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ESTIMATING AIRFIELD CAPACITY
FOR AMC OPERATIONS

GRADUATE RESEARCH PROJECT

Marshall T. Morrison, Capt, USAF

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ESTIMATING AIRFIELD CAPACITY
FOR AMC OPERATIONS

GRADUATE RESEARCH PROJECT

Presented to the Faculty of the Graduate School of
Logistics and Acquisition Management of the
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Requirements for the Degree of
Masters of Air Mobility

Marshall T. Morrison, B.S.

Captain, USAF

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Marshall T. Morrison

Table of Contents

	Page
Acknowledgments.....	ii
List of Figures	v
List of Tables	vi
Abstract	vii
I. Introduction	1
Background	1
Importance of Research	3
Problem Statement.....	5
Research Objectives.....	6
Investigative Questions.....	7
Chapter Summary	7
II. Examining the Current Concept of Airfield Capacity	8
Current Definitions of Airfield Capacity	8
Current Method of Determining Airfield Capacity.....	13
Chapter Summary	19
III. Examining the Logic of the ACE Model	21
How the ACE Model Defines Airfield Capacity	21
The Concept Behind the ACE Model	22
Examining the Basics of the Analytical Method	25
Calculations With Multiple Resources	28
Calculations With Resources and Multiple Uses.....	29
Calculations With Multiple Parking Areas	31
Calculations With Multiple Missions	32
Model Summary.....	36
Chapter Summary	40
IV. Summarizing the MOG and ACE Model Approaches	42
Current Approach to Defining and Computing MOG	42
The ACE Approach to Defining and Estimating Airfield Capacity	43

	Page
Recommendations.....	44
Chapter Summary	45
Appendix.....	46
Bibliography	47
Vita.....	49

List of Figures

Figure	Page
1. Structure of the ACE Model	23
2. Aircraft and Airfield Activities	38

List of Tables

Table	Page
1. Resources Modeled by ACE.....	35
2. Operations and Resources of Aircraft Generation	39

Abstract

Airfields are as important to the American military's ability to rapidly project power or provide relief as are the aircraft that deliver the necessary people and material to points around the globe. In the past, airfield capacities have been estimated for deployment planning purposes primarily on the basis of three items of information: maximum-on-the-ground, which is the largest number of aircraft of a particular type that can be parked on the airfield at the same time; aircraft parking equivalencies, which are the ratios telling how many aircraft of other types can park in the same space as a standard aircraft; and standard service times, which are the average lengths of time different aircraft spend on the ground when they land.

This approach, although simple and mathematically sound, has led to unreliable and inaccurate measurements of airfield capacities in the past. This has contributed to overestimates of the ability of the airlift system to move forces and supplies into overseas theaters of operation. In order to achieve more accurate estimates of airfield capacities, a model must be implemented that more closely models factors that affect an airfield's throughput capacity-- the airfield capacity estimator (ACE) model could be that tool.

ESTIMATING AIRFIELD CAPACITY FOR AMC OPERATIONS

I. Introduction

Background

Strategic airlift is a critical part of our nation's ability to carry out its foreign policy. Throughout the last fifty years, our nation has repeatedly called upon its airlift resources to support the projection of power and to provide humanitarian assistance around the globe. An integral component of these worldwide operations, in addition to the personnel and aircraft that fly the missions, is the vast number of airfields that our aircraft use in their operations.

The fact that every airfield possesses a limited amount of space and resources presents a challenge. Planners and operating personnel must decide how many aircraft can operate on any given airfield during a given time period. This information is important in ensuring that the number of aircraft deployed to a location and the quantity of people and equipment destined for an airfield are planned as effectively as possible.

Past operations and deployments, such as Operation Desert Shield/Desert Storm, have proven that accurate estimates of airfield capacity are crucial to the success of an operation. Although our nation has been able to meet past challenges associated with inaccurate airfield capacity estimates with some success, perhaps a different method of

calculating airfield capacity will yield more accurate estimates, and thus improve our operating efficiency; this paper will examine one of these methods, the Airfield Capacity Estimator Model, in an attempt to determine its potential validity for AMC.

The perspective with which our nation, and even our own Air Force, views our airlift capability has changed dramatically throughout the past fifty years. The United States entered World War II “with only the basic types of military aircraft, the bomber and the fighter,” Major General Robert M. Webster, Air Transport Command (ATC) Commander, informed a National War College class in 1947. He added, “I feel that we have come out of that war with an additional type, the transport plane, and that we should think in terms of bomber-fighter-transport--since they are all equally important--and they must be properly balanced to each other if we are to be prepared to conduct successful war operations” (Launius & Cross, 1989: 1). Initially demonstrating its unique abilities in helping to break the Berlin Blockade of 1948-1949, airlift has repeatedly demonstrated its flexibility as an instrument of United States foreign policy. Because it has been so successful in responding as a tool for our nation in such a myriad of ways and a variety of situations, airlift has come to be a respected part of our nation’s defense capability. From the Berlin Blockade to Operation Joint Endeavor in Bosnia, our nation depends on our ability to reach any point on the globe in a minimum of time.

Because our nation’s airlift assets operate worldwide, there are some challenges that are inherent in the way these operations are conducted. On a majority of missions, our aircraft fly incredibly long distances--our air refueling capability gives our aircraft an

unlimited range. In reality, the mission's range is most often limited by the rest required by the crew after operating a certain number of hours. On strategic airlift missions, another challenge is the vast number of different airfields that our aircraft fly into; because our operations are truly global, it is not uncommon for a U.S. aircraft to fly into a location that has never been visited before by that type of USAF aircraft. Even in operations such as Desert Shield/Desert Storm, when the U.S. is using a fixed number of normal operating locations, determining how many aircraft a particular airfield can accommodate in any one period of time can be a challenge.

Importance of Research

Without question, the ability of our nation to achieve its foreign policy goals rests, to a significant degree, in its capability to project power around the globe. Recent history has proven this point many times over; From Desert Shield/Desert Storm to Operation Restore Hope in Somalia, to Operation Joint Endeavor in Bosnia, the United States operates daily in a variety of foreign countries. As our aircraft fly to these distant locations to accomplish their missions, they must often operate into airfields that offer significant challenges. Depending on the location, size, and duration of the operation, our aircraft may saturate several airfields. In Desert Shield/Desert Storm, U.S. aircraft routinely operated from airfields in the United Kingdom, Spain, and Germany. Each offered its unique challenges. Operations from a particular airfield may be affected by a

variety of factors; fueling capability, parking space, cargo loading procedures, and maintenance capability are just a few of these potential limiting factors.

Determining how many aircraft can operate into an airfield in a certain time period is a critical part in ensuring the success of an operation. Because so many factors rely on an accurate estimation, the efficiency and thus the effectiveness of any given operation can depend on the accuracy of this calculation. I was fortunate to serve as an aide-de-camp to Lieutenant General Armstrong, Twenty-First Air Force Commander from June 1994 to August 1995. As Twenty-First Air Force Commander, General Armstrong was responsible for half of our nation's entire airlift capability; his official area of responsibility covered the area from the Mississippi River to just beyond Pakistan. Throughout my year with him, I traveled to numerous countries and watched him observe several operations in his area of responsibility. Airfield capacity was an important subject to him, in part because it affected every AMC mission. In his words during a private conversation with me, "airfield capacity jumps up and bites us every time we decide to conduct an operation; we just seem to keep having to learn the same lessons again and again" (Armstrong, 1994). My own personal experience as a C-141 pilot supported the General's concern over airfield capacity.

I was fortunate to fly several missions into a variety of locations in support of Desert Shield/Desert Storm. Flying into airfields such as Torrejon Air Base in Madrid Spain, Upper Heyford Air Base in the United Kingdom, and Ramstein Air Base in Germany, I experienced many problems associated with inaccurate airfield capacity

estimates first-hand. In certain circumstances, an inaccurate airfield capacity estimate can have a negative impact on airlift operations. During Desert Shield/Desert Storm, there were numerous instances in which my aircrew had to cancel a mission, or divert to an alternate airfield because of capacity limitations at our planned operating location. Because our nation's defense capability relies so heavily on our global reach ability, it is important to have accurate estimates for the number of aircraft any given airfield can handle at any one time-- the very success, and certainly the efficiency of the particular operation may depend on it.

Problem Statement

To a certain extent, airfields are as vital to the United States' ability to project power or provide humanitarian relief as are our strategic aircraft and aircrews. Airfield resources are used to prepare aircraft, aircrews, passengers, and cargo loads for movement from originating airfields and also to receive them at destinations. Planners need detailed information on the capacities of applicable airfields to accurately estimate the quantities of personnel and equipment that can be moved through that airfield during an operation. Accurate estimates of airfield capacity are important to planners in both long-range planning and short-term planning. Long-range planners may use airfield capacity estimates to decide which airfields may be most suitable to use for a particular operation, given that circumstances exist which offer a choice of locations. In addition,

short-term planners use airfield capacity information to help determine how many aircraft, personnel, and equipment can be moved through an airfield at any one time.

Several major AMC operations, such as Provide Hope in Rwanda, have highlighted the importance of accurate airfield capacity estimates. The efficiency of some of these operations was hampered by inaccurate capacity estimates--estimates which were overly-optimistic concerning the number of aircraft that applicable airfields could handle. Several factors involved in determining these estimates for an airfield present challenges. For example, the number of aircraft that can park in a given area may vary with the type of cargo being carried, some parking areas on an airfield may not be stressed for certain aircraft, and the definition of airfield capacity may differ for different types of personnel (civil engineers versus aircrew personnel) (Friedrichsen, 1996). The challenge is to use an airfield capacity model that more accurately estimates the capacity of airfields than the informal method currently in use by AMC.

Research Objectives

The objective of this paper is twofold. The first objective is to formulate a working definition of airfield capacity that can be used by all primary parties in planning and executing an AMC operation. This will alleviate the confusion that is generated by the various definitions of airfield capacity currently in use. The second objective is to examine, on a conceptual level, the Airfield Capacity Estimator (ACE) Model, a new airfield capacity model being considered by AMC, to determine its potential usefulness to

Department of Defense (DoD) planners and USAF personnel involved in AMC operations. The advantages and disadvantages of the current method of estimating airfield capacity and the ACE model will be detailed and discussed.

Investigative Questions

In fulfilling my research objectives, this paper will answer the following investigative questions:

1. How does AMC currently define airfield capacity?
2. What is the process currently being used to determine airfield capacity estimates?
3. On a conceptual level, how does the Airfield Capacity Estimator Model (ACE) calculate airfield capacity?

Chapter Summary

The significant number of strategic airlift operations AMC has supported during the past few years highlights the need to conduct these deployments as efficiently as possible. Ensuring that DoD planners have access to accurate information will help our nation's military use the right quantity and mix of strategic airlift aircraft to transport people and equipment to any particular airfield involved in the applicable operation; having accurate airfield capacity estimates is an important part of the information that defense planners and operating personnel need.

II. Examining the Current Concept of Airfield Capacity

Current Definitions of Airfield Capacity

One of the most challenging tasks related to determining accurate airfield capacity estimates for strategic airlift operations is finding one definition of airfield capacity that is useful for every potential player involved. At first glance this may seem to be a basic problem that should be easily solved. However, because of the large number of personnel involved in determining an airfield's capacity coupled with the different areas of expertise of each of these groups, finding one acceptable definition that captures the entire concept of airfield capacity is difficult. Currently, Air Mobility Command (AMC) discusses airfield capacity in terms of a concept known as Maximum-On-The-Ground (MOG). Although most people involved with airlift operations are familiar with this acronym, it often means different things to different people. In addition, the current concept of MOG is extremely situational, with a variety of interpretations based on specific operational circumstances (Merrill, 1996).

While there is no current formal definition of MOG in AMC today, one that is often used that considers most factors in determining a MOG is "the maximum number of aircraft on the ground that can land, taxi-in, park, be unloaded, refueled, maintained, inspected, loaded, taxi-out, be cleared for departure, and takeoff within a planned time interval" (Merrill, 1996: 1). This particular definition implies the involvement of six major factors: aircraft type, particular location, planned ground times, physical ramp

space, logistics resource availability, and the competition for limited resources. Each of these factors is defined more specifically in an attempt to make them more useful for planning purposes.

A wide variety of strategic airlifters can be used simultaneously in any given operation--C-17s, C-5s, and C-141s. Each of these different types of aircraft possesses specific characteristics that affect its MOG values at a particular location. Some of these aircraft-specific factors include the plane's footprint (size and weight), fuel capacity, maintenance requirements, material handling equipment (MHE) requirements, and ground maneuverability. A given airfield's particular location can also be a major factor in defining MOG. Circumstances such as limited operating hours, Air Traffic Control (ATC) constraints, and host nation political considerations all contribute to forming a location MOG. Planned ground time is another major category in defining the MOG concept. A variety of possible reasons for stopping at a given airfield necessitate different planned ground times, and each aircraft type should be given a MOG value that is based upon the specific servicing requirements scheduled for that particular en route stop. For example, a plane that stops en route to offload, refuel, and undergo maintenance will obviously be assigned a longer planned ground time than a plane that stops only to offload cargo. Although standard planned ground times have been established for AMC aircraft and are included in the 1994 Omnibus Plan, these standard times are not always used by planning personnel (Norton, 1995: 1).

The physical ramp space available for parking and maneuvering aircraft also factors into the overall definition of MOG. Constraints unique to a particular airfield such as the aircraft ramp's shape and size, load bearing capacities, widths of taxiways, and obstructions are some examples of an airfield's physical constraints that define the physical MOG (McCaughan, 1996: 2). Although this particular factor that helps define MOG may at first seem basic, it is an important part of an airfield's MOG; it becomes even more crucial if the size of an airfield is particularly small. During Operation Restore Hope in Somalia, the capacity of the ramp at Mogadishu was extremely limited. Because so few airplanes could fit on the ramp at any one time, the flow of operations was severely restricted when even one aircraft did not depart on time for any reason; the size and shape of an airfield's ramp is often one of the most limiting factors on airlift operations (Beck and Brunkow, 1994: 26; Tenoso, 1993: 4).

The next major category involved in this particular general definition of MOG is the availability of logistics resources. Based on recent operations such as Desert Shield/Desert Storm, the availability of and access to logistics resources are probably the most common limiting factors associated with MOG. There are a significant number of logistics factors involved in defining a logistics MOG, including fuel storage capacity, fuel pump rates, number of fuel trucks, maintenance parts availability, and material handling equipment (MHE) availability. This particular component of the MOG concept was a major limiting factor on operations during Desert Shield/Desert Storm. The importance of MHE equipment was highlighted at Dhahran Air Base in Saudi Arabia

when our nation's aging equipment succumbed to the harsh desert conditions. The failure of our equipment caused a significant backlog of cargo and served as a catalyst for AMC setting the procurement of state-of-the-art MHE as a top priority for the command (Matthews, 1995: 75).

The final major category associated with this definition of MOG is the competition for ramp space and resources; decisions regarding mission beddown for one type of aircraft will affect the amount of ramp space and logistics resources available for other types of aircraft. With the arrival of several different aircraft types at an airfield during a typical airlift operation, countless combinations of different aircraft types can compete for available resources (Merrill, 1996: 2).

The major aspects of MOG just discussed help formulate just one primary current definition of MOG. There is such a wide variety of definitions of MOG currently in use, that how MOG is defined literally depends on the functional specialty of the individual being asked (Brewer, 1996). The basic definition of MOG is often further divided and defined into concepts known as *parking MOG* and *working MOG*. The concept of parking MOG is concerned with how many aircraft can be physically parked in a given airfield's available ramp space. Some of the factors associated with parking MOG are a ramp's weight bearing capacity, taxiway widths, and the size and shape of the ramp. An airfield's working MOG is a much more detailed concept, one that involves more factors than those associated with a parking MOG. In addition to being concerning with available ramp space, working MOG also considers such factors as the number of aircraft

that can be serviced with fuel, maintenance, and aerial port operations, and aircrew related operations that must be performed during the aircraft's planned ground time. The types of questions that must be answered to determine a working MOG include the following issues: What is the refueling capacity in terms of delivery to the aircraft and stock replenishment? How many aerial port personnel and how much MHE equipment is available? How many aircrews can be billeted for aircrews requiring crewrest? What restrictions will the host nation put on the airfield's operations? (Mitchell, 1992: 1-2). Answering questions such as these helps to determine a working MOG. Comparing our previous general definition of MOG to the issues involved in determining a working MOG, we can see that the six major categories we examined in our general definition are most closely associated with the concept of working MOG. One final interpretation of the concept of MOG further illustrates the lack of one accepted definition. Smoothed MOG is another derivative of the MOG concept that is used by some planning personnel to "smooth the peaks in the air flow" (Brewer, undated: 1-2). This interpretation, along with parking MOG, working MOG, and others we have discussed highlights the absence of one, command-wide definition of MOG within AMC. While all of these numerous definitions of MOG currently in use have some degree of validity, none of them alone captures the overall concept of MOG.

Current Method of Determining Airfield Capacity

As a participant in several strategic airlift operations in recent years, in deployments such as those involved in Desert Shield/Desert Storm and Restore Hope in Somalia, AMC has been providing MOG estimates for some time. To estimate MOG values for a particular airfield, AMC planners typically rely on three basic items of data: the number of aircraft that can be serviced at one time, the number of hours per day that the necessary resources are available, and the average planned ground time for a particular type of aircraft (Stucker, 1996). The number of aircraft that can be worked at an airfield depends on several factors, such as ramp size and resource availability. The working hours are determined by factors specific to that given airfield, factors such as resource availability and limits on operating hours. Finally, average ground times are typically, but unfortunately not always, taken from the AMC Omnibus Plan for standardization (Berg and others, 1995: 4).

A specific MOG value is calculated by multiplying the number of aircraft that can be worked at one time by the number of hours per day resources are available; this figure is then divided by the aircraft's average planned ground time. Normally, MOG values are calculated with each of these three variables being expressed in whole numbers. For example, if an airfield can service five C-141 aircraft at one time, the resources are available 20 hours per day, and the planned ground time for C-141s is three hours and 15

minutes, then the MOG value for C-141s is estimated to be $(5 \times 20 / 3.25)$ which equates to approximately 31 C-141 aircraft per day (Stucker, 1996: 9).

X = 5 C-141 aircraft can be worked at a time
Y = airfield is operating 20 hours per day
Z = the standard planned ground time for C-141 aircraft is 3 hours and 15 minutes

$$(5 * 20) / 3.25 = \text{approximately 31 C-141 aircraft per day}$$

This calculation would normally be interpreted as a C-141 MOG value of five, because five C-141s could be accommodated at one time. This calculation would need to be reworked for each type of aircraft to determine the airfield's overall MOG.

This basic method of calculating airfield capacity in terms of MOG brings with it some inherent limitations. By using single standard ground times for a specific aircraft type at any given airfield, several potential differences among airfields and different servicing operations required by aircraft are lost. Strategic airlift operations may require offloading and onloading cargo at one airfield, refueling at another airfield, and then allowing the aircraft's crew to crewrest at still another airfield. The time an aircraft is required to be on the ground at an airfield depends significantly on which of these servicing requirements must be performed. For example, offloading and then onloading cargo normally takes more time than just refueling an airplane and resting the aircrew normally takes more time than aerial port, refueling, or maintenance operations; the

specific time required for an airplane's service needs must be determined and used in order to achieve more accurate MOG estimates (Weinberg, 1996).

Similarly, the use of a whole number for the variable of the number of working hours may contribute to inaccuracy in computing MOG values. Depending on constraints specific to a particular airfield, the value of the variable used to represent the number of operating hours per day that aircraft or aircrew tasks may be performed is dependent on which particular resource is required. At some airfields, billeting support for aircrews may be available 24 hours every day, while fueling support is available only for a 12 hour period on weekdays, and maintenance can be supported only during certain shifts. Potential differences such as these and others demonstrate that using one whole number to represent an airfield's operating hours can mask several important limitations.

Finally, representing the third variable used in the computation of MOG, the number of aircraft that can be serviced at one time, with a single number reduces the flexibility required in different servicing scenarios. In using our previous example, to say that five C-141s can be serviced at one time at a particular location-- which would typically be expressed as a C-141 MOG of five-- may be accurate for some servicing requirements but inaccurate for others; all resources required for aircraft servicing are seldom available for every aircraft at one time. Because the times required to perform different services can vary significantly, the estimated MOG value may be too high in situations in which several services must be performed and thus a considerable amount of ground time is consumed by the aircraft, but may be too low in situations when servicing

requirements can be performed simultaneously or quickly. Using a single number to represent all potential services required by an aircraft implies that resources are readily available for all aircraft simultaneously; this is normally not the case (Berg and others, 1995: 5; Cook, 1996).

Our discussion has highlighted the fact that there is no command-wide, formal process for determining MOG values within AMC. Although some common techniques are used in computing an airfield's MOG, such as the basic calculation shown previously, there is significant variability in the way values of variables used in computing MOG are estimated; this variability causes problems in finding consistently accurate MOGs which truly represent airfield capacity for AMC. Because there is no documented process for determining an airfield's MOG, there is significant variability in techniques used to estimate these values. In addition, because many different functional groups participate in estimating an airfield's capacity and each group has its particular area of expertise, this variability is as widespread as the number of groups involved in the process. For example, one of the fundamental items of data required in the current process of determining MOG is the measurement of available ramp space. This information is used to help determine the variable of how many aircraft of a certain type an airfield can accommodate at one time. Typically, specialized groups of people in AMC known as Tanker Airlift Control Elements (TALCEs) are responsible for completing this measurement as part of the airfield survey (Cirafici, 1995: 13). The absence of a documented way to measure this data causes potential inaccuracy, because the same

TALCE does not survey every airfield, or even necessarily the same airfield for different airlift operations (Berg and others, 1995: 10). This particular example illustrates a small part of the widespread variability in finding MOG values, and it demonstrates a primary disadvantage of the current lack of a standardized procedure for determining an airfield's MOG; MOG values are not reproducible.

Currently, AMC typically uses a MOG value to describe how many aircraft of a specific type can be accommodated at an airfield during a certain time period; using our previous calculation shown in figure one as an example, the C-141 MOG was five. Unfortunately, because there is no standardized process, and MOG values are calculated by different groups of people, each with their own expertise and understanding of what MOG is, a MOG value is only accurate for the airfield it was estimated for--it is not currently possible to use one MOG value to easily compute a comparable value for a different airfield; three primary factors contribute to this problem: the lack of a standard definition of MOG, the absence of a formal process for finding MOG values, and undocumented assumptions used in computing the values. The lack of a consistently applied definition of what MOG is contributes significantly to its tendency to become a situational value. As we discussed earlier, definitions of MOG vary significantly; not only are there different types of MOGs, such as parking MOGs and working MOGs, but there is also no command-wide concept of what MOG describes. Some consider it to be the number of a particular aircraft type that can be worked on simultaneously-- the definition used in our previous calculation-- while some planners assume it to be the

number of aircraft that can be received, serviced, and launched within planning factor ground times (Berg and others, 1995: 7).

The confusion surrounding the MOG concept that is caused by the lack of a formal definition is aggravated by the absence of a consistent process for calculating MOG values. Although our previous example showed one technique that is currently used to estimate MOG values, it is not a universally-accepted method across AMC. In addition, even that calculation has potential problems with accuracy. Even though the previous example illustrated the use of specific variables to reach a MOG value, the fact that these variables are typically represented by a single number causes their accuracy to be suspect. Currently, no mathematical formula is used to determine MOG values. One of the primary reasons behind the absence of such a formula is the variety of specialties of each of the people involved in the MOG process. Each group of people involved has a functional specialty and each group wants to know, in general, how many aircraft an airfield can accommodate with respect to that particular specialty. Logisticians may concentrate on resource availability while planners may focus on factors such as ramp size and weight-bearing capacity. Because these groups have their own areas of expertise and view MOG in terms of how it applies to their specialties, AMC has not yet developed a formula that accurately aggregates all of the inputs which determine MOG (Stucker, 1996: 10).

The final problem that contributes to the MOG calculation process not generalizing well across different airfields is the lack of documented assumptions made

by those involved with determining these values. Obviously, it is not possible to calculate an airfield's MOG without making certain assumptions. Factors such as the availability of resources and how much ramp space will be available must be assumed to calculate a MOG. However, again because of the lack of a formal process, and due to the large number of different groups who participate in computing an airfield's MOG, assumptions used in estimating MOG values are not well documented and thus are not standardized across AMC. One additional reason for this lack of documented assumptions lies in the fact that each participating group has its own area of expertise--assumptions used by one functional group which affect an airfield's MOG value may be obvious to them, but not at all obvious to other functional groups (Berg and others, 1995: 8).

Chapter Summary

Despite the fact that AMC has been involved in several recent strategic airlift operations, there is currently no standardized definition of MOG, the term AMC uses to describe airfield capacity. The numerous definitions currently in use represent the fact that each group of experts who are involved in worldwide AMC deployments have their own individual interpretations of the MOG concept. While none of the various definitions are incorrect, each fails to capture the overall concept of MOG. Similarly, there is no standard procedure in AMC for determining MOG values for an airfield. Although there are informal methods for estimating airfield capacities which consist of

common techniques, the variability among these different and inconsistent methods causes inaccuracy and inefficiency in airfield operations. Having established the lack of a current common framework for defining and computing MOG values, we will now examine a model that may help to compute more accurate values of capacities for AMC airfields.

III. Examining the Logic of the ACE Model

How the ACE Model Defines Airfield Capacity

In AMC today, there are many different variations of definitions for MOG, the term AMC planners, analysts, and operating personnel use to describe airfield capacity. Currently, the interpretation of what MOG is depends on the perspective and functional expertise of the group being asked (Tyler, 1996). Airfield capacity depends on several important factors such as the size, shape, and weight bearing capacity of the parking area, the availability of resources used to service aircraft, the reason the aircraft is stopping at the en route base (for example, a single task such as refueling versus multiple tasks such as refueling, offloading and unloading cargo), and the operating hours of the airfield.

In 1994, the Mobility Division of the Directorate of Forces, HQ U.S. Air Force, and the Force Projection Directorate in the Office of the Secretary of Defense, requested that RAND Corporation develop a method that improves upon the current MOG approach of measuring airfield capacity; the ACE Model is the result of RAND's efforts in responding to that request.

In contrast to the variety of definitions currently in use in AMC for MOG, the ACE Model, in an attempt to use one precise definition for airfield capacity that captures the major factors that affect it, such as operating conditions, resources, and aircraft traffic, describes airfield capacity with the following specific definition: the maximum number of aircraft of the kinds specified that can be routed through and supported by a particular

airfield during a specified day, given specified operational conditions and specified resource constraints (Berg and others, 1995: 3). As opposed to a single number used to represent a MOG value, which typically describes how many of a specific type of aircraft an airfield can handle at one time, the ACE definition of airfield capacity is a set of numbers which refers to a range of capabilities representing different combinations of aircraft and missions that can be accommodated in a day; this range will change as mission demands, operating conditions, and airfield resources change.

Specifically, the more of one type of airplane handled per day, the fewer of another kind the airfield may be able to accommodate. The various combinations of aircraft in the achievable range will vary with the service requirements those aircraft demand. For example, the more maintenance, fuel, or cargo-handling equipment a group of aircraft require, the longer their actual ground times are likely to be and thus the fewer of them the airfield will be able to accommodate. As a strategic airlift operation evolves and the type and mix of aircraft used at a particular field change, that airfield's capacity will also change. In addition, the capacity may also be affected by increases or decreases in resources located at the airfield which are used to service the aircraft (Stucker, 1996: 14).

The Concept Behind the ACE Model

In general, the Airfield Capacity Estimator Model uses an analytical approach to determine an airfield's capacity. This type of approach incorporates some of the

simplicity of the MOG approach, along with other more complex methods. Even so, the fundamental logic used is relatively straightforward; most importantly, it allows the significant number of airfield resources involved with an airfield's capacity to be modeled, thus limiting the analysis required by planners of the interrelationships among the applicable resources and processes. Figure 1 depicts the overall operation of the ACE Model. It analyzes the functional operations of aircraft generation (maintenance), aerial port (loading and offloading cargo), and fueling, and it isolates the constraining resource for each case.

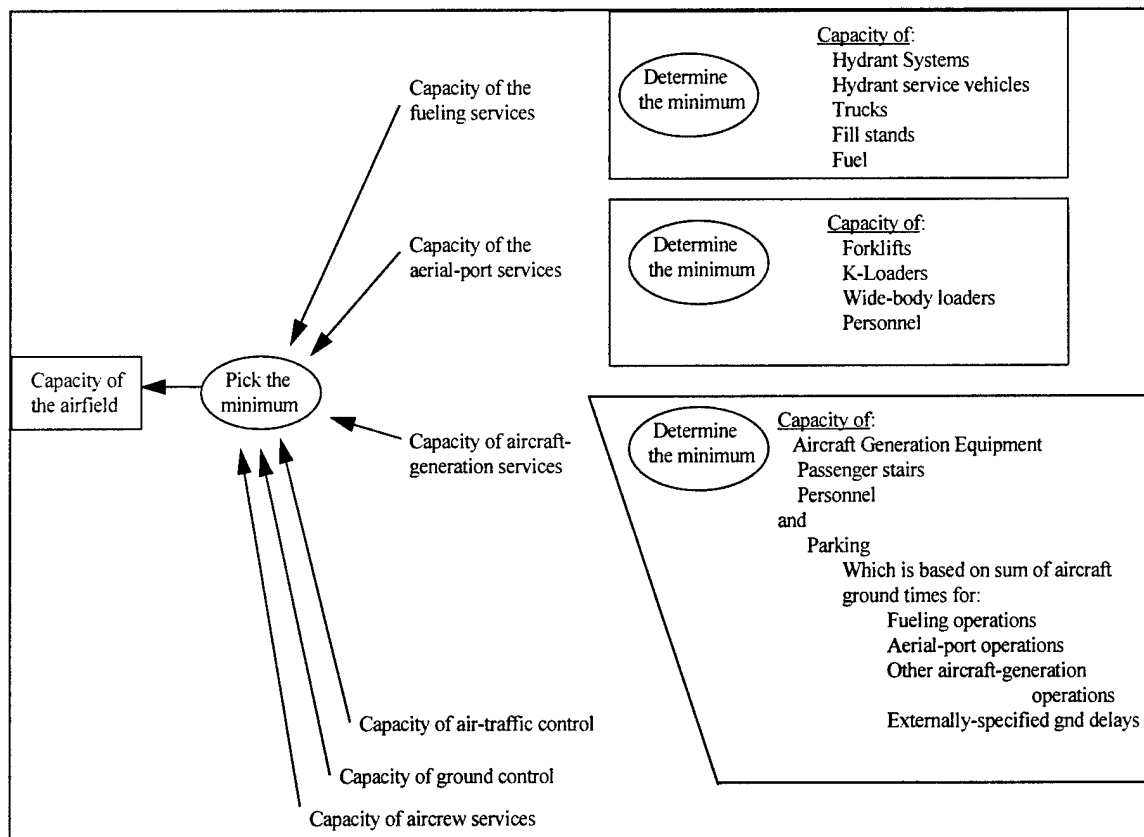


Figure 1. Structure of the ACE Model (Berg and others, 1995: 15)

Then the model compares this information with the limiting operations among air traffic control, ground control, and aircrew services. Finally, the model identifies the minimum in all of these functional areas to estimate the airfield's capacity (Berg and others, 1995: 15).

The ACE Model relies on certain data inputs to achieve its outcomes; this data will be provided by AMC planners and analysts. The model is constructed to depend on three different categories of data, global data, airfield data, and mission data. It separates those categories into distinct groups:

1. Global data represents characteristics of aircraft and cargo that do not change from one airfield or operational scenario to the next (examples of global data are the number of fueling ports on an aircraft, its fuel, passenger, or cargo capacity, or the capacity and speed of fuel trucks or k-loaders).
2. Airfield data refers to the physical characteristics of the airfield itself (parking areas available for mobility operations, built-in fueling systems, distances from the aerial port and tanker truck fill stands, and daily hours of operation are examples of airfield data) and the quantity and availability of ground personnel and equipment.
3. Mission data describes the airlift and tanker missions to be used in the traffic flow (factors such as the types of aircraft used, required

maintenance inspections, necessary servicing, passenger and cargo mixes, and loading/unloading requirements comprise mission data) (Berg and others, 1995: 23-24).

Examining the Basics of the Analytical Method

The fundamental relationship between airfield resources and the particular airfield's capacity is captured in the following formula in which the variable C represents the capacity of the resources at the airfield used to service aircraft (capacity is defined in this equation as the number of aircraft of a particular type requiring a particular set of services that can be serviced at the airfield in one day). R_i describes the quantity of a specific resource. A_i indicates the hours per day that the resource is available. S_i represents the time required of that particular resource to service one aircraft.

$$C = \text{Minimum of } (R_i * A_i / S_i)$$

In using this model, AMC planners would input data on the resources and their availability and on the specific tasks that would be required to perform a particular mission. The model would use this information to estimate the service times associated

with those tasks and resources and would then determine the number of aircraft the resources could support in one day (Stucker, 1996).

The basic iterative process that the model uses to estimate an airfield's capacity is summarized in the following three steps.

1. Initially, the model calculates the total service time available for each airfield resource being considered (such as the number of fuel trucks or k-loaders) and multiplies this figure by the average amount of time each unit of resource is available during the day(s) under consideration.
2. Secondly, the model calculates the time needed from each resource to service each type of mission (such as the type of aircraft and the type of ground servicing required) to be included in the particular day's throughput for the airfield. These times depend on the type of aircraft, the types and quantities of any cargo being handled, the number of any passengers to be loaded/unloaded, the amount of fuel to be loaded, and the types of maintenance or other aircraft generation services to be performed.
3. Finally, in proportion to the service time needed for a particular mission type, the model decrements the total service time available from each resource. To illustrate this process, if one type of C-141 mission the airfield accommodates requires three hours of k-loader time and if ten of these missions are to be included in the day's throughput, then 30 hours of k-loader time is subtracted

from the total number of k-loader hours available that particular day. This step is then repeated as necessary, adding more different types of missions or more missions of each particular type until the available time of one or more of the airfield's resources is totally consumed (Stucker, 1996: 12).

Although the fundamental logic of this approach is relatively straightforward, intricate relationships among some of the variables involved in the computations must be accounted for; this requirement makes the process complex. For example, the service times calculated in the second step may depend on exactly where aircraft are parked (because the exact location of the aircraft's parking spot affects the amount of k-loader time spent driving between aircraft and the cargo offloading point); the refueling and cargo/passenger loading/unloading times can affect the amount of time that crew chiefs spend at the aircraft (thus affecting aircraft generation times); and mission-specific requirements for parallel or sequential accomplishment of some tasks (such as cargo loading/unloading and refueling) may affect an aircraft's ground time, thus influencing available parking space and time for other airplanes. The following examples will illustrate how the ACE Model accommodates the relationships among the primary variables that the model considers (Berg and others, 1995: 16).

Calculations With Multiple Resources

In a situation where there are only two types of resources, each of which performs one task on an airplane, and assuming that one task must be completed before the other task can be started, then the mathematical formula that would represent that case is:

$$C = \text{Minimum of} \quad \begin{cases} C1 = R1 * A1 / S1 \\ C2 = R2 * A2 / S2 \\ Cp = Rp * Ap / (S1 + S2) \end{cases}$$

in this case, the subscripts 1 and 2 represent the two different resources. C1 is the capacity of the first resource, expressed in the number of that mission type (for example, the type of aircraft and type of servicing required by that aircraft) that it can service per day, C2 is the capacity of the second resource, and Cp represents parking capacity. The logic of the ACE Model that this formula represents is that each airplane serviced at the airfield uses resource one for S1 minutes, resource two for S2 minutes, and it must remain on the ground, consuming ramp space and time, for S1 + S2 minutes. This final term is an integral part of the ACE Modeling logic, because it accounts for the relationship between multiple resources and the fact that while an aircraft is being serviced, it is taking up parking space and service time.

An example of a case closely related to the previous example further illustrates the fundamental concept of these relationships. Given a situation in which there are two

resources required by an aircraft which can be consumed concurrently, not in sequence as before, then the mathematical formula would be:

C = Minimum of	$\begin{cases} C1 = R1 * A1 / S1 \\ C2 + R2 * A2 / S2 \\ Cp = Rp * Ap / \text{Max}(S1, S2) \end{cases}$
----------------	---

This equation represents the fact that the longer of the two tasks represents the parking time or ground time, not the sum of the two tasks as in the previous example. It is important to note that only the results of the parking equation may differ according to whether the tasks performed by the two types of resources can be performed simultaneously or whether they must be accomplished sequentially.

Calculations With Resources and Multiple Uses

The flexibility of the ACE Model is further demonstrated in its ability to model the situation in which there is only one type of resource that is used to perform two different tasks on an airplane; an example of such a resource is manpower. Given that each aircraft requires two services, and each service takes a set amount of time, then those tasks require a total of $S1 + S2$ minutes of manpower time, regardless of whether the tasks are performed simultaneously or sequentially. In this case, the subscripts represent the two different tasks. The capacity of the manpower resource, in terms of aircraft per day, would be expressed as:

$$C_m = R_m * A_m / (S_{m1} + S_{m2})$$

When a resource has multiple uses, the formula used to represent parking capacity is less intuitive because it depends on the status of all involved resources, including manpower. There are two distinct possibilities concerning manpower. In a situation where manpower is limited at the airfield, then the same personnel may perform both tasks on the aircraft; in this case, the parking time would be $S_1 + S_2$, and the parking capacity would be:

$$C_p = R_p * A_p / (S_{m1} + S_{m2})$$

Conversely, if workers are plentiful and more personnel are working on each aircraft, then the parking time could be as little as the maximum of (S_1, S_2) . In this particular case, parking capacity would be estimated with the following formula:

$$C_p = R_p * A_p / \text{Max}(S_{m1}, S_{m2})$$

Because the model estimates the maximum capacity of the airfield, the formula's logic assumes that as many aircraft as possible are worked per day at any time possible.

These equations demonstrate that the quantity of the resource available at the airfield is important in determining service time.

Calculations With Multiple Parking Areas

The ACE Model is also able to accommodate situations in which there are two resources (for example, manpower and parking) and two parking areas. Logically, the manpower can be allocated among work in either parking area, while the ramp space is specific to each area; it is fixed and cannot be moved. To determine the maximum airfield capacity in this case, the model allocates the manpower resource between the two parking areas. The model accomplishes this by first estimating the capacity of each different parking areas assuming it has all of the manpower resource. These estimates are represented by $C1^*$ and $C2^*$ in the following formulas:

$$C1^* = \text{Minimum of} \quad \begin{cases} C1m = Rm * Am / S1m \\ C1p = R1p * A1p / S1p \end{cases}$$

and

$$C2^* = \text{Minimum of} \quad \begin{cases} C2m = Rm * Am / S2m \\ C2p = R2p * A2p / S2p \end{cases}$$

After this step is complete, the model then selects the parking area with the larger parking area capacity to utilize first. Then the equation for that particular parking area is examined to determine whether or not all of the manpower resource has been used there. If it has, then that $C1^*$ or $C2^*$ represents the capacity of the entire airfield. However, if all of the manpower is not being consumed in that parking area, then the model calculates an adjusted capacity for the other parking area, with the assumption that the more productive area is already being used to full capacity. In our example, if we assume that area one has the higher capacity, then we can represent the amount of time of the manpower resource that is used is $C1^* * C2^*$, and the combined capacity of areas one and two is expressed as:

$$C = C1^* + \text{Minimum of } \begin{cases} \{C2m = [(Rm * Am) - (C1m^* * S1m)] / S2m \\ \{C2p = R2p * A2p / S2p \end{cases}$$

Calculations With Multiple Missions

The final example that demonstrates how the ACE Model accommodates the relationships among the primary variables deals with airfields servicing aircraft engaged in different missions. For simplicity, this example assumes that the airfield has only one type of resource, one parking area, the resource performs only one operation on each aircraft, the operation being performed at the airfield is fueling, and that aircraft on one mission are flying further and so they require more fuel than aircraft on the other type of

mission. Because some aircraft need more fuel than others (depending on which type of mission they are flying), service times between the two types of missions will differ. The subscripts in the following mathematical formulas will represent the different mission types. If the airfield were servicing only airplanes conducting the first type of mission, then that mission's capacity would be represented by:

$$C1 = R * A / S1$$

Similarly, if the airfield were servicing only aircraft engaged in the second type of mission, that capacity would be expressed as:

$$C2 = R * A / S2$$

When the airfield services airplanes engaged in both types of missions, the following formulas are used:

$$C1 = R * A1 / S1$$

$$C2 = R * A2 / S2$$

$$A = A1 + A2$$

where A_1 and A_2 represent the portions of the resource's total availability A (which is the work time of the resource) allotted to each of the two different mission types. This type of problem requires apportioning that availability, so that the correct capacities can be computed; AMC planners would be responsible for allocating the availability to the different types of missions according to the requirements and objectives of the deployment.

These examples demonstrate the core of the ACE Model, relating resource availabilities and capabilities to airfield capacity. The model computes the service time (in minutes per aircraft) for each resource shown in Table 1.

Table 1. Resources Modeled by ACE (Berg and others, 1995: 25)

Resources Modeled by ACE	
Aircraft Generation	Fueling
Aerospace-Ground Equipment	Hydrant Systems
Ground power units	Type II systems
Gaseous oxygen carts	Laterals
Liquid nitrogen carts	Pumps
Liquid nitrogen trucks	Type III systems
Liquid oxygen carts	Pumps
Oil carts	Fill Stands
Service stands	Hydrant Service Vehicles
Low-reach	R-12s
Medium-reach	Commercial HSVs
High-reach	Tanker Trucks
De-ice trucks	R-9s
Calivars	R-11s
Passenger stairs	Storage & resupply fuel
AGS personnel	
Aerial Port	Aircrew support
Material Handling Equipment	Aggregate
Forklifts	Air Traffic Control
K-loaders	Aggregate
25K-loaders	
40K-loaders	Ground Control
60K-loaders	Aggregate
Wide-body elevator loaders	
Cochran	Parking
Wilson	Ramp space
TA-40	
60K-loader proxy	
AP personnel	

That time, which is expressed as S_i , is then divided into $R_i A_i$. R_i is the number of units of the resource and A_i represents their availability in minutes per day. This computation gives the capacity of that resource in terms of the number of aircraft that it can service in one day. In calculating the resource-service times, the model accumulates information for computing the parking time, which is expressed as S_p . Our previous examples demonstrate that parking time is a complex function of the individual task and operation times, depending on how they interact with each other. In contrast to aerial port, fueling, and aircraft generation, the Airfield Capacity Estimator Model considers the factors of air-traffic control, aircrew support, and ground control in a general way. For each of these factors, the model uses a single number to represent the number of airplanes that can be accommodated by each of these factors in one day. It then compares the daily capacity of these operations with the daily capacities of the four factors modeled in detail, to determine whether or not they constrain the overall capacity of the airfield (Berg and others, 1995: 17-25).

Model Summary

The ACE Model estimates the capacity of specified resources to support aircraft engaged in particular missions. AMC planners can effectively employ the model by inputting information such as specifications of an airfield, quantity of support equipment available for servicing aircraft, hours of operation of the airfield, and the type and number of missions to be analyzed (again, a mission type specifies a particular type of aircraft and

the ground servicing the aircraft requires). The ACE Model determines capacity one mission type at a time and in a user-determined sequence. It calculates the maximum number of aircraft of one mission type the airfield resources can support, it lists the resources used in supporting those aircraft, and it highlights the resource or resources that constrain the number of that particular type of mission that can be serviced. After estimating the maximum number of aircraft engaged in the first mission type that can be accommodated, planners specify the number of aircraft they wish to assign to that first mission and instruct the ACE Model to allocate resources for servicing just those aircraft. After that step, through an iterative process, the planners can then systematically allocate the remaining capacity of the airfield's resources to support aircraft engaged in other missions (Stucker, 1996: 12).

The ACE Model accommodates seven major functional areas which affect an airfield's capacity: fueling, aerial port, aircraft generation, aircrew support, parking, air-traffic control, and ground control. Figure 2 illustrates the aircraft, aircrew, and airfield operations currently modeled by the Airfield Capacity Estimator and thus demonstrates a typical type of stop over for a strategic airlifter--in this case, the extended-servicing stop.

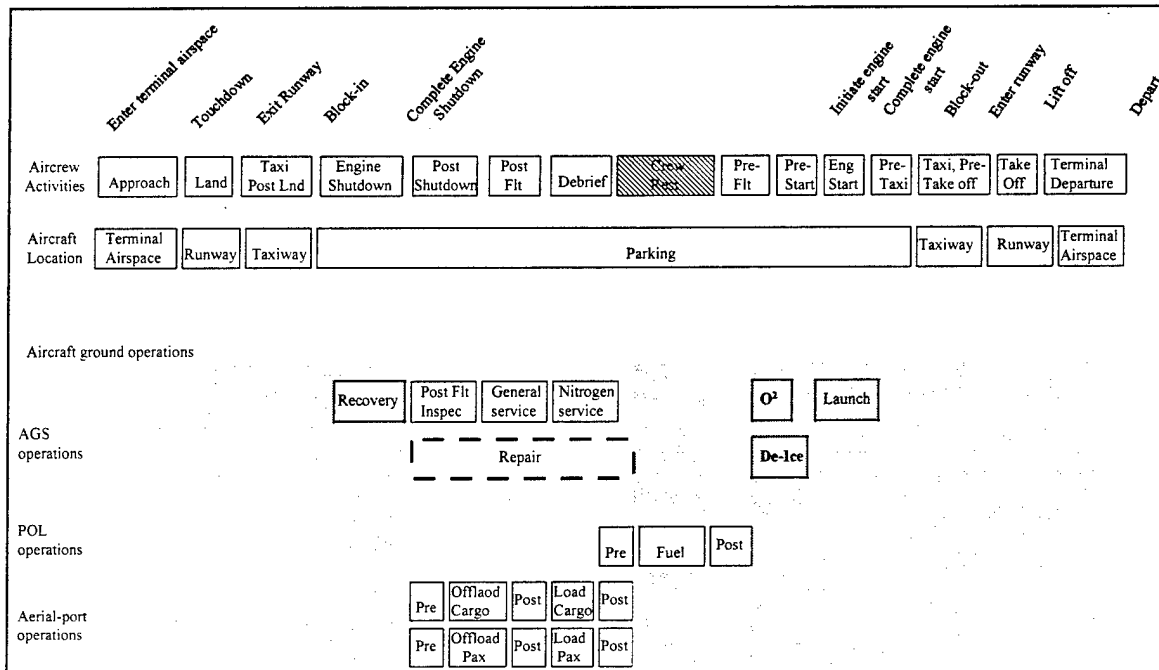


Figure 2. Aircraft and Airfield Activities (Berg and others, 1995: 22)

In general, for the three most prominent factors modeled, aerial port, fueling, and aircraft generation, the Airfield Capacity Estimator models resources and the tasks those resources perform in completing operations on aircraft. However, there is a slight difference in how the model views resources, tasks, and operations among these three factors. In considering aircraft generation, operations are viewed as composed of single tasks and the focus is on the operations. The 12 operations listed in Table 2 are modeled and the specific resources also shown in the table are allocated directly to those operations.

Table 2. Operations and Resources of Aircraft Generation (Berg and others, 1995: 23)

Operations and Resources Modeled in Association with Aircraft Generation	
Operations	Resources
Recovery	Aerospace-ground equipment
Inspection	Ground power units
Through-flight	Gaseous oxygen carts
Post-flight	Liquid nitrogen carts
Pre-flight	Liquid oxygen carts
Servicing	Oil carts
Pre-fuel	Service stands
Transfer-fuel	Calivars
Post-fuel	De-ice trucks
General	Passenger stairs
Nitrogen	AGS personnel
Oxygen	
Deicing	
Maintenance	
Launch	

Conversely, for fueling and aerial port operations, the model assumes that distinct operations such as refueling and loading cargo are composed of series of tasks; specific resources and times are related to those tasks before those tasks are aggregated into operations. For example, refueling an aircraft involves several tasks such as filling a fuel

truck, driving it to the airplane, connecting its hose to the aircraft, transferring the fuel, etc. Again, the resources and times involved with these tasks are assigned to them before the tasks are aggregated into the operations (Stucker, 1996).

Chapter Summary

To avoid potential confusion over the meaning of airfield capacity in relation to the Airfield Capacity Estimator, this model offers a specific definition of the term. In addition, the model employs a very defined, systematic process to use planner-input data to determine an airfield's capacity. In general, this model is able to compute accurate airfield capacity estimates because of its ability to relate an airfield's resource capacities to its overall maximum capacity.

The Airfield Capacity Estimator Model was developed by RAND to comply with the DoD's need for a model that improved on the MOG method of determining an airfield's capacity. Because of the large number of contingencies and operations the United States military is currently involved in, coupled with the fact that this number is not likely to decrease significantly in the foreseeable future, the DoD requested that a suitable model be developed in the short term. The ACE Model complied with this stipulation, in addition to being a straightforward approach to determining airfield capacity.

Although more complex models have been in development for some time, optimistic estimates for their implementation are approximately six years into the future

(Merrill, 1996); however, the ACE Model is already developed. Initial evaluations by RAND show that the model is mathematically sound and appears to demonstrate validity during test runs; further testing by AMC planners and analysts should continue. Once AMC planners and analysts are fully convinced of the ACE Model's validity with real world data, the model should be considered for implementation.

IV. Summarizing the MOG and ACE Model Approaches:

Current Approach to Defining and Computing MOG

Currently in AMC, there is considerable confusion and disagreement concerning the concept of airfield capacity. Several different groups of people have an interest in knowing how many, and what mix of strategic airlift aircraft an airfield can accommodate during a given period of time. In addition to numerous planners and analysts, groups of operating personnel, such as civil engineers, maintenance personnel, and senior military leaders have vested interests in knowing exactly how many strategic airlifters can be accommodated in a given time period by an airfield being used in a strategic deployment or operation. The specific functional expertise of each of these groups, coupled with their different objectives and roles during deployment, tend to cause each group to view airfield capacity in terms of its own expertise. This dynamic has caused several different definitions to evolve concerning the acronym known as MOG, the term AMC currently uses to describe airfield capacity. In addition to various definitions of MOG, there are also different types of MOG; parking MOG, working MOG, and smoothing MOG are some examples of the different types of MOG that have been adopted as meaningful, (and in reality, confusing) adaptations of MOG (Weinberg, 1996).

Not only is there no one, command-wide accepted definition of MOG, there is also no documented, standardized method of calculating a MOG value; this lack of a standardized method to compute MOG leads to inaccurate MOG values and the fact that MOG values, once computed, are not reproducible. Although common processes are

used in some cases, at least some degree of variability in the way MOG values are reached does exist because there is no command-directed method currently in use. Furthermore, there is a significant potential for inaccuracy in computed MOG values exemplified in one of the most common methods used to calculate a MOG. Chapter two discussed the equation that is typically used to calculate a MOG: the number of aircraft an airfield can service at one time, the number of hours per day that necessary resources are available, and the average ground time for a particular type of aircraft. AMC normally represents each of these variables with single numbers; however, when these variables are expressed with single numbers, important differences among airfields and operations are lost and thus several important relationships among the factors which affect an airfield's capacity are often masked (Stucker, 1996: 10).

The ACE Approach to Defining and Estimating Airfield Capacity

The Airfield Capacity Estimator (ACE) Model is a model that was developed by RAND Corporation at the request of the DoD. The ACE Model specifies a distinct definition of airfield capacity that can be used by both planners and operational personnel which could serve to help alleviate the confusion that currently exists concerning the concept of MOG. In addition, the ACE Model uses a systematic methodology to compute an airfield's maximum capacity. This particular model, by way of an analytical approach, accounts for the intricate relationships that exist between the factors that affect an airfield's capacity. Specifically, the ACE Model identifies seven items as primary

factors: aircraft generation, aerial port, fueling, parking, aircrew support, air-traffic control, and ground control. The first four of these are considered in great detail by the ACE Model, while the other three are modeled more simply (Berg and others, 1995: 25). The core of the ACE Model is based on its ability to account for the relationships among these factors, and this capability is its most significant advantage over the current MOG-based approach.

Recommendations

Although the ACE Model is a significant improvement over the informal process currently used to calculate MOG values, if it is adopted by AMC, there are some steps that could be taken to further increase its potential usefulness to AMC planners. The model could be made more accessible to planners and analysts by making it compatible with personal computers used by applicable AMC personnel. Secondly, designers of this model can consult with AMC users to determine whether or not it is necessary to include a more detailed analysis of air-traffic control, ground control, and aircrew support factors that affect airfield capacity. Due to rapidly changing host nation considerations and volatile deployment-specific requirements, modeling air-traffic control, ground control, and aircrew support factors in detail may be infeasible; however, the potential usefulness of analyzing these three factors in more detail should be explored. Finally, the model could potentially be further expanded to include some of the more sophisticated aspects of airfield operations. One example of these unique requirements is known as double-

blocking; when an aircraft double-blocks, it receives different services in different parking areas. For instance, an aircraft may land, taxi to a parking area, offload cargo, and then taxi to another parking area for refueling. Modeling these types of requirements would increase the accuracy and detail of information that the model provides (Berg and others, 1995: 170).

Chapter Summary

Numerous interviews with a broad cross-section of AMC and Headquarters Air Force airlift experts, along with my own personal operational experience, have highlighted the confusion in current AMC methods of defining and determining an airfield's capacity. At the request of DoD planners, RAND has developed a model that uses an analytical approach to determine an airfield's capacity. By systematically modeling the relationships among the primary factors which influence how many aircraft and what mix of aircraft an airfield can accommodate during a specified time period, the ACE Model appears to do a competent job of providing an accurate estimate of an airfield's maximum capacity. AMC planners, analysts, and senior military leaders should carefully consider the Airfield Capacity Model as a valid solution to the command's short-term quest for a straightforward way of estimating airfield capacity.

Appendix

Acronym List

ACE	Airfield Capacity Estimator
AMC	Air Mobility Command
ATC	Air Transport Command
DoD	Department of Defense
MOG	Maximum on the Ground
MHE	Material Handling Equipment
ATC	Air Traffic Control
TALCE	Tanker Airlift Control Element

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Vita

Captain Marty Morrison was born near Bitburg AB Germany on 13 November 1965. He graduated from Westlake High School in 1983, and entered undergraduate studies at the United States Air Force Academy (USAFA), Colorado Springs, CO. He graduated with a Bachelors of Science degree in Behavioral Science in 1987.

He received his regular commission upon his graduation on 27 May 1987. After completing Undergraduate Pilot Training at Reese AFB, Texas, his first assignment was flying C-141B aircraft at Charleston AFB, South Carolina. While at Charleston AFB, he flew several missions in support of Operations Just Cause, Desert Shield, and Desert Storm. In December 1992, Captain Morrison was selected to become an instructor pilot and flight examiner at the C-141 schoolhouse-- Altus AFB, Oklahoma. In May 1994, he was chosen by Lt Gen Armstrong, Twenty-First Air Force Commander, to serve as his aide-de-camp. Captain Morrison fulfilled those duties until September 1995, when his studies began at the School of Logistics and Acquisition Management, Air Force Institute of Technology under the Advanced Study of Air Mobility (ASAM) program.

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13. ABSTRACT (Maximum 200 Words) Airfields are as important to the American military's ability to rapidly project power or provide relief as are the aircraft that deliver the necessary people and material to points around the globe. In the past, airfield capacities have been estimated for deployment planning purposes primarily on the basis of three items of information: maximum-on-the-ground, which is the largest number of aircraft of a particular type that can be parked on the airfield at the same time; aircraft parking equivalencies, which are the ratios telling how many aircraft of other types can park in the same space as a standard aircraft; and standard service times, which are the average lengths of time different aircraft spend on the ground when they land. This approach, although simple and mathematically sound, has led to unreliable and inaccurate measurements of airfield capacities in the past. This has contributed to overestimates of the ability of the airlift system to move forces and supplies into overseas theaters of operation. To achieve more accurate estimates of airfield capacities, a model must be implemented that more closely models factors that affect an airfield's throughput capacity--the airfield capacity estimator (ACE) model could be that tool.				
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a. Highly b. Significant c. Slightly d. Of No
Significant Significant Significance

5. Comments (Please feel free to use a separate sheet for more detailed answers and include it with this form):

Name and Grade

Organization

Position or Title

Address