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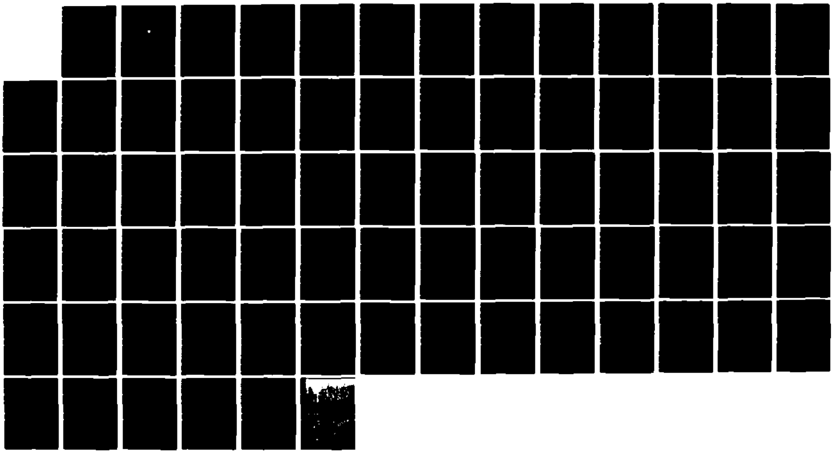

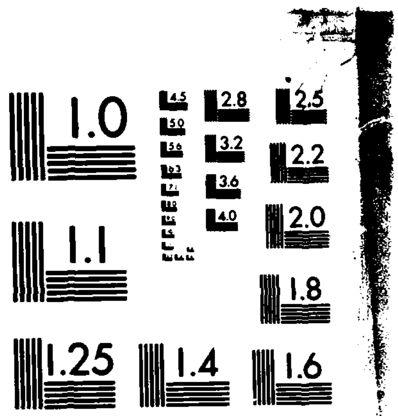
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AD-A133 342

NAVAL POSTGRADUATE SCHOOL

Monterey, California

THESIS

SELECTION OF AN OPTIMUM AIR DEFENSE WEAPON PACKAGE USING MAUM

by

Wilton L. Ham

June 1983

Thesis Advisor: R. G. Nickerson

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This thesis has developed a planning aid to be used by the airborne air defense commander in the development of his air defense force structure recommendation to the brigade commander. The planning aid presented is a version of multi-attribute utility measurement (MAUM) that provides the commander with a simple and understandable means of organizing multiple inputs in selecting equipment. By working through the steps of the model the commander will be required to rely heavily on use of his

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Selection of an Optimum Air Defense Weapon Package Using MAUM

by

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Captain, United States Army
B.S., University of Colorado, 1974

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN MANAGEMENT

from the

NAVAL POSTGRADUATE SCHOOL
June 1983

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ABSTRACT

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I. INTRODUCTION

Airborne brigades are designed to deploy rapidly and efficiently. As part of this fast moving organization, the air defense commander recommends an air defense force to counter the enemy air threat while meeting the constraints of time and aircraft space.

The selection and recommendation of the optimal package of air defense equipment is an important function of the army air defense commander. This thesis develops a technique to assist the battery air defense commander in quickly developing an effective air defense package.

A. DESCRIPTION OF THE SITUATION

Within the divisions of the U.S. Army there are several independent battalions that provide numerous combat support and service support functions (See Figure 1.1). One such special-purpose battalion is the air defense battalion. An air defense battalion has four line batteries and one headquarters battery. The four line batteries have the combat air defense assets necessary to provide the air defense coverage required to support the major commands of the division (See Figure 1.2). The major commands of the division are the three infantry brigades, the division support command (DISCOM), and the division artillery (DIVARTY). Normally, one line battery (A, B, or C) is allocated to each of the three infantry brigades. The fourth line battery (D) supports designated units within the division. The other independent battalions (signal, armor, engineers, aviation), normally referred to in the division as the "separate battalions", are organized in a similiar fashion.

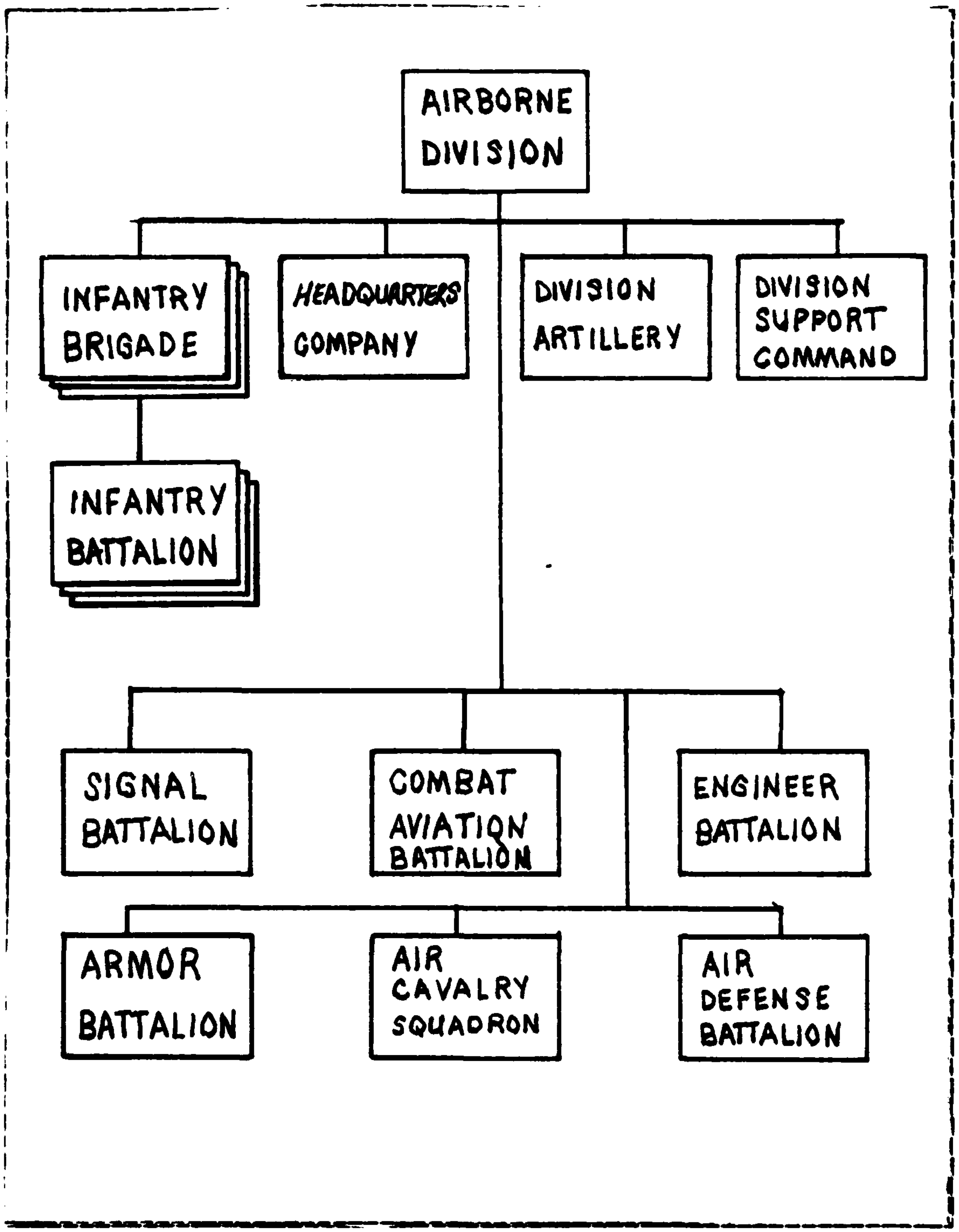
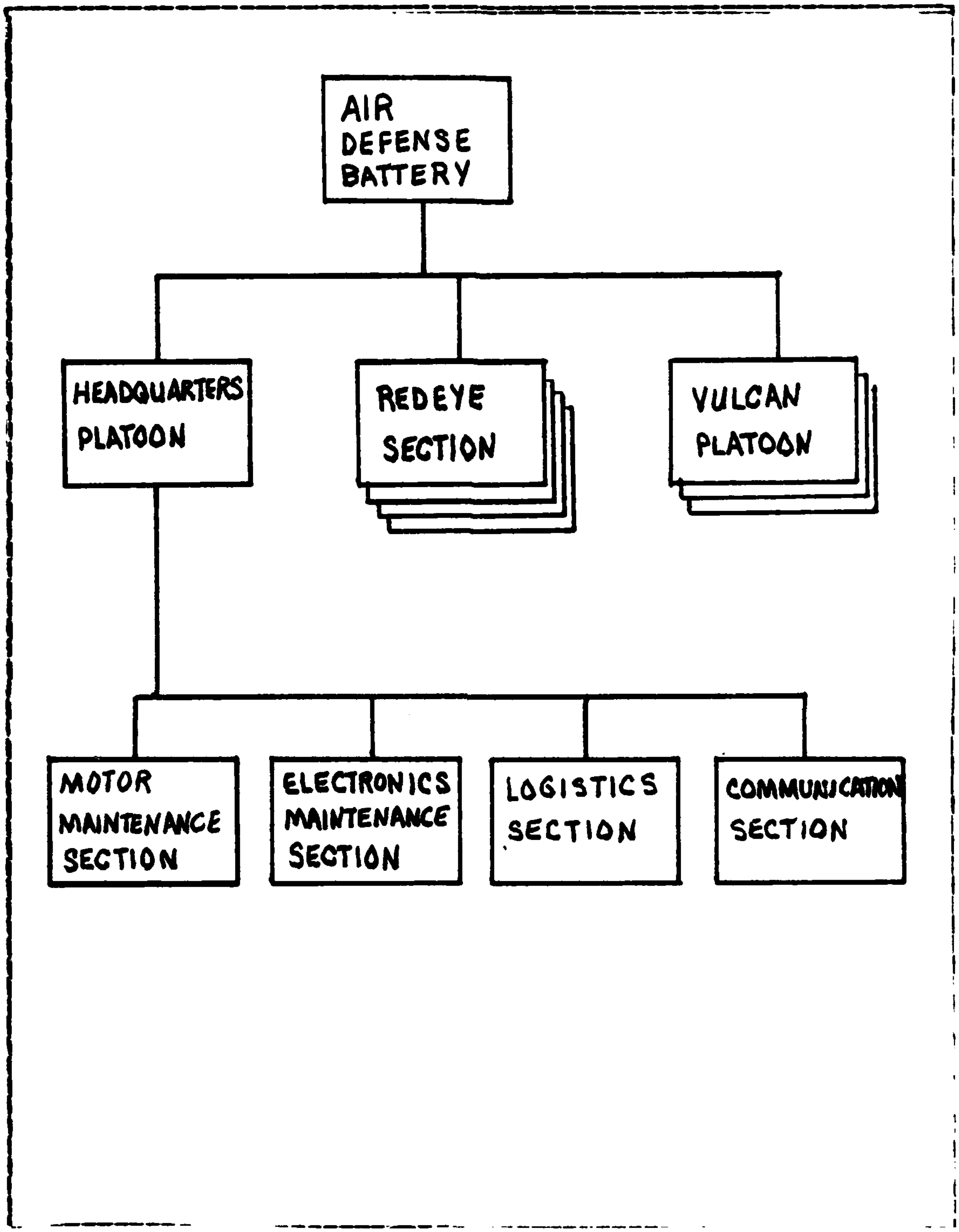


Figure 1.1 Airborne Division.



Fi. re 1.' Airborne Air Defense Battery.

The commander of a line battery is part of the brigade commander's special staff when his line battery is assigned to the brigade. The battery commander is responsible to the brigade commander for all air defense matters within the brigade area. This responsibility includes providing training and conducting educational classes for the officers and NCO's of the brigade concerning the air defense unit's capabilities, limitations, employment techniques, and requirements, as well as assisting the brigade operations officer with air defense plans for operations (training or actual).

The 82d Airborne Division, as part of the Rapid Deployment Force (RDF), is the Army's most combat ready division [Ref. 1]. This division constantly maintains a portion of its combat forces in a state of prepareness to meet the RDF contingency mission of deployment. This prepared force, called Division Ready Force (DRF), has the mission of being able to deploy its first elements within 18 hours of notification. In order to accomplish this task in an orderly manner, the DRF is broken down into three smaller units called Division Ready Battalions 1, 2, and 3 (DRB-1, DRB-2, DRB-3). These units are at different stages of preparedness for deployment. DRB-1 is the most prepared, and will be the portion of the DRF that will be airborne in 18 hours. Part of the deploying force can be made up of some of the elements from the separate battalions. Therefore these units, also identify and partially maintain part of their assets in a prepared state. In the case of the air defense battalion this means that one of the four line batteries has the tactical mission to support the DRF. This line battery has elements at various stages of preparedness with at least one Redeye section (seven M-151A2 jeeps, 14 personnel and 42 Redeye missiles), and one Vulcan platoon (4 Vulcan guns, 18 personnel) prepared for immediate

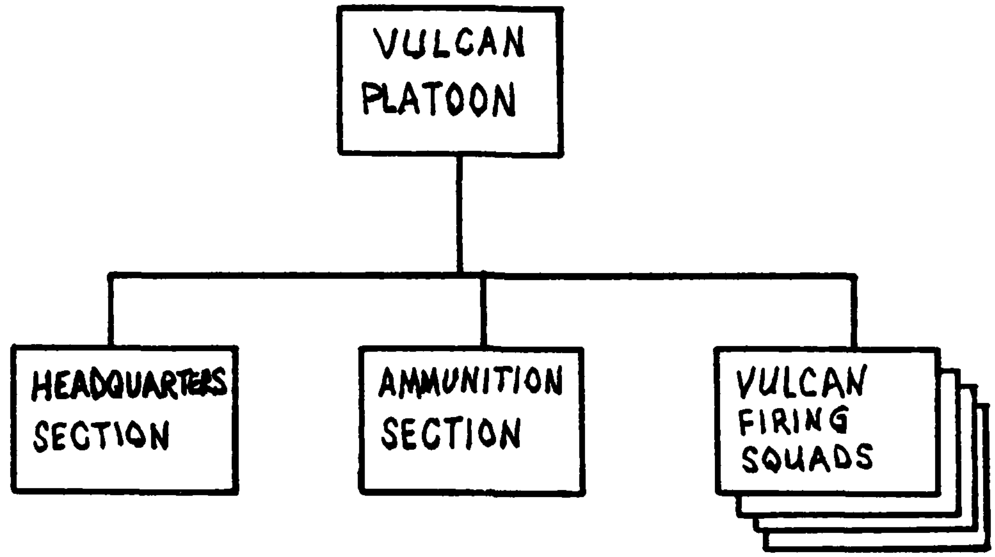


Figure 1.3 Vulcan Platoon.

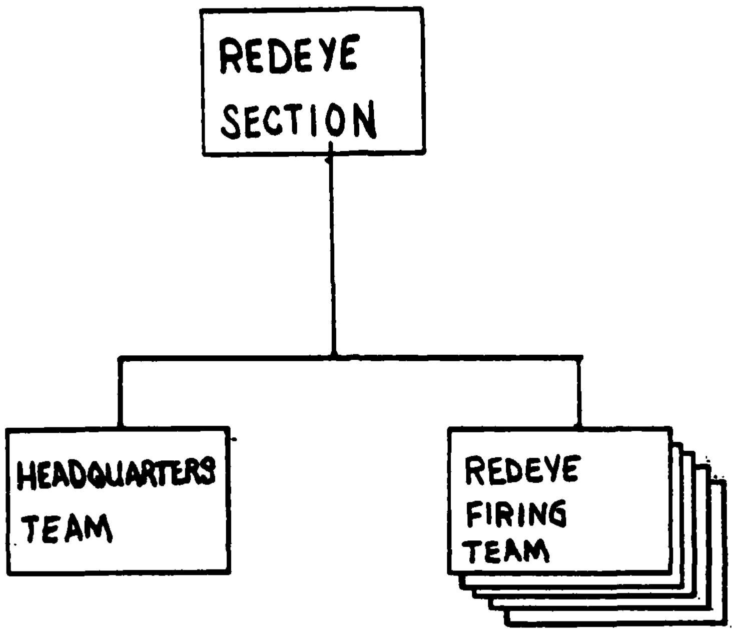


Figure 1.4 Redeye Section.

rigging operations (See Figures 1.3 and 1.4). "Immediate rigging operations" simply means that all a battery has to do is place the designated equipment on heavy-drop platforms, strap the equipment to the platforms, attach parachutes, and load the "rigged equipment" on the planes for deployment. Later in this section is a description of the 18 hour sequence the deploying force goes through in making final preparation for movement.

In the early stages of the 18 hour sequence, the DRF commander needs to identify what combat assets will be needed from the separate battalions to support his deployment mission. This decision will be based largely on his concept of the operation (tactical ground plan), his experience and knowledge of the separate units' combat assets, the number of aircraft available for movement, and the salesmanship of the separate units' commanders.

In this situation the brigade commander is similiar to the housewife in a grocery store with her limited budget. The separate battalions' combat assets are items on the shelf with various prices and functional values, and the number of cargo airplanes available for movement is the brigade commander's constraining budget. He can buy anything that will fit on his airplanes, and no more. But, he does not want to buy just anything. He wants to maximize his combat power with his limited resources. He wants to purchase the assets that will best support his operation plan, and give him the greatest chance of obtaining success.

The question is, what combat assets best support his operation plan? This is where the air defense battery commander, along with all the other separate company/troop/battery commanders, comes into play. Based on the brigade commander's operation plan (ground tactical plan) and, in the case of air defense, his priority list for air defense coverage, the air defense battery commander makes his recommendations for the type and number of assets to be included in the total force structure. It should be recognized that each subordinate commander's recommendation of how best to optimize the brigade force structure will be presented from a biased point of view. It should be expected that each subordinate commander would feel that his combat weapons would contribute more to optimizing the brigade force structure than the combat weapons of the other independent battalions. This recommendation is somewhat like a commerical in a magazine or on television:

1. The air defense commander is competing with the subordinate commanders of the other independent battalions for the brigade commander's limited cargo space. Each commander has a desired force he would like to take, but recognizes the fact that the brigade commander has a constraining factor; thus, the commanders need to make the brigade commander aware of the versatility of their weapons.
2. The battery commander's recommendation also presents the brigade commander with relevant information concerning the special needs of air defense design with the intention of making the brigade commander a "smarter consumer". The objective is to give the brigade commander the facts necessary to make his trade-off decisions concerning combat weapons.

The battery commander's professional skill as a soldier, his technical knowledge of his air defense equipment, and his understanding of the deployment situation are the marketing tools that insure his success. How well organized his thought process is in developing his recommendation could make the difference between taking a good air defense package or taking an air defense package that will fit on the aircrafts that are left over.

B. THESIS PURPOSE

The purpose of this thesis is to develop an evaluation framework or decision-making technique to serve the air defense commander in developing his force structure recommendation; a technique that when implemented will offer the user flexibility, speed, and organization. The thesis does not directly address the major topics of air threat assessment, equipment performance, weapon system reliability and other system characteristics, or how to evaluate the force's measure of effectiveness as the result of the battery commander's recommendation. These are beyond the scope of this thesis. Rather, the thesis concentrates on how to organize multiple and sometimes unrelated inputs to develop a rational recommendation that will provide optimium results for the airborne brigade. Only the air defense weapons assigned to the airborne air defense battery will be considered in this thesis. These weapons are the towed Vulcan gun, and the Redeye missile.

C. ORGANIZATION OF THE THESIS

This thesis consists of five chapters. Chapter II introduces the reader to the terminology and doctrine of the airborne division and the air defense battery.

Chapter III provides the reader with a familiarization of the principles of multi-attribute utility measurement (MAUM). It also introduces the reader to a version of MAUM found to be compatible with the objectives of the air defense model.

Chapter IV explains the format of the air defense model, and Chapter V contains the conclusions and recommendation of the thesis.

II. PRELIMINARY INFORMATION

A. INTRODUCTION

This chapter is included to give the reader a basic understanding of air defense and airborne topics as seen by current U. S. Army tactical doctrine. The intent is to familiarize the reader with the terminology and some of the operational meanings of the expressions. The majority of this data was extracted from Army Field Manual (FM) 44-1, U. S. Army Air Defense Artillery Employment, dated 26 February 1979. Additional guidance was obtained from FM 44-3, U. S. Army Air Defense Artillery Employment Chaparral/Vulcan, dated 30 September 1977.

B. INTRODUCTION TO AIRBORNE OPERATIONS

The mission of the United States Army is to win a land battle. To do this, the Army is organized into divisions. A division is further organized into three brigades, and a brigade is a grouping of three maneuver battalions.

The brigade conducts two general types of operations. The first broad type is offensive operations.

> The primary purpose of offensive operations is to destroy the integrity of the enemy's defense by breaking through his defensive system and driving rapidly into rear areas to destroy artillery, air defense, command posts, logistical support, and command control systems. [Ref. 2]

The second broad type of operations is called defensive operations.

> The purpose of defensive operations is to cause enough casualties and destroy enough vehicles to convince the enemy that his attack is too costly and should therefore

be discontinued. From time to time, defensive operations are conducted to gain time when concentrating forces elsewhere on the battlefield; to prepare forces, facilities, and installations; or to control essential terrain. [Ref. 2]

The airborne brigade, like a conventional infantry brigade, conducts both type of operations, but the preparation phase for the airborne unit is a little different. The major difference is time allowed for planning and execution. The airborne brigade achieves its greatest tactical advantage by surprise entry into or near the battlefield. Surprise means short notice, limited number of individuals involved with planning, and rapid movement.

Planning for operations is conducted in great detail. Four plans are developed for the execution of an airborne operation: (1) the ground tactical plan, (2) the landing plan, (3) the air movement plan, and (4) the marshalling plan. The plans are developed in reverse order of execution.

The first plan, the ground tactical plan, includes the mission of the force, the sector of operation, location of the force security element, task organization, fire support (artillery), and combat service support. The ground tactical plan is developed from an analysis of the mission, enemy, terrain, weather, force strength, and duration of the operation. The ground tactical plan serves as a basis for the other three plans, and as the brigade commander's guidance to all subordinate commanders.

The landing plan contains the sequence and method of delivery into the area of operations. The landing plan also includes how units will assemble, and the assembly aids to be used by specific units. The landing plan is a used in developing the marshaling and air movement plans.

The three methods of delivery are airland, low-altitude parachute extraction system (LAPES), and parachute drop (heavy drop). In the airland method, the aircraft lands, the equipment drives off while the aircraft engines are running, and then the aircraft takes off. The airland method insures minimum damage to equipment; delivers vehicles ready for immediate drive-away; delivers crews with their weapons and vehicles; and provides for the return of casualties, prisoners of war, and damaged equipment.

With low-altitude parachute extraction system (LAPES) the aircraft slows down, flies five to ten meters off the ground, and drops a parachute out the rear of the airplane. The parachute inflates and pulls the equipment out. The parachute offers no air support to the load; it is just a means of extracting the equipment from the plane. LAPES requires less preparation time, fewer personnel, and less equipment support than heavy drop. LAPES is a pinpoint delivery system for combat equipment (e.g. Sheridan tank); however equipment is more susceptible to damage with LAPES than with airland.

The third method is parachute drop. This method requires more preparation time, more personnel, and more support equipment than does LAPES. Loads are strapped to a metal platform referred to as a heavy drop platform. The platform is adjustable in length and is usually just long enough to cover the base of the load. Then two or three cargo parachutes are attached to the load. The number of parachutes depends on the weight of cargo. While airplane flies at a reduced speed (130 knots), and at an altitude of 800 feet above ground level (AGL), the parachute pulls the equipment out the rear and supports the load to the ground. Equipment is even more susceptible to damage with heavy drop than with LAPES, and this delivery method is not as accurate as the above two. Variables such as wind speed and pilot error play a major role in the accuracy of this method.

The air movement plan specifies aircraft loads. It includes a schedule for loading of aircraft, and the routes to be used in moving the prepared equipment and personnel from rigging areas to the planes.

The marshaling plan provides the details necessary to assemble personnel, equipment, and supplies to be employed in the deployment mission. It provides a schedule for the completion of major events in preparation phase such as preparation of equipment, rigging of equipment, movement of loads, and pre-flight inspections of loads.

C. AIR DEFENSE DOCTRINE

Army air defense doctrine consists of the principles of operations, organization, and tactics required to fight an air battle. These principles provide for the employment of a mix of complementary weapon systems to counter the various air threats used by the enemy. The U. S. Army weapons for air defense are divided into two categories:

1. Low altitude, short-range air defense (SHORAD). This category of air defense weapon systems includes the Vulcan gun, Chaparral missile, and the man-portable air defense system Redeye missile.
2. High and medium altitude air defense (HIMAD). Within this category of air defense assets are the Nike-Hercules missile and the Improved Hawk.

These categories are based on the altitudes at which most aerial engagements by the weapon system would normally take place. Most SHORAD engagements will take place below 5000 feet above ground level (AGL), and at ranges less than 5km. With the HIMAD systems, the engagements are normally above 5000 feet AGL, and at ranges to 140 km. HIMAD systems have the capability of engaging targets at lower altitudes and shorter ranges, but their mission is to engage the hostile force at maximum distances. This allows for follow-on shots if necessary.

SHORAD systems are normally employed in support of maneuver elements to defend their critical assets against attack by close support aircraft and helicopters. SHORAD systems must be capable of moving with the force they support. (A battalion-size element is normally referred to as a maneuver element).

HIMAD systems are deployed with a division-size or larger unit. Longer range air defense missile systems provide area coverage; these systems have more equipment than SHORAD systems, and therefore require more time to move and set up. These systems are not designed to be delivered by heavy drop or LAPES from airplanes.

In most army divisions, these air defense systems would be integrated with friendly fighter aircraft into an overall air defense design. The fighter aircraft would strike the enemy aircraft well forward of the friendly force (a distance of approximately 10-15 km) to effect maximum attrition, and to break up concentrated attack formations. This tactic removes some of the organization and smoothness of the enemy's attack techniques, and adds to his uncertainty (e.g., more concern for his fuel reserve or possible damage to his plane). This also presents to the enemy a continual air defense threat throughout the friendly's engagement zone.

D. COMMAND AND CONTROL

Normally the senior air force officer in the area is the overall air defense commander. His title will vary depending on the size of the organization he is charge of, but he usually will be called the region air defense commander, or the area air defense commander in an unified or joint command. Within the division, the senior air defense commander is the battalion commander of the air defense battalion. The battalion commander coordinates his activities with the area air defense commander.

Engagements of air defense weapons are controlled by the area air defense commander through the establishment of air defense rules and procedures. The authority to order an air defense engagement is retained at the highest unit able to effectively control the air battle. For Hercules and Hawk, this is usually battalion level, for Vulcan it is normally the battery level, and for a Redeye team it could be the enlisted team leader in charge of the team.

The rules and procedures include the following:

1. Rules of Engagement. These are directives from the area air defense commander that are included in all tactical standard operating procedures (TSOP) of each unit having an air defense mission or air defense capability. Briefly, they outline general hostile criteria, and airspace/geographical control directives. They also state in clear, direct language that the right of self-defense is always preserved.
2. Hostile Criteria. This is the means the air defense units use to designate a target as friendly or hostile . This can be electronic devices, such as IFF, or visual techniques. Visual criteria can be positive identification of the aircraft. Other visual criteria that classify an aircraft as hostile could be aircraft attacking friendly troops, or aircraft dropping unauthorized substances.
3. Weapons Control. Based on the air situation, the area air defense commander can impose varying degrees of control on air defense systems. Lower commanders may impose a more restrictive control on organic equipment, but must request the area air defense

commander to change to a less restrictive weapon control. Commonly used terms are "weapons free": weapons may fire at any aircraft not postiviely identified as friendly; "weapons tight": fire only at aircraft positively identified as hostile; and "weapons hold": do not fire except in self defense.

4. Firing Commands. These are commands issued regardless of the weapons control in effect. There are three commonly used terms. The first of the three is "hold fire": this command is used to protect specific friendly aircraft. The second is "cease fire". Cease fire is the command used to prevent simultaneous engagements of a target. The third command is "cease engagement". Cease engagement is the command used to prepare the firing unit to engage a higher priority target. If rounds are not already in flight, the engagement sequence is stopped and the firing unit prepares to engage the new target. If rounds or missile are already launched, the firing unit continues with its present engagement until the rounds or missile intercept the target; then it prepares to engage the new target.

E. AIR DEFENSE MISSION

In general terms, the air defense objective is to limit the effectiveness of enemy offensive air efforts. Air defenses are those actions required to nullify or reduce an enemy's capability to use airspace to attack friendly forces. The ultimate goal of air defense units is to protect friendly forces from an enemy aircraft or missile attack, to allow freedom of use of the airspace for friendly forces, and to allow freedom of movement of surface units/ ground troops.

F. AIR DEFENSE TACTICAL MISSIONS

Briefly, there are four tactical missions that can be assigned to an air defense commander. The first is general support (GS). An air defense commander that recieves a GS mission will provide air defense for the force as a whole. The commander supports the entire force, and is not committed to any specific element of the force. The air defense commander coordinates, develops, and implements his air defense design and is responsible for positioning his weapons systems.

The second tactical mission is that of general supporting-reinforcing (GSR). The air defense commander provides air defense for the force as a whole, and augments the coverage of another air defense unit. GSR units are not committed to any specific element of the force. Positioning of his units may have to be coordinated with the air defense unit he is augmenting.

The third tactical mission is reinforcing (R). The air defense commander's primary mission is to augment the coverage of another air defense unit. The reinforcing commander is the subordinate commander, and coordinates the deployment and positioning of his weapons with the reinforced commander. The reinforcing commander establishes liaison and communications with the reinforced unit.

The fourth tactical mission is direct support (DS). The air defense commander with a DS mission provides dedicated air defense for a designated maneuver unit within the force, and coordinates his movements with the element he supports. The air defense commander positions his weapons to properly support the operations of the supported element.

G. AIR DEFENSE PRIORITIES

There will always be more needs for air defense in an area of operation than there are air defense resources to protect them. On developing a list of priorities for air defense, the force (brigade) commander and the air defense commander should consider the following:

1. Vulnerability. How well can an asset survive an attack?
2. Criticality. How critical is the asset to the mission?
3. Recuperability. If the asset is attacked, how quickly can damage be repaired?
4. Enemy air threat. What is the enemy's capability to attack the asset?
5. Relocation. Can assets be regrouped to result in fewer separate assets?

H. TACTICAL PRINCIPLES

There are four fundamental principles of employment which form the basis for accomplishing the air defense objective. The first of these is weapon mass. Mass is the allocation of a sufficient amount of air defense resources to adequately defend the brigade commander's priority assets. In this situation, 'more is better'.

The second principle is weapon mix. Mix is the employment of air defense weapon systems with different characteristics and capabilities. An example of air defense mix for an airborne infantry brigade would be a defense that includes the Vulcan gun and the Redeye missile. The intent is for the Redeye to complement the weaknesses of the Vulcan, and the Vulcan to complement the weaknesses of the Redeye.

The third principle is mobility. Air defense units must be able to move, and move at the same speed as the maneuver element, if they are to provide the unit with continuous air defense coverage. Mobility also increases the air defense units' chances of survival.

The final principle is that of integration. This simply means that the air defense design must be integrated into the overall plan of the brigade to be effective. That is, all subordinate units of the brigade must be working in unison towards a common goal.

I. DESCRIPTION OF SHORAD WEAPONS

Rudolf Walter commented:

> ...low level flying is used increasingly by our own and enemy air forces. This trend to move strike operations to altitude ranges between 30 meters and 300 meters is clearly demonstrated by technical and operational concepts embodied in the F-111, Tornado, the SU-19, A-10, and the SU-25, as well as by the increasing importance of the helicopter on the battlefield. [Ref. 3]

As a result of this trend to lower altitude of attack aircraft, greater emphasis has been placed on low-altitude, short-range air defense systems. This thesis will focus only on low-altitude, short-range (SHORAD) weapons, and only those weapons organic to the airborne division. The first system is the Vulcan.

The Vulcan is a mobile air defense gun system used to counter the low-altitude air threat. It is effective against both high-performance aircraft and slower fixed-wing aircraft and helicopters at ranges out to 1200 meters. Vulcan can also provide effective ground fire against personnel, weapons, and thin-skinned vehicles to a range of about 2000 meters.

As pointed out by Lieutenant Colonel Frankoski:

> The antiaircraft (AA) gun has been proved one of the most valuable and flexible battlefield resources available to the ground commander. Ground commanders who have such weapons and trained units at their disposal

have the resources to substitute for or reinforce their field artillery, coast defense, and antitank forces. [Ref. 4]

The towed Vulcan gun system consists of an M-168 cannon mounted on an M-42 gun carriage. The prime mover is usually an M-561 Gamma Goat. Maximum speed while towing the Vulcan is 45 mph on improved roads.

The comparatively light weight of the towed Vulcan (3150 pounds) permits its use in support of airborne operations. Emplacement time for the towed Vulcan is about five to ten minutes. Reaction time, the time between acquisition of target and firing on target, is about ten seconds.

The Vulcan is a six-barrel 20 MM Gatling-type gun that has a low-firing rate of 1000 rounds per minute and a high-firing rate of 3000 rounds per minute. Using a firing rate switch, the Vulcan may be fired at the high rate in bursts of 10, 30, 60, and 100 rounds. Its onboard range-only radar (ROR) provides ranging information for the fire control system. The cannon can be transversed 360 degrees in azimuth and elevated between 0 degrees and 80 degrees. Although equipped with a night sight for ground fire support, the Vulcan is a fair-weather, daylight air defense system with a maximum effective range against aerial targets of about 1200 meters.

Vulcan normally uses air defense, incendiary tracer, self-destruct ammunition (HEIT-SD). Approximately 500 rounds of ready-to-fire ammunition are carried on the weapon. Reload time is less than three minutes. Another 3500 rounds, which completes the basic load of 4000 rounds, are carried on the prime mover.

Mutual support, the tactic of placing a weapon within the engagement capabilities of at least one adjacent system, is accomplished by positioning a Vulcan within 1000 meters of another Vulcan. As a result of this positioning requirement, Vulcans are normally deployed in pairs or in platoon strength units on or around the asset being defended.

Vulcan's major stength is its dual capability against air or surface targets. Major limitations of the Vulcan include its lack of armor protection, dependence on the M-561 for mobility, limited ammunition load, and limited range for aerial targets.

The other air defense weapon organic to the airborne division is the Redeye missile. Redeye is a man-portable, shoulder-fired, air defense, infrared-seeking, guided missile system that is normally deployed in teams of two individuals each. It has an effective range of about 3000 meters. Engagement ranges and effectiveness are dependent on such factors as the speed, size, aspect, and altitude of the target. Reaction time for this system is about ten seconds.

The team's prime mover is an M-151 jeep. The vehicle carries the team's basic load of six rounds, the team's combat communication equipment, and the team's two personnel.

The Redeye weapon is also a fair-weather, daylight air defense system. The weapon has no capability to engage ground targets, and contributes little to night perimeter security.

Mutual support for a Redeye team is accomplished by positioning a Redeye team within 2400 meters of another team. To insure early engagement of the target, Redeye teams are usually placed away from the critical asset. This positioning requirement provides the brigade area with more of an area air defense coverage. This same requirement also makes the team more vulnerable to enemy ground fire. The Redeye team normally operates one Redeye missile at a time. While the gunner is preparing the missile, the team leader is supervising the gunner and scanning the skies for targets. The team leader is also a qualified gunner; therefore, the team has the potential of launching two missiles simultaneously.

Redeye's major strengths are its light weight and easy deployment capability. Major limitations of Redeye include the "smoke signature" of the weapon when fired, the "tail-chase" nature of the weapon, and the limited possibilities for multiple firings at a given target. The smoke signature of the weapon is a smoke trail the weapon leaves as it moves from the launch area to the target. Other targets in the area can use this trail as a means of locating and directing suppressive fire on the Redeye team's position. The tail-chase nature of the weapon has to do with the weapon's infrared-seeking device. Most high performance aircrafts' engines emit their exhaust towards the rear of the plane. The Redeye weapon seeks the hottest area of this exhaust which normally is the rear edge of the engine. As a result the missile tends to fly along a curved path ending with the missile "chasing" the target from behind. This tail-chase nature of the Redeye has two possible weaknesses. The first is that for a target to be engaged by Redeye it must have already passed the Redeye's position and be moving into the asset area to deliver the aircraft's ordnance. The second possible weakness is the result of technological developments; some aircraft can simply outrun the Redeye missile.

The limited possibilities for multiple firings is the function of the number of members on the team (two), and the time required to place a Redeye missile into operation (ten seconds). Normally, the maximum number of firings per target will be two.

J. DESCRIPTION OF 18-HOUR SEQUENCE

The 18-hour sequence is a predetermined order of events that insures the deploying force conducts its preparation phrase in an effective and complete fashion. How well the personnel of the deploying force understands the sequence will determine partly how efficient the unit is in its deployment.

The material for this section was extracted from the Readiness Standard Operating Procedure (RSOP) of the 82d Airborne Division dated February 1981.

The 18-hour sequence starts by notifying the deploying unit of its mission. The time of notification is called N-hour. The standard operating procedure for the 18-hour sequence is:

<u>N-hour</u>

1. Unit recieves notification message of exercise.
2. Unit starts procedures necessary to notify all personnel of the unit to return to their place of duty. This is normally called "recall procedures".

<u>N+1:00</u>

1. Unit continues to assemble personnel.

<u>N+2:00</u>

1. Brigade commander briefs his subordinate commanders on the upcoming exercise (this is normally called a warning order or a tentative ground plan). At this point there are still many unanswered questions.

<u>N+2:30</u>

1. The rigging area is opened. At this time the exact equipment has not been designated for the exercise, but the personnel at the rigging site can start some preliminary preparation. These preparations could include assembling platforms, cutting materials necessary to secure equipment to the platforms, and drawing parachutes from storage warehouses.

<u>N+4:30</u>

1. Brigade commander briefs his selected ground tactical plan. At this point the brigade commander will have decided who is going, and what equipment is going.
2. Subordinate commanders issue instructions to their units.

N+5:00

1. The designated equipment begins to move to the rigging area where it will be prepared for airland, LAPES, or heavy drop.

N+8:00

1. Unit personnel draw parachutes. Personnel prepare their individual weapon and equipment for the upcoming jump. This includes taping loose straps, packing equipment, and rigging equipment so that it can be attached to the jumper for the jump.

N+10:00

1. First increment of the combat equipment (airland, LAPES, or heavy drop) is moved from the rigging area to the aircraft parking area. The prepared equipment is loaded as planes are made available by Air Force personnel.

N+16:30

1. All rigged combat equipment for the deploying force is loaded.
2. Unit personnel start the process of putting on their individual parachutes and rigged individual equipment.

N+17:30

1. All personnel are properly rigged with their parachutes and ready to be loaded.
2. Personnel are loaded on their designated airplanes.

N+18:00

1. First airplane is airborne followed at 30 seconds or prescribed intervals until the deploying force has all taken off.

As with all SOPs in the U. S. Army, these are guidelines to be used to increase the smoothness of the ongoing event. There may be occasions where the guidelines must be modified to accomodate the current mission. The division commander, in this situation, is the individual that will approve all changes to the SOP. Unless a change has been approved by the proper authority the SOP should be followed to the letter.

III. MULTI-ATTRIBUTE UTILITY MEASUREMENT (MAUM)

The purpose of this chapter is to expound on three areas. The first area will direct the reader to a few of the works that emphasize the advantages of having a judgmental model assist a decision maker in developing his plan of action. Many of the advantages or objectives of the judgmental models are desirable features for a model for selecting equipment for air defense purposes. The objectives that coincide will be covered in some detail in the text, and then explicitly restated at the end of the section.

The second area will provide a brief, informal explanation of multi-attribute utility measurement (MAUM) intended to familiarize the reader with the basic procedures. There are many versions of MAUM in use today. While all are based on the same basic ideas, the details of implementation vary from one to another. Due to the numerous variations a detailed explanation of each version of MAUM is not feasibile here.

In the third area, the version of MAUM selected for this thesis will be explained in more detail. The version selected for this thesis, Edwards' 10 Step MAUM called "SMART", is a 'quick and dirty' variant of the technique. As Gardiner and Edwards say, it,

> ...is oriented not toward mathematical sophistication or intimacy of relation between underlying formal structures and the practical procedures that implement them but rather toward easy communication and use in environments in which time is short and decision makers are busy. [Ref. 5]

Edwards and Newmann [Ref. 6], introduced SMART in 1980. This version of SMART is a modification of earlier techniques introduced by Edwards in 1971 and 1979.

Edwards' approach was selected for the following reasons: (1) it has the great advantage of being easily taught to and used by a busy decision maker; (2) its framework applies to most MAUM procedures; (3) it meets the six characteristics Little [Ref. 7], states are necessary for a model to be useful to management. According to Little a model should be simple and easy to understand; a model should be easy to communicate with; a model should be robust (an user should find it hard to make the model give bad answers); a model should be easy to control (behave the way the user wants it to); a model should be adaptive (easy to update); a model should be complete on important issues (optimal level of detail). According to Little,

> ...an important aid to completeness is the incorporation of subjective judgment. [Ref. 7].

But why does an air defense commander (especially a battery commander) need a model? This point will be examined first.

A. OBJECTIVES OF THE AIR DEFENSE MODEL

The purpose of this section is to discuss those objectives of modelling that are to be included as objectives of the air defense model. These objectives are:

1. To develop a planning model for organizing thoughts; a framework that, once completed, will assist the air defense commander in communicating his recommendations to his superior.
2. To develop a model that emphasize the role of judgment.

3. To develop a model that can be adapted to various situations.

4. To develop a model that is simple and understandable.

This thesis is developed on the premise that a model which includes the interaction of the individual's judgment as part of the model system will produce results which are superior to the situations where (1) the individual relies solely on his intuition (based on military judgment or experience), or (2) the individual relies on statistics as a means of predicting, or (3) the individual relies on the processes of a model alone. As Holt concluded:

> ...a search of the literature fails to reveal any studies in which clinical judgment alone has been shown to be superior to statistical prediction when both are based on the same codable input variables. [Ref. 8].

The subject of intuition alone versus model-plus-judgment has received much emphasis in recent years. This section will review some of the arguments. The intent is not to cover or summarize the entire works of the many authors on either side. An interested reader who desires the benefits of an elaborate discussion is encouraged to start with Paul Meehl's book [Ref. 9], or Dawes' article [Ref. 10]. These references will direct the interested reader to numerous other articles and books written on the subject.

In his study of organization, Edelman [Ref. 11] provides an interesting comparison of the quality of managerial decisions in a competitive bidding situation, with and without the use of a judgment-based model. In seven tests, managers-plus-model won the bid, while managers alone won only three. The model used was extremely simple and did little more than assist the managers' own estimating procedures. It provided organization to a time constrained and unstructured process. It was assumed by Edelman that in situations where time management was critical, managers without the model tended to overlook some important aspects of bidding, whereas those with the model had an established procedure to follow. This established procedure assisted in preventing accidental oversights, and in the long run provided the decision maker with better estimates. This is one of the objectives to be included in the air defense model: to develop a planning tool for organizing thoughts. This model will assist the battery commander in organizing his estimates (to make the most use of his time). By working through the steps, the air defense model will serve as a checklist, a memory aid to insure he will not overlook an important planning element in his severe time limitation. The air defense model will also be a support document which the commander will use as a reference in presenting his ideas in an orderly fashion.

Another study, done by Little [Ref. 7] in 1975, resulted in the design of the Brandaid system. The Brandaid system is an interactive Decision Support System (DSS) that supports the decision process in commercial marketing, planning, and estimating overall profitability. The main feature of the Brandaid system is its emphasis on the role of judgment in the decision process. Little found that managers generally have a good understanding of the dynamics of the market, or at least of the interrelationship among its components, taken in pairs. But they are not capable of determining the full interactions of different components simultaneously. According to Little, by forcing a quantitative technique, Brandaid encourages managers to become more explicit and analytic in their problem solving, but it still strongly relies upon their experiences, knowledge base, and personalized judgment. This highlights another objective to be included in the air defense model: to develop a tool for analysis that emphasizes the role of judgment in decision making. The air defense model will encourage commanders (by working through the steps of the model) to become more analytic in their problem-solving abilities. It is a model that will rely heavily upon the air defense commanders experencies, judgment base, and military intuition for the final decisions.

The air defense model assumes that the air defense commander will have a good understanding of the principles of air defense, but he may require some assistance in comprehending the many interrelationships among them. By working through the steps of the model, the commander will be forced to analyze the interdependencies of the principles, to exercise his judgment base as to what principles are or are not important, and to place a value on the principles in the current situation.

The air defense model will also allow the commander flexibility in the choice of input parameters. This is necessary to insure that the model will be adaptable so as to handle all the various world-wide scenarios. Dawes concluded that, although models in general are better at integrating information,

> ...the model cannot replace the expert in deciding such things as "what to look for." People are important. The model may integrate the information in an optimal manner, but it is always the individual who chooses variables. Moreover, it is the human judge who knows the directional relationship between the prediction variables (attributes), or who can code the variables in such a way that they have clear directional relationships. [Ref. 10].

Dawes also concluded that:

> ...models work for a very simple reason. People are good at picking out the right predictor variables and at coding them in such a way that they have a conditionally monotone relationship with the criterion. People are bad at integrating information from diverse and incomparable sources. Models are good at such integration. [Ref. 10].

The final objective of the air defense model is summarized very precisely by Johnson

> ...a decision model needs to be uncomplicated and easy to understand-simple. [Ref. 12].

Edwards puts a great amount of emphasis on the simplicity of his technique [Ref. 13]. While this method may lack the theoretical elegance of techniques proposed by Raiffa [Ref. 14] or Keeney [Ref. 15], it has the great advantage of being easily learned and used by a busy battery commander.

Bartholomew concludes that:

> ...indeed a simple model is often more effective in the sense its results may be more likely to be heeded simply because management find it easier to understand and therefore more acceptable. [Ref. 16]

Keen [Ref. 17] describes a desired managerial decision model as being:

> ...very simple and crude, rather than mathematically sophisticated. It is often based on heuristic rules and standard procedures for analysis.

Summarizing the above comments: a model should provide a format for organizing ideas; a model should allow for the maximum use of judgment; a model should encourage a more analytic analysis; a model should be flexible; and a model should be simple to understand. The results of a judgmental model are more likely to be used and understood by management, and to be more reliable than intuition.

B. THE BASICS OF MAUM

As Peter C. Gardiner said:

> The essence of multiattribute-utility measurement, in any of its versions, is that each outcome to be evaluated is located on each dimension of value by a procedure that may consist of experimentation, naturalistic observation, judgment, or some combination of these. The location measures are combined by means of an aggregation rule, most often simply a weighted average. The weights in the weighted average are numbers describing the importance of each dimension of value relative to the others, such numbers are judgmentally obtained. [Ref. 18].

Put a little differently, each alternative (referred to as outcome in the above) may have value on a number of different attributes (referred to as dimensions in the above). The MAUM technique, in any version, is to discover those values, one attribute at a time, and then to aggregate them using a suitable rule and weighting procedure. Probably the simplest and the most widely used aggregation rule and weighting procedure consists of simply taking a weighted linear average; this is the only procedure that will be discussed in this thesis. (Readers are encouraged to read Edwards [Ref. 19] for a broader coverage of the subject). According to Edwards

> ...theory, simulation computations, and experience all suggest that weighted linear average yield extremely close approximations to very much more complicated nonlinear and interactive functions, while remaining far easier to elicit and understand. [Ref. 20].

So, what are the basics? Simply stated they are:

1. Identify the decision maker.
2. Identify the purpose of the decision.
3. Identify the alternatives for the problem.

4. Identify the attributes of interest for the particular problem. Edwards' [Ref. 20] rule of thumb is that eight attributes is plenty and fifteen attributes is too many.
5. Rank the attributes from most important to least important.
6. Rate the attributes in importance.
7. Measure or estimate the alternatives of interest one attribute at a time.
8. Sum the measures assigned to each alternative.
9. Decide.

C. SIMPLE MULTIATTRIBUTE RATING TECHNIQUE (SMART)

This version of Edwards' MAUM was extracted from Gardiner's article [Ref. 5]. This implementation emphasizes simplicity.

Step1. Identify the persons whose utilities are to be maximized-the stakeholders. A stakeholder is simply an individual with a reason to care about the decision, and with enought impact on the decision maker so that the reason should be taken seriously. The basic question here is "Whose Utility?" In the air defense problem, the brigade commander is the only stakeholder considered. The air defense battery commander, the decision maker, develops a recommendation in expectation of optimizing the brigade commander's combat capability.

Step 2. Identify the reason for the decision. For what purpose is the evaluation being made? What is the reason for assessing the decision maker's preferences? For the air defense problem, the reason the decision is being made is to optimize the brigade's combat force and thus increase brigade's likelihood of success with its mission.

Step 3. Identify the alternatives to be evaluated. In the air defense model to be discussed in Chapter IV, there will be no more than three alternatives. These alternatives could include all Vulcans, all Redeyes, or a combination of the two weapon systems. The actual quantities for each weapon alternative will be stated at the start (e.g. six Vulcans versus six Redeyes versus three Vulcans and three Redeyes). This way the result of the aggregrated rule will represent a measure of effectiveness (MOE) for each alternative. The commander will then have a means for comparing the alternatives.

Step 4. Identify the relevant dimensions or attributes. What attributes are important to the evaluation of the alternatives for this particular scenerio? As was mentioned in the last section, the number of attributes should be kept to a minimum (eight was recommended). It is important not to be too expansive at this stage. The number of attributes should be kept down for reasons that will be apparent shortly. This can often be done by restating and combining attributes. It can be done also by simply omitting the less important ones. The intent is not to evolve a complete list. The attributes for the air defense model will be considered in Chapter IV.

Step 5. Rank the attributes in order of importance. In the air defense model, for example, a commander working in a heavily wooded area might consider the effects of terrain and vegetation more important on his air defense design than, maybe, logistics or vulnerability of weapons.

Step 6. Rate attributes in importance, preserving ratios. To do this, start by assigning the least-important attribute an importance of 10. Now consider the next-least-important attribute. How much more important (if at all, the model allows for ties) is it than the least-important? Assign this attribute a number that reflects that ratio. Continue on up the list, checking each set of implied ratios as each new judgment is made. Thus, if an attribute is assigned a weight of 10 while another is assigned a weight of 80, it means that the 80 attribute is eight times as important as the 10 attribute, and so on. By the time the last attribute is reached, there will be many checks to perform to insure that the implied ratios reflect what the decison maker intended. Typically, decision makers will want to revise previous judgments to make them consistent with present ones. This step in the air defense model is where the model forces the air defense commander to conduct an informal analysis. Each attribute, (eg., terrain) its importance to the scenario, its importance to overall mission accomplishment, and its importance relative to the other attributes needs to be considered. Here is where the commander's experience and judgment come into play.

Step 7. Sum the importance weights, divide each by the sum, and multiply by 100. This gives each attribute an importance rating between 0 and 100 such that the sum of the ratings equals 100. This step is purely computational. The choice of a 0-to-100 scale is arbitrary. At this step the folly of including too many attributes in Step 4 becomes very obvious. If 100 points are to be distributed over a set of attributes, and some attributes are more important than others, then the less important attributes will have significant weights only if there are a limited number of them. Again Edwards' rule of thumb is that eight attributes are plenty and fifteen attributes are too many.

Step 8. Measure the location of each alternative being evaluated on each dimension (attribute). This measuring of the location of an alternative for each attribute is commonly referred to in the literature as developing an utility function. The discussion of utility theory (or development of utility function) will not be covered in this thesis. An interested reader could start his study by reading Keeney and Raiffa. [Ref. 21]

The technique of utility theory used in SMART is called direct assessment of utilities by Keeney and Raiffa [Ref. 21]. It is called direct assessment since it requires a subjective input from the decision maker for each measurement. It assumes, with the completion of Step 4, that the decision maker realizes the reason for assessing his preferences (or developing the numeric measure given for each alternative) and is sufficiently motivated to think hard about his feelings for the various alternatives. It must be understood there are no objectively correct preferences, the measurements represent the subjective feelings of the decision maker. If, at any time, the decision maker feels uncomfortable with any of the measurements, it is perfectly correct for him to adjust them. It is also assumed that each of the alternatives can be adequately described in terms of each of the attributes. The measurement scale recommended by Edwards [Ref. 20] is a straight line procedure. The decision maker associates with each alternative a real number on the scale of 0-to-10 that indicates his subjective appraisal (or estimate) of the position on that attribute. The orientation of the scale is crucial to the decision maker: Are higher numbers more or less desirable? In the air defense problem higher numbers are more desirable than lower numbers (that is, more is better than less throughout the range of the attribute).

Edwards' recommendations also include limiting the measurement region to a small and reasonable area. This limitation was done for convenience more than anything else, but Keeney and Raiffa [Ref. 21] point out that this range needs to be meaningful to the decision maker. They recommend along with bounding the region that the decision maker set the utility for two of the alternatives and evaluate the other alternatives in terms of the first two. For example, "X" alternative is more preferred than all the other alternatives, so "X" is given a ten. "Y" alternative is the least preferred alternative and is given zero. The remaining alternatives are then assessed (or measured) relative to those two. The advantage of this option (referred to later as the two fixed end option) is that the user needs to spend little time deciding on what utility (or measurement) to give to each alternative for each attribute. For a given attribute, the decision maker informally ranks the alternatives from best to worst. The best is measured ten, the worst is measured zero, and the middle alternative or alternatives are measured relative to the two established end points. This option gives the user swift and prompt measurements.

The disadvantage with this option is the rigidity of the measurement procedure. The decision maker gains speed, but forfeits the flexibility of developing measurements commensurate with alternative's relative worth. That is, he loses the ability to consider the explicit tradeoffs between alternatives. Various options exist which allow the decision maker to trade speed for time. One such option is to fix one end point of the measurement region, the upper end point (in Chapter IV this is called the single fixed option). The best altenative is measured ten, and the remaining alternatives are measured relative to the best. The lower end point, zero utility, is assigned to an imaginery or theoretical alternative that contributes (practically) nothing to this attribute; it may be that all the actual alternatives have scores greater than zero. The advantage here is flexibility in developing measurements commensurate to the alternative's relative worth. The decision maker gains the opportunity to consider the tradeoffs between alternatives in making his measurements decisions. This option is slower to use than the two fixed end point option, but the disadvantage of the rigidity of the measurement procedure is also less.

Another option is to assign neither end point to any of the actual alternatives. The decision maker must now imagine a (practically) worthless alternative and assign it a score of zero, as above, and he must also imagine a (practically) perfect alternative and assign it a score of ten. Then all actual alternatives will be measured relative to these two imaginery alternatives and scored accordingly. This option requires the decision maker to spend more time developing his measurements in thinking about what constitutes a ten or zero alternative. This means (1) the time required to develop the measurements for the alternatives under consideration increases, but (2) the ability to consider explicit tradeoffs among alternatives also increases.

As an example, assume for a given attribute that the three alternatives to be measured are ranked best to worst as "X", "Y", and "Z". "X" alternative is the best, and suppose "Y" is rated 80% as good as "X", and "Z" is rated 50% as good as "X". Using the two fixed end procedure, "X" would measure ten, "Z" would measure zero, and "Y" would be measured relative to "X" and "Z", say six. The value given to "Z", zero, indicates that "Z" contributes nothing to the attribute being considered. This may not be a good measurement because "Z" was assumed to be 50% as good as "X", and may actually contribute some positive utility toward the attribute. If this attribute was the only attribute being considered by the decision maker for this particular problem, then the procedure provides the decision maker with more information then he requires to make a decision. The decision maker is looking for the best alternative; "X" alternative is the best alternative for this one-attribute decision, and the utilities given to "Y" and "Z" contribute nothing to the decision process. The assumption that "Y" is 80% as good as "X" and "Z" is 50% as good as "X" means nothing to the decision maker. But in situations where there are more attributes then one, the evaluation that "Z" as 50% as good as "X" may have effects (or tradeoffs) on the final outcome that the decision maker may not recognize as a result of using this option. The importance of this implication will appear in Step 9 when attribute scores are summed.

To continue the example, in the above "X" alternative was measured ten, "Z" was measured zero and "Y" was measured six relative to "X" and "Z". Assume this was for attribute "A". Now assume for a second attibute, "B", considered equally as important as the first attribute, the ranking of the alternatives from best to worst is "Z", "Y", and "X". "Z" alternative is the best, "Y" alternative is 60% as good as "Z", and "X" is 20% as good as "Z". Using linear scoring over the range: worst alternative equal to zero to best alternative equal to ten, the following totals would be generated:

	"X"	"Y"	"Z"
attribute "A"	10	6	0
attribute "B"	0	5	10
Total	10	11	10

If the decision maker was to select the best alternative on just these two attributes, using the two fixed end procedure he would select "Y".

However, considering the same example using the single fixed end option for scoring. Now the best alternative equals ten (as above) but the other two alternatives are given scores (values) linearly proportional to where they lie between "best" and practical worthlessness. Assume the decision maker decides that saying "alternative Q is P% as good as best" is equivalent to saying "alternative Q has P% of the utility of best (i.e., of ten)". Then the scores would be:

	"X"	"Y"	"Z"
attribute "A"	10	8	5
attribute "B"	2	6	10
Total	12	14	15

These new totals indicate that alternative "Z" is best, and alternative "Y" is second.

It can be seen that the choice of which scoring procedure to use will have implications on the tradeoffs defined between attributes; tradeoffs the decision maker may not be aware of. Thus the decision maker by using the two fixed point option has gained speed in making his measurements decisions, but the rigidity of the measurement procedure may provide the decision maker with unexpected results. The measurement option selected by the decision maker will depend upon the amount of risk (risk in terms of obtaining undefined tradeoffs) the decision maker is willing to accept versus the speed desired to make those measurement decisions.

For the air defense model, the option using one fixed end point will be used. This option provides some speed in developing measurements, and some flexibility to consider the tradeoffs between alternatives.

Step 9. Calculate utilities for each alternatives. Simply add up the products of the Step 8 scores ("measurements") multiplied by their respective Step 7 weights, for each alternative. This one number now represents the ultility of each alternative.

Step 10. Review the decision for accuracy.

Step 11. Decide. A single alternative is to be chosen, therefore the rule is simple: choose the alternative whose sum obtained in Step 9 is the largest.

IV. AIR DEFENSE MODEL

This chapter has three sections. The first develops a list of attributes. The reference list of attributes can be used by the air defense battery commander as a guide (or reference or aid to memory) in developing his list of attributes (the ones he desires to use in conjunction with the air defense model). Definitions of the attributes are provided not to imply that these are the only meanings, but rather to create an awareness in the user of the need for establishing a common definition between himself and the individuals he will be briefing.

The second section presents the working format of the air defense model. Within this discussion, SMART will be modified by eliminating some steps. This will be done to reduce redundancy and to make the model more accommodating to the combat situation.

The final section presents an example scenario followed by a possible solution to the situation.

A. AIR DEFENSE ATTRIBUTES

The collection of attributes presented in this section was developed by conducting a literature search of current army air defense documents. The list is not intented to be restrictive, nor is it presented to the reader as an all inclusive list. The purpose of the list is to guide the user of the model and assist the air defense commander in developing his own list based on his judgment, air defense experience, and military intuition. Some of the attributes presented here have been defined in previous chapters; these definitions will be repeated here for the convenience of the reader. Some of the definitions will be expanded to provide the reader a fuller and more comprehensive meaning.

1. Mass. Mass, an air defense principle, is the allocation of a sufficient number of air defense weapons to the defense of each priority asset to adequately protect it against the air threat. This principle applies to all air defense weapons. It entails the provision of mutual support or overlapping fire between weapon systems and all-around defense in depth. Mass seeks to establish a favorable ratio of defensive weapons to attack aircraft in the protection of assets that are critical to the supported force. The intent of mass is to be able to maintain a continuous volume of fire on any attacking aircraft. The general rule is to deploy short-range air defense weapons in platoon-sized units around the protected asset. The deployment of short-range weapons in less than platoon strength risks the sequential or simultaneous neutralization of both the air defense weapons and the defended asset by aircraft attacking in number [Ref. 22].

Obviously, more air defense is always better, and much more is even better still; but to take more must cost something. The air defense commander is the individual whose judgment mentally measures the marginal cost of additional weapons against marginal benefit. The risks of the uncertain environment (combat) he is entering are very real. He would prefer to hedge his bet with massive quantites of equipment but the constraints of reality force the commander to make trade off decisions between what is recommended by the general rule (the classroom theory) and what is permissible by the real world. Giving up a little mass could mean a defense design that is less than perfect (according to the definition of mass), but reality requires the mission to be accomplished. How much of the mass principle to include or not to include will be a decision that is a function of the commander's judgment and experience.

2. Mix. Mix is the employment of a complementary family of weapons. The capabilities of one system offset the limitations of another system to prevent the air threat from defeating any particular weapon system [Ref. 23]. The mixing of complementary weapon systems goes hand-in-hand with the principle of mass. By employing a variety of weapon systems in sufficient mass, air defense complicates the problem of the enemy who must consider the characteristics of each weapon system in the formulation and execution of his offensive strategy. The enemy may be able to design his tactics and techniques to minimize the effects of one defensive system, but when faced with two or more air defense weapons, his price of admission into the defended area rises [Ref. 22].

3. Mobility and maneuverability. Mobilility of the military force is the capability to move from place to place while retaining the ability to fulfill its military mission. Maneuverability of a weapon system is an indication of its ability to change its position in a tactical situation in order to secure an advantageous offensive or defensive position. Maneuver is the tactical employment of mobility. Air defense weapons must be mobile on the battlefield to apply the principle of mass and mix. Continual movement of air defense weapons is required to provide protection for the brigade elements, to accommodate changes in missions, and to enhance the survivability of the air defense weapons in both the ground and air battle. Mobility will be affected by environmental factors (e.g. terrain and weather), and vehicle characteristics (e.g. tractive force, range, speed, reliability).

4. Integration. Integration means that the air defense design must fit into the overall plan of the brigade to be effective. The best way to define integration is by an example: the defensive squad of a football team. Consider

just the defensive backs and tackles; ignore the rest of the squad. In this simple example the defensive backs protect the air and thus prevent the opposing team from moving the ball. The tackles protect the ground avenue of approaches and thereby prevent the opposing team from moving the ball. Together as a squad they prevent the opposing team from moving the ball or scoring. The defensive squad's overall mission is to stop the opposing offensive; they accomplish this overall mission by insuring that each individual player has the correct understanding of his expected responsibilities that he is to accomplish from the overall plan. Integrated action is best accomplished by insuring that subordinate forces have the correct understanding of their assigned missions that they are expected to accomplish in support of the overall mission (e.g. air defense units protect the air over airfield X, and the infantry protects the ground around airfield X, not airfield Y. Together the force protects airfield X). In summary, integration is individual elements working in unison towards a common goal.

5. Balanced Defense. Balanced defense is a defense designed to cope with attacks from any direction with approximately the same volume of fire.

6. Weighted Defense. Weighted defense is a defense designed to place a greater amount of the air defense weapons along expected routes or forced air avenue of approaches leading into the protected asset area (e.g. an airfield located in a deep valley which reduces the probability of attack from some directions). Of course, weighting the defense unavoidably results in some degradation in defense balance, another trade off decision. Factors that could influence the air defense commander's decision include terrain, vegetation, and characteristics of the defended asset (total area of asset, general shape of asset).

7. Mutual Support. The principle of mutual support is the positioning of each weapon system so that its dead zone (the area in which the weapon cannot engage a target) is within the engagement capability of at least one adjacent, like weapon system. To be mutually supporting, Vulcans' positions should be separated by no more than 1000 meters, which is two-thirds maximum effective range of the weapon. Mutual support for Redeye is 2400 meters, which is 80% of the range at which a target can be positively identified by an observer with the naked eye.

8. Overlapping Fires. Overlapping fires is the ability of one weapon's engagement capability to overlap the engagement capability of an adjacent like weapon.

9. Air Threat. Air threat is that combination of airplanes, helicopters, weapons, and tactics the enemy is capable of employing against the friendly area. For this attribute a commander may want to consider quantity of air assets available to the enemy; location of enemy's air bases and flying time to friendly location; and the training level of the enemy's pilots.

10. Terrain. Terrain is defined as the physical features of the earth. The following items will be considered within this definition: relief (the elevations of the land surface, such as mountains, and valleys), drainage (rivers, streams, lakes, swamps, marshes), surface materials (soil, mud, rocks), man-made objects (roads, bridges, dams, cities), and vegetation. For this attribute a commander may want to consider how terrain may effect the firing positions of the weapons (fields of fire, observation); the effects of terrain on the enemy's avenues of approach (open area, mountains, dense forests); the effects of terrain on resupply operations, command and control, and security.

11. Weather. Weather is defined as a condition of the atmosphere with respect to heat or cold, wetness or dryness, clearness or cloudiness. In this situation a commander will be concerned about the effects of weather on visability. If a target cannot be seen, it cannot engaged (by SHORAD weapons).

12. Reliability. Reliability is defined as the weapon system's chance of successful operation for a given application (engagement or engagements) for the stated time period. In this situation the stated time period is the duration of the mission. Other factors that could be considered here are: time required for system reload, time required to conduct scheduled maintenance, state of training of the squads, and availability of repair parts.

13. Logistics. Logistics are those capabilities having to do with procuring, maintaining, and transporting material and personnel.

14. Defense in depth. Defense in depth is the positioning of one air defense weapon in front of another. For example, Redeye are deployed out from the asset 2 to 3 km. This will usually place Redeye in front of the Vulcans' positions which are located very close to the asset. The purpose of defense in depth is to subject an air threat to an ever-increasing volume of fire from the moment it is detected and identified as hostile until it is destroyed.

15. Characteristics of the asset. Characteristics of the asset are such things as size, shape, hardiness (how fortified the asset is), and nature of specific targets within the asset. These characteristics will affect the defense design and the enemy's method and direction of attack. For example, a small asset, such as a bridge or ammunition storage area, will generally require the enemy to use more accurate delivery techniques. A larger asset, such as an airfield or a portion of a city, tends to increase the

number of enemy attack options. The nature of specific targets within the asset can be described as homogenous or heterogenous. An example of a homogenous asset is the division tactical operation center (TOC). The TOC is made up of many small, but equally valued elements. An example of a heterogenous asset is an airfield. The specific targets include the airstrip, the control tower, buildings, and maintenance area. Each of these elements probably would have different degrees of importance to an unit.

B. THE AIR DEFENSE MODEL

This section will present the structure of the Air Defense Model. The steps of SMART have been modified for use for this context. Additional explanation is provided for some of the steps where major changes have occurred.

In figure 4.1 is an example of the format that will be completed by the commander working through the steps of the model.

The first two steps of SMART have been eliminated. The air defense commander is part of the brigade commander's special staff, the brigade commander will always be the person whose utility is being optimized. The purpose of the decision is selecting equipment for deployment within the context of the combat scenario.

Step 1. Identify the relevant attributes. At this point the air defense commander knows the combat scenario, the brigade commander's ground tactical plan, and the brigade commander's priority list for air defense. From the combat scenario and ground tactical plan he knows where he is going, and who he is fighting; now he needs to conduct a map reconnaissance to obtain a feel for the terrain at that location. With this information the air defense commander selects the attributes (no more than eight) that he feels

				#5 FIRST ALTERNATIVE		SECOND ALTERNATIVE		THIRD ALTERNATIVE	
#1 RANK	#2 NAME OF ATTRIBUTE	#3 RAW SCORE	#4	(a)	(b)	(a)	(b)	(a)	(b)
TOTAL:									

Figure 4.1 Air Defense Model.

are important to the evaluation of any alternative for this scenario. The attributes are listed in the second column of Figure 4.1.

Step 2. Rank the attributes in order of importance. The air defense commander ranks the attributes in order of importance from most important to least important. The most important attribute to this defense is labeled number 1, the next important attribute is labeled number 2, and the process continues until all attributes are numbered. If two attributes are tied for a particular level of importance, they are both labeled with the same number. For example, if mass and mix are tied for number four, each is labeled number four, and the next attribute would be labeled number five, the next attribute number six, and the least important attribute number seven (assuming eight attributes and only one tie). The rank order for the attributes are recorded in the first column.

Step 3. Rate the attributes in importance, preserving ratios. To do this, start by assigning the least-important attribute a weight of ten. Now consider the next-least-important attribute. How much more important (if at all, the model allows for ties) is it than the least-important? Assign this attribute a weight that reflects that ratio. Continue up the list, checking each set of implied ratios as each new judgment is made. Thus, if one attribute is assigned a weight of ten while another is assigned a weight of 80, it means that the 80 attribute is eight times as important as the ten attribute, and so on. By the time the last attribute is reached, there will be many checks to perform to insure that the implied ratios reflect what the battery commander intended. Typically, battery commanders will want to revise early judgments to make them consistent with later ones. Enter the results in the third column.

Step 4. Sum the importance weights, and divide each of the attribute weighs by the sum. Enter these results in the fourth column. This is a minor difference from the method discussed for SMART. For the air defense model the quotient will not be multiplied by 100. The values for w will be between 0 and 1, and the sum of the w ($j = 1, 2, 3, \ldots, n$ where n is the number of attributes) will equal 1. Using this method causes the user to work with smaller numbers and decimals. If the user does not feel comfortable with decimals, then he should use the method explained in Step 7 of SMART. The choice is arbitrary.

Step 5. Identify the alternatives to be evaluated. As stated in Chapter III, there will be no more than three alternatives considered. These alternatives could be all Vulcans, all Redeyes, and/or mixtures of the two. The question for each scenario is how many Vulcans versus how many Redeyes versus what mixture or mixtures? The answer rests with the number of cargo airplanes the air defense commander anticipates receiving. A tentative number usually can be obtained from the brigade operations officer, but generally an air defense commander should have a feel for how many aircraft he can expect based on past exercises. For planning purposes an air defense commander can use the following numbers to assist him in developing an estimate for the number of weapon systems. A Vulcan squad rigged for a heavy drop operation (dimensions: 177 inches long by 98 inches wide by 90 inches high, weighting 6740 pounds) will need .25 of a C-141B cargo airplane (4 Vulcan squads can be loaded on a C-141B) or .50 of a C-130 cargo airplane (2 Vulcan squads can be loaded on a C-130). A Redeye team rigged for a heavy drop operation (dimensions: 133 inches by 98 inches by 77 inches, weighting 5690 pounds) will require the same cargo space as a Vulcan. If an air defense commander expects three C- 141B aircraft then he would have space for 12 units, where each unit is either a Vulcan squad or Redeye team.

How does the commander arrive at a ratio of the two weapons for a mixture-of-weapons alternative? The commander uses his judgment based on a preanalysis of the asset being defended (size of asset, terrain around the asset, avenues of approach to the asset, enemy air threat) to develop a ratio. For example: if the defended asset is small (e.g., an ammunition storage area) this will be a harder target for the enemy to locate. In fact, it is probable that the enemy air may have to fly over the target to locate it. In this situation, the air defense commander may want to position his air defense close to target. Vulcans are placed on or near the defended asset, thus an air defense commander would want to take more Vulcans when defending small targets. The ratio used in the analysis would be a subjective decision: a decision affected by preference, skill, and past assignments. An air defense commander whose past assignments have been mostly Vulcan related will probably always lean towards a Vulcan-heavy ratio. On the other hand, an air defense commander whose past experience was with Redeyes will feel more confident with Redeye and will probably lean towards a Redeye-heavy ratio.

Step 6. Measure the location of each alternative being evaluated for each attribute. This is purely a subjective measurement, and forces the air defense commander to rely heavily on his experience, judgment, and intuition. To start, assume a straight line scale for each attribute measured from 0 to 10, where 0 is defined as the minimum value for that attribute, and 10 is defined as the maximum value. This step is conducted in the same manner as Step 8 of SMART. The air defense commander informally ranks the alternatives from best to worst. In this discusion the single fixed option for developing measurements will be used. As explained in Chapter III, the upper end point will be assigned to the best alternative; the lower end point, zero utility, is assigned to an imaginary or theoretical alternative that contributes (practically) nothing to the attribute. The remaining two alternatives are measured relative to the best alternative and the imaginary zero point. Record these values assigned in column 5a.

The values thus far obtained are raw measurements of the location of each alternative for each attribute. Each measurement will be weighted by multiplying the raw measurement by the normalized weights obtained in Step 4. Record the weighted value for each alternative in column 5b.

Step 7. Calculate the utility for each alternative. Simply add up column 5b for each alternative. This total will represent a subjective measure of effectiveness (MOE) for each alternative.

Step 8. Review the decision for accuracy.

Step 9. Decision. Select the alternative with the highest total score.

C. EXAMPLE

This section presents a discussion of some of the thought process that might be involved in the application of the air defense model. The combat scenario and ground tactical plan are purposely kept simple. The detail involved in writing them can be found in any good handbook for Army staff officers (e.g. FM 101-5).

In the example, steps of the air defense model that involve iteration of the same thought process are presented only once (e.g., Step 4). For the sake of brevity, the other iterations are assigned values without further explanation.

Combat scenario. The unit is in direct support of a brigade-sized-element which has received notification of a deployment exercise. The deployment will be to a Middle-East country having terrain, political, and military characteristics similiar to Iran or Iraq, called Oilland. The mission of the DRF is to secure the airhead for follow-on elements of a larger contingency force. The follow-on elements will start arriving at Oilland on D+3 (three days after the DRF arrives). The airhead will consist of two commerical airports located north of the city Blues. The airports are six miles apart, both capable of supporting C-141B traffic and about twenty miles inland from the Persian Gulf. The DRF is to establish control, and maintain control of the airhead until relieved by higher headquarters. The airhead is very critical to the overall accomplishment of the mission.

Brigade commander's priorities are: airfield A, airfield B, and the brigade tactical operation center (TOC). The TOC will be located in the area of airfield A.

Map reconnaissance. General reconnaissance shows the area to be flat (small changes in relief) with unrestricted visibility in all directions. The waterways are generally located in the southern sector of the country. The soil condition appears to be sandy in texture; man-made objects are restricted to the roads and some two-story buildings located on the airfields.

Step 1. Identify relevant attributes (column 2). The air defense commander simply identifies the attributes or factors that are important to him in the design of his air defense for the brigade commander's priority list. The answer is very much a function of the individual's experience, preference, and understanding of the overall mission. The air defense commander for this example selected the following:

characteristics of the asset
air threat (quantity, tactics, ordnance, experience)
terrain (visibility, avenues of approach, road networks, cover)
balanced defense
defense in depth
mass
mix
logistics

Step 2. Rank the attributes. The task here is simple: put the attributes of Step 1 in order of importance to the air defense design. What factor will affect the decision more than the other seven? This is a judgmental step and the final results will probably vary from one air defense commander to another. The example air defense commander selects "characteristics of the asset" as most important. The DRF commander specified airfield A and airfield B as priority 1 and 2, but the air defense commander realizes that the airfield is an asset of many components and each component may have a different value of importance to the mission of the DRF. Thus his thought process has to do with the nature (the functional activities or components) and design (the size and shape) of the airfield. The most critical part of the airfield to the DRF is the airstrip, especially the central portion of the runway. If the enemy is successful in cratering the center of the runway they have a high probability of rendering the strip useless to the DRF. Cratering the center will require the DRF commander to expend man-hours to make repairs; cratering the center could also disrupt the movement time table of the DRF. The design of most airfields provide natural avenues of approach. The avenues may be pronounced enough to justify a weighted defense. Even if there are no forced avenues of approach due to the terrain, the design of the airfield (long axis of airstrip) increases the probability of what likely directions the air attack will come from. An approach down the major axis of a long, straight target gives pilots time to align on target, means fewer last minute adjustments, and greater probability of hit.

The size and shape of the airfield make it an easily identifiable target from the air at night or in the day time. Other considerations are the other components of the airports, such as: possible fuel storage (POL), buildings, airplane parking (a future contingency), control tower, and aircraft maintenance area (also a future contingency). To the DRF the airstrip is the most important, but the buildings would provide shelter to personnel, equipment, and supplies. POL supplies, if captured intact, would provide for an unexpected windfall in terms of fuel. Supplies are very critical for the first 72 hours, and any unexpected windfall would help. Airplane parking for disabled aircraft is a future consideration. Location of the TOC is a consideration. An air defense commander might also want to find out how important the airports are to the enemy. This information will give some indication of the weapons he might expect to be used against him.

With the above information the air defense commander would want to consider his air defense weapons' capabilities. The volume of fire that a Vulcan can put into the air will have some affect on pilot's concentration. Placing Vulcans near the central portion of the strip will have significant impact on enemy air. Vulcans can add much fire power to night perimeter defense, and if necessary daytime ground defense. Redeyes would be placed away from the airfield to get early engagement. Redeyes can be used to provide a weighted defense, or can be employed to provide defense in depth. Redeye teams are smaller, easier to hide, and will have early effects on the pilot's ability to concentrate. Early Redeye engagements could possibly disrupt formations, destroy or damage airplanes some of which might be flown by key individuals, and force the enemy into early evasive formations.

The air defense commander would also want to consider the interrelationships of his other selected attributes to this attribute. As was mentioned earlier, the importance of the airports to the enemy will have some effect on the weapons selected to be used by the enemy air threat.

Without further discussion assume the air defense commander ranks the attributes as follows:

Rank	Attribute
1	characteristics of the asset
2	air threat
3	balanced defense
4	defense in depth
5	terrain
6	mass
6	mix
7	logistics

Step 3. Rate the attributes in importance. The ratings are also subjective, and will be different from individual to individual. The air defense commander in this example ranked logistics as least important. He rated it with a score of 10. Mix and mass were tied for the next position, and they were evaluated as twice as important as logisitics. The next attribute, terrain, was determined by the battery commander to be twice as important as mix and mass, and it was rated 40. This rating also implies that terrain was four times as important as logistics. If the air defense commander had not agreed with this implied ratio, he could adjust his rating for terrain until the implied ration did agree. Of course, the change in the terrain rating would

also change the establish two-to-one ratio for mix and mass. An air defense commander needs to recognize a change in one rating may require him to re-evaluate all ratios involved.

The remaining ratings are developed in a similar fashion.

Attribute	Raw	Normalized
logistics	10	.03
mix	20	.05
mass	20	.05
terrain	40	.11
defense in depth	45	.12
balanced defense	60	.16
air threat	80	.21
characteristics of the asset	100	.27
Total	375	1.00

Step 4. Sum weights and divide each attribute's raw weight by the sum to get the normalized weight, as shown above.

Step 5. Identify the alternatives to be evaluated. The commander has received guidance from the operations officer that he can expect three C-141B. This means 12 Vulcans, or 12 Redeyes, or a mixture of the two. The commander decides on four Vulcans and eight Redeyes as a mix for alternative 3.

Step 6. Measure the location of each alternative on each attribute. The first attribute will be explained in some detail. The rest of the attributes will be given measures without explanation, as the thought processes are similar. The first attribute to be considered is the characteristics of the asset. In the definition of characteristics of the asset, it was mentioned that the nature of the specific targets within the asset could classified as homogenous or heterogenous. The airfield is an example of a heterogenous asset. The components of the airfield have different degrees of importance to the DRF, and require different considerations in developing an air defense design. For example, as was mentioned in Step 2, the airstrip is long and narrow, a target that is easy to recognize from a distance, and is probably the most important element of the airport to the DRF. As a result of the size of the airstrip (long and narrow) the enemy can use a variety of attack options. He can use standoff weapons from a distance, or he can fly over the target and drop his weapons. The effectiveness of these options can be reduced depending on the air defense weapons deployed. The effectiveness of the standoff option can be reduced with the deployment of Redeye, and the effectiveness of the flyover can be reduced with the deployment of Vulcan. For this attribute, the commander decides the mix alternative can accommodate the demands of this attribute the best, and thus is scored ten. Vulcan weapon can provide pinpoint coverage to the central portion of the strip and still provide some coverage for the other items (POL, control tower, etc). The Vulcan range is limited and therefore the protected asset is vulnerable to standoff attacks. Redeye weapons will be employed away from the asset to provide area coverage. They cause the pilots to fly lower to avoid Redeye engagements. Redeye early engagements will give Vulcan gunners early warning, will attrite some of the hostile threat, and will generally disrupt the enemy's attack.

"All Vulcans" are rated second best, and the air defense commander measures this alternative as 7. The Vulcans can handle the point air defense without much problem; their weaknesses are range, limited ammunition load, and lack of armor protection. The enemy air can avoid the Vulcan fire by changing attack tactics from flyover attacks to standoff attacks. This means the enemy might lose some accuracy in delivering his ordnance, but save airplanes.

"All Redeyes" is measured at 5. Redeye can handle the area coverage without much difficulty; their weaknesses are the tail-chase nature of the weapon, and vulnerability of the team to enemy ground fire.

The remaining attributes are measured as indicated in Figure 4.2.

Step 7. Calculate utility for each alternative. This is just simple addition. Add up all the numbers in column 5b for that alternative and record the sum in the total block. This sum will be the MOE for that alternative.

Step 8. Review. Does outcome make sense?

Step 9. Decision. Select the alternative whose MOE is the largest.

				#5 FIRST ALTERNATIVE VULCAN		SECOND ALTERNATIVE REDEYE		THIRD ALTERNATIVE MIX	
#1 RANK	#2 NAME OF ATTRIBUTE	#3 RAW SCORE	#4	(a)	(b)	(a)	(b)	(a)	(b)
1	CHARACTERISTICS OF THE ASSET	100	.27	7	1.89	5	1.35	10	2.70
2	AIR THREAT	80	.21	5	1.05	7	1.47	10	2.10
3	BALANCED DEFENSE	60	.16	10	1.60	6	.96	8	1.28
4	DEFENSE IN DEPTH	45	.12	5	.60	10	1.20	8	.96
5	TERRAIN	40	.11	6	.66	8	.88	10	1.10
6	MASS	20	.05	5	.25	10	.50	9	.45
6	MIX	20	.05	4	.20	7	.35	10	.50
7	LOGISTICS	10	.03	8	.24	10	.30	6	.18
TOTAL:				6.49		7.01		9.27	

Figure 4.2 Completed Air Defense Format.

V. CONCLUSIONS AND RECOMMENDATION

A. CONCLUSIONS

This thesis has developed a planning aid to be used by the airborne air defense commander in the development of his air defense force structure recommendation to the brigade commander. There were four characteristics that this desired model had to have. These were: (1) The model had to provide a means of organizing the commander's thoughts. (2) The model had to include the interaction of the commander's judgment as part of the overall process. (3) The model had to be adaptive so that all scenarios could be used with it. (4) The model had to be simple and easy to understand.

In Chapter III the arguments for having a model versus intuition were presented. The SMART version of MAUM was reviewed, and found to be compatible with the four desired characteristics. In Chapter IV, the SMART version of MAUM was modified to fit the general combat scenario used by the air defense commander. The air defense model format is flexible, adaptable, easy to learn and understand, provides organization, and requires an extensive use of the commander's judgment. The model also insures, by working through the steps, that a commander will conduct some form of analytic analysis, and thus gain a better understanding of the interrelationships of the attributes choosen.

B. RECOMMENDATION

It is recommended that the air defense model be used by air defense commanders as a planning aid in developing their recommendations for force structures. The model would be especially useful for those air defense commanders that are commanding a unit for the first time. It will provide them the guidance and organization necessary to handle their first deployment mission.

LIST OF REFERENCES

1. Sun Tzu, "U. S. Army Takes Lesson From Chinese Warlord," Peninsula Herald, p. 6A, February 1983.

2. Infantry, Airborne, and Air Assault, FM 9-30, Headquarters, Department of the Army, p. 4.1, April 1981.

3. Walter, Rudolf, "Air Defence on the Battlefield," Nato's Fifteen Nations, pp. 108-112, Oct-Nov 1982.

4. Frankoski, Joseph P., "AA Gun Flexibility," Air Defense Magazine, pp. 19-21, Apr-June 1981.

5. Gardiner, P.C., and Edwards, W., "Public Values: Multiattribute Utility Measurement For Social Decision Making," Human Judgment and Decision Process, pp. 1-37, Academic Press, 1975.

6. Edwards, W., and Newmann, R. J., The Evaluation of Criminal Justice Programs: An Approach to the Use of Multiattribute Utility Technology, Unpublished manual developed under grant from the National Institute of Law Enforcement and Criminal Justice, November 1980.

7. Little, J. D. C., " Models and Managers: The Concept of Decision Calculus," Management Science, Vol. 16, No. 8, pp. B466-485, April 1970.

8. Holt, R. R., "Yet Another Look at Clinical and Statistical Prediction," American Psychologist, pp. 337-339, 1970.

9. Meehl, P., Clinical Versus Statistical Prediction: A Theoretical Analysis and a Review of the Evidence, Wiley and Sons, 1954.

10. Dawes, R. M., "The Robust Beauty of Improper Linear Models in Decision Making," American Psychologist, Vol. 34, No. 7, pp. 571-582, July 1979.

11. Edelmen, F., "Art and Science of Competitive Bidding," Harvard Business Review, Vol. 43, No. 4, pp. 53-66, July-August 1965.

12. Johnson, E. M., "The Technolgy of Utility Assessment," Transactions of Systems, Man, and Cybernetics, Vol. SMC-7, No. 5, May 1977.

13. Edwards, W., "Use of Multiattribute Utility Measurement for Social Decision Making," in D. E. Bell, R. L. Keeney, H. Raiffa, eds., Conflicting Objectives in Decisions, John Wiley and Sons, New York, 1977.

14. Raiffa, H., Preferences for Multi-attribute Alternatives, RM-4968-DOT/RC, The Rand Corporation, Santa Monica, Ca., 1969.

15. Keeney, R. L., and Raiffa, H., Decision with Multiple Objectives: Preferences and Value Tradeoffs, John Wiley and Sons, New York, 1976.

16. Bartholomew, D. J., and Forbes, A. F., Statistical Techniques for Manpower Planning, p. 21, John Wiley and Sons, 1979.

17. Keen, P. G. W., and Morton, M. S. S., Decision Support Systems: An Organizational Perspective, Addison-Wesley Publishing Company, Reading, Ma., 1978.

18. Gardiner, P. C., Public Values, p. 13, Academic Press, 1975.

19. Edwards, W., "Social Utilities," The Engineering Economist, Summer Symposium Series, Vol. 6, 1971.

20. Edwards, W., "How to Use Multiattribute Utility Measurement for Social Decisionmaking," IEEE Transactions on Systems, Man, and Cybernetics, 1977.

21. Keeney, R. L., and Raiffa, H., Decisions with Multiple Objectives: Preference and Value Tradeoffs, pp. 66-344, Wiley and Sons, 1976.

22. Air Defense Artillery Employment: Chaparral/Vulcan, FM 44-3, Headquarters, Department of the Army, April 1968.

23. U. S. Army Air Defense Artillery Employment, FM 44-1, Headquarters, Department of the Army, February 1979.

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