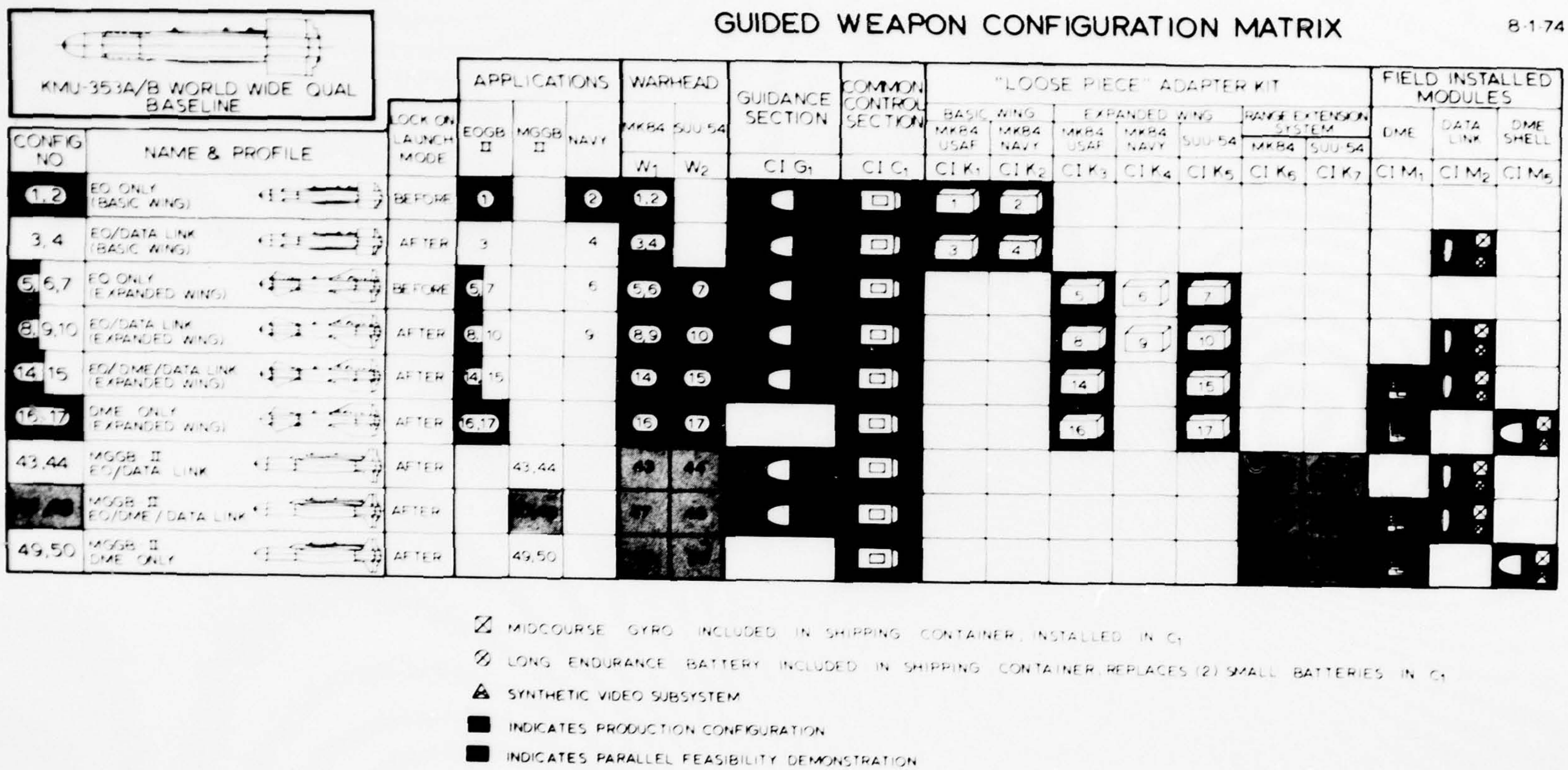


Figure 25. Guided Weapon Configuration Matrix

AD-A067 594 AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OHIO SCH--ETC F/G 19/2
A TRADEOFF STUDY TO DETERMINE THE PREFERRED DISTANCE MEASURING --ETC(U)
DEC 74 F C GIDEON
UNCLASSIFIED AFIT/GSM/SM/74D-3 NL

2 OF 2
AD
A067594

END
DATE
FILMED
6-79
DDC

IV. Analysis of Data

This chapter explains more fully the similarities and differences among the four proposed DME procurements. In order to arrive at a reasonable choice among the alternatives, a comparison of both quantitative and qualitative characteristics was undertaken. The quantitative criterion for the choice is least life cycle cost. Criteria for the qualitative choices will be presented later. The word "option" appears often in the remaining chapters and is used synonymously with "alternative."

Further Discussion of Alternatives

Each of the alternatives consists of two modules. Module 1 is M_1 in all cases. Module 2 is G_2 for Alternative 1, and M_5 for Alternatives 2, 3 and 4. Alternatives 2, 3 and 4 have different packaging arrangements of the internal components between Modules M_1 and M_5. In order to compare costs, the alternatives were subdivided into units which could be costed, and then recombined in order to obtain an estimated purchase cost. Figures 26 and 27 depict this process. The estimated costs (RIC's price to the AF) were gathered from several sources at Rockwell International Corporation and reflect a sizable amount of uncertainty. These costs were estimated by experts at RIC by extrapolation of historical cost data on their HOBOS weapon. A measure of their confidence in these estimates was expressed by obtaining "best" estimates, and then asking for "high" and "low" values which represented

ESTIMATED COSTS

Estimated Cost($)	A. VIDEO PACK (1) Built-in	A. VIDEO PACK (2) Separate	B. DV GYRO	C. WGSS	D. Dummy M_5	E. M_1 Structure	F. G_2 Structure
+20%	420	480	2400	11,160	9360	240	9360
Best	350	400	2000	9,300	7800	200	7800
-20%	280	320	1600	7,440	6240	160	6240

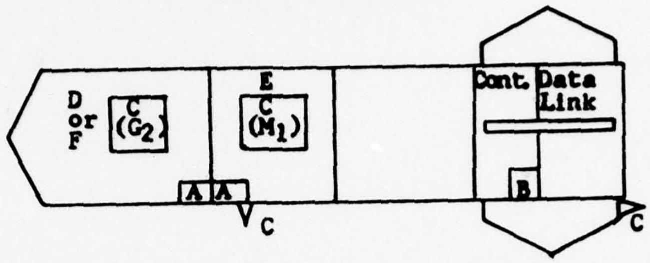
COMBINATIONS

	Option 1		Option 2		Option 3		Option 4	
	Module 1	Module 2	Module 1	Module 2	Module 1	Module 2	Module 1	Module 2
	C E	A(1) B C F	A(1) C E	B D	C E	A(1) B D	C E + $50*	A(2) B D
	9300 200	350 2000 9300 7800	350 9300 200	2000 7800	9300 200	350 2000 7800	9300 250	400 2000 7800
TOTALS	9500	19,450	9850	9800	9500	10,150	9550	10,200

*For video plug-in provision

Figure 26. Subsystem Costs and Combinations (production of approx. 100/mo, 1000/yr)

HARDWARE LOCATION



A. Video Sync Pack
B. DV Gyro
C. WGSS
D. Dummy M_5
E. M_1 Structure
F. G_2 Structure

SHIPPING KIT CONFIGURATION

Option 1

M_1	G_2
C	A*
E	B
	C
	F

Option 2

M_1	M_5
A*	B
C	D
E	

Option 3

M_1	M_5
C	A*
E	B
	D

Option 4

M_1	M_5
C	A**
E	B
	D

* Built in
**Separate

Figure 27. Hardware Location and Shipping Kit Configuration

a 95 per cent confidence on their part. This turned out to be ± 20 per cent of the "best" estimates. The writer has added those bounds in Figure 26.

It is thus easy to sum the appropriate costs to compute RIC's price to the Air Force, or purchase cost of a particular module. Determination of option cost is not quite so simple however, because Modules M_1 and G_2 for Option 1 are not purchased in the same ratio as M_1 and M_5 for Options 2, 3 and 4. For example, if 2000 warheads were being dedicated to the GBU-15 family, Option 1 would require the purchase of 500 G_2's and 500 M_1's. Options 2, 3 and 4 would require 500 M_5's and 1000 M_1's (see Assumption 3, page 77). This is because 50 per cent of the missions are to be EO-only (no DME modules needed, only 1000 EO guidance modules, G_1); 25 per cent of the missions are to be EO/DME (500 M_1's needed in combination with the EO Modules, G_1, for any option); and 25 per cent of the missions are to be DME-only (500 G_2's for Option 1, or 500 M_1/M_5 for Options 2, 3 or 4). This assumption is contained in the LCC model and was not originally to be analyzed as a variable. In the case of Option 2 where the video synchronization package is built into the M_1, there will be a redundancy of that package every time M_1 and G_1 are used in combination for the EO-DME mission since G_1 has that package also (500 unnecessary video sync packages in this example).

The RIC tradeoff study presented at the 8-12 July 1974 Preliminary Design Review pointed out two differences between G_2 and M_1 + M_5 for DME guidance. The first was the redundancy problem noted above when the Option 2 M_1 is used in combination with G_1. Second was the observation that operational squadrons would have to open two kits for a DME-only mission with Option 2 and only one kit for Option 1. On the strength of these two differences and the statement that logistics and maintenance problems would be reduced, it was recommended that both G_2 and $M_1 + M_5$ be procured. There was mention that the G_2 could use the already-procured G_1 reusable shipping containers, but that M_5 could not. Further discussion by the writer and RIC personnel revealed that, in fact, the reusable shipping containers would have to be extensively modified to accommodate either M_5 or G_2. Modification is almost as expensive as producing new containers. For this reason, new shipping container costs were used in the model for all options, and the input JRSC (presently available reusable shipping containers) was entered as zero in all cases.

There are many other aspects to this packaging tradeoff problem not mentioned in the RIC study, however, including life cycle costs and numerous qualitative considerations such as maintainability, electrical interference problems, and operational flexibility. These topics are the subject of the rest of this chapter.

In order to understand the quantitative analysis, it is necessary to be aware of the sources of LCC model input data. The following data elements were obtained from the Logistics Support Cost Model in use by the Air Force Logistics Command. This model is used by AFLC to compute logistics life cycle costs for any weapons system and the values below were taken as standard values by the writer in his LCC model. They were based on averages over several years for all types of inventory items. The writer found no such values applicable to DME or electronic components only. They were not varied throughout the analyses.

Standard Values

Initial Inventory Management Cost	\$663/Item
Initial Technical Data Documentation	\$160/Page
Delivery Costs	\$.98/lb overseas
	\$.52/lb stateside
Recurring Inventory Management Costs	\$663/Item/year
Base Supply Item Management Cost	\$12/Item/year

The following values were estimated by RIC experts as previously explained:

Estimated by RIC Experts

Reusable Shipping Container Costs (RSC)	\$400/M_1
	\$500/G_2 or M_5
Storage Cost	Identical for all options
Price/Unit	See Figure 26
Throw-away Shipping Container Cost	\$50/Container
Already Available RSC's	0
Shipping Weights of Kits	Varied from 50-80 lbs.

Since the above values were considered accurate within ± 20 per cent, they were varied by that amount during sensitivity analysis to check for a change in rank order of the alternatives. The following values were estimated by the writer:

Salvage Values
Disposal Costs
Number of Federal Stock Numbers
Number of Items in Base Supply System

Values vary with each alternative and the best estimates are inserted as constants in the LCC Model as shown in Chapter III. Salvage value and disposal costs were estimated from the USAF Materiel Utilisation and Disposal Summary, years 1970-72 (Ref 11, 12, 13: Tables IX, X, XI). The number of Federal Stock Numbers was figured by counting the individual number of kits and sub-kits associated with each alternative, and adding the number of complete weapon configurations which contain the modules of those alternatives. For example, Option 2 has two kits

(M_1, M_5), three sub-kits in M_1 (M_1 structure, two antennas), two sub-kits in M_5 (DV gyro, M_5 structure), and eight possible weapon combinations involving M_1 or M_5 as follows, each of which will have its own Federal Stock Number:

$$G_1M_2M_1C_1K_3W_1$$

$$G_1M_2M_1C_1K_6W_1$$

$$G_1M_2M_1C_1K_5W_2$$

$$G_1M_2M_1C_1K_7W_2$$

$$M_5M_1C_1K_3W_1$$

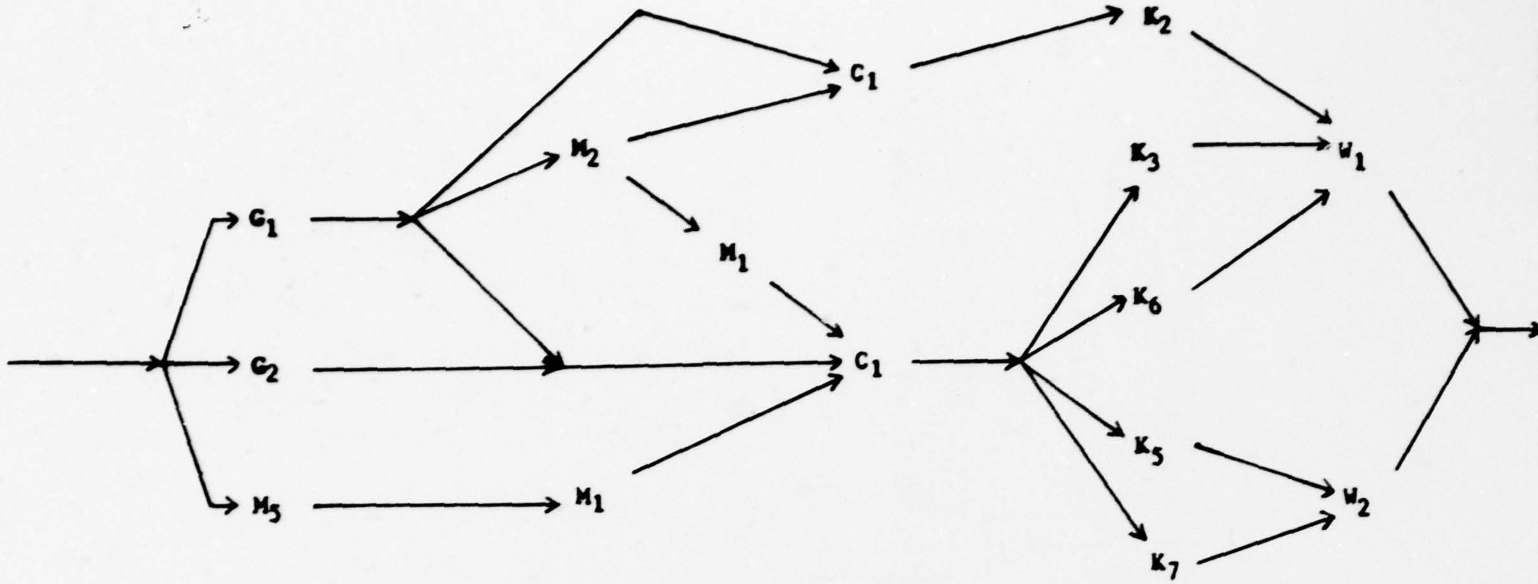
$$M_5M_1C_1K_6W_1$$

$$M_5M_1C_1K_5W_2$$

$$M_5M_1C_1K_7W_2.$$

There are 18 possible combinations of assembled weapons whether G_2/M_1 or M_5/M_1 are bought. They and the above list come from the matrix or from Figure 28, which is another way to picture the matrix. For Option 2, then, the total number of Federal Stock Numbers is 15.

Calculation of the number of items in the base supply system was impossible. This is primarily due to the unknown spares policy to be applied to the GBU-15. In order to allow this cost to have some influence on the alternative ranking, it was decided to use the number of Federal Stock Numbers for each module times the number of those modules shipped to the base in a given year. Obviously, there will also be many spare parts, but it was assumed that for any given warhead, the number of submodule spare parts would not differ among alternatives. Since there was a low level of confidence on the above values, they were expanded by ± 50 per cent to check for sensitivity.



18 possible combos
8 combos containing G_2 or M_1
8 combos containing M_5 or M_1

Figure 28. Possible Weapon Module Combinations

Quantitative Analysis

Before proceeding with a discussion of the LCC quantitative analysis, two points about the use of the model should be made. First, it is realistic to use the model only in the range of 2000-6000 warheads purchased/year. This is primarily because some of the assumptions in the model would be different outside that range. For example, planned use and deployment of the weapons may be entirely different if only 1000 were produced/year. Second, if the magnitude of a particular cost were extremely inaccurate, the effect might be to give an incorrect LCC rank among alternatives. For example, if the WGSS cost were actually 100 times greater than the value used herein, the effect might overshadow all other effects that tend to rank Option 1 as best. The true ranking would then possibly show Option 2 to be best. Although this may be fairly obvious, it is mentioned for the benefit of those who may question the cost figures used. Those readers may question the results as well but will be provided a methodology (LCC model) to exercise their estimates. How each cost was determined was explained in the first section of this chapter. Those who accept the cost figures as reasonable should agree with the final ranking, too.

The results of the quantitative analysis part of this chapter can be summed up into one statement. In all cases, OPTION NO. 1 (G_2/M_1) WAS DOMINANT USING THE LEAST-COST CRITERION ON THE LCC MODEL. The other options followed in order 4,2,3 as indicated in Table I. By "all cases" is meant the complete range of analysis as follows.

Contingency Analysis

Contingency analysis investigates the stability of the ranking of alternatives when a major change in the general environment is assumed

Table I
Example Contingency Data

(1) Costs held constant at best estimates
(2) Order of data input is:
USAGE/REQUIREMENTS/NO.MANUFACTURED/RELIABILITY

Input	Option	Differential LCC($)	Rank
300/300/6000/0.8	1	223,253,121	1
	2	227,911,845	3
	3	228,283,625	4
	4	226,418,632	2
0/300/6000/0.8	1	223,408,821	1
	2	228,239,741	3
	3	228,898,921	4
	4	226,716,588	2
0/150/3000/0.8	1	111,809,632	1
	2	114,201,646	3
	3	114,531,236	4
	4	113,445,519	2
150/150/3000/0.8	1	111,731,782	1
	2	114,037,696	3
	3	114,223,586	4
	4	113,296,539	2
0/120/2000/0.8	1	74,634,742	1
	2	76,215,801	3
	3	76,433,931	4
	4	75,716,839	2
0/40/2000/0.8	1	74,583,082	1
	2	76,155,213	3
	3	76,382,923	4
	4	75,651,491	2
0/40/2000/0.9	4	75,642,041	N/A
0/40/2000/0.5	4	75,670,734	N/A
300/300/6000/0.9	1	223,186,939	N/A
300/300/6000/0.5	1	223,435,107	N/A

(Ref 35:13). This is defined by the writer as varying the number of units manufactured, the number used and stored at the bases, and the assumed reliability ("R" in the model). Reliability of the DME modules is unknown to the writer and even if it were known, would be classified. Therefore, a value of 0.8 (that is, 80 per cent of the undamaged modules worked without fault once the weapon was loaded and checked out on the aircraft) was assumed during sensitivity analysis for the following reason. R was varied from 1.0 to 0.5 during contingency analysis without changing the ranking of the options and without changing the magnitude of the cost for each option by more than .23 per cent.

Results of the contingency analysis are shown in Table II. Sample computer output is shown in Figure 29. Effects of varying module use was the first variable checked. For 6000 warheads produced/year, use was varied from 0 to 300. For 3000 and 2000 produced/year, use was varied from 0 to 120. The effect was to change, for any option, the LCC by from -.45 per cent to .27 per cent. Next, the number of modules required to be maintained at each base was varied from 40 to 120 at 2000 manufactured, 50 to 120 at 3000 manufactured, and 100 to 300 at 6000 manufactured, all at 0 use and 0.8 reliability. Again, the effect was minimal-- .05 per cent to .09 per cent for any option's LCC. Third, the number manufactured was changed from 2000 to 3000 and from 2000 to 6000 at 0 use, 0.8 reliability, and requirements of 120. The results showed an almost direct multiple relationship between total number bought and LCC cost. That is, a 50 per cent increase in numbers bought resulted in a 50 per cent increase in LCC. An additional computation here showed that in all cases approximately 19.5 per cent of that increase in LCC was caused by the initial purchase cost of the modules.

Table II
Contingency Analysis

A. USAGE: (R=.8)

(1) 6000 Manu., 300 Req:

LCC % CHG. FROM 0→300	OPTION 1	2	3	4
USE 0→300	-.07	.14	.27	.13

(2) 3000 Manu., 150 Req:

LCC % CHG. FROM 0→120	OPTION 1	2	3	4
USE 0→120	-.07	-.14	-.27	-.13

(3) 2000 Manu., 120 Req:

LCC % CHG. FROM 0→120	OPTION 1	2	3	4
USE 0→120	-.09	-.17	-.45	-.16

B. REQUIREMENTS:

(1) 6000 Manu., 0 Use:

LCC % CHG. FROM 100→300	OPTION 1	2	3	4
REQ 100→300	.06	.07	.06	.07

(2) 3000 Manu., 0 Use:

LCC % CHG. FROM 50→120	OPTION 1	2	3	4
REQ 50→120	.05	.06	.05	.07

(3) 2000 Manu., 0 Use:

LCC % CHG. FROM 40→120	OPTION 1	2	3	4
REQ 40→120	.07	.08	.07	.09

C. NUMBER MANUFACTURED: (0 Use, 120 Req.)

LCC % CHG., LOWER → UPPER

OPTION	1	2	3	4
2000→3000	49.81	49.84	49.84	49.83
2000→6000	199.16	199.27	199.31	199.21

% OF % CHG. CAUSED BY PURCHASE COST

OPTION	1	2	3	4
2000→3000	19.46	19.35	19.07	19.35
2000→6000	19.48	19.44	19.15	19.44

D. RELIABILITY: (CHG. FROM 1.0→0.5)

.03 % LCC change at 2000 Manu./0 use/50 Req.
.23 % LCC change at 6000 Manu./300 use/300 Req.

```
 1,0,100,6000,9500.,19450.,0.8

      FOR OPTION    1    LIFE CYCLE COST EQUALS       223279669
=2,0,100,6000,9850.,9800.,0.8

      FOR OPTION    2    LIFE CYCLE COST EQUALS       228088279
=3,0,100,6000,9500.,10150.,0.8

      FOR OPTION    3    LIFE CYCLE COST EQUALS       228771409
=4,0,100,6000,9550.,10200.,0.8

      FOR OPTION    4    LIFE CYCLE COST EQUALS       226553226
=
```

```
 1,0,50,3000,9500.,19450.,0.8

      FOR OPTION    1    LIFE CYCLE COST EQUALS       111752227
=2,0,50,3000,9850.,9800.,0.8

      FOR OPTION    2    LIFE CYCLE COST EQUALS       114128288
=3,0,50,3000,9500.,10150.,0.8

      FOR OPTION    3    LIFE CYCLE COST EQUALS       114472248
=4,0,50,3000,9550.,10200.,0.8

      FOR OPTION    4    LIFE CYCLE COST EQUALS       113366106
=
```

Figure 29. Sample Contingency Analysis Output

The fourth contingency analysis consisted of changing reliability from 1.0 to 0.5. It was felt that this was a reasonable range within which the actual reliability might lie since reliability less than 0.5 would surely be unacceptable. LCC varied from .03 per cent at 2000 manufactured to .23 per cent at 6000 manufactured.

In summary of the contingency analysis, for all contingencies, the least-cost LCC option ranking is 1,4,2,3. Option 4 ranged from 1.37 per cent to 1.48 per cent higher than Option 1. Option 2 ranged from 2.03 per cent to 2.17 per cent higher than Option 1. Option 3 ranged from 2.17 per cent to 2.46 per cent higher.

Sensitivity Analysis

"Suppose in a given analysis there are a few key parameters about which the analyst is very uncertain. Instead of using mean values for these parameters, the analyst may successively use several values (say, high, medium, and low) in an attempt to see how sensitive the results (the ranking of the alternatives being considered) are to variations in the uncertain parameters" (Ref 35:12). This precisely describes the process which was used by the writer for each of the costs and parameters previously listed as being estimated by RIC experts or the writer. Those estimated by RIC were varied by ± 20 per cent of the best estimate, and those by the writer by ± 50 per cent. During sensitivity analysis, as a result of contingency analysis which showed very little effect caused by the contingency parameters, contingency parameter values were held constant at numbers which seemed close to what might actually happen. These values are:

Number of warheads bought (NWHK) = 3000/year
Number required (NQ) = 100/base

Number used (NUSE) = 12/base/year (1/month for training)
Reliability (R) = 0.8

The results of this analysis are shown in Table III. The only two sub-module purchase costs analysed were WGSS cost and G_2 or M_5 structure cost. It was felt that the other costs would have negligible effect (Figure 26). Sample computer output is shown in Figure 30.

As might be expected since there is so little component difference among alternatives, effects of varying any of these costs or parameters were almost identical on each alternative and resulted in no change in alternative ranking.

A Fortiori Analysis

In all the above analyses, Option 1 appears favorable. To make an even stronger case for this conclusion, all variable quantities from contingency and sensitivity analyses were combined in such a way as to have the greatest increase-cost influence on Option 1, or the greatest decrease-cost influence on Option 4. It was felt that if Option 1 still showed dominance over Option 4, the second best, Option 1 logically had even more support for its selection. This was in fact the case. Option 4 was still 1.15 per cent higher in LCC than Option 1. See Table IV.

Expected Versus Actual Use

This is a difficult topic that was originally going to be discussed in the qualitative section, but which was found to be applicable to the LCC model. It addresses the expected mission use of the GBU-15 weapon family. The expected use is 50 per cent Electro-optical, 25 per cent DME-only, 25 per cent EO/DME. This was the basis for Assumption 3,

Table III
Sensitivity Analysis

	% Change in LCC from Best Estimate Values			
	OPTIONS			
	1	2	3	4
(1) RSC (M) ± 20%	±.59	±.52	±.84	±.52
(2) IPG (J) ± 20%	-	-	-	-
(3) DPL (J) ± 50%	±.48	±.71	±.71	±.72
(4) SVR (M) ± 50%	±.67	±.65	±.66	±.67
(5) WGSS + 20%	12.48	12.17	12.16	12.54
(6) WGSS - 20%	-12.44	-12.17	-12.13	-12.02
(7) G_2 or M_5 Structure + 20%	5.22	5.10	5.09	5.41
(8) G_2 or M_5 Structure - 20%	-5.22	-5.10	-5.02	-4.89
(9) TSC ± 20%	-	-	-	-
(10) Container Weights ± 20%	-	-	-	-
(11) NBS ± 50%	-	-	-	-

```
*RUN
                DIFFERENTIAL LCC CALCULATION
                      FOR DME OPTIONS
=1,11369.,21311.                                        WGSS + 20%

      FOR OPTION   1   LIFE CYCLE COST EQUALS       83931867
=2,11710.,9800.

      FOR OPTION   2   LIFE CYCLE COST EQUALS       85481866
=3,11369.,10150.

      FOR OPTION   3   LIFE CYCLE COST EQUALS       85730626
=4,11410.,10200.

      FOR OPTION   4   LIFE CYCLE COST EQUALS       84983324
=


 1,7640.,17590.                                         WGSS -20%

      FOR OPTION   1   LIFE CYCLE COST EQUALS       65306867
=2,7990.,9800.

      FOR OPTION   2   LIFE CYCLE COST EQUALS       66881865
=3,7640.,10150.

      FOR OPTION   3   LIFE CYCLE COST EQUALS       67085625
=4,7690.,10200.

      FOR OPTION   4   LIFE CYCLE COST EQUALS       66383323
=


 1,9500.,21010.                          G3 OR M5 STRUCTURE +20%

      FOR OPTION   1   LIFE CYCLE COST EQUALS       78506867
=2,9850.,11360.

      FOR OPTION   2   LIFE CYCLE COST EQUALS       80081866
=3,9500.,11710.

      FOR OPTION   3   LIFE CYCLE COST EQUALS       80285626
=4,9550.,11760.

      FOR OPTION   4   LIFE CYCLE COST EQUALS       79583324
=
```

Figure 30. Sample Sensitivity Analysis Output

Table IV
A *Fortiori* Analysis

The following parameters were changed in the manner shown to bias the result as much as possible in favor of Option 4 over Option 1:

RSC	+ 20%
DPL	- 50%
TSC	best estimate
SC	best estimate
NBS	best estimate
IPG	best estimate
SVR	best estimate
WGSS, G_2, M_5 Structure Cost	best estimate
NUSE	150
NRQ	150
NWHK	3000
R	0.8

page 77. What happens if instead, because of wartime necessity, 75 per cent of the weapons are used on EO missions and 25 per cent are used for DME-only? In other words, is one option a better hedge against a planning error which results in unexpected use of the weapon family? Answering this question would never provide a strong argument in favor of a particular option, but may be one consideration. Return to our example of 2000 warheads bought. If missions for these 2000 warheads were flown as planned, Option 1 would result in use of 500 M_1's and 500 G_2's. Options 2, 3 or 4 would result in the use of 1000 M_1's and 500 G_2's. If the actual mission percentage were, instead, 75 per cent EO and 25 per cent DME-only, Option 1 would result in use of zero M_1's and 500 G_2's. Options 2, 3 or 4 would see 500 M_1's and 500 M_5's used. In this eventuality all options would result in 500 unused M_1's. In addition, even if this mission percentage were expected and planned for, alternative ranking remains as before - 1,4,2,3. This was calculated from the LCC model.

A different outcome results from an actual use of 75 per cent EO and 25 per cent EO/DME. In this case, 500 G_2's would go unused for Option 1 ($19,450 x 500 = $9,725,000 initial purchase cost wasted, not to mention other logistic costs). For Options 2, 3 or 4, 500 M_5's and 500 M_1's would be unused ($9,825,000 for Options 2 or 3, and $9,875,000 for Option 4). This eventuality, therefore, also tends to support Option 1 as the best choice.

As a final example, suppose actual desired use were 50 per cent EO/DME, 25 per cent EO, and 25 per cent DME-only. For Option 1, all the modules would be used, but 500 of the EO/DME missions (one-half of them) would not be flown. Options 2, 3 or 4 allow more tactical flexibility in this case. Five hundred of the desired missions will still be impossible, but the commander has the choice of dividing these between the DME-only missions and the EO-DME missions. Each time he chooses not to fly one of the DME-only missions, however, another M_5 becomes surplus (approximately $10,000 purchase cost).

Further exploration into this area is beyond the scope of this thesis, but these examples lend some support to the choice of Option 1 using a least-cost criterion.

Qualitative Analysis

Up to this point discussion has centered on costs, which are "quantifiable," and which are considered a negative attribute. Benefits are positive outcomes of one alternative or another and should be weighed against cost in reaching a decision. The following sections analyze benefits identified by the writer to have applicability to DME guidance equipment. This is one area where the expertise of the decision-maker may be more enlightening to the whole cost-benefit analysis than that of the analyst. The analyst's function with these non-quantifiable considerations lies more in bringing them to the attention of the decision-maker (with such observations as he may have) than in dealing explicitly with them in some sort of mathematical model.

Non-Differentiable Benefits

These are the benefits which are thought by the writer to be the same among options. Neither one option nor another would yield higher gains in these areas:

A. Effectiveness - all options are designed to the same specifications and should meet operational requirements equally well.

B. Accuracy - same as above. Accuracy between DME and another form of guidance may vary, but that is outside the scope of this thesis though it bears careful study. Among the four DME options, accuracy is identical.

C. Reliability - same as above. Mission reliability requirements are the same for all.

D. Availability - two kits are required for any option, and there is no reason to suspect one would be easier to make available to the user than another.

E. Service Life - all options are designed for 10-year shelf life.

F. Safety - handling problems and operation of the guidance modules should be the same.

G. Vulnerability to Enemy Jamming - same electronic components for all options.

H. Training Skill Levels - same for all options.

I. Performance - all will meet technical performance specifications equally.

Maintainability

The maintenance concept for DME guidance provides for minimum maintenance at base level. If a module fails check-out tests, in most cases it will be sent back to the contractor for repair. Small units like antennas or the DV gyro are handled in the same way. Option 4 does contain one minor replacement part which the others do not, however, and that is the plug-in video synchronization package. This package is built into the other options, so failure would require the whole module to be replaced in their cases. Creation of an additional piece of hardware may outweigh this improvement of maintainability, though, if attendant logistics costs were high (addressed in the LCC model) or spares became difficult to get. In addition, the video sync package is simply two or three printed circuit boards which have a high reliability.

Manageability

The ease with which munitions maintenance personnel can handle the GBU-15 weapon family varies somewhat among the options for a DME-only mission. It is identical for any other mission. Option 1 requires the least amount of handling, with only the G_2 to unpack, check out, and mate with the weapon. Options 2, 3 and 4 have two kits to open, M_1 and M_5. All four options also have the antennas and DV gyro to check out and install on the weapon. Option 4 then has one additional bit of handling with the plug-in video package. It is packaged with the M_5 kit but is plugged into M_1 during weapon assembly.

Volume Growth Potential

This paragraph also refers to what has been previously called compatibility with future modules. Option 1 has very little space in the G_2 for additional electronic equipment, but the adapter area between the nose and the warhead is virtually empty and available for use. The M_1 of Option 1 is identical to the M_1 of Option 3 and has only a little space for additional equipment. The M_1 of Options 2 and 4 are incapable of receiving any more electronic components; they are full. M_5 of Options 3 and 4 have some space occupied by the video package, whether it is built in or plugged into M_1. Option 2 has an empty M_5. Ranking strictly by most available volume would be Option 2 and 3,1,4.

Schedule Impact on RIC

Schedule impact is almost identical for any option. At this writing there is great possibility of an Air Force-directed schedule slip, so RIC would be able to meet it regardless of the option selected.

Options 1 and 3 have had layout work done already on M_1. Since no such work had been done on any M_5 configuration, Option 1 would be easiest for RIC to move rapidly toward production, followed by 3, and finally, 2 and 4. Options 2, 3 and 4 require more work, and therefore more design cost, but it is doubtful that effect on the schedule would be different among the options.

Operational Benefits

Options 2, 3 and 4 allow the operational commander more flexibility in the types of missions available for the numbers which have been postulated as procured. Option 1 would allow the following missions for the 2000 warhead example of the quantitative analysis:

0-500 DME
0-500 EO/DME
0-1500 EO

Options 2, 3 or 4 allow the following:

0-500 DME or } or some combination
0-1000 EO/DME }
0-1500 EO.

Flexibility evolves from the choice of use of the M_1's. Option 1 allows no choice in the matter, but the others allow 500 M_1's to be used either for DME or EO/DME. The decision by the Air Force not to buy the G_2 was apparently heavily influenced by Tactical Air Command's desire to have the flexibility described above (telephone conversation, 26 July 1974, between writer and Guided Bombs SPO).

Electrical Interference

Only Option 3 is different from the others in the technical problem of electromagnetic interference (EMI) between modules. Whenever wires are required for electrical connection between components, the possibility of EMI exists. This occurs only in Option 3 in the M_1 - M_5 interface. The magnitude of the problem, if there is one, is unknown at this time (September 1974).

Benefit Summary

The non-quantifiable benefits which are different among options are listed as the writer sees their order of significance (this order was ratified by Mr. McCormack of the Guided Bombs SPO), and then ranked among the options according to the discussions above. The same ranking means no difference between options. No attempt has been made to weight these rankings.

		Rank			
	Benefit	Option 1	Option 2	Option 3	Option 4
1.	Operational Flex.	2	1	1	1
2.	Vol. Growth Potential	2	1	1	3
3.	Manageability	1	2	2	3
4.	Maintainability	2	2	2	1
5.	Schedule Impact	1	3	2	3
6.	EMI	1	1	2	1

On the basis of this summary, the writer would have to rank order the options as follows for this qualitative benefit analysis:

3,2,1,4.

V. Conclusions and Recommendations

This chapter emphasizes the important points covered in Chapter IV and draws such conclusions as are appropriate from the analyses. This is all finally synthesized into the four recommendations of the final section.

Conclusions

After four months of living with this costing problem, the writer is convinced that LCC can be a valuable tool for Defense Department decision makers. Probably its most important service is to force analysts and decision makers to look at all facets of the system. The intricate relationships within the system are not always fully explained, but their existence is identified. After a full LCC study, the decision makers can be fairly sure that no unimportant consideration has been left undiscovered.

Conclusions following from the quantitative analysis are as follows:

1. Varying planned use of the weapons once they are in place at the base has minimal effect on the differential life cycle costs of any one alternative-- $\frac{1}{4}$-$\frac{1}{2}$ per cent. This is in the range of $100,000 for a 15-year life cycle of the weapon family.
2. Varying the number of warheads (and therefore DME guidance modules) required at a base changes the differential life cycle cost of any one alternative by less than .1 per cent.

3. Differential life cycle costs for any alternative are directly proportional to the number of units of that alternative procured.

4. Varying reliability to as low as 0.5 increases differential life cycle costs for any alternative by less than .24 per cent. This does not consider added sorties necessary to re-strike a target missed because of a malfunctioning GBU-15.

5. For the above contingencies, least-cost alternative ranking is 1,4,2,3. The difference shown by the LCC model between 1 and 3 is a maximum of 2.46 per cent at 6000 manufactured/year, 0 use, 300 at a base. This amounts to $5.4 million over the weapon life cycle.

6. Sensitivity and _a fortiori_ analyses as done showed no change in alternative ranking.

Qualitative benefit analyses led to the following conclusions:

1. Maintainability for Option 4 is slightly better than for the others.

2. For a DME-only mission, Option 1 is easiest for munitions maintenance personnel to manage at the base. Option 4, with its one additional sub-kit is slightly harder than Options 2 and 3 to manage.

3. Volume growth potential is ranked in the following order:
   Option 2 and 3, 1, 4.

4. Options 2, 3 and 4 equally provide more flexibility than Option 1 to the operational commander in terms of the type of missions he can choose.

5. There will be small schedule impact on RIC regardless of the option chosen, but design costs will increase slightly for Options 2, 3 and 4.

6. Electro-magnetic interference between modules may be a technical problem for Option 3.

7. Overall ranking for the benefit analysis is 3, 2, 1, 4.

Recommendations

Option 3 is recommended as the best DME guidance procurement for the GBU-15 Weapon System. The recommendation is based on the belief that operational flexibility and growth potential are the most important qualitative benefits, and the fact that differential life cycle costs between the best and worst alternative are only $5.4 million over a 15-year life cycle. The intuitive feeling that there is very little difference in life cycle costs, since there is very little component difference in the four alternatives, is confirmed. Therefore, qualitative benefits are overriding. Option 2 is a close second choice for the same reasons.

It is recommended that Life Cycle Costing procedures be made a part of future weapon acquisition programs at the Guided Bombs SPO. By making LCC data a requirement of contractor cost proposals, necessary data for life cycle analysis can be obtained much more easily than they were for this thesis. Documents such as DODI 7041.3, LCC-1, and LCC-2 (Ref 31, 27, 25) may be used as excellent source material for initiating LCC procedures in the SPO.

Application of the above recommendation would require an additional Guided Bombs SPO manpower authorization. It is therefore recommended that an Integrated Logistics Support (ILS) Office be created as a functional part of the SPO, and that it be manned as required. The personnel of this office should lend support and ILS expertise to all program managers in the Guided Bombs SPO.

It was suggested in Chapter II that the management approach at the Guided Bombs SPO may not have kept pace with the concept of modularity as applied to the GBU-15. This is an area worthy of additional study - possibly another thesis. It is recommended that such a management study be undertaken if the Guided Bombs SPO Director feels it would be helpful. References 22 and 74 are excellent places to start.

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Appendix A

Glossary

ADI	attitude/directional indicator
ADTC	Armament Development and Test Center
AF	Air Force
AFB	Air Force Base
AFIT	Air Force Institute of Technology
AFLC	Air Force Logistics Command
AFSC	Air Force Systems Command
AGE	aerospace ground equipment
AGM	air-to-ground missile
ALSS	Advanced Location and Strike System
ARS	Airborne Relay Station
ASD	Aeronautical Systems Division
ATE	automatic test equipment
AW&ST	*Aviation Week & Space Technology*
CEI	configuration end item
CI	contract item
DC	direct current
DCP	development concept paper
DL	data link
DME	distance measuring equipment
DOD	Department of Defense
DODI	Department of Defense Instruction

DV	directional/vertical
EO	electro-optical
EOGB	electro-optical guided bomb
EW	electronic warfare
FORTRAN	Formula Translator
FSN	Federal Stock Number
FY	fiscal year
GBU	guided bomb unit
GCS	ground control station
GFE	government furnished equipment
GIM	guidance interface module
GRBS	ground relay beacon station
HOBOS	homing bomb system
IBM	International Business Machines
IIR	imaging infrared
KMU	kit, modular unit
LCC	life cycle costing
MGGB	modular guided glide bombs
MMS	munitions maintenance squadron
NATO	North Atlantic Treaty Organization
PDR	preliminary design review
PLSS	Precision Location Strike System
PMD	program management directive
PMP	program management plan
POL	petroleum, oil, lubricants
PV	present value
QRC	quick reaction capability

R&D	research and development
RES	range extension system
RF	radio frequency
RIC	Rockwell International Corporation
RPV	remotely piloted vehicle
SAM	surface-to-air missile
SPO	System Program Office
SOW	Statement of Work
TAC	Tactical Air Command
TSS	time sharing system
USAF	United States Air Force
WGSS	weapon guidance sub-system
WSMR	White Sands Missile Range

Appendix B

Definitions

a fortiori - all the more certainly, with greater reason.

AGM-65 - Maverick, air-to-ground weapon.

alternative - one of a number of things offered for choice.

ALQ-99 - electronic jamming pod.

analysis - a detailed examination of anything complex by breaking up a whole into fundamental elements or component parts.

benefit - something that promotes good, well-being, advantage.

BLU-63 - submunition bomblets in the SUU-54.

cost element - a part of the cost that will be considered.

criterion - a standard on which a decision or judgment must be based.

cruciform - forming or arranged in a cross.

discount rate - the interest on an annual basis computed in advance for a stream of accrued expenditures/income.

effective - meeting operational requirements.

electro-optical - adjective descriptive of seeker heads which use the effects of an electric field upon light traversing it (TV).

EOGB II - electro-optical guided bomb II (improved)

FMU-110 - fuze suitable for the SUU-54

GBU-15 Weapon System - modular weapon family consisting of all the variations of the EOGB II and MGGB II modules.

hypothesis - a proposition tentatively assumed in order to draw out its logical or empirical consequences and so test its accord with facts that are known or may be determined.

KMU-353A/B - baseline weapons kit used by RIC for Contract 0046-P00001.

Linebacker - code name for bombing operations in North Vietnam - 1972-3.

Laser - light amplification by stimulated emission of radiation.

MGGB II - modular guided glide bomb (improved).

MK-84 - 2000 lb. unitary warhead.

model - a theoretical projection in detail of a possible system of relationships; pattern; structural design.

option - see "alternative."

SUU-54 - 2000 lb. cluster munition containing BLU-63's.

Appendix C

List of Personnel Interviewed

Name	Organization	Phone
Anderton, F.	AFSC/CCZ	Andrews AFB
Carnaghie, J.	ADTC/SDTE	882-4261
Davidson, A. L.	MSD/RIC	239-2412
Dittrich, W.	ADTC/DLMW	882-3233
Egbert, R. A.	MSD/RIC	239-2733
Eisiminger, R. E.	MSD/RIC	239-2856
Foster, R. M.	AFLC/MMG	257-6681
Gallagher, R. F.	MSD/RIC	239-3090
Gast, R. K.	MSD/RIC	239-2338
Halloran, R. P.	MSD/RIC	239-3273
Joyce, F. W.	MSD/RIC	239-2860
Karner, R. J.	ADTC/SDTE	882-4261
Lindsey, H. A.	ASD/RWEL	255-4352
Maltby, G. E.	IBM	687-2121 Ext. 3179
McClelland, W. J.	ADTC/SDT	882-4104
McCormack, J. J.	ADTC/SDTM	882-4104
McElrath, W.	Retired	-
Monts, D.	ASD/RWEL	255-4352
Rafter, M. J.	MSD/RIC	239-2587
Vrona, P., Jr.	MSD/RIC	239-2046
Weaver, P. R.	AFLC/MMOAA	257-2051

Vita

Francis C. Gideon, Jr. was born on 9 June 1944 in Washington, D. C. He graduated from high school in Fairborn, Ohio in 1962, and attended the United States Air Force Academy from which he received the degree of Bachelor of Science in Engineering Sciences and a commission in the USAF in 1966. He attended pilot training and received his wings in October 1967. For the next five years he flew F-100 fighters, first in South Vietnam and later at RAF Lakenheath, England. After retraining into the F-4, he spent a short time in Thailand in 1972 before completing a four-year tour in England. He attended the Air Force Institute of Technology where he received the degree of Master of Science in Systems Management in December 1974.

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This is a report of a cost-benefit analysis of four alternative guidance packages for a guided weapon system. Life Cycle Costing (LCC) is used to analyse those inputs which were quantifiable in terms of costs. An original computer program was devised to sum the life cycle costs and to handle the computations for sensitivity analysis. Those inputs not found to be quantifiable are discussed qualitatively, and the basis for their contribution to the final recommendation is explained. As expected, close similarity of the alternatives in most respects led to very little difference in life cycle costs, so the recommendations are heavily influenced by the qualitative considerations.

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