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MEASURING AIRLIFT EFFECTIVENESS

IN THE NEW MILLENIUM

BY

ADAM J. MCMILLAN

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About the Author

Major Adam J. McMillan received a regular commission through the Reserve Officer Training Corps at Arizona State University in 1984. He graduated from Undergraduate Pilot Training at Reese Air Force Base (AFB), Texas, in 1986. From 1985 to 1990 he was assigned to the 438th Military Airlift Wing, McGuire AFB, New Jersey, where he was a C-141 airdrop and air refueling aircraft commander, instructor pilot, squadron Safety Officer, Pilot Scheduler, Mission Control Officer, and Tactics Officer. While there, he flew the first Intermediate Nuclear Forces missions into Moscow and the initial airlift element to the Persian Gulf during DESERT SHIELD. In 1990 he became a T-38 Instructor Pilot at the 82d Flying Training Wing, Williams AFB, Arizona. Along with teaching students advanced piloting, he was a Flight Commander, Supervisor of Flying, Runway Supervisory Unit Control Officer, and Special Assistant to the Wing Commander for Base Closure activities. In 1993, he joined the Combined Test Force at Edwards AFB, California, performing duties as C-17 Operational Test Pilot, C-17 Instructor Pilot, C-17 Examiner Pilot, and T-38 Chase Pilot. In 1995 he moved to Scott AFB, Illinois, where he joined the Headquarters Air Mobility Command staff as the Chief of the C-17 Follow-on Operational Test and Evaluation program. He then attended the Army's Command and General Staff Officer College in 1997-1998 and the Air Force's School of Advanced Airpower Studies (SAAS) from 1998-1999. Major McMillan has a bachelor's degree in Computer Systems Engineering, a master's degree in Aeronautical Sciences from Embry-Riddle, and a master's degree in Airpower Arts and Sciences from SAAS. He is a senior pilot with over 3,500 flying hours and will continue to McChord AFB, Washington, as a C-17 pilot upon graduation from SAAS. He is married to Major (retired) Linda L. McMillan and they have two daughters and a son.

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Abstract

Since the birth of strategic airlift during World War II, the major measurements of airlift effectiveness have been based on tonnage delivered. As our nation's requirements expanded and airlift capabilities improved, these measurements evolved from tonnage per month, tonnage per day, ton-miles per month, ton-miles per day, million ton-miles (MTM), and finally settled on million ton-miles per day (MTM/d). While "getting there the fastest with the mostest" was a good paradigm for the Cold War, the international environment has greatly changed since the demise of the Soviet Union and we now need a paradigm based on getting the "right stuff" to the "right place, at the right time." In this paper, two case studies are studied to determine how and why the airlift community centered on tonnage delivered as the primary measurement of strategic airlift effectiveness. The premise is that the "Hump" operation during World War II and the Berlin crisis shortly after the war not only proved the efficacy of airlift, but also firmly seated the use of tonnage delivered as the primary metric through today. But as the Air Force is increasingly called upon to support national security objectives in the post-Cold War world, as the Air Force moves towards an expeditionary posture, and as airlift capabilities and requirements continue to expand, we need a better way to measure airlift effectiveness. The purpose of this paper is to present an alternative methodology than just tonnage delivered to evaluate airlift's effectiveness. This methodology uses a system-of-systems approach to compare airlift capabilities to actual scenario

requirements—an area where the current overall metric, MTM/d, is severely deficient. The flexibility of this new methodology provides the user with a way to evaluate airlift effectiveness for current situations, planned scenarios, and future airlift proposals. Ultimately, the hope is this paper will stimulate others to rethink how airlift is evaluated and to provoke change. Research was conducted using primary and secondary sources to include personal interviews, staff packages, white papers, staff studies, USAF Science Advisory Board reports, major command and higher headquarters briefings, the library, and the internet.

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Chapter 1

Introduction

In general, whoever occupies the battleground first and awaits the enemy will be at ease; whoever occupies the battleground afterward and must race to the conflict will be fatigued.

— Sun-tzu
The Art of War, c. 500 B.C.

Getting thar fustest with the mostest.

— Nathan Bedford Forest
Confederate General, c. 1864

The United States Air Force (USAF) needs an alternative methodology to evaluate the effectiveness of airlift. Since airlift was first used as a viable force enabler in World War II, the overarching metrics for measuring airlift effectiveness have been based on the movement of the maximum amount of cargo in the shortest time period. This methodology is primarily based on getting there the "fastest with the mostest." Since the end of the Cold War, and with the Air Force adopting an expeditionary force structure, we need to change to a methodology based on getting there with the "right stuff, right place, at the right time."

The End of the Cold War and the EAF

During the Cold War, the U.S. relied heavily on robust forward basing, extensive infrastructure, and a large military to thwart global aggression. But since the end of the

Cold War, the USAF has reduced its active-duty force by 36 percent and its overseas basing by 60 percent—while Air Force deployments have increased four-fold.[1]

Admittedly, while the world is now relatively safe from nuclear armageddon, it has also become more complicated. US national security has shifted from the main goal of thwarting communism to the multiple goals of promoting worldwide democracy, enhancing global security and peace, expanding global economy, and countering the proliferation of weapons of mass destruction.[2] As events since the end of the Cold War have shown (e.g. Haiti, Somalia, Bosnia, and Kosovo), the US has increasingly become involved with a myriad of global issues in a way that would not have been feasible before the demise of the Soviet Union.

As just one instrument of American power (the others being diplomacy, economics, and information), the military likewise must change. To support US national security strategy, our national military strategy has adopted the objectives of *Shape*, *Respond*, and *Prepare Now*. Building on the premise that America will remain globally engaged to create conditions favorable to US interests and to enhance global security, the military will help *Shape* the international environment through deterrence, peacetime engagement activities, and active participation in leadership alliances. To do this, it must be prepared to *Respond* to a spectrum of crises ranging from humanitarian assistance to major theater war. But since the world today is unstable and uncertain, the US armed services must *Prepare Now* to ensure they maintain the military superiority necessary to empower our global leadership.[3] As just one component of the DOD, the USAF must also change if it is going to meet our national and military security objectives.

No longer can the USAF rely on forward basing, extensive support infrastructure, and large pools of personnel to accomplish its mission. But despite an active duty force that has been greatly reduced since early 1990, Air Force deployments have drastically increased. As of early 1998, the USAF had over 14,000 people deployed overseas to conduct operations in Saudi Arabia, Kuwait, Bahrain, Diego Garcia, Vicenzia, Tuzla, Tazar, and Korea.[4]

To meet the challenges posed by the international environment and to meet the demands of our national security policy, the USAF has decided to take an expeditionary approach. The Expeditionary Air Force (EAF) is an innovative vision for how to organize, train, and equip the USAF. It will create an environment and mindset that capitalizes on the unique characteristics of aerospace power: speed, range, flexibility, and precision.[5]

While the EAF is the vision, the Air Expeditionary Force (AEF) is the tool to make it a reality.[6] AEFs will be tailored packages of air and space forces assembled to meet the needs of the National Command Authority (NCA) and theater commanders-in-chief (CINCs).[7] AEFs will provide rapid and responsive aerospace power that can meet the full spectrum of conflict ranging from humanitarian relief missions to joint or combined combat operations.[8] They will have the smallest possible forward footprint, will only deploy those resources absolutely necessary to accomplish the mission, and will “reach back” to the United States to obtain information, additional personnel, weaponry, supplies, and ammunition when needed.

The requirement to rapidly deploy anywhere at anytime in response to global crisis dictates a heavy dependency on strategic airlift. The USAF recognizes the criticality of limited strategic airlift assets and hence has adopted a strategy of "light, lean, and lethal" to minimize the amount of personnel and equipment that must be forward-deployed.[9]

Since there will be little forward infrastructure from which AEFs can operate, they must be able to function from austere locations.[10] And since access to austere locations by land may be difficult, the dependency on strategic airlift is greater.

When you combine rapid global mobility, small forward footprint, "reach back", and austere locations, the result is an AEF that is unable to perform its mission unless strategic airlift is responsive, flexible, effective, and efficient. One way to help the USAF determine if airlift is meeting its requirements and to facilitate the planning for future airlift is to develop a better methodology to measure airlift effectiveness.

Measuring Strategic Airlift Effectiveness

Since World War II, the overarching metric for evaluating airlift effectiveness has been based on "getting there the fastest with the mostest." These metrics were expressed in terms of tons per month, tons per day, million ton-miles flown, and finally, million ton-miles per day. While these forms of measurement were adequate before and during the Cold War, they have limited application today.

Previous metrics revealed only part of the story—a story much better told through the use of a better methodology. There are so many other factors than tonnage delivered that are critical to the success of the airlift mission. For example, the required minimum cargo delivery per day during the Berlin Airlift was 4,500 tons. While this was the overall objective, there were numerous other factors that greatly affected this operation. The number of runways available, the ability to expeditiously onload and offload the aircraft, the capacity of the aircraft used, the amount of ramp space available and so on were all areas of great concern. A disruption in any of these areas would have impaired the ability to support over two million people during the Berlin crisis.

Illustration by example of the inadequacy of tonnage per day as the sole metric may help illuminate the problem. During the Berlin Airlift, it took over 330 cargo airplanes to get the job done—but some have argued the C-5 *Galaxy* (if it had existed) could have done it with only 11 aircraft.[11] But, while the C-5 could have accomplished the airlift with fewer aircraft and sorties, the runways, taxiways, and ramps in Germany would not have supported the colossal *Galaxy*.[12]

The same problems with ramp congestion and airfields that cannot support heavy aircraft are still prevalent today. There are thousands of airfields around the world that still cannot accommodate the C-5. As shown in the above example, using tonnage per day as the primary measurement of airlift effectiveness can be misleading. What is needed is a methodology that combines what is required of airlift with what airlift is capable of doing. The point is that in today's world, there are many other factors other than tonnage airlifted that must be considered. Some of these factors include the amount of ramp and runway space available, minimum ground time permitted, the range to the destination, how fast it needs to get there, and whether outsize or oversize cargo needs to be delivered. If the Air Force continues to use the current metric of million ton-miles per day (MTM/d) as the primary measure of strategic airlift effectiveness, we will continue to inadequately portray current airlift capabilities, will improperly identify shortfalls, and will constrain our ability to evaluate future airlift proposals.

But how did the U.S. end up with a measurement of strategic airlift effectiveness that relied on "getting there the fastest with the mostest?" I propose that the "Hump" operation during World War II and the Berlin Airlift only three years after the end of the war solidified this concept in the minds of strategists, analysts, and senior leadership for the next fifty years. In fact, this mindset is still prevalent today with the use of MTM/d as the overall measure of strategic airlift effectiveness.

In this paper, we will look at the birth of strategic airlift and how it was used during the "Hump" operation and the Berlin Airlift. This provides the historical reference for how metrics were first used to measure the effectiveness of airlift. From there, we will briefly trace the evolution of strategic airlift metrics from tons per month to today's million ton-miles per day. A new methodology for evaluating airlift effectiveness, the air mobility evaluation process (AMEP), will then be introduced followed by a demonstration of how the AMEP can be used for a major theater war scenario. Finally, we will briefly explore how the AMEP can be applied to other scenarios and to evaluate future airlift proposals.

If this paper is successful, then the following questions will be satisfactorily answered: "In the post Cold War world with the USAF moving towards an expeditionary force structure, are the current strategic airlift measures of effectiveness adequate?" "Is there a more accurate and illustrative methodology that can be used?" "How can this new methodology be applied to actual scenarios, planned conflicts, and future airlift proposals?"

Scope and Limitations

This paper is not an advocacy piece on airlift. Promotion of airlift importance is used to highlight the seriousness of this topic. As US military presence continues to be less forward-based and as we transition to an EAF, the dependency upon airlift for force projection becomes even greater. With this dependency comes a great responsibility for senior leaders, planners, and analysts alike to use the right methodology and the appropriate metrics to evaluate strategic airlift effectiveness both now and in the future.

Case studies of the "Hump" operation and the Berlin Airlift are not comprehensively examined. While care is given to describe each of these events in some detail, this is done to clarify the contextual elements surrounding each situation, which in turn helps explain why certain metrics were used. For a comprehensive study of those events, the reader must turn to other works.

The utility sought in this paper is in the methodology used to aggregate airlift metrics into an overall mobility value. This mobility value can be used to evaluate the effectiveness of one airlifter or several different types of airlift aircraft for a current operation, or forecast the effectiveness for a future operation. The strength behind this methodology lies in its direct relationship to the scenario under evaluation. Weighting permits a relative application of emphasis on those metrics that are more important than other ones. If this new methodology helps decision makers, staff officers, planners, and analysts better evaluate current airlift effectiveness and potential future airlift options, then this paper has accomplished its objective.

A couple words on terminology. For this paper, strategic and intertheater airlift are both used to describe missions that depart a continental United States (CONUS) aerial port of embarkation (APOE) or a theater main operating base (MOB), traverse intercontinental distances, and then land at an overseas aerial port of debarkation (APOD) or another theater MOB. Intratheater (or theater) airlift applies to missions that depart and land in the same theater—although some also call this tactical airlift. For this paper, tactical airlift pertains to missions such as airland, airdrop, or other delivery techniques that directly support tactical operations and the accomplishment of tactical objectives.

Notes

[1] Gen Michael E. Ryan, chief of staff, US Air Force, *Building an Expeditionary Aerospace Force*, address to the Air Force Association National Symposium, Orlando, Fl., 27 February 1998, n.p.; on-line, Internet, 4 December 1998, available from http://www.aef.org/ol18.html.

[2] *A National Security Strategy For A New Century* (Washington, D.C.: The White House, 1998), 6-12.

[3] *National Military Strategy, 1997*, n.p.; on-line, Internet, 7 December 1998, available from http://www.dtic.mil/jcs/nms.html.

[4] Gen Michael E. Ryan, chief of staff, US Air Force, *Expeditionary Aerospace Force for America*, address to the Air Force Association Convention, Washington, D.C., 14 September 1998, n.p.; on-line, Internet, 7 December 1998, available from http://www.afa.org/library/press/keyadd98.html.

[5] For a seminal work on the new expeditionary Air Force, see US Air Force Scientific Advisory Board (USAF SAB), *Report on USAF Expeditionary Forces*, vol. 1, *Summary: SAB-TR-97-01* (Washington, D.C.: Department of the Air Force, November 1997) and vol. 2, Appendices E-H: SAB-TR-97-01 (Washington, D.C.: Department of the Air Force, February 1998).

[6] Briefing to the Air War College, Lt Col Barry Coble, HQ USAF/XOPE, subject: The Expeditionary Aerospace Force, 29 Oct 1998.

[7] As currently planned, the US Air Force will reorganize into ten AEFs. Two AEFs will be on alert and ready to deploy to handle any global contingency. Each AEF will consist of fighter, bomber, tanker, tactical airlift, and special use aircraft (AWACS, JSTARS, MC-130, U-2 etc.) accompanied by minimum support infrastructure (e.g. security forces, logistics, maintenance, administration). The other eight AEFs will train and prepare to respond to other crises as they arise. When needed, an AEF will move into a contingency area bringing only those assets necessary to perform its mission. The remaining assets for that AEF will stay in the U.S. If additional assets are needed, they will be brought from the US ("reach back"). For more information, see http://www.aef.org/ryan.html or http://aef.org/cook.html.

[8] USAF SAB, vol. 1, 1-2.

[9] Briefing by Lt Col Barry Coble.

[10] Austere airfields typically have little ground support equipment, sparse facilities, and limited or no instrument approach capability. Small austere airfields (SAAF) have short runways and are limited in one or a combination of the following: taxiway systems, ramp space, security, material handling equipment, aircraft servicing, maintenance, weather observation, and communications. Joint Publication (JP) 1-02, DOD Dictionary, *Approved Terminology*, 14 March 1997, 488.

[11] In 1965, Boeing claimed that 11 C-5As could do the same job in Berlin as 336 C-54s. When you consider the primary aircraft, the C-54, could only carry around 10 tons

Notes

of cargo versus the C-5 with its 116-ton payload, it initially makes sense that larger aircraft are better. While the argument that aircraft with greater payload capacity equates to fewer airplanes and sorties, less aircrew, less maintenance, and quicker delivery is persuasive, it overlooks other factors that can greatly impact an operation. Aircraft ground maneuverability, aircraft utilization rate, and the requirement to operate on airfields with short runways, sparse ramp space, and with limited or no support equipment can be as important, or sometimes more important, than just tonnage delivered. Boeing's argument also demonstrates the opinion of early airlift thinkers towards airplanes that were larger, faster, and could haul more cargo over greater distances. While this thinking may have been acceptable during the Cold War, it is not as applicable for an Air Force that continues to withdraw from overseas locations, reduces its infrastructure, and must operate on austere airfields. Boeing, *Berlin Airlift—Then and Now* (Seattle: Military Airplane Division, 1965).

[12] The C-5 requires heavily stressed runways for landing, wide taxiways, and expansive ramp space. Of the 3 Berlin airfields available, only one (Gatow) had a concrete runway (the others used pierced steel planking or crushed brick) and even this runway would have quickly deteriorated if heavy aircraft were used. One could argue that the airfields could have been upgraded if larger aircraft were available. But, this ignores the issue that today there is a premium placed on aircraft that can operate on small austere airfields which are not normally stressed to support such heavy aircraft as the C-5. For more information on airfield facilities used during the Berlin Airlift, see "A Special Study of Operation Vittles," *Aviation Operations Magazine*, vol. 2, no. 5. April 1949, 53-68.

Chapter 2

The Eve of Strategic Airlift

> *The value of military history. . .the student can discover, not only the sequence of past events, but their tendencies, and, above all, the probable direction of these tendencies in the future. We do not want drama; we want truth. We require not merely a chronology of past events, but means of analysing their tendencies—means of dissecting the corpse of war, so that we may understand its mysterious machinery.*
>
> — Colonel J.F.C. Fuller[13]

To understand how transport aircraft were used during the "Hump" operation and the Berlin crisis, we need to briefly review the state of airlift at the beginning of World War II.

The Army Air Force (AAF) fought the Second World War primarily with aircraft that were either in production or under development prior to US entry into the war.[14] This is not too surprising since it can take a lot of time to develop an aircraft from conception to production.[15] Fortunately for the Allies, US airpower debates during the years before 7 December 1941 did result in the development, production, and employment of various variants of bombers, fighters, and observation aircraft for use in World War II. Unfortunately, competing service doctrine, emphasis on the combat arms, limited resources, and an undeveloped vision for airlift's use in warfare resulted in little in the way of specialized military transport aircraft before the war.[16]

Early Commercial Transport Aircraft

Even though the development of transport aircraft strictly for military use before the Second World War was neglected, there was a fairly robust commercial airline industry that had several aircraft suitable for the military. Building upon advances in aircraft technology since the First World War, the commercial airline communities in Europe and America set out to profitably carry personnel from one place to another. In 1918, the Germans established a modest Berlin-Weimar and Paris-Brussels airline service, and by 1920, the British and French were routinely flying a London-Paris route. While initially a fairly small operation (the British and French each averaged 10,000 passengers per year from 1920 to 1924), the ability to expeditiously fly passengers from one place to another showed much promise.[17] In America, the Army Signal Corps inaugurated the first U.S. airmail service in May 1918 with the delivery of four sacks of mail from New York City to Washington D.C. in 3 hours and 20 minutes. Several other nations also instituted an airmail service.[18]

Most of the early aircraft used in Europe for transportation were derived from bombers developed during the First World War. The aircraft typically were either biplanes or monoplanes with plywood wings and had one or two engines—although the Germans had already developed an all-metal aircraft that was more durable than the wood and fabric airplanes. These early aircraft only carried four to twelve passengers, cruised from 70 to 105 mph, and could only fly 200 to 500 miles.[19]

While there was little governmental effort to develop dedicated military aircraft for transport use, emerging commercial airlines in Europe and America received varying levels of subsidy. It was this governmental subsidy that enabled the airlines to remain solvent until profits from carrying passengers could be realized. For example, in 1928 the French airlines obtained only 10.6 percent of their income from commercial activities with the rest coming from other subsidies—of which 7 percent was through mail service.[20] To meet the growing demands of passenger travel, the commercial airlines also established a more robust infrastructure by building more airfields, setting up additional en route and local navigational aids, and erecting meteorological outposts.[21]

As public transportation via airline travel grew, the commercial airline industry wanted aircraft with greater range, capacity, speed, and reliability. In the mid-1920s, the trimotor airplane was introduced which was safer than the single or twin-engine models since it could still remain airborne after losing an engine. By 1928, transport aircraft were carrying up to 18 passengers, cruising at 120 mph, and routinely flying 500 miles.[22] By the 1930s, US air passenger and mail service covered much of the American continent and the commercial aviation industry was starting to traverse the Atlantic and Pacific oceans.[23]

In 1931, American public antipathy with wood-and-fabric airliners and disdain over the Fokker trimotor design that crashed and killed Knute Rockne (of Notre Dame University fame) forced the U.S. airlines to pursue other aircraft. By this time, advances in aeronautical engineering techniques and state-of-the-art engines permitted the development of several transport aircraft suitable for military use.[24]

Early U.S. Airlift Aircraft

As noted, it was largely due to the commercial industry that airlift was available when the war started. When the US entered World War II, the only four-engine transports available were the modified B-24 *Liberator* bombers (designated the C-87), the

Boeing C-75 *Stratoliner*, and two types of seaplanes; all of which were only present in small numbers.[25] To meet the expanding requirements for airlift, the Air Transport Command (ATC) used modified commercial transports and contracted with the civilian aviation industry.[26]

To help fulfill requirements for air transport, the military turned to the twin-engine Douglas DC-3.[27] The DC-3 made its maiden flight on 17 December 1935, and by the time the AAF had acquired a military variant in 1941, the DC-3 was already in full production and extensive use by the commercial aviation industry.[28] Throughout the war, three military versions of the DC-3 (C-47 *Skytrain*, C-53 *Skytrooper*, and the C-84) saw extensive service with ATC. The C-47 *Skytrain* (*Dakota* to the British, R4D to the US Navy) quickly became the backbone of the AAF's air transport service.[29] The C-47 could cruise at 150 mph and transport a maximum of 27 troops or 3.8 tons around 1,500 miles and had a large port-side door on some variants that facilitated the loading of bulky cargo items.[30] During the war, the C-47 performed such missions as cargo hauling, troop transport, airdrop, rescue, reconnaissance, glider towing, navigator training, air evacuation, and special operations.[31] At the peak of military operations in August 1945, ATC had 3,090 transports of which over 40 percent were DC-3s.[32] Before the war was over, the AAF accepted more than 10,000 DC-3 variants (nearly half of the transport planes received between 1940 and 1945) and continued to serve the US in many ways for the next thirty years.[33]

ATC also procured the twin-engine Curtiss-Wright C-46 *Commando* for airlift purposes. The C-46 cruised over 170 mph and could carry a combat load over 10,000 pounds (or 50 combat troops or 22 litter patients) around 1,200 miles.[34] Originally designed as a 36-passenger commercial transport, the unproven C-46 had several engineering difficulties that prevented extensive use before 1944.[35] While the *Commando* had greater payload and speed than the early C-47 models, it was temperamental to fly and its instability at slow airspeed made it unsuitable for the airdrop mission. Narrow center-of-gravity tolerances required careful distribution of cargo which in turn extended time required to load the aircraft.[36] While initially getting a bad reputation, design changes and operational experience helped resolve many of the engine and maintenance problems and the *Commando* became one of the workhorses for ATC.[37] By 1943, there were 247 C-46s in ATC service, and by the end of the war, a total of 3,144 were accepted for military use.[38] The C-46 served in every theater during the war and was used extensively during the "Hump" operation in Asia.

Another military aircraft utilizing a civilian design was the C-54 *Skymaster*. Based on the Douglas DC-4, the *Skymaster* proved to be one of the finest long-range transports designed to date.[39] It had four engines, could cruise around 170 mph while carrying approximately 20,000 pounds of cargo on short-hop missions.[40] The maximum range under ideal conditions was over 2,500 miles.[41] Early models of the C-54 could carry only twenty-one passengers, but later stretched versions could haul between forty and eighty people. Unlike the C-46 and C-47 tail draggers, the C-54 had a tricycle landing gear that gave it a horizontal cargo deck that greatly eased the loading of cargo and personnel. The C-54 also had an oversized cargo door that permitted the loading of some trucks and road-building equipment.[42] While not available in large numbers until 1944, the AAF accepted more than 1,000 *Skymasters* before the end of the war and it remained in US service until 1973.[43]

Another airlifter introduced toward the end of the war was the Lockheed C-69 *Constellation*. Unlike previous airlifters, the C-69 was a large pressurized aircraft that could fly at higher altitudes to avoid many of the weather problems encountered below 25,000 feet. The *Constellation* cruised at 300 mph, and could carry more than 32,000 thousand pounds, or 64 passengers, nearly 2,500 miles. While military versions of the C-69 saw limited service (only 22 were produced for the AAF) in the war, they did provide promise for larger, faster, and more capable airlifters in the future.[44]

While other US airlifters were available, many were simply modified bombers. For example, the C-87 *Liberator* was a B-24 altered for transport use and could carry only 20 people or 3 to 5 tons.[45] It had four engines, a top speed of 300 mph, and a range of around three thousand miles.[46] Due to center-of-gravity problems and limited carrying capacity, the C-87 was replaced by the C-54 and was almost entirely phased out of the service by 1947.[47]

Civilian Contract Airlift

Early in the war, the AAF did not have enough men or equipment to fulfill the rapidly expanding airlift mission. Predating the Civil Reserve Air Fleet (CRAF) agreement by over ten years, ATC contracted domestic air carriers to make up the difference.[48] In 1941, almost all US commercial carriers were involved in the war effort. The original agreements allowed the US government to purchase the airlines' aircraft and then operate them using civilian pilots and support personnel. In 1942, almost 88 percent of the transport work performed by ATC was done under contract with the civil air carriers. By early 1943, the War Department had switched to an "on-call" service. This allowed the military to ask the civilian carriers to do most any task that they were capable of performing without spelling it out by contract. But as the AAF fleet of transports expanded, they became less reliant on commercial contracts. For example, in 1943 the amount of airlift performed by civilian contracts was approximately 68 percent, but by the end of 1944 it had fallen to 33 percent. At the end of the war, military aircraft were performing all but 19 percent of the air transport missions.[49]

Moving to a completely militarized air transport service greatly improved airlift's flexibility and responsiveness. It permitted the AAF to allocate people and aircraft as needed, enabled the establishment of an integrated command, control, and communication system, and allowed standardization of aircraft types, training, and maintenance.[50]

As we have seen in this chapter, military airlift was in its infancy at the start of World War II. But a combination of government subsidies and a foresighted commercial airline industry ensured that airlift was available when needed for the war. The commercial industry had made great strides in creating transport aircraft that could haul cargo over intercontinental distances in a timely fashion. As the war ensued, advances in technology and increased emphasis on airlift enabled the range, payload, and speed of transport aircraft to be improved further.

Air Marshal Tony Mason asserts that by the end of World War I, "all subsequent roles of air power had either been established or attempted."[51] But where the Great War was the catalyst for the development of strategy, doctrine, and tactics for the use of combat aircraft, it really took World War II to prove the efficacy of airlift. The campaign that really drove home the importance of transport aircraft was the "Hump" operation in the Far East during Second World War.

Notes

[13] Col J.F.C. Fuller, *The Foundations of the Science of War* (London: Hutchinson & Co., 1926), 18-20.

[14] Wesley Frank Craven and James Lea Cate, eds., *The Army Air Forces in World War II*, vol. 6, *Men and Planes* (Chicago: Chicago Press, 1955), 193.

[15] Today, it can take over 10 years to develop an airplane depending on the budget, urgency of the requirement, politics, etc. For a good discussion on transforming the DOD acquisition process, see Jacques S. Gansler, *Defense Conversion: Transforming the Arsenal of Democracy* (Cambridge: The MIT Press, 1996).

[16] During the 1920s and 30s, there were only a few dozen airplanes designated to deliver cargo or personnel. In the mid-1920s, the US Army purchased 11 Fokker trimotor transports (designated C-2) and 13 Ford trimotors (C-3, C-4, and C-9). The Army also operated around two dozen Douglas Dolphin twin-engine amphibians for coastal patrol and use in the Philippines and Panama Canal Zone. Roger E. Bilstein, *Airlift and Airborne Operations in World War II* (Washington, D.C.: Office of Air Force History, 1998), 14. While there was little debate that an aircraft that could deliver both cargo and troops was needed, the C-82 was the only aircraft specifically designed to do this, and it did not see service until after the end of the war. Craven and Cate, vol. 6, 223. Col Robert C. Owen provides a comprehensive discussion of airlift doctrine and policy in "The Rise of Global Airlift in the United States Air Force 1919-1977: A Relationship of Doctrine, Power, and Policy," work in progress, 1999.

[17] Ronald Miller and David Sawers, *The Technical Development of Modern Aviation* (London: Routledge & Kegan Paul Ltd., 1968), 12-13.

[18] Initially, the U.S. believed that flying the mail would provide a way to increase pilot flying proficiency, but after only two months it became apparent the airmail service would never flourish under Army control and so was subsequently transferred to the Post Office. *Anything, Anywhere, Anytime: An Ilustrated History of the Military Airlift Command, 1941-1991* (Scott AFB: MAC Office of History, 1991), 1.

[19] Ronald Miller and David Sawers, 12-13, and Laurence K. Loftin, *Quest for Performance: The Evolution of Modern Aircraft* (Washington, D.C.: U.S. Government Printing Office, 1985), 68-69.

[20] Ronald Miller and David Sawers, 14-15.

[21] *Anything, Anywhere, Anytime*, 1-15, 36, and William H. Tunner, *Over the Hump* (1964; new imprint, Washington, D.C.: Office of Air Force History, 1985), vii.

[22] Ronald Miller and David Sawers, 14-15.

[23] *Anything, Anywhere, Anytime*, 1-15, 36, and Tunner, vii.

[24] Ronald Miller and David Sawers, 18-20. Aeronautical engineering advances included improved wing flaps, retractable landing gear, engine cowlings, deicing equipment, flush riveting, stressed-skin construction, and variable pitch propellers. Bilstein 6-16

[25] *Anything, Anywhere, Anytime*, 32.

[26] Wesley Frank Craven and James Lea Cate, eds., *The Army Air Forces in World War II*, vol. 1, *Plans and Early Operations, January 1939 to August 1942* (Chicago: University of Chicago Press, 1948), 310-365, and Col Owen, 29.

Notes

[27] *Anything, Anywhere, Anytime*. 34. The DC-3 evolved from the DC-2 and the DC-1. The DC-1 (test aircraft) first flew in 1933. By 1942, the AAF had around eighty DC-2s (production version of DC-1) designated as C-32, C-33, and C-39. A total of 130 DC-2s were built. Evolving from the DC-2, the DC-3 used additional advances in aerodynamics, improved engines, a larger fuselage, and an optional side door for handling bulky cargo. Bilstein, 6-16, and Tunner, 62.

[28] By 1938, nearly eighty percent of all U.S. passengers traveled on DC-3s. Bilstein, 15.

[29] Bilstein, 16.

[30] *Berlin Airlift: An Account of the British Contribution* (London: His Majesty's Stationary Office, 1949), 41, and Bilstein, 16.

[31] Bilstein, 1-25.

[32] *Anything, Anywhere, Anytime*, 32.

[33] Craven and Cate, vol. 6, 224.

[34] Gordon Swanborough and Peter M. Bowers, *United States Military Aircraft Since 1909* (Washington D.C.: Smithsonian Institution Press, 1989), 240. The C-46 could also carry some fairly bulky cargo. For example, it could haul a Caterpillar RD-8 grader without cutting it apart and then welding together again—something the C-47 or few other planes could do at that time. Brewer, 151-152, and Wesley Frank Craven and James Lea Cate, eds., *The Army Air Forces in World War II*, vol. 7, *Services Around the World* (Chicago: University of Chicago Press, 1958), 24.

[35] Early experience with the brand new C-46 saddled it with a poor reputation. Plagued by hydraulic and fuel system problems, it became known as a "plumbers nightmare." Especially vexing was the tendency to lose an engine during flight—a real problem since the aircraft could not stay airborne with a heavy load with only one engine operating. A fuel check valve was found to be the primary culprit. The aircraft also had a leaky fuselage that created problems for aircrews who had to frequently fly at high, freezing altitudes while soaking wet. The water entering the fuselage also caused extensive corrosion problems—not a good situation when the flight controls were affected. *Anything, Anywhere, Anytime*, 32, Craven and Cate, 24-25, and James F. Brewer, ed., *China Airlift—The Hump* (Dallas: Taylor Publishing Co., 1981), 151.

[36] A properly balanced load was critical for getting the best performance out of the C-46, and an imbalance could cause serious controllability problems. Otha C. Spencer, *Flying the Hump: Memories of an Air War* (College Station: Texas A&M University Press, 1992), 105.

[37] Bilstein, 18, and Brewer, 151-152.

[38] *Anything, Anywhere, Anytime*, 32, and Craven and Cate, vol. 7, 224.

[39] *Anything, Anywhere, Anytime*, 33.

[40] *Berlin Airlift: An Account of the British Contribution*, 41.

[41] Later versions of the C-54 could carry more than 28,000 pounds and fly missions more than forty-four hundred miles. Bilstein, 21.

[42] Bilstein, 20.

[43] Craven and Cate, vol. 7, 224, and *Anything, Anywhere, Anytime,* 33.

Notes

[44] Bilstein, 23.

[45] The C-109 version of the B-24 was modified to haul large quantities of aviation gasoline across the Himalayas from India to China during the "Hump" operation. Craven and Cate, vol. 7, 224, and Spencer, 67-68.

[46] Bilstein, 19, and Spencer, 66-67.

[47] *Anything, Anywhere, Anytime*, 33.

[48] The CRAF was established in 1951 as a formal way for the US government to tap into the vast American commercial airlift resources during a national crisis—CRAF participants in turn received peacetime military business. Fully mobilized, the CRAF was expected to airlift 95 percent of the passengers and 35 percent of the cargo to overseas theaters. Since the airlines have been very forthcoming with aircraft during national emergencies, there was no need to activate the CRAF until the huge airlift effort during the Gulf War in 1990-91. *Anything, Anywhere, Anytime*, 81-87.

[49] *Anything, Anywhere, Anytime*, 36.

[50] Ibid.

[51] Air Vice Marshal Tony Mason, *Air Power: A Centennial Appraisal* (London: Brassey's Ltd., 1994), 18.

Chapter 3

The "Hump" Operation, 1942-1945

> *The major significance, for the future, of all air operations in CBI [China-Berma-India theater] was the development of air transport operations. During the first year of the war, the magnitude to which air transport operations could be developed was not appreciated. However, the terrain of Burma and China and the absence of land lines of communication forced all agencies in the theater to turn to the airplane—initially as an afterthought and an emergency last-chance measure. The inherent flexibility of air power permitted it, without adequate preplanning, to meet the exigencies of the various situations. Air transport operations expanded beyond the wildest prediction of 1942—expanded because it was the one agency which could succeed.*
>
> —USSBS[52]

The most extensive aerial supply effort accomplished during World War II was the "Hump" operation in the China-Burma-India (CBI) theater (map at Appendix A). Unlike other theaters that could depend on land and sea delivery of people and supplies, the Chinese and American forces depended on the delivery of "every vehicle, every gallon of fuel, every weapon, every round of ammunition, every typewriter, every ream of paper" by air from India.[53]

When the Japanese first invaded China in 1937, the Chinese employed a scorched-earth strategy of trading territory for time while simultaneously asking the West for military aid. Since the Chinese were keeping over one million Japanese soldiers tied down and the Allies wanted theater airfields for future air raids against Japan, the US provided lend-lease supplies and sent the American Volunteer Group (Flying Tigers).[54] To crush Chinese opposition and stop Allied support, the Japanese severed all major land routes within Burma in early 1942. Since Japan already controlled the Chinese Pacific coast, this effectively isolated China from the rest of the world.[55] When the China National Aviation Company (CNAC) was unable to keep the Allied forces supplied, the AAF's Tenth Air Force, headquartered in India, took control of the operation in April 1942.[56]

In the first two months, the Tenth Air Force airlifted 196 tons of cargo and CNAC delivered an additional 112 tons.[57] By late 1942, CNAC and the Tenth together were hauling around 1,000 tons per month which was not enough.[58] Not enough aircraft and personnel combined with poor theater living conditions, inadequate maintenance facilities, treacherous terrain, no en route navigational aids, poor aircrew training, and interference from Japanese fighters made flying the four-hour-long, 550-mile route difficult at best.[59] Hazardous weather along the route was a major concern and a frequent cause of aircraft accidents.[60] One can imagine the aircrew's consternation when they had to fly aircraft that were frequently overloaded and under-powered over 14,000 to 15,000 foot-high mountains in severe weather conditions. Notable World War II historians Wesley Craven and James Cate called the air route one of unsurpassed "danger and difficulty."[61]

In early 1943, Generalissimo Chiang Kai-shek asked the US to increase the monthly delivery rate to 10,000 tons.[62] While somewhat skeptical of the Chiang Kai-shek's demands, the AAF realized that increasing tonnage would permit the Allies to continue the fight in China and facilitate an accelerated offensive against Japan.[63] After President

Roosevelt agreed to the Generalissimo's demand, the AAF reevaluated the situation and decided ATC was better qualified and organized to handle the air transportation.[64] On 1 December 1942, the Tenth Air Force transferred control of the airlift to ATC's India-China Wing.[65]

The combined effects of specialized airlift knowledge, a more adept organization, greater AAF support, more personnel and aircraft, better aircrew training, more airfields, improved maintenance, more aggressive search and rescue, and a comprehensive safety program enabled ATC to reach the ten-thousand-ton goal by 26 December 1943.[66] By the end of that same month, 12,590 tons were delivered. The tonnage delivered per month steadily increased so that in August and October of 1944, over 23,000 tons and nearly 25,000 tons were delivered respectively.[67] By November the amount had increased to almost 35,000 tons. In January 1945, the Hump airlift delivered over 44,000 tons and in the last month of the war, over 71,000 tons were delivered.[68]

Airlift in the "Hump" operation sustained Chinese and American forces for over three years during World War II. It helped repel Imperial Japanese aggression and preserved a base of operations from which American bombers could attack enemy shipping, vital enemy industrial installations in eastern China, and even the homeland of Japan itself.[69] It also helped tie down over a million Imperial Army troops that could have been used elsewhere. It demonstrated the viability of using large-scale airlift to deliver troops and cargo over vast distances and the feasibility of supplying friendly troops almost completely by the air.[70] As Craven and Cate put it, ATC's "crowded airways to China were the proving ground, if not the birthplace, of mass strategic airlift.

Here the AAF demonstrated conclusively that a vast quantity of cargo could be delivered by air, even under the most unfavorable conditions."[71]

Between 1942 and 1945, 81 percent of all supplies into China were delivered via the "Hump." Aircrews flew over 167,000 missions and delivered nearly 740,000 tons of war material to keep China in the war against Japan.[72] Of that amount, 75 percent was delivered in the last year of the war, which included the movement of entire armies from India and Burma to the battlefronts in China.[73]

General Tunner ("Hump" commander during the last year of the effort) had this to say about the airlift effort:[74]

> Never in the history of transportation had any community been supplied such a large proportion of its needs by air. No other air operation, civilian or military, had ever before even attempted to keep its fleet in continuous operation around the clock, in all seasons, and in all weathers. And our cargo was varied to say the least—from V-mail to mules to machinery. The age of air transportation was born right there on the Hump.

The Metrics Used

As shown above, the primary objective of the "Hump" was the maximum amount of tonnage delivered in the shortest time possible. The overall measurement of airlift effectiveness was tonnage per month. This is not too surprising since tons per month was relatively easy to measure, simple to display on graphs and charts, and conducive to comparison with other months to discern how the operation was going. It was an obvious measure of effectiveness that was simple to explain to senior military and civilian leadership—an important consideration when trying to describe how well (or not) the operation was going.

But tons per month did not tell the whole story. Since aircraft payloads were relatively small, a mechanism was needed to ensure the "right stuff" was delivered at the "right time." When ATC took command of the "Hump" operation in late 1942, they took a systematic approach to accomplish this task.[75] They broke the problem into workable pieces with maximum tonnage per month being the final objective. But to get there, ATC needed to find those critical components that when combined would enable realization of the final objective. Tunner, called this statistical analysis. As he put it, the goal was to develop a system of critical components that when combined, portrayed the "complete situation at a glance."[76]

One of the metrics to track and subsequently correct was the high accident rate. Between June and December 1943, there were 135 major accidents with 168 crew fatalities on the Hump route. The introduction of twenty-four-hour-a-day operations in October helped push the total for November up to 38 major accidents.[77] To reduce the accident rate, ATC brought in some highly experienced check pilots that could conduct a training program for upgrading personnel. An aggressive search-and-rescue program to extract crewmembers that had either crashed or bailed out along the "aluminum trail" was also implemented.[78] ATC also implemented an extensive flying safety program that thoroughly investigated each accident to determine whether the root cause was due to structural failure, faulty maintenance, crew fatigue, aircrew error, or airdrome mistakes. By finding the root cause, ATC was then able to implement changes to fix them.[79]

Introduction of the flying safety program, increased aircrew experience, and partial replacement of the two-engine aircraft with the more reliable four-engine C-54 resulted in raised tonnage levels and reduced accidents. In January 1944, the rate was 1.968

accidents per 1,000 flying hours.[80] By January 1945, the rate was reduced to 0.301.[81] While the rate varied for the remainder of the war, it never went above 0.580 and yet the amount of cargo delivered continued to climb. In April, 44,245 tons were delivered with an accident rate of 0.511. By July 1945, the last big month of cargo movement (71,042 tons delivered), the accident rate was 0.358.[82]

Aircrew ratio was another metric used during the “Hump.” Crew ratio is the number of aircrews available to fly relative to the number of usable aircraft. An ideal crew ratio permits maximum utilization of every aircraft. This is especially important in a high-operations-tempo environment like the “Hump” where the only way to increase the tonnage was either increase the number of airplanes available (with crews to fly them), or fly those airplanes available more often. Early in the operation, there were not enough aircrew for the planes available. The crews on hand were worked to the limits of their endurance and often flew over 100 hours per month.[83] Colonel Alexander (one of the “Hump” commanders) understood the importance of good crew ratio when he stated that he hated “to see good, serviceable aircraft sitting on the ground with no one to fly them. An airplane doesn’t need to sleep.”[84] To fix this problem, ATC obtained more aircrews and instituted an extensive training program to ensure they were capable and qualified.

Maintenance also greatly impacted aircraft utilization rates. Good maintenance keeps the maximum number of airplanes airborne. If the airplanes are not flyable then they cannot carry cargo. For example, at one time during the operation, twenty-six C-46s were unable to fly due to a lack of spare engines and other parts.[85] To achieve “maximum performance”, General Tunner instituted an extensive production-line maintenance (PLM) program that put each aircraft through different stages that cleaned, inspected, and repaired each airlifter from the nose to the tail.[86] By implementing this program, one ATC base was able to keep forty C-54s averaging twelve hours of flying time per day.[87] Tunner insisted that PLM was an over-all success and credited it with the steady increase in daily utilization of the aircraft available.[88]

An obvious factor in the operation was the use of aircraft that could carry the most cargo. Toward the end of the war, the ATC had upwards of five hundred transports operating in the CBI theater. The various types of airlifters used were the C-46, C-47, C-54, C-87, and the C-109.[89] When the "Hump" began, there was a small fleet of C-47s available, augmented later by the C-46. But as discussed in Chapter 2, while the C-46 could carry more cargo than the C-47, it had a lot of maintenance problems, was temperamental to fly, and was prone to engine failure.[90] This made it very dangerous if an engine was lost while traversing the "Hump" route, since a fully loaded C-46 could not remain airborne with only one engine. What was really needed was a plane that had greater range, payload, and speed than the C-46 and that had the same high utilization rate as the C-47. Consequently, the ATC got as many four-engine C-54s as possible with their intercontinental range, ten-ton cargo capacity, and 170-mph cruising speed. General Tunner greatly admired the increased capability of the C-54 and stated that it had really "proved itself in 1942 and 1943."[91]

Still another issue during the "Hump" concerned ground time. While there were 13 airfields in India and 6 in China, each airfield still had limited ramp space and could handle only a certain number of airplanes per hour.[92] By minimizing the amount of time an aircraft spent on the ground, one could get the maximum throughput of cargo possible on any given day. Ground time is a function of many factors to include ease of aircraft loading and unloading, routine maintenance, and airfield capabilities. With all else being equal, maintenance and loading / unloading are two of the most critical factors that affect ground time. An aircraft that is reliable and easy to maintain improves aircraft utilization rate and reduces aircraft ground time.

The ease of loading and unloading an aircraft also greatly affects ground time. The large port-side door on some of the transporters permitted the loading of large bulky items. The tricycle landing gear on the C-54 enabled the cargo deck to be nearly horizontal while on the ground which facilitated the transfer of cargo. ATC understood the importance of minimizing ground time, and spent a lot of effort to expedite aircraft throughput. They improved airfield runways, ramps, and parking areas and made sure enough people and equipment were always available to offload and service the aircraft.

The "Hump" operation was the largest sustained airlift effort of the war. It is likely the first time that major metrics were used so extensively to define the airlift system. By systematically tracking, analyzing, and improving the efficiency of each metric, ATC accomplished the unprecedented movement of cargo and personnel in support of military operations.

In the next chapter, we will look at how the "Hump" operation was soon eclipsed by the massive airlift effort accomplished during the Berlin crisis.

Notes

[52] *Air Operations in China, Burma, India, World War II* (Washington, D.C.: United States Strategic Bombing Survey (USSBS), 1947), 101.

[53] Craven and Cate, vol. 7, 116.

[54] Lt Col Roger Miller, *Airlift Doctrine* (Maxwell AFB: Air University Press, March 1988), 139, and *Anything, Anywhere, Anytime*, 37.

[55] Craven and Cate, vol. 7, 114, Miller, 139, and Bilstein, 39.

[56] Craven and Cate, vol. 7, 114, Tunner, 8, Spencer, 70, and Bilstein, 39.

Notes

[57] Bilstein, 39.

[58] General Arnold stated in early 1943 that 4,000 tons per month would "not come anywhere near meeting the demands of either the Chinese army or the air forces operating in China." Craven and Cate, vol. 7, 120-122.

[59] These are average distances and flight times. With thirteen bases in India and six bases in China, the round-trip distance varied as much as fifteen hundred miles between the nearest and the farthest airfields. Tunner, 46-49, 110-113, and Craven and Cate, vol. 7, 118-120.

[60] Violent mountain-wave turbulence, heavy rain, thunderstorms, hail, zero visibility, and icing plagued "Hump" routes. Pilots often experienced 100-mph winds at flight altitude and risked exposure to severe weather if they bailed out or crash-landed along the route. Especially troubling was the limited aircrew experience and training with actual weather flying prior to coming to the CBI theater. Spencer, 70-72, 77-83, and Craven and Cate, vol. 7, 116-117.

[61] Craven and Cate, vol. 7, 116. Craven and Cate produced seven World War II volumes from 1948 to 1958 that provide an exceptional account of Allied involvement during the war.

[62] Craven and Cate, vol. 4, 438-441.

[63] Bilstein, 40, Spencer, 93-94, and Craven and Cate, vol. 7, 124-126.

[64] Craven and Cate, vol. 7, 121.

[65] Craven and Cate, vol. 7, 120-121, and *Anything, Anywhere, Anytime*, 37.

[66] Craven and Cate, vol. 7, 120-129, and *Anything, Anywhere, Anytime*, 40.

[67] Tunner, 113, and Craven and Cate, vol. 7, 138.

[68] Craven and Cate, vol. 7, 143, and *Anything, Anywhere, Anytime*, 42.

[69] Craven and Cate, vol. 7, 151.

[70] Miller, 142, and Craven and Cate, vol. 7, 116.

[71] Craven and Cate, vol. 7, 151.

[72] *Anything, Anywhere, Anytime*, 37.

[73] *Anything, Anywhere, Anytime*, 36-37.

[74] Tunner, 59, 129.

[75] ATC went to great lengths to ensure the delivery of the "right stuff" at the "right time." To accomplish this, they established a centralized staff that coordinated troop and cargo delivery with the requirements of the Chinese and Allied forces in the CBI theater. Tunner, 322.

[76] Tunner, 67.

[77] Craven and Cate, vol. 7, 131.

[78] Craven and Cate, vol. 7, 132.

[79] Tunner, 68.

[80] Craven and Cate, vol. 7, 142.

[81] ATC initially insisted on reporting "Hump" accidents in actual numbers rather than relative to hours flown or ton-miles of delivery. ATC's commander at the time, Major General Hal George, ultimately agreed to follow a relative standard—accidents per thousand airplane hours flown. Craven and Cate, vol. 7, 143.

Notes

[82] Ibid., 143.

[83] Craven and Cate, vol. 7, 122.

[84] Ibid.

[85] Craven and Cate, vol. 7, 127.

[86] The concept for PLM was borrowed from the AAF's Training Command. Craven and Cate, vol. 7, 140.

[87] Tunner, 94.

[88] Craven and Cate, vol. 7, 141.

[89] Tunner, 110, 155.

[90] Problems with the C-46 forced ATC to place its "heaviest dependence" on the undervalued C-47. At the peak of operations in August 1945, well over a third of ATC's major transports (1,341 out of 3,090) were C-47s. After the war, ATC elected to keep 402 C-47s in service while only retaining 5 C-46s. Craven and Cate, vol. 7, 26-27.

[91] Tunner, 71.

[92] Tunner, 110.

Chapter 4

The Berlin Airlift, 1948-1949

The Story of the Berlin Airlift—an enormous technical achievement that has revolutionized the role of aviation in transportation and logistics.

— A Special Study of
"Operation Vittles"[93]

Preceding the Crisis

Before World War II was over, the Allies had already decided to divide Germany into four occupation zones.[94] The French, British, and Americans would occupy western Germany, and the Russians the East (see Appendix B).[95] The military forces from each allied nation would occupy their respective zones and a four-powered Allied Control Council would govern Germany.[96] The Allies also decided to divide Berlin, the capital and the most important city in Germany, into four zones for occupation.[97] The fact that Berlin was over 100 miles inside the Soviet sector would later create problems for the western occupied areas.

Before the war, Berlin was a prized jewel. It was one of largest cities in the world when the war started and was a leading political, cultural, and industrial center of central Europe. By 1943, Reich conquests permitted Hitler to control a large portion of Europe from Berlin. But, by the end of the war Germany was devastated. The Allied bombing campaign had destroyed over three million German homes, and killed some 300,000 civilians while wounding an additional 780,000.[98] Berlin was shattered. At the end of the war, only 2.8 million people still lived in the city (a reduction of over 60 percent) and only 28.5 percent of the workforce remained. Around 20 percent of the housing was completely destroyed and over 70 percent had at least some damage. The center of the city was almost completely demolished and less than half of the work places survived the war. A failed sewer system, unusable water supply, and a severe lack of medical personnel resulted in the spread of diseases such as typhus and dysentery.[99] Berlin could only produce around 2 percent of the staples required and was unable to survive without food imports from the Soviet zone.[100]

Exacerbating the problem was the refusal by the Russians to permit Western troops to enter the city for two months after the war. During this time, the Russians raped, looted, and pillaged Berlin in a deliberate attempt to avenge German atrocities and to obtain reparations.[101] It was a city devastated by war and demoralized by Russian occupation the Allies encountered when they were finally permitted to enter Berlin. The military governor of the American zone, General Lucius D. Clay, stated that Berlin was like a “city of the dead.”[102]

While initially thinking German industry should be eliminated and the economy restricted to the minimum level required to support the immediate needs of the people, western policy gradually shifted to the belief that a “strong, stable, democratic Germany would make a good partner and ally in central Europe.”[103]

The Allied occupation forces would reshape the former enemy by disbanding the German Army, eliminating its arms industry, destroying all aspects of the Nazi regime, and punishing the war criminals. To help Germany recover its war-torn economy, the

Allies instituted controls to ensure appropriate distribution of resources through all the zones and to help Germany turn from a war-fighting country into an agrarian state with peace-related industries. Ultimately, the occupation would continue until all reforms were completed, a satisfactory constitution was written, and supervised elections were held.[104] Where the West permitted Germany to recover via the Marshall Plan and other initiatives, the Soviets showed little interest in rebuilding their zone and permitted the occupied areas to remain near wartime destruction levels.

Soviet policy towards Germany remained adversarial. Joseph Stalin wanted a weakened unified Germany under communist control. This would provide a buffer zone between Russia and Europe, permit the recovery of war reparations, give unlimited access to German scientific and technological knowledge, and allow the seizure of industrial and military assets.[105] For several years after the war, the Russians systematically stripped Soviet occupied territory that resulted in the loss of 3,500 plants and factories, over one million pieces of equipment, and 2 million industrial jobs. Thousands of German technicians, scientists, managers, and other skilled labor were forced to move to Russia. Even more appalling was the rape of over one million German women.[106]

The slow realization by the western nations that Russia would not remain “friendly” much longer combined with the unique collective occupation of Germany provided the necessary ingredients for the Berlin crisis.

The Crisis

By early 1948, the western powers were unable to reach an agreement with the Soviets on how to stabilize the German economy. Meeting in February and March, the

West discussed merging their zones, introducing a new currency to stimulate the economy, and the creation of a separate West German government.[107] In response to these meetings (from which the USSR was excluded), the Soviets imposed transportation restrictions on rail routes to Berlin on 1 April 1948.[108] Rather than submit to Soviet inspection of military rail traffic, the West cancelled all military passenger trains to and from Berlin. Concerned over the possible loss of all surface routes, General Clay immediately organized a small airlift effort to deliver cargo to US troops in Berlin. Over the next ten days, some 327 tons of cargo were airlifted. On 12 April, the Soviets decided to lift the transportation restrictions and the "baby blockade" came to an end. But the headquarters for the US Air Forces in Europe (USAFE), was concerned the Soviets may try another blockade and so they continued to fly around 10 missions per day into Berlin.[109]

What enabled the West to use the vertical dimension when the ground routes were blocked was a written agreement coordinated with the Russians in November 1945 to improve air safety near Berlin (see Appendix C for depiction of the corridors).[110] While no formal contract existed concerning land travel, it was the air agreement that later proved pivotal to the survival of Berlin.[111]

The "baby blockade" showed the West how vulnerable Berlin really was and both the British and the Americans increased stockpiles (especially coal) and evacuated unneeded equipment and people. The Soviets believed the mini-blockade had humiliated the British and Americans and that the miniscule airlift effort had failed. Encouraged by what they saw, the Russians increased pressure over the next couple of months. They harassed incoming flights with fighter aircraft, reinitiated demands that the West inform them of all incoming aircraft 24 hours in advance, and demanded that they approve all civil traffic that flew within the air corridors.

Finally, the combination of disputes over resources, currency reform, deteriorating East-West relations, concern of a unified Western sector, and Soviet desire for control of Germany resulted in the Russians blocking all land access to Berlin on 24 June 1948.[112]

While initially claiming "technical difficulties", the Soviets severed western Autobahn and railroad access to Berlin. They also stopped water traffic, coal shipments, and, citing severe shortage of "electrical current," they limited electricity to the western sectors to 2 hours per day.[113] Clearly the Soviets had the upper hand. If the blockade was successful and the West pulled out, then Russia would control the whole city and in turn could have reunified Germany under communist rule. Initially a forceful response was considered, but the western Allies decided that superior Soviet military strength, potential world condemnation for initiating military aggression, and fear of escalation to World War III dictated another way to counter the blockade.[114]

While the western Allies could have pulled out of Berlin, President Truman was not going to let that happen. Truman understood Russia was trying to force the Allies out of Berlin but he unwilling to abandon the German people and succumb to Soviet attempts to undermine the occupation agreement made before the end of the war.[115] If this was going to be a test of Western resolve and commitment to free society, then the British and Americans were not going to back down.

Since another form of resistance was needed and with the majority of all the land routes cut off, the natural thing to do was to look to airlift. But while airlift could buy time while negotiations took place, the West was not confident that transport aircraft alone could furnish Berlin with the necessary staples to keep it alive.[116] They believed the small number of airplanes available could keep their garrisoned troops supplied but not the two million plus Berlin citizens.[117] Two days after the Soviets' announced closure of the land routes, the US flew 32 C-47 missions and airlifted 80 tons of milk, flour, medicine, and other high-priority cargo into Berlin. But this was not going to be enough. Initial estimates showed that at least 4,500 tons of supplies per day were needed to sustain Berlin.[118]

From the start, it was questionable whether airlift alone could keep the city alive. The "baby blockade" had shown some promise, but there were not nearly enough aircraft or usable airfields to support the delivery of 4,500 tons of cargo every day. Bad weather and the threat of Russian fighter aircraft interference exacerbated the issue. But during World War II, the "Hump" operation had demonstrated the efficacy of airlift and so USAFE rounded up as many C-47s as possible and asked Washington for more C-54s. The British in turn decided to send every available transport aircraft to Germany once their new runway at Gatow was completed. On 28 June, the US flew the first missions for the citizens of Berlin with the delivery of 250 tons of cargo on 87 C-47 sorties and the British flew 21 missions and airlifted 59 tons. Slowly the airlift effort expanded and USAFE estimated they could deliver 1,500 tons per day by early July.[119]

When it became clear the blockade was going to last more than a few days, General Curtis LeMay (USAFE commander) ordered the creation of a provisional airlift task force on 29 June with Brigadier General Joseph Smith as the commander.[120] General Smith dubbed the effort "Operation Vittles" since "we were hauling grub," and the British called it "Operation Plainfare."[121] Though General Smith was not an airlift expert (neither was his staff), he integrated the efforts of the American and British to achieve the maximum number of cargo missions. He also made several fundamental decisions that shaped the Berlin airlift effort.[122] For example, Smith established a block system that sequenced the different types of aircraft through the corridors depending on their cruise airspeed.[123] The British instituted a similar system.[124]

Smith also implemented a strict system of position reporting and had aircraft use specific call-signs depending on the type of aircraft, where they departed from, and the direction of travel.[125] He wanted maximum utilization out of every usable aircraft and insisted that each plane fly no less than three round-trip missions per day. He also ordered more navigational aids and the construction of several new runways.[126]

The arrival of additional C-54s, improvements to airfields, and increased operational experience helped the airlift effort grow. On 31 July, the Americans delivered 1,719 tons of cargo, and the British hauled 1,437 tons. Although the combined total of 3,156 tons was still less than the required 4,500 tons per day, the effort showed a lot of promise.[127]

While General Smith and USAFE did an admirable job, it appeared the airlift effort would need to expand further due to failed diplomacy efforts and the approach of winter.[128] With some politicking, Major General Tunner lobbied the Air Force to put the newly formed Military Air Transport Service (MATS) in charge of the operation which resulted in the creation of the Combined Airlift Task Force (CALTF) with Tunner in command.[129] Though not in direct control, MATS provided some trained aircrews, furnished transatlantic airlift, and coordinated maintenance. Using his experience and lessons learned during the "Hump" operation, Tunner set out to airlift the maximum amount of cargo possible to Berlin.[130] By building on General Smith's efforts to increase the number of available airfields, exchanging the smaller C-47s for the larger C-54s, getting additional aircraft and personnel, and enhancing efficiency through a number of management innovations, the CALTF soon airlifted an unprecedented amount of cargo to Berlin.

To make the operation work, CALTF modified the route system initially set up by USAFE and General Smith for the flow of aircraft through the air corridors.[131] CALTF honed the "conveyer belt" system with additional controls that directed pilots to execute specific takeoff and climb-out procedures, exact en route altitudes and airspeeds, and precise approaches and landings.[132] All flights were conducted using instrument flight rules that did not allow any variation in flight path. An extensive system of electronic aids to navigation and ground-controlled approach (GCA) radar was used to expedite arrivals and departures during all kinds of weather, to reduce the chance of accidents, and to keep the airplanes flying around-the-clock.[133]

The framework established by General Smith combined with General Tunner's drive towards machine-like efficiency paid off. During the first two months of the Berlin Airlift, the US averaged around 1,300 tons per day to Berlin. The UK averaged an additional 967 tons per day. In August, the tonnage increased to almost 2,400 tons per day for the Americans and 1,460 tons for the British. September saw an average daily tonnage rate of 3,200 for the Americans and 1,200 for the British. By the end of November, nearly 600,000 tons of cargo had been delivered to Berlin.[134]

By April 1949, the airlift effort was running like a well-oiled machine and General Tunner decided to up the ante by ordering a surge effort on 16 April 1949 to celebrate Armed Forces Day. Instead of celebrating the day with parades, speeches, and parties, the CALTF airlifted more cargo into Berlin than ever before in a twenty-four-hour period. During the “Easter Parade” surge, an airplane landed in Berlin every 62 seconds, 12,941 tons of coal were delivered, and 1,383 flights were accomplished.[135] During this twenty-four hour operation, there were no accidents and not a single person was hurt. After the “Easter” demonstration, cargo rate never fell below 8,000 tons per day.[136]

A combination of Allied resolve and diplomacy, formation of NATO (4 April 1949), a deteriorating Russian economy, US deployment of B-29 bombers to Europe, and the phenomenal airlift effort all contributed to Stalin’s decision to end the blockade on 12 May 1949.[137]

The western Allies continued to stockpile supplies after the blockade was lifted in case the Russians had a reversal of attitude. By the time the airlift was stopped on 30 September, the Allies had delivered over 2,325,500 tons of cargo into Berlin and flew over 277,000 sorties.[138] Of this, approximately 536,705 tons was food, 1,586,029 tons was coal, and 202,775 tons was other items such as factory equipment, earth graders, clothing, and paper products.[139] The Allies also delivered over 60,000 people into Berlin and flew over 167,500 people out.[140] The Berlin Airlift was the first major confrontation of the Cold War and proved to Germany, Russia, and the rest of the world that the West had the resolve, willingness, and determination to oppose communist aggression and stand firmly with our friends in Europe.

President Truman’s Air Force aide called the Berlin Airlift the “greatest feat of its kind in the history of air transport” and the Air Force Chief of Staff, General Hoyt Vandenburg, called the airlift effort the “Air Force’s Number One Achievement.”[141] Few would disagree that it was the most impressive airlift effort ever accomplished.

For airpower enthusiasts, the Berlin Airlift showed there were other ways to win a conflict than by destroying things and killing people. The airlift to Berlin bought time for diplomacy to work its way through the United Nations and presented an alternative than the use of force. Airlift presented a more peaceful approach to a difficult situation and provided one more tool in the arsenal of diplomacy and statesmanship.

The Metrics Used

Similar to the "Hump" operation during World War II, the Berlin Airlift had an overall measurement of airlift effectiveness. In the CBI theater, this measure was tons per month. During the Berlin Airlift, it was tons per day. For many of the same reasons stated at the end of Chapter 3, it is not surprising that tonnage was the parameter used. It was an obvious measurement, was easy to display on graphs and charts, facilitated comparison of one day to the next, and was simple to explain.

But why did the CALTF use tons per day and not tons per month as a gross measure of how the operation was going? There are several likely reasons. First, 40 percent more missions were flown and 68 percent more cargo delivered in 58 percent less time during the Berlin Airlift than during the "Hump" operation. In the last month of the "Hump", a little over 71,000 tons were delivered. During the final month of the blockade, nearly 251,000 tons were airlifted to Berlin. The intense pace and massive amount of cargo delivered necessitated the use of a metric based on days instead of months.

Another reason for using tonnage per day vice tonnage per month concerns the distance flown. During the "Hump" operation, the average distance flown was 550 miles whereas for the Berlin Airlift, the average distance was around 200 miles.[142] The shorter distances permitted aircraft to deliver cargo almost 63 percent faster to Berlin than to

China during World War II. When you combine the increase operations tempo with more aircraft available and shorter distances, it made sense to measure the effort in tons per day since a lot more cargo was hauled in a much shorter amount of time.

The fact that few believed the Berlin Airlift would last more than a couple of weeks also facilitated the use of tons per day. Even after the initial expectation of the short duration proved false, tons per day remained the overall measurement since no one really knew how long the effort would continue.

Another factor to consider was there were only thirty days of coal, liquid fuel, and food in reserve. By rationing and cutting industry to a minimum, it was calculated that 4,500 tons per day should suffice to keep the city alive and functional. Since this was the initial target (CALTF was later told to deliver the maximum tonnage possible) it made sense to use tonnage per day as the overall measure of merit.

But like the “Hump” operation, tons per day did not tell the whole story. While it did provide one type of measurement of the operation, it did not ensure the “right stuff” was delivered at the “right time.” To do this, centralized control was exercised at the CALTF headquarters to coordinate the delivery of cargo from inside and outside the theater into western Germany before it was airlifted to Berlin. The CALTF also worked closely with the local government and garrison commanders to determine what cargo was needed and when it had to get there. By coordinating the efforts of the western Allies, the CALTF could shift the effort to the delivery of food, coal, liquid fuel, medicine, heavy machinery, or any other commodity that was most needed at the right place and time.[143]

Like ATC during the "Hump", the leadership during the Berlin Airlift used extensive "statistics."[144] And like the operation in China, the metrics added up to the overall objective: the maximum amount of tonnage delivered in the shortest possible time. By charting these "statistics," the CALTF had an "at a glance" overview of how the operation was going every single day.[145] By finding those major metrics that contributed to the overall objective, standardizing activities wherever possible, tracking them closely, and correcting problems where needed, the Allies accomplished something few (including the Russians) ever thought possible: the aerial sustainment of over two million people for almost a year.[146]

The Berlin Airlift again demonstrated the importance of using the right aircraft for the job. Shortly after the blockade started, USAFE was operating 52 C-54s and 80 C-47s.[147] When MATS got involved after the establishment of the CALTF, the airlift force was increased to 225 C-54s, 105 C-47s, and five C-82s (for very bulky cargo).[148] By 1 October 1948, most of the American C-47s were removed from the effort due to their smaller cargo capacity and slower cruising speed than the C-54.[149] Fewer aircraft reduced en route congestion, demands on the extremely busy GCA radar, required ramp space, and the total number of landings.[150] These were big issues since there were only three air corridors, only three runways in Berlin, and many of the runways required frequent repairs due to the high volume of heavy aircraft traffic. Fewer aircraft also meant fewer aircrews and a smaller maintenance force that directly equated to less billeting, less medical support, fewer recreation facilities, and not as many mouths to feed.

Aircraft utilization rate was a decisive factor during the Berlin Airlift and was critical to the delivery of the maximum amount of cargo possible. To keep aircraft utilization rate as high as possible, the CALTF needed effective maintenance to inspect and repair the aircraft and enough aircrews to fly them. They also needed aircraft that were reliable and relatively easy to maintain. The CALTF understood the synergism between these factors and their impact on utilization rate and so they reduced the problem into workable pieces. They charted, analyzed, and compared the number of assigned aircraft, the daily hours flown, the daily trips flown, maintenance man-hours required, and the number of aircrews available to build an overall aircraft utilization picture for each type of aircraft flown.[151] This comprehensive overview helped the CALTF identify and correct problems when needed. For example, when the "statistics" clearly showed the C-47 required more sorties, more aircrews, and more maintenance to deliver the same amount of cargo as the C-54, the CALTF had empirical evidence that the C-54 was the best aircraft for the job. When it became clear the British did not have enough aircrew or maintenance personnel to maximize the utilization of their aircraft, the CALTF elected to have them concentrate on more awkward cargo (such as liquid fuel) that took extra time to load and unload. This in turn helped reduce scheduling interference and maximized the efficient flow of supplies into Berlin.[152]

Further recognizing the importance effective maintenance had on the operation, the CALTF instituted production line maintenance (PLM) similar to that used during the "Hump" operation to minimize aircraft down time. The implementation of 50-, 200-, and 1,000-hour preventive maintenance inspections mitigated unforeseen aircraft problems and helped keep the frantic airlift schedule on track. The maintenance status and inspection cycle of every aircraft was closely monitored and charted to provide an overall picture of the airlift fleet status and to help spot any problem areas. All these efforts contributed to keeping the maximum number of aircraft flying as possible.[153]

Ground time was another metric used. Ramp space was limited and minimum ground times increased aircraft throughput which meant the delivery of more cargo. To expedite ground time, an efficient cargo handling and thru-flight maintenance inspection system was established. Before landing, the aircrew radioed the airfield with an estimated time of arrival and aircraft maintenance status which set the system in motion. Cargo handlers and maintenance personnel waited for the aircraft at its designated parking spot. For aircraft landing in Berlin, a truck was pulled along side and laborers unloaded the cargo while maintenance fixed any aircrew "squawks" and performed through-flight inspections. When the transports landed in western Germany, prepared batches of cargo were ready and waiting to be loaded on the aircraft.[154] The CALTF used various cargo loading and unloading systems (today we call this material handling equipment) to include brute manpower, trucks, automobiles, fork lifts, and they even experimented with conveyer-belt platforms.[155] Toward the end of the operation, the average loading time for coal was 15 minutes and food / industrial cargo took 28 to 30 minutes.[156] To ensure the airplane was ready to leave once cargo operations were complete, the aircrew remained with the aircraft where they received weather updates, status briefings, and a small snack. Everything was done to minimize ground time and maximize throughput. By the end of the airlift effort, the average turn-around time at onload bases was 1 hour and 25 minutes and was 49 minutes at offload locations.[157]

Aircraft range in an oblique way impacted the amount of tonnage delivered every day. While long range was not as critical for the short routes flown in Germany, it was important for those aircraft that delivered cargo from outside the theater into western Germany before it was moved forward into Berlin. Indirectly, aircraft range was important for the routes flown in Germany. Using aircraft that could fly from the western sector to Berlin and back again without having to refuel permitted minimum aviation fuel reserves in Berlin. If great quantities of aviation fuel had to be airlifted as well, this would have reduced the amount of food and other critical cargo items that could be delivered to Berlin.

Aircraft payload and speed were two other primary factors during the operation. Aircraft like the C-54 that had greater payload capacity than the C-46 and C-47 were able to move more cargo with fewer aircraft in a shorter period of time. Aircraft with higher cruise speeds could fly quicker round-trip sorties and deliver cargo from other theaters more expeditiously than their slower counterparts. Speed was expressed in other areas as well. Production line maintenance and preventive maintenance inspections reduced aircraft down time and helped keep a high rate of aircraft flowing into Berlin. Extensive efforts to expedite loading and unloading the airplanes ensured the transports spent more time delivering cargo than sitting on the ground.

In true systematic fashion, the CALTF tracked all of the above metrics, corrected problems, and maximized efficiency wherever possible. The Americans, British, French, and Germans accomplished the phenomenal task of keeping a whole city alive for nearly a year—an aerial achievement without parallel in scope and intensity in the history of airlift and humanitarian operations.[158]

The Berlin Airlift firmly established the efficacy of airlift and provided another way to resolve crisis than the overt use of force. Airlift proponents such as General Tunner argued that the Air Force needed transports that were easy to maintain, that had high utilization rates, low operating costs, and that could be directly loaded and unloaded without any special cargo handling equipment.[159]

The Berlin Airlift also demonstrated the importance of large aircraft with greater range, payload, speed, and flexibility—a lesson the Air Force took to heart in their quest for more capable airlifters. The Air Force would go on to develop the Douglas C-124 (4,000 mile range with 26,000 pounds of cargo and cruising at 230 mph), the Lockheed C-130 (2,500 miles, 25,000 pounds, 374 mph cruise), the Lockheed C-141 (2,500 miles, 60,000 pounds, 500 mph cruise), the Lockheed C-5 (3,500 miles, 220,000 pounds, 537 mph cruise), and the direct delivery capable McDonnell-Douglas C-17 (2,500 miles, 130,000 pounds, 500 mph cruise).[160]

But while airlift capability greatly expanded with the introduction of newer aircraft, the airlift community continued to use tonnage delivered as the primary measurement of airlift effectiveness.

Notes

[93] "A Special Study of Operation Vittles," i.

[94] Daniel F. Harrington, *The Air Force Can Deliver Anything!" A History of the Berlin Airlift* (Ramstein AB: USAFE Office of History, May 1998), 3.

[95] Roger G. Miller, *To Save a City. The Berlin Airlift 1948-1949* (Washington: Air Force History and Museums Program, 1998), 1-2, and *Berlin Airlift: An Account of the British Contribution*, 7.

[96] The military governors during the Berlin crisis were General Lucius D. Clay, General Sir Brian Robertson, Marshal Vassily D. Sokolovsky, and General Pierre Joseph Koenig. Roger Miller, 2

[97] Roger Miller, 2, and Frank Donovan, *Bridge in the Sky* (New York: David McKay Company, 1968), 10.

Notes

[98] *The United States Strategic Bombing Surveys: Summary Reports* (1945 & 1946; reprint, Maxwell AFB: Air University Press, 1987), 6.

[99] *Berlin Airlift: An Account of the British Contribution*, 59.

[100] Roger Miller, 2-3.

[101] Donovan, 4-15.

[102] Roger Miller, 2.

[103] Ibid., 4-5.

[104] Ibid., 1.

[105] Ibid., 5-7.

[106] Ibid., 6-7.

[107] Harrington, 7-8.

[108] Ibid.

[109] This "baby blockade" was aimed at the Western military garrisons located within Berlin not at the city's population. Ibid., 8-9.

[110] The pact also created a four-power Air Safety Center responsible for controlling the airspace over Berlin. The Berlin control zone which extended 20 miles in every direction from the center of the city basically allowed air access to any part of the city even if it was part of the Soviet sector. The three air corridors permitted the West to access Berlin at any altitude below 10,000 feet without prior notice to the Russians. Roger D. Launius and Coy F. Cross II, *MAC and the Legacy of the Berlin Airlift* (Scott AFB: MAC Office of History, April 1989), 4.

[111] Even though Berlin was 100 miles within Soviet occupied territory, the agreement that divided Germany into four zones did not guarantee Western land access into the city. While this may seem strange, it was understandable at the time since many believed the zones were a temporary measure until a more permanent arrangement could be arranged. Also, the zones were designed for the garrison of the Allied armies, not as political boundaries. Hence, it was expected that movement across the zones would be unrestricted. There was also some expectation that the East and West powers would continue wartime cooperation in the reformation of Germany. Harrington, 1-2.

[112] A common misperception is that all land routes were severed and that no food, materials, or people could cross the East-West boundary. While many of the major land lines were obstructed, Miller shows that the blockade was in fact somewhat porous and that some food stuffs, raw materials, production products, and people were allowed to cross the blockade. Roger Miller, 28-29.

[113] Most of the electricity for Berlin was produced by the eastern sector. Launius and Cross, 6-7.

[114] The Soviets had around 18,000 troops in Berlin compared to 6,500 Allied forces. Launius and Cross, 6.

[115] Roger Miller, 31.

[116] Launius and Cross, 11.

[117] When USAFE surveyed the airplanes immediately available, they found they only had 102 C-47s (able to carry three tons each) and two C-54s (able to carry around ten

tons) available. The British also had some *Dakotas* (their version of the C-47) to help. Ibid.

[118] Initially the situation was not critical. It was estimated there was enough food and supplies to support the city from three to four weeks. But as winter approached, the ability to supply over two million people in Berlin solely by air became a major concern. Harrington, 12-13.

[119] Ibid., 20-21.

[120] Ibid., 21-22.

[121] Ibid.

[122] Roger Miller, 32.

[123] The route system initially flown established a pattern of one-way traffic within the corridors. Within each corridor, the first plane flew at 5,000 feet with following aircraft taking off at three-minute intervals and flying 500 feet higher up to 7,000 feet. The pattern was then repeated. The closest any two aircraft at the same altitude would come to each other was fifteen minutes. The flight levels were reduced to three for simplicity thus reducing the interval between aircraft at the same altitude to nine minutes. Aircraft with different cruise speeds were sent at different "block times" so similar aircraft could fly together thereby keeping precise time intervals fairly constant. By utilizing this system, USAFE was able to maintain a three-minute interval for aircraft going into Berlin. While not accomplished twenty-four hours a day, it did establish a system that was later built on by the CALTF. Ibid.

[124] Harrington, 26.

[125] Eastbound C-47s used "Easy" followed by the number representing the order in which they took off and the last three digits of the aircraft's serial number. Likewise, westbound C-47s used "Willy", and "Big Easy" and "Big Willy" delineated the C-54s. Roger Miller, 33-34.

[126] Ibid.

[127] Ibid.

[128] Ibid., 44-46.

[129] In mid-1948, the Air Transport Command and Naval Transport Command were combined to form MATS. CALTF was formed in October 1948 and reported to USAFE. Roger Miller, 46. CALTF put the entire system of air bases, air traffic control facilities, and services working the airlift effort under one commander—this greatly helped improve the overall efficiency of the operation. Lt Col Charles Miller, 178.

[130] *Anything, Anywhere, Anytime*, 69.

[131] General Smith established five different altitudes to separate aircraft within the air corridors. To simplify descent and approach to Berlin, the CALTF later used only two different altitudes to separate aircraft flying the route. Harrington, 48.

[132] Roger Miller, 47.

[133] Harrington, 48-50, and Lt Col Charles Miller, 179-180.

[134] Harrington, 109.

[135] Roger Miller, 99-101.

Notes

[136] See Appendix D for total tonnage delivered to Berlin from June 1948 to September 1949.

[137] Mason, 80-89.

[138] Often overlooked is that over 81,000 tons of cargo was airlifted out of Berlin. Harrington, 109. Mostly consisting of Berlin-manufactured goods, the outbound cargo was instrumental in the effort to rebuild the German economy following the devastating effects of World War II. *Berlin Airlift: An Account of the British Contribution*, 59-60.

[139] Harrington, 109. There were five general categories of supplies airlifted to Berlin with food being the top priority. 1) Food and supplies for the garrisoned troops. 2) Food for the civilian population. 3) Coal for public utilities (electricity supply, sewage disposal, hospitals, etc.), for the industrial furnaces, and a small allocation for domestic heating. 4) Liquid fuel (mostly for motor transport), diesel oil (heavy transports and power plants), and some industrial high-grade fuels. 5) Special freight: newsprint (to inform and improve the morale of the citizens), raw materials (to keep some factory production going), and miscellaneous (medical supplies, shoes, equipment for the airfields and factories, etc.). *Berlin Airlift: An Account of the British Contribution*, 30-31.

[140] Harrington, 110. A little known fact is that twenty-five separate civilian companies provided 104 aircraft for the airlift effort. This civilian fleet flew 21,921 sorties and hauled 146,980 tons of cargo. Roger Miller, 40.

[141] Harrington, iii, and Tunner, 223.

[142] "A Special Study of Operation Vittles," 19, and Harrington, 2.

[143] *Berlin Airlift: An Account of the British Contribution*, 8-10, 30-39, and "A Special Study of Operation Vittles," 7-15.

[144] "A Special Study of Operation Vittles," 30.

[145] Ibid., 77.

[146] Roger Miller, 48.

[147] Ibid., 34.

[148] The U.S. Navy also provided 24 R5Ds (C-54 variants) to the airlift effort. Lt Col Miller, 178.

[149] The British continued to use *Dakotas* (a C-47 variant) and *Yorks* as their primary airlifters. The *York* was developed from the *Lancaster* bomber and had four engines, a cruise speed of 185 mph, and could carry 15,000 to 20,000 pounds. *Berlin Airlift: An Account of the British Contribution*, 41.

[150] For example, 122 C-54 sorties could deliver 1,072 tons while 200 C-47 sorties could only deliver 647 tons. Roger Miller, 34.

[151] "A Special Study of Operation Vittles," 30-32.

[152] British aircrew shortages severely affected aircraft utilization rate. On average, the Americans had twice as many crews for each airplane than the British. Roger Miller, 38.

[153] "A Special Study of Operation Vittles," 75-83.

[154] "A Special Study of Operation Vittles," 72.

[155] Harrington, 9.

[156] Ibid., 50.

Notes

[157] Lt Col Miller, 180.

[158] Harrington, 103.

[159] Lt Col Miller, 182-183.

[160] Swanborough and Bowers, 298, 389, 400, 403, and *C-17 Globemaster III*, on-line, Internet, 25 February 1999, available from http://www.af.mil/news/factsheets

Chapter 5

Evaluating Strategic Airlift Effectiveness

> *Mobility is the third controlling principle of war, a principle which endows all military operations with activity, whether offensive, protective, or logistical, and it finds its expression through the element of movement which draws its power from physical energy.*
>
> — Colonel J.F.C. Fuller[161]

The "Hump" and Berlin Airlift operations not only proved the efficacy of airlift but also appears to have solidified the use of tonnage delivered as the overall measurement of airlift effectiveness. World War II and expanding post-war global interests added another factor for the U.S.—the need to airlift cargo and people over vast distances. While tonnage per month or tonnage per day was a usable metric for the short distances flown in the China-Burma-India theater and in Germany, it was not very usable for the vast distances flown such as those from the U.S. to Europe or the Far East. Another metric was needed.

Strategic Airlift Measures of Effectiveness

During World War II, Air Transport Command (ATC) greatly expanded the number of routes it was flying from 57,000 miles in June 1942 to over 184,000 miles of routes in May 1945.[162] Another metric for the measurement of strategic airlift effectiveness was needed to account for the distances flown and the tonnage delivered. To do this, ATC adopted the use of ton-miles. A ton-mile is the airlift of one ton, one mile.[163] For World War II, ATC reported ton-miles flown for every month from 1942 to 1945 and provided cumulative totals for each of those years. For example, 6,439,011 ton-miles were flown in July 1942, 8,106,280 ton-miles flown in August, and so on with a total of 64,367,514 ton-miles flown in 1942. During the last year of World War II, an average of 121,718,650 ton-miles was flown per month with a total of 1,460,623,804 ton-miles for 1945.[164]

By the 1950s, the overall measure of strategic airlift was still measured in ton-miles flown per month with cumulative totals provided by year. But one important change had taken place. Ton-miles flown were now compared with ton-miles available. In 1957, it was reported that out of 1,018,406,650 available ton-miles, only 770,846,255 were actually flown.[165] Ton-miles was now a methodology used to allocate money for airlift operations and a yardstick the Air Force used to track what was flown relative to Congressional appropriations.

Less than ten years later, the U.S. was heavily involved in the Vietnam War and was also supporting NATO against the Soviet threat.[166] As contingencies mounted and airlift requirements increased, the annual average increased to 3,331,441,000 ton-miles between 1966 and 1971.[167]

During the 1970s, the elevated Soviet-Warsaw pact threat resulted in significant increases in force estimates needed to support NATO while also drastically lowering the estimated time available to deploy forces. A high premium was placed on the reinforcement of Europe in the quickest manner possible. Planners were also instructed to include force estimates for a potential conflict with Russia over Arab oil.[168] By July 1973, the Military Airlift Command (MAC) was using million ton-miles (MTM) per month and MTM per year as the primary metrics for strategic airlift effectiveness.[169] But the impetus was for mobility planners to develop a methodology that also accounted for the increased emphasis on closure time.[170]

To accommodate the vast distances flown, the huge amounts of cargo delivered, and the requirement to consider closure time, the Congressionally Mandated Mobility Study (CMMS) of 1981 normalized strategic airlift capability to million ton-miles per day (MTM/d).[171]

The CMMS based the cargo requirements on four possible wartime scenarios and determined that strategic airlift must deliver at least 66 MTM per day.[172] The CMMS also determined that during the first fifteen days of a Persian Gulf conflict, 52 percent of the airlifted cargo would be oversized, 19 percent outsized, and 27 percent bulk. Ultimately, the Air Force would be responsible for delivering 700,000 tons of cargo within thirty days of the required delivery date.[173]

In 1991, Congress mandated another Mobility Requirements Study (MRS) due to the demise of the Soviet Union and the changed nature of the global threats. By analyzing six potential contingencies (Middle East / Persian Gulf, Korea, Europe, Southeast Asia, Western Hemisphere, and a dual contingency scenario) and using the Middle East as the restrictive scenario, the MRS established a new strategic airlift fleet requirement of 57.5 MTM/d.[174]

The MTM/d requirement was again revised in 1995. Basing their calculations on the support of two major theater wars, the Mobility Requirements Study Bottom-Up Review Update (MRS BURU) looked at current capability, planned future airlift availability, and fiscal constraints to develop the current strategic airlift fleet requirement of 49.7 MTM/d.[175]

What is Million Ton-Miles per Day?

MTM/d has been used since the 1981 *CMMS* as the primary measurement of strategic airlift effectiveness. But what is MTM/d and how is it used? The MTM/d equation for a single aircraft is:[176]

$$\text{MTM/d} = \frac{(\text{Objective Utilization Rate}) \times (\text{Block Speed}) \times (\text{Payload}) \times (\text{Productivity Factor})}{1{,}000{,}000 \text{ nautical miles}}$$

As shown in the above formula, MTM/d has four variables. *Objective Utilization Rate (UTE)* is the average number of hours per day that an airplane is expected to fly. There is a UTE rate for every type of airlift aircraft for a "surge" period (first 45 days of a contingency) and "sustained" period (after the surge). During the "surge" period, every effort is made to utilize the aircraft to the maximum extent possible and deliver the most cargo and personnel. After 45 days, the flying rate is reduced to a sustainable rate to permit logistics personnel to catch up on repairs and inspections deferred during the "surge." *Blockspeed* is the average ground speed (kts) from takeoff to block in (parking at the destination) and assumes an average leg distance of 2,500 nm. *Payload* is based on operational experience from the Gulf War and is a planned average cargo load for each type of airlifter. *Productivity Factor* attempts to account for aircraft returning empty from the theater to onload locations.[177]

To calculate the MTM/d capability for a fleet of aircraft (e.g. the C-141), you multiplied the number of aircraft in that fleet (e.g. 200 C-141s) by the MTM/d for a single aircraft. To calculate MTM/d capability for the whole strategic airlift fleet (KC-

10, C-5, C-141, C-17, and CRAF) you calculate the fleet capability for each type of aircraft and then add them together. This in turn provides a methodology to compare the strategic airlift fleet's capability to the actual requirement. Any shortfalls between requirements and capabilities necessitates the acquisition of more airlifters, a reevaluation of the MTM/d requirement, a modification of the planning scenarios, or some other risk mitigation to offset deficiencies.

How is MTM/d Used?

According to the Air Mobility Master Plan (AMMP), MTM/d is used as a force structure planning tool and as a top-level comparative metric.[178] As a planning tool, MTM/d is used to determine how many airlifters of various types are needed to satisfy national security tonnage requirements. For example, the 1995 Milestone III decision to obtain 120 C-17s was largely based on the 49.7 MTM/d requirement developed by MRS BURU. While the C-17 fleet alone cannot carry this much cargo per day, its addition to the strategic airlift fleet coupled with the retirement of the C-141 within the next 6-7 years, necessitated the purchase of at least 120 C-17s.[179]

As a top-level comparative metric, MTM/d is used to compare an airlift fleet of a specific type of aircraft against its expected MTM/d capability, to compare it against a fleet of other airlifters, and can be used to evaluate the effectiveness of future airlift proposals. But while MTM/d can be used for these things, there are some major shortfalls when using this methodology.

Concerns With MTM/d as a Primary Metric

The AMMP identifies several problems with using MTM/d. First, since it is an unconstrained, top-level comparative metric, it does not adequately capture airlift's true capability nor does it provide an accurate measure of airlift requirements. In other words, it is a general metric that does not have a requisite level of detail.

Second, since MTM/d is centered on the paradigm of "getting there the fastest with the mostest", it does not cover the full spectrum of conflict. As discussed earlier in this monograph, the end of the Cold War has greatly changed the international security environment. While the chance of major theater war (MTW) has decreased, the threats due to situations like Bosnia, Somalia, Haiti, and Kosovo has greatly increased. To use MTM/d as the overall metric for airlift effectiveness in this changed world greatly underestimates the flexibility of airlift. While MTM/d may work for MTW scenarios, we need a methodology that also works for a myriad of other operations to include humanitarian, peacekeeping, and disaster relief.

Third, MTM/d does not differentiate between traditional and direct delivery airlift methods (see Appendix E for a graphical representation of traditional and direct delivery airlift). Traditional strategic airlift delivers personnel and cargo from the CONUS or Aerial Point of Embarkation (APOE) to a theater main operating base (MOB) or Aerial Point of Debarkation (APOD). MOBs are bases that have extensive infrastructure, vigorous maintenance support, and robust command and control. Once in-theater, the personnel and cargo are then airlifted using more tactically capable aircraft to a forward operating base (FOB) or forward operating location (FOL). From the FOB or FOL, the personnel and cargo then usually travel via land to the final destination (although some smaller air assets, such as C-130 or helicopters may be used).[180] The traditional method of strategic airlift can cause delays from the MOB / APOD to the final destination and a loss of in-transit visibility and unit integrity.[181]

Direct delivery airlift can provide the most expeditious method to carry cargo and personnel to the intended AOR while also maintaining unit integrity.[182] But direct delivery to forward areas is not normally possible for aircraft such as the KC-10, C-5, and the CRAF. These aircraft require long runways, wide taxiways, and expansive ramp space not typical of FOBs and FOLs. They also require greater surface stressing than smaller / lighter aircraft such as the C-130, C-141, and C-17. And the only aircraft that can accomplish direct delivery into small austere airfields are the C-130 and C-17. Since FOBs and FOLs are typically much smaller and less robust than MOBs, these large aircraft cannot operate into them. But MTM/d does not account for the direct delivery concept. It assumes the operating bases will have runways and ramps available to support large strategic airlift aircraft. With the USAF moving to an expeditionary force structure that depends on the quick delivery of cargo and personnel as far forward as possible into austere airfields, we need a metric that can better capture direct delivery concepts.[183]

Fourth, MTM/d does not account for one of the major limiting factors when dealing with large wide-body commercial aircraft. Commercial aircraft with high cargo-loading platforms (typically 16 to 18 feet above the ground) such as wide-body CRAF aircraft and the KC-10 require special material handling equipment (MHE) to onload and offload cargo.[184] Since the majority of MHE is designed to work with military airlift aircraft (with much lower cargo decks), special MHE must be available if commercial wide-body or military tanker aircraft are used. While special MHE may be available at MOBs, it is not usually available at FOBs or FOLs.[185] For example, during Desert Shield / Desert Storm, the lack of MHE to offload wide-body commercial aircraft was a serious problem. Frequently, MHE for commercial aircraft had to be moved around to various airfields which greatly delayed offloads within the theater. Since MHE can be a "show stopper," we need a metric that captures this requirement.

Fifth, MTM/d does not directly account for ground time. As shown in the discussion of the "Hump" operation and the Berlin Airlift, ground time directly affects the ability to move the most number of aircraft through an airfield in the shortest possible time. Ground time is primarily a function of aircraft and airfield capabilities. Airlift aircraft that have large cargo doors and that are close to the ground greatly facilitate the loading and offloading of cargo. Airfields that have adequate refueling points, maintenance personnel, base operations support (weather, flight planning, etc.), and communications equipment help turn the aircraft as quickly as possible. When operating from an airfield that has limited ramp space, short ground time is even more critical. Otherwise, airplanes may have to divert to other airfields or remain airborne until parking space becomes available.[186] While MTM/d attempts to accommodate ground time in its Objective UTE rate, it is unclear how and is difficult to audit.[187] As the Air Force Component Commander during Somalia stated: "I never saw a ton-mile get off the aircraft. You can not touch it and it has no relationship to the loading and unloading of aircraft quickly which meant a lot to me."[188]

Sixth, MTM/d does not take into consideration oversize or outsize cargo.[189] This is especially sobering when one considers that during a major conflict such as the Gulf War, over 50 percent of the cargo airlifted could be oversized and 30 percent outsized.[190] With the success of an operation hinging on the ability to deliver this cargo in as short a time as possible, it seems reasonable that an airlift metric must be able to include this critical factor.

Seventh, MTM/d does not capture tactical missions such as airdrop or special operations. The ability to airdrop troops, equipment, and supplies is still a requirement, and yet the current major measurement of airlift effectiveness, does not address this critical mission. Nor does it address covert missions such as special operations low level (SOLL).

Earlier in this monograph, I showed that tonnage delivered has been the major measure of strategic airlift effectiveness since World War II. In my opinion, this was not due to any oversight or failure of planners and analysts who attempted to distill the complicated airlift mission into a simple methodology that was logical, reasonable, and usable. But another factor that likely played a role in the development of tonnage delivered as the major metric concerns other modes of cargo delivery. Since ships, trains, and trucks also use tonnage as their primary metric, it seems reasonable to use this for airlift as well. But since these other modes of travel use tonnage and since this methodology has been used with airlift for over five decades, there will likely be a lot of resistance to change. Colonel Robert Owen cautions that the current "US military airlift system is the product of at least six decades of doctrinal, organizational, and technological development . . . One should impose change on this system or its individual components only with clear reference to its dearly derived general wisdom."[191]

But I profess that the airlift mission is much more diverse and has many more critical variables than other forms of cargo delivery. For example, while a train or a truck must follow established ground routes, airlift is not so restricted and can easily change its route of travel anywhere between takeoff and its destination. While transport ships are designed for the sole mission of delivering personnel and cargo from one port to another, airlift is designed for many diverse missions. For example, airlift missions include airland, airdrop, special operations, aeromedical evacuation, prime nuclear airlift force (PNAF), joint airborne command center/command post (JACC/CP), and senior executive support (e.g. President and Congress). And unlike other modes of travel, airlift is expected to operate under various levels of threat, from permissive to potentially lethal. Airlift's speed, range, and flexibility make it inherently different than other forms of surface travel. Because of this, we need a different measure of effectiveness to capture these unique capabilities other than just tonnage delivered.

The above MTM/d concerns are not inclusive but do show the need for another methodology. The point of this paper is not to denigrate the efforts of those who have tried to simplify the complicated airlift system and provide a usable methodology for top-level comparisons and to help formulate an appropriate airlift force structure. While no methodology can capture every intricacy of the airlift mission, I believe there is a better way than using MTM/d.

Notes

[161] Fuller, 250.

[162] Headquarters Air Transport Command (ATC), *Statistical History of the Air Transport Command, 29 May_1941–31 May 1948*, (Washington D.C.: Office of Statistical Control, 1948), i.

[163] *Statistical History*, 29.

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[164] *Statistical History*, 32.

[165] Headquarters Military Air Transport Service (MATS), *Military Air Transport Service: Command, Control Data Book, FY 54 to FY 57*, Traffic-D.

[166] Department of Defense, *Congressionally Mandated Mobility Study (CMMS)* (U), vol. 2, 30 April 1981, 1-3. (Secret) Information extracted is unclassified.

[167] *Military Airlift Command (MAC) Summaries: FY 1966 Thru FY 1971 ACIS*, 25 September 1970, 7.

[168] As expanding Western economies became more dependent on Arab oil, the threat of Soviet intervention in the Persian Gulf could not be overlooked. *CMMS*, vol. 2, 1-4.

[169] The evolution from ton-miles to million-ton-miles was logical since over one trillion cargo ton-miles per year were flown since 1966. The cumulative total ton-miles for military and commercial aircraft in 1966 was 1,482,423,000. From 1967 to 1970, over three trillion ton-miles were flown for each of those years—of which commercial aircraft delivered 16 to 39 percent. *MAC Summaries: FY 1966 Thru FY 1971*, 7. In 1972, MAC began to report tonnage as million ton-miles. *Military Airlift Command (MAC): Command Data Book*, June 1973, 67.

[170] Closure is the process of a unit arriving at a specified location. It begins when the first element gets to a designated location and ends when the last element (or large percentage) arrives at that location. Air Force Pamphlet (AFPAM) 10-1403, *Air Mobility Planning Factors*, 1 March 1998, 24.

[171] Department of Defense, *Congressionally Mandated Mobility Study (CMMS)* (U), vol. 1, 30 April 1981, 15. (Secret) Information extracted is unclassified. To implement the recommendations of the *CMMS*, MAC developed the Airlift Master Plan (AMP). Point Paper, Lt Col Pete Bailey, HQ AMC/XPDI, 66 MTM/d Goal and the Congressionally Mandated Mobility Study (CMMS), 22 April 1993.

[172] Wartime scenarios included two in Southwest Asia, one in NATO, and a nearly simultaneous confrontation in Southwest Asia and in NATO. The CMMS determined that total tonnage requirements was between 73 to 125 MTM/d. Since an airlift-only solution was considered unaffordable, the *CMMS* recommended a balanced program of airlift, sealift, and pre-positioned war materials to meet shortfalls. An additional 20 MTM/d of oversize / outsize capability was to be added to the FY86 projected capability of 46 MTM/d resulting in a total of 66 MTM/d required. While 66 MTM/d did not satisfy the lift requirements of any of the four *CMMS* scenarios, it did represent a reasonably attainable / fiscally constrained goal. *US Air Force: Airlift Master Plan*, 29 September 1983, III-2 to III-5.

[173] Required Delivery Date (RDD) is the date established by the CINC for when cargo, personnel, etc. must be delivered to a theater to support an operation. *CMMS*, vol. 1, 5.

[174] Southwest Asia was considered the most restrictive scenario since the Middle Eastern roads, terrain, and infrastructure would not support timely overland travel which required the use of airlift. *1983 AMP*, III-5. The Mobility Requirements Study (*MRS*) of 1991 tried to establish a requirement that was fiscally constrained and yet obtainable. Like the *CMMS*, the *MRS* recommended a fiscally prudent program of sealift, pre-

positioned stocks, and airlift. The *MRS* projected FY99 airlift capability was: C-5 (16.4 MTM/d), C-141 (8.4 MTM/d), C-17 (12.1 MTM/d), KC-10 (2.5 MTM/d), and CRAF (18.1 MTM/d) for a total of 57.5 MTM/d. Point Paper, Lt Col Pete Bailey, HQ AMC/XPDI, 57 MTM/D and the Mobility Requirements Study, 22 April 1993.

[175] Like previous mobility studies, the airlift MTM/d requirement was predicated on a balanced program of airlift, sealift, and pre-positioned war materials. It is also important to keep in mind that 49.7 MTM/d is based on the whole strategic airlift fleet (C-17, C-5, C-141, KC-10, and CRAF) and not just one type of aircraft. *1998 Air Mobility Master Plan*, 24 October 1997, 2-29.

[176] *1998 AMMP*, 2-26.

[177] *1998 AMMP*, 2-26 to 2-28.

[178] *1998 AMMP*, 2-26.

[179] One should keep in mind that the strategic airlift fleet (C-5, C-17, C-141, KC-10) is unable meet minimum MTM/d or minimum air passenger requirements without activation of the CRAF. Until DESERT SHIELD, the CRAF had never been activated since its inception in 1951. To offset shortfalls in airlift capability, the Commander in Chief, U.S. Transportation Command (CINCTRANS), with Secretary of Defense approval, activated Stage II of the CRAF. This gave CINTRANS an additional 76 long-range international (LRI) commercial passenger, 40 LRI commercial cargo, 23 short-range international (SRI) passenger, 38 domestic cargo, and 4 Alaskan cargo aircraft for the airlift effort. By the end of the war, civilian airline carriers had flown 3,604 missions, airlifted 171,170 STONs of cargo, and delivered 405,448 passengers. CRAF aircraft delivered 64 percent of the passengers and 27 percent of the cargo for the Gulf War. James K. Matthews and Cora J. Holt, *So Many, So Much, So Far, So Fast* (Washington, D.C.: Joint History Office, 1992), 37, 42-47.

[180] Theater airlift such as the C-130 can operate on small austere airfields (SAAF) and can even land on semi-prepared runways (i.e. non-paved). Theater airlift is also able to maneuver in congested / limited ramp areas where larger / less capable aircraft could not operate. But the ability to accomplish these tasks generally results in an aircraft that is much smaller and has much less cargo capacity than larger aircraft such as the C-5, C-141, and the B-747. Currently, the C-17 is the only transport aircraft that can carry outsized or oversized cargo into a SAAF.

[181] Lt Col Miller, 405.

[182] A big problem during the Gulf War was Intransit Visibility (ITV) and "marrying up" ground combat equipment with personnel. ITV was a serious issue since cargo was loaded onto aircraft and delivered into the AOR without ground commanders knowing where their cargo was. Often cargo went months without ever being claimed. The problem was compounded by the fact that most of the tanks, armored personnel carriers, and munitions arrived via sea points of debarkation (SPODs) while most of the soldiers arrived at air points of debarkation (APODs). Often, the SPODs and APODs were not co-located which required overland travel and additional time to rejoin the soldiers with their equipment. Matthews and Holt, 26-28.

Notes

[183] Currently, the C-17 is the only airlifter that can carry outsized or oversized cargo over intercontinental distances and land at a SAAF. With the U.S. decision to replace the C-141 fleet with the C-17, a metric that better measures the unique capabilities of C-17-type aircraft is needed.

[184] Special MHE includes loading platforms such as the K-loader ("K" designates the weight in 1000s of pounds the loader can accommodate. e.g. 40K Loader). Most military K-loaders can only raise their platforms to 13 feet (they were designed for military transporters with high wings, rear or front loading cargo doors, and low cargo decks) and so they cannot be used with commercial wide-body aircraft. Consequently, either the special MHE must be available at the airfield, or commercial wide-body aircraft must be restricted from operating into bases that do not have it. Lt Col Gary B. May, *The Impact of Materials Handling Equipment on Airlift Capabilities* (Maxwell AFB: Air University Press, August 1983), 4-5.

[185] Eliot A. Cohen, ed., *Gulf War Air Power Survey* (Washington D.C.: U.S. Government Printing Office, 1993), 106-107.

[186] As a C-141 aircraft commander during the Gulf conflict, I frequently remained airborne in a holding pattern until ramp space opened up. It was rather frustrating (and potentially dangerous) to hold for several hours at the end of a twenty-four hour duty day.

[187] In 1993, the Government Audit Agency (GAO) questioned the authenticity of objective UTE rate and how it was used in MTM/d calculations. Their dispute lay within the Air Force's inability to meet advertised airlift fleet capability during the Gulf War. In response, the Air Mobility Command (AMC) reevaluated the planning factors and reduced the advertised UTE rate and average payload per aircraft. While this may have quelled GAO criticism, it did not address the fact that while the calculation of MTM/d may appear simple, it is in fact rather difficult to understand and possibly too generalized. AMC Staff Summary Sheet, Col Stephen R. Cornish, Plans and Programs, Mobility Forces Planning Factors, 30 December 1992.

[188] Brig Gen Tom Mikolajcik, correspondence via e-mail, 22 February 1999.

[189] *Oversize* cargo exceeds the dimensions of bulk cargo (fits within the dimensions of a 463L pallet) but is equal to or less than 1,090" in length, 117" in width, and 105" in height. *Oversize* cargo is transportable on C-5, C-17, C-141, C-130, and the KC-10. *Outsize* cargo exceeds the dimensions of oversize cargo and requires the use of a C-5 or C-17 aircraft. For example, while the C-5 and C-17 can carry the Abrams M1A1 tank, THAAD, or the 70K scissors-bridge (all outsized cargo), the C-141 and C-130 cannot. Joint Publication (JP) 1-02, DOD Dictionary (JMTGM-024-97), *Approved Terminology*, 14 March 1997, Glossary-5.

[190] During Desert Shield / Desert Storm, out of 526,277 STONs airlifted, 277,210 STONs were oversized and 184,805 STONs were outsized. Matthews and Holt, 79.

[191] Lt Col Robert C. Owen, "The Airlift System: A Primer," *Airpower Journal*, vol. IX, no. 3, 1995, 18.

Chapter 6

A Better Methodology?

Strategic mobility, the capability to transport military forces rapidly across intercontinental distances into an operational theater, lies at the heart of military strategy.[192]

— Gen John M. Shalikashvili
CJCS

The Air Mobility Evaluation Process (AMEP) introduced below consists of four levels and is based on a system-of-systems approach. The first three levels are used to calculate an aggregate mobility value (AMV) for each type of airlift aircraft relative to a given scenario. Level four of the AMEP is the analysis portion of the process.

The first level consists of the various aircraft capabilities and user scenario requirements divided into areas of *range*, *payload*, *speed*, *operations*, and *cost* (see Figure 1). For example, within the *operations* category is aircraft utilization (UTE) rate. Aircraft UTE rate is the number of flying hours a given aircraft (or fleet of aircraft) is expected to fly each day and is made up of other systems to include aircrew ratio, aircraft maintenance, and inherent aircraft reliability, maintainability, and availability (RM&A).[193] The measurement of effectiveness (MOE) for a specific scenario's UTE rate is expressed as a question—"What is the desired aircraft UTE rate for this scenario?" The corresponding question for each type of aircraft is: "What is this aircraft's UTE rate?" By establishing MOEs that best represent each area and comparing the requirements to actual aircraft capabilities we complete Level I of the AMEP. In this fashion, we have a group of MOEs that create a separate system for *range*, *payload*, *speed*, *operations,* and *cost.* It is important to keep in mind that each of the MOEs for each of the areas should be mutually exclusive—otherwise duplication and inaccurate accounting will result when the MOEs are later aggregated in Level III into an overall mobility value.

Level II is simply the application of a weight value to each MOE. This permits the user to appoint relative importance for each MOE depending on the requirements of the scenario. For example, one scenario may require a large amount of outsized or oversized cargo airlifted and so the weight value for these MOEs (a subset of *payload*) would be relatively high. Another scenario may require the ability to perform the Strategic Brigade Airdrop (SBA) mission (a subset of *operations*) which would result in a high weight factor for this MOE. Similarly, both of these scenarios may not need a high emphasis placed on *cost* (especially if the operation is required to protect vital national interests) and so the weight factor for this MOE would be relatively low. After applying the relative weight value to each MOE, we have completed Level II of the AMEP.

Level III combines all the MOEs (with weight factor applied) into an overall aggregate mobility value (AMV).

Level IV provides a methodology to compare each type of aircraft's AMV with the other aircraft to determine the best aircraft for a given scenario. The fourth level also includes the comparison of the different aircraft capabilities relative to each other to determine why some aircraft excel and others are deficient. Finally, the fourth level includes a comparison of fleet cargo and passenger capability relative to gross theater requirements. In this fashion, the AMEP provides everything that MTM/d does and also accommodates the deficiencies associated with using a measurement of airlift effectiveness based primarily on tonnage delivered.

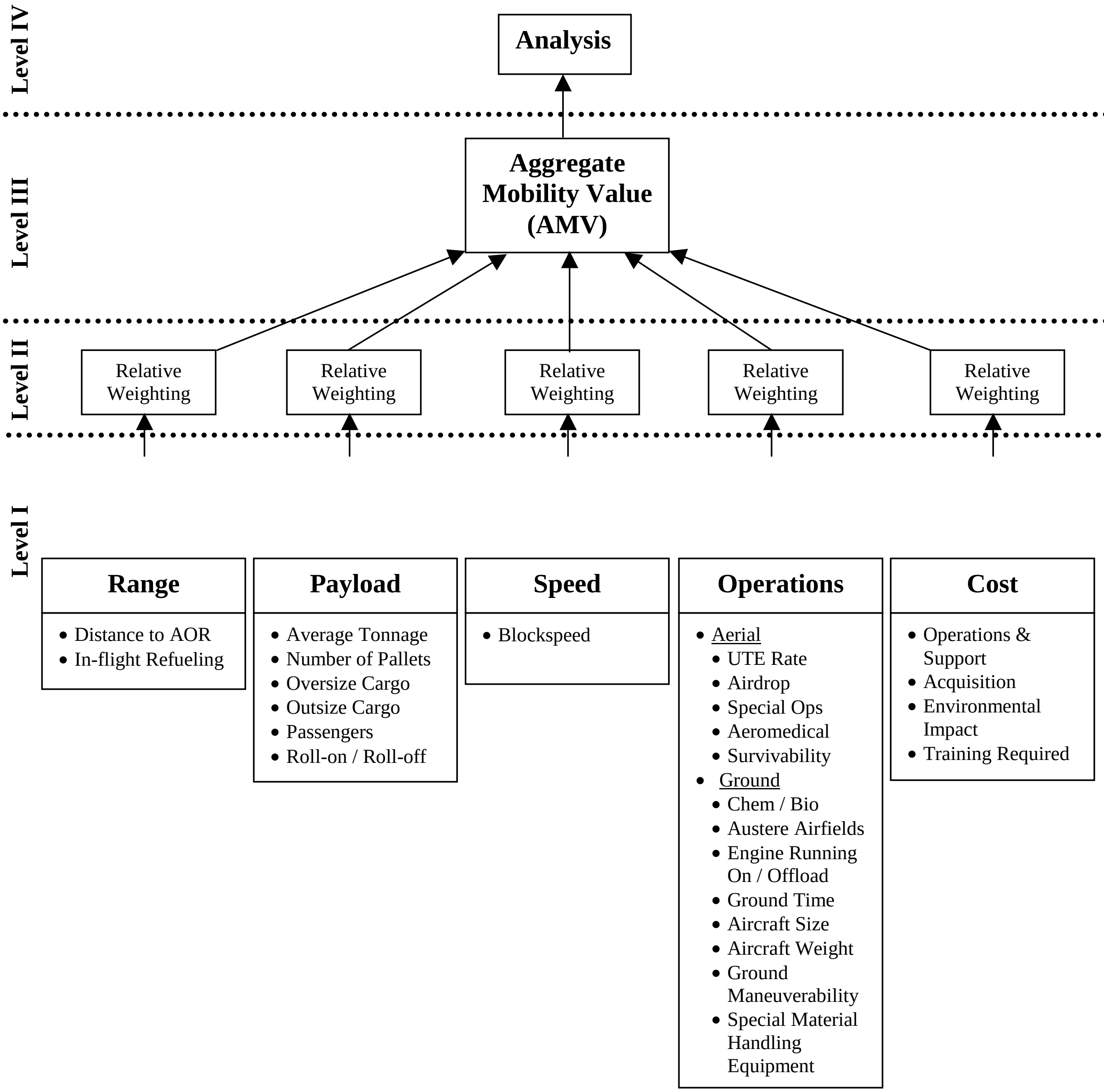


Figure 1. The Air Mobility Evaluation Process (AMEP)

By aggregating the MOEs for each major area into an overall air mobility value, we can get a more accurate depiction of what airlift can do relative to what it is required to do. While one could argue about the whether the MOEs in this paper are valid or not, I ask the reader keep in mind that the MOEs used are for demonstration purposes only. I do not propose that these MOEs are the final ones for any given situation. This paper attempts to provide another methodology that can be used to evaluate airlift effectiveness and to stimulate interest and debate for others to build upon.

Strengths and Weaknesses with the AMEP

There are many positive aspects with the AMEP. It accommodates diverse MOEs and provides an overall "at-a-glance" depiction of airlift capability relative to scenario requirements. It gives a visible picture of the MOEs under evaluation without burying them into a single formula and is easier to understand and more comprehensive than other high-level methodologies currently used (such as MTM/d). MOEs can be added, removed, or modified to reflect the scenario, doctrinal changes, and / or technological improvements which in turn gives a more accurate depiction of the "real world." If increased fidelity is required, then more MOEs can be added.

The AMEP permits us to span the gap left by MTM/d concerning airlift concepts such as direct delivery and allows us to cover the full spectrum of airlift missions. The assignment of a *relative weight* for each MOE permits us to refine the importance of each metric which in turn puts emphasis on those MOEs that are more important than other ones for a given situation. Finally, this methodology can be used to evaluate future airlift proposals by changing those MOEs that reflect future requirements.

Like any methodology, there are several disadvantages. User knowledge is required to add, remove, or modify the MOEs that represent the scenario under evaluation. But since analysts and planners should already know enough about the requirements of the situation and those capabilities needed to accomplish the mission (if they don't, they need to find out anyway), it should not be a major issue to determine the appropriate MOEs. For example, if the tactical insertion of paratroopers was planned, then the MOEs concerning airdrop and aircraft survivability should be included in the calculation of the AMV.

Next, the user must give serious consideration on how each MOE should be weighted. Again this should not be a problem since the importance of each MOE should be discernable depending on the situation. For example, if operations were planned into an area with limited infrastructure, sparse airfield facilities, and short runways, then the ability to operate on small austere airfields (SAAF) should receive heavy emphasis.

Finally, while this methodology attempts to model the "real world" to some extent, it is not a replacement for more precise computer modeling and simulation. While the AMEP is several orders of magnitude better than MTM/d, it is not as accurate as some of the mobility computer modeling and simulation programs currently used by planners and analysts. But unlike computer models, the AMEP provides more information "at a glance" with very little "hidden" behind the scenes. With that said, it is time to demonstrate AMEP with an example.

The Major Theater War (MTW) Scenario and AMEP

For the MTW scenario, we will simulate that Iraq has massed troops and armor on its southern border. Through classified channels and other sources, intelligence estimates that Iraq could invade Kuwait within the next two days. Strategic planners also surmise that Iraq will not make the same mistakes they did during the Gulf War. They will not remain idle while a coalition deploys superior strength and firepower to thwart their aggressive intentions, and when they strike it will be quick and decisive.

Iraq will likely pursue an asymmetrical approach by initially using weapons of mass destruction (chemical and biological) to inflict heavy casualties and to offset the superior technical advantage enjoyed by the Western states. Iraq ultimately hopes that using chemical / biological weapons will cause such carnage that the coalition will back out of what they see as a conflict between Iraq and their Arab neighbor. It is also suspected that Iraq has a good supply of man-portable air defensive systems (MANPADS) that pose a medium threat to air assets flying in the theater of operations.

As part of the Central Command (CENTCOM) crisis action team, we have been tasked to develop a course of action. After much deliberation, CINCCENTCOM forwards the following phased recommendation to the President—Phase I: Immediately deploy four AEFs to the Middle East to delay Iraqi forces should they cross the border. Phase II: Be prepared to airdrop the 82d Airborne to secure forward airfields so additional troops, equipment, and supplies can be flown in and to prepare for the counteroffensive. Phase III: Use all air, land, and sea assets jointly to force Iraq out of Kuwait, destroy Iraqi military forces, and forcibly remove the Iraq government from power to restore a "better peace" to the Middle East.[194] Phase IV: Airlift will then shift from wartime standing to the support of post-war peacekeeping operations as mandated by the United Nations and the US government. The success of this operation hinges on getting the right forces to the right place in the quickest fashion possible—and this requires airlift.[195]

In the interest of brevity, the simulation presented below only covers the first two phases of this operation. With little additional effort, the AMEP could also be used for the last two phases as well.

The AMEP: Level I

With this scenario in mind, let's look at how the AMEP is used. The first step is to determine what airlift capabilities are required for this scenario. Based on the planned course of action and the scenario airlift requirements, the baseline MOEs in Table 1 below were developed.

Table 1. MTW Scenario Baseline Planning Factors

	Range	**Desired or Required Capability**	**Weight Factor** (1 to 10)
R1	What is the average distance from the APOEs to theater APODs? (nm)	9,000	8
R2	Is in-flight refueling capability desired? (Y/N)	Y	8
	Payload		
P1	What is the planned average tonnage per aircraft? (STON)	50.0	8
P2	How many 463L pallets are planned per aircraft?	15	6
P3	Is oversized capability needed? (Y/N)	Y	10
P4	Is outsized capability needed? (Y/N)	Y	10
P5	What is the average passenger capacity needed per aircraft?	200	9
P6	Is Roll-on / Roll-off capability required? (Y/N)	Y	7
	Speed		
S1	What is the desired average en route blockspeed? (kts)	400	5
	Cost		
C1	What is the planned average flying cost? (per acft hour)	$8,000	1
	Aerial Operations		
A1	What is the desired aircraft "surge" utilization (UTE) rate? (hrs)	12.0	8
A2	Is Strategic Brigade Airdrop (SBA) capability needed? (Y/N)	Y	10
A3	Is Special Operations Low Level (SOLL) planned? (Y/N)	Y	5
A4	Is aeromedical evacuation (AE) capability needed? (Y/N)	Y	8
A5	What level of airborne survivability is required? (N, L, M, H)	M	9
	Ground Operations		
G1	What level of aircraft resistance to WMD (chem & bio) is needed? (N, L, M, H)	M	7
G2	What level of aircraft decontamination for WMD (chem & bio) is needed? (N, F, T, P)	T	7
G3	What is the average minimum ground time allowed? (minutes)	150	8
G4	Is any special MHE initially available? (Y/N)	N	7
G5	Is small austere airfield (SAAF) capability desired? (Y/N)	Y	6
G6	Is engine running on / offload capability desired? (Y/N)	Y	7
G7	What is the largest aircraft the average airfield can support? (S, MS, M, ML, L, XL)	L	9
G8	What is the heaviest aircraft the average airfield can support? (L, ML, M, MH, H, XH)	H	9
G9	What level of aircraft ground maneuverability is required? (A, S, D, C)	S	8

G10	What maximum aircraft on the ground (MOG) that the average airfield can support per day? (C-130 equivalents)	25	8

The next step is to determine the weight value for each MOE. To save space, only a couple MOEs will be discussed. This should give the reader a good idea of the thinking behind how the MOEs were developed and why some of them received a higher weight value than others. For a full explanation of all the MOEs for this scenario, see Appendix G.

Since a large percentage of the airlifted cargo will be outsized and oversized, a high weight factor is assigned to these MOEs (P3 and P4). Likewise, with a large percentage of the personnel deployed expected to travel by air, the weight factor for this MOE (P5) is set at a high value as well. Since the theater has several airfield limitations and throughput is of primary importance, most of the ground operations MOEs have high weight factors (G3, G4, G6, G7, G8, G9, and G10). Also significant is the threat due to small arms fire and MANPADS so required aircraft survivability has a high weight value (A5). Since this operation may require the airdrop of a brigade-sized force to secure airfields for follow-on airland missions, the Strategic Brigade Airdrop (SBA) MOE (A2) gets the highest weighting possible. The MOE for cost (C1) provides a counter example. Since this operation concerns vital national interests, cost is not a major consideration so it receives a relatively low weight.

The next step is to evaluate each aircraft's actual capability relative to the baseline MOEs (see Table 2 below for the C-17). For those MOEs that have numerical values (e.g. P1.1), this is done through simple division to determine a fractional representation of the aircraft's capability relative to the baseline. For MOEs (e.g. R2.1) that have a yes or no answer, the result of the comparison is one if the aircraft meets the baseline requirement or zero if it does not. For MOEs with more than two responses, a variable scale is used depending on how close the aircraft's capability comes to meeting the baseline requirement (e.g. G1.1). For a full discussion of the math behind these calculations, see Appendix H.

Table 2. C-17 MOEs and AMV for MTW Scenario[196]

	Range	**Actual Aircraft Capability**	**Capability vs Baseline**	**x Weight Value**
R1.1	What is the aircraft's average range with a planned cargo load? (nm)	3,000	0.33	2.67
R2.1	Is this aircraft in-flight refuelable? (Y/N)	Y	1.0	8.0
	Payload			
P1.1	What is this aircraft's planned average tonnage? (STON)	45.0	0.90	7.2
P2.1	How many 463L pallets can this aircraft carry?	18	1.0	6.0
P3.1	Can this aircraft accommodate oversized cargo? (Y/N)	Y	1.0	10.0
P4.1	Can this aircraft accommodate outsized cargo? (Y/N)	Y	1.0	10.0
P5.1	What is the aircraft's planned passenger capacity?	90	0.45	4.05
P6.1	Can this aircraft accommodate Roll-on / Roll-off cargo? (Y/N)	Y	1.0	7.0
	Speed			
S1.1	What is this aircraft's average blockspeed? (kts)	410	1.0	5.0
	Cost			
C1.1	What is this aircraft's hourly flying cost?	$7,418	1.0	1.0
	Aerial Operations			
A1.1	What is this aircraft's "surge" utilization (UTE) rate? (hrs)	15.15	1.0	8.0
A2.1	Can this aircraft perform the Strategic Brigade Airdrop (SBA) mission? (Y/N)	Y	1.0	10.0
A3.1	Can this aircraft perform Special Operations Low Level (SOLL)? (Y/N)	Y	1.0	5.0
A4.1	Is this aircraft aeromedical evacuation (AE) capable? (Y/N)	Y	1.0	8.0
A5.1	What is this aircraft's airborne survivability level? (N, L, M, H)	M	1.0	9.0
	Ground Operations			
G1.1	What is this aircraft's resistance to chemical & biological agents? (N, L, M, H)	M	1.0	7.0
G2.1	What is this aircraft's level of decontamination? (F, T, P)	T	1.0	7.0
G3.1	What is this aircraft's planned ground time? (minutes)	135	1.0	8.0
G4.1	Is any special MHE required for this aircraft? (Y/N)	N	1.0	7.0
G5.1	Is this aircraft small austere airfield (SAAF) capable? (Y/N)	Y	1.0	6.0
G6.1	Can this aircraft perform engine running on / offload? (Y/N)	Y	1.0	7.0
G7.1	What is this aircraft's qualified size? (S, MS, M, ML, L, XL)	L	1.0	9.0
G8.1	What is this aircraft's qualified weight? (L, ML, M, MH, H, XH)	H	1.0	9.0
G9.1	What is this aircraft's qualified ground maneuverability? (A, S, D, C)	S	1.0	8.0
G10.1	What is this aircraft's MOG-equivalency relative to the C-130?	2.26	0.44	3.54
	C-17 Aggregate Mobility Value (AMV)			**6.9**

The AMEP: Level II

The next level in the AMEP is to multiply the user assigned weight factor by each "capability vs baseline" comparison (see Table 2 above). This ensures that those MOEs that are considered more critical than others to mission accomplishment receive greater emphasis.

The AMEP: Level III

In Level III of the AMEP, we combine all the MOEs into an aggregate mobility value (AMV). The AMV provides an overall numerical representation of each aircraft's capability relative to scenario requirements (see Table 2 above). By performing Levels I through III for each type of aircraft we can calculate the AMV for every airlifter under consideration (see Appendix J for other aircraft AMV calculations).

The AMEP: Level IV

By graphing each aircraft's AMV, we can readily determine which airlifters are best suited for this scenario (see Figure 2 below).

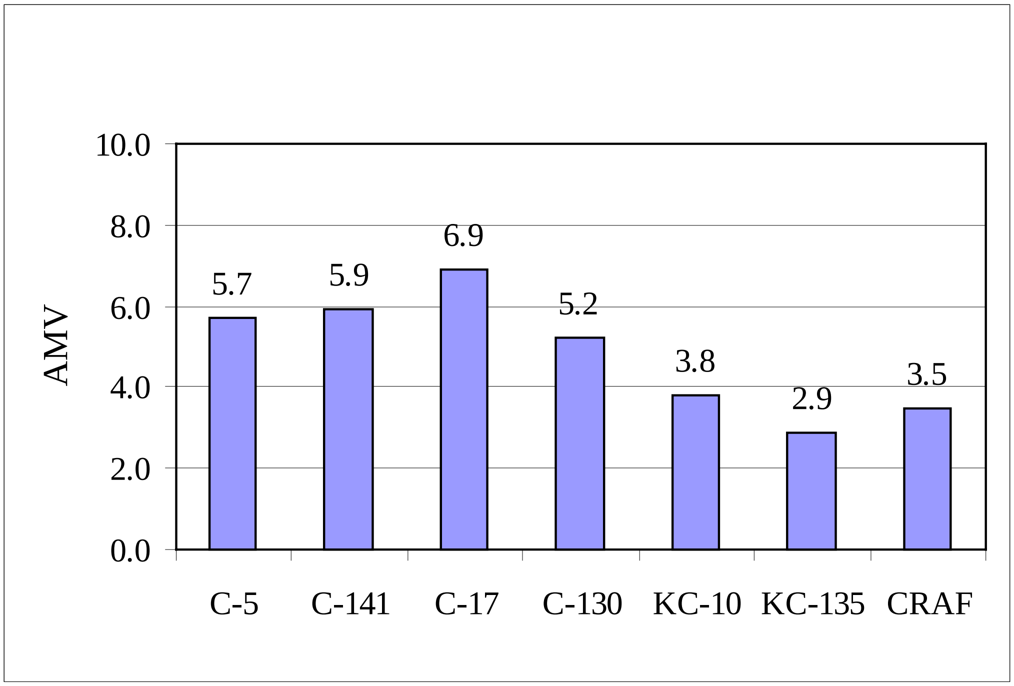


Figure 2. AMV Comparison

As we can see in the above figure, the C-17 is apparently the best aircraft for this scenario. But since there are likely not enough C-17s to fulfill all requirements (there are only 37 total for this scenario), Figure 2 also shows that the C-141 and C-5 are also good candidates for this scenario. By using the AMEP methodology, planners can readily determine which aircraft best fulfill scenario requirements. But the analysis does not stop there. We can also plot the MOEs by major category and visually compare the different types of aircraft against each other. Keep in mind the aircraft MOEs are plotted relative to their ability to meet baseline requirements (with weight value included), not relative to the other aircraft. For example, MOE P1.1, Average Tonnage, in Figure 3 below shows that the C-5 and the CRAF both have a capability-versus-baseline-requirement value of 8. While the CRAF planning factor for bulk cargo (78 STON) is greater than the C-5 (61.3 STON), they both have an overall value of 8 since no extra credit is given for exceeding the baseline requirement (50.0 STON). See Appendix H for a full explanation of the mathematics and the reasoning for the calculations.

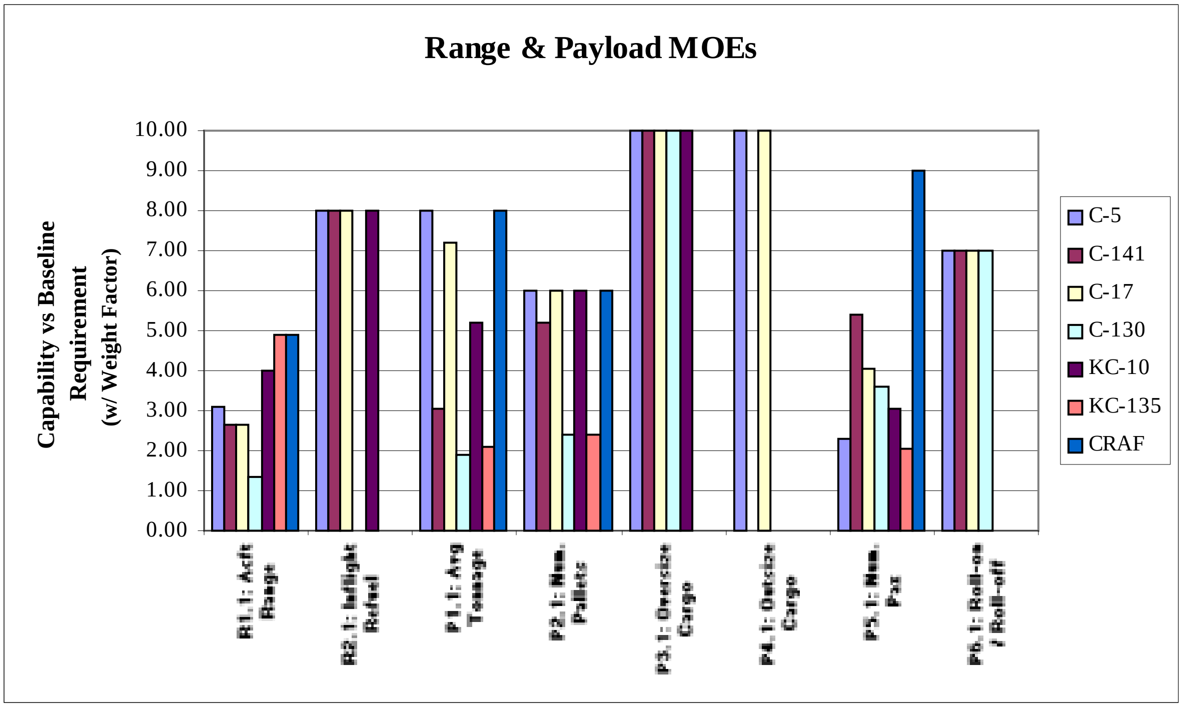
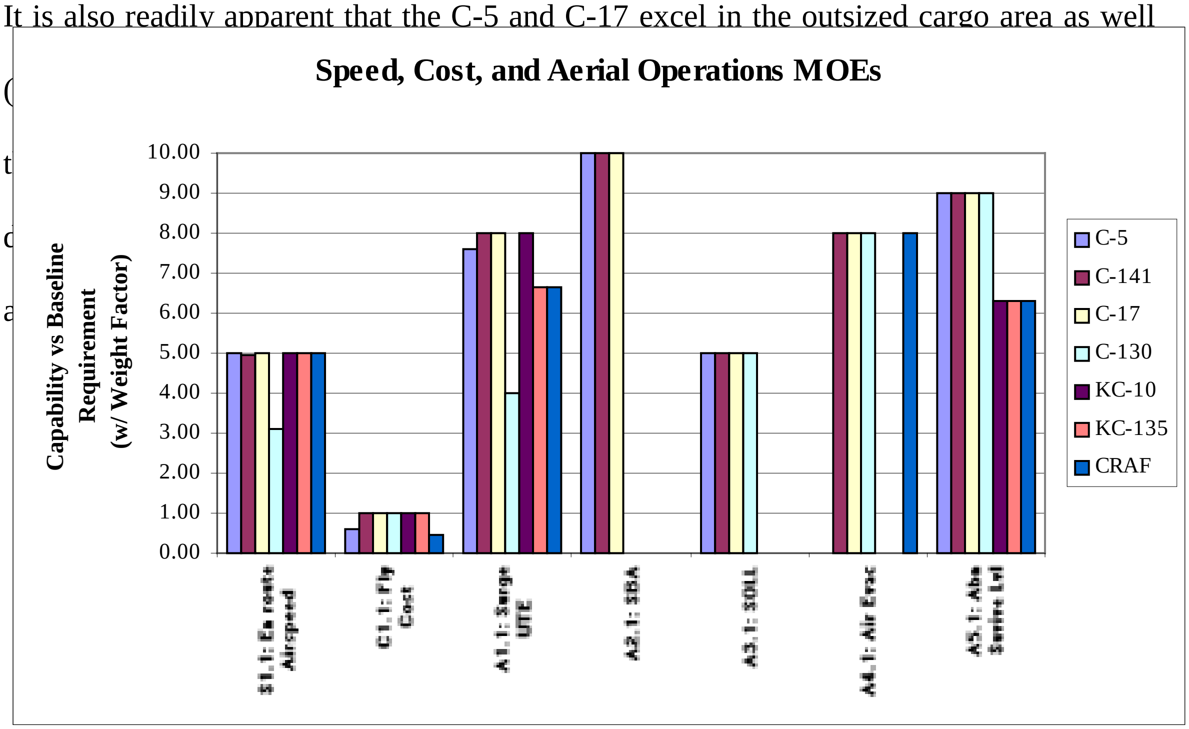


Figure 3. Range & Payload MOEs Relative to Baseline

Figure 3 above shows that the C-5, C-141, C-17, and C-130 exceed the capabilities of the other aircraft due to their ability to carry oversized (P3.1) and rolling cargo (P6.1). It is also readily apparent that the C-5 and C-17 excel in the outsized cargo area as well



Looking at Figure 4 above, the aircraft that can perform the strategic brigade airdrop mission (A2.1), and that have higher airborne survivability levels (A5.1), rate higher than the other aircraft. This should not be surprising since an airdrop operation is planned and there is some threat due to small arms fire and MANPADS. Likewise, the ability to perform the aeromedical evacuation mission (A4.1) rates relatively high due to expected casualties early in the operation and the need to airlift these personnel out of the theater in an expeditious manner. We can also easily tell that aircraft with high surge utilization rates (A1.1) are also important for this scenario due to the requirement to get as much cargo and personnel into the theater as quickly as possible.

The Ground Operations MOEs are divided between two charts for clarity and are shown below.

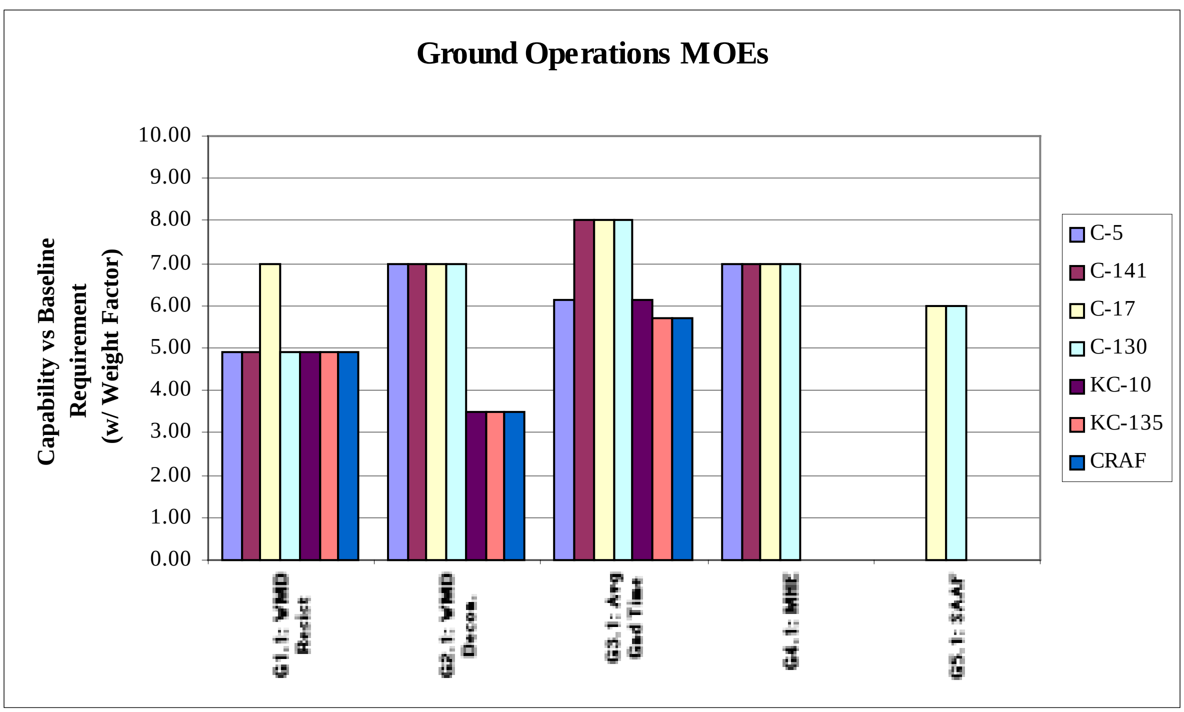


Figure 5. Ground Operations MOEs Relative to Baseline

As shown in this figure, the C-17 is the only aircraft that meets the weapons of mass destruction (WMD) resistance criteria (G1.1). The only aircraft that meet the WMD decontamination requirement (G2.1) are the C-5, C-141, C-17, and the C-130. If we were willing to accept some additional risk, these aircraft would still be good candidates for this scenario when considering the WMD threat.

The above figure also shows that those aircraft with shorter ground times (G3.1), those that do not require any special material handling equipment (G4.1), and the two aircraft that can operate on small austere airfields (G5.1) rate very high for this scenario.

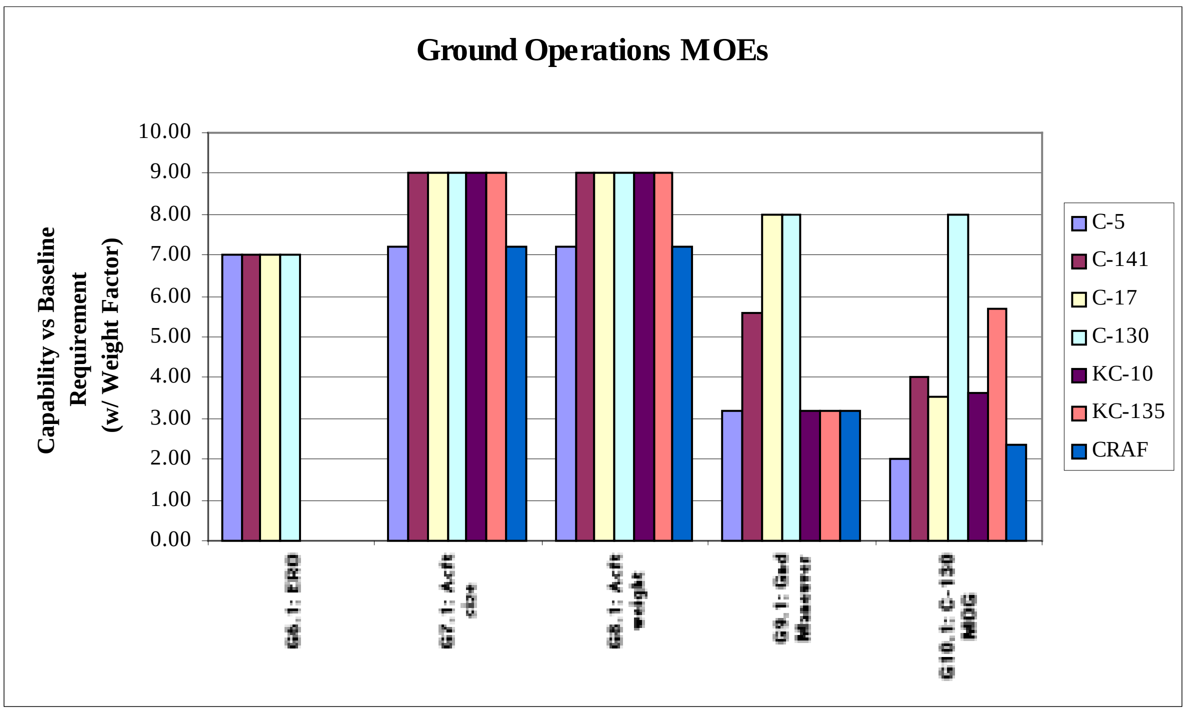


Figure 5 (cont.): Ground Operations MOEs Relative to Baseline

This figure also shows that aircraft that can perform engine running on / offloads (G6.1) are highly desirable. Finally, those aircraft that are smaller (G7.1), lighter (G8.1), and more ground-maneuverable (G9.1) rate higher since these aircraft are best suited to operate on the airfields in this scenario.

Using the AMEP to Determine Fleet Capability

The AMEP can also be used to evaluate fleet aircraft capability relative to actual scenario requirements—another area that MTM/d is deficient. By accounting for additional enablers such as in-flight refueling and direct delivery, the AMEP provides closure rates at forward operating areas which is what a theater commander is most concerned about.

For any scenario, the tonnage (CR1) and personnel requirements (PM1) per day should already be known (from the operations plan) or readily determined by airlift planners. We should also have a good idea how many military transport aircraft will be available (UM1) and the CRAF stage (UC1) that may be activated. Familiarity with the area of operations will also provide the average distance from the theater APODs to the FOBs (R3) and average ground (or water / air) travel time from the APOD to the FOB (T1).[197] See Table 3 below.

Table 3. Gross Requirements for MTW Scenario[198]

Total Tonnage & Passenger Theater Requirements		
CR1	How many tons must be airlifted to the theater every day? (STON)	4,000.0
PR1	How many passengers must be airlifted to the theater every day?	7,000
Usable Aircraft		
UM1	What percentage of the primary mission aircraft inventory (PMAI) will be used?	80%
UC1	What level of the CRAF will be activated? (None, Stage I, II, or III)	I
Travel Distance & Time From Theater APOD to FOB		
R3	What is the average aerial distance from the APOD to the FOB? (nm)	100
T1	What is the average travel time from the APOD to the FOB? (hr)	12.0

With this additional information, we can calculate the average daily tonnage and personnel delivered to the forward operating bases. See Table 4 below for the calculations done for the C-17. Keep in mind these values are based on the total number of usable aircraft for this scenario. Since there are only 37 (FY99) C-17 aircraft, of which only 30 are usable for this scenario (37 * 80%), the tonnage and personnel delivered for the C-17 are fairly low when compared to transport fleets with many more aircraft. In other words, quantity can have a quality of its own. But that does not reduce the utility of the C-17 in any way. We saw in Figure 2 that the AMV for the C-17 was higher than any other aircraft due to its ability to meet more scenario requirements. This should tell us that for this scenario, more C-17s are desirable.

Table 4. C-17 Fleet Capability[199]

	Usable Aircraft	**Total PMAI**	**Usable**
U1.1	What is the primary mission aircraft inventory (PMAI) for this airlifter?	37	30
	Cargo Closure Rates to FOB	**Average Tons per day**	**Capability vs Baseline**
CR1.1	Cargo closure rate without in-flight refueling (Aerial Refueling). (APOE→APOD→FOB)	357.82	8.95%
CR1.2	Cargo closure rate with in-flight refueling (AR). (APOE→APOD→FOB)	376.53	9.41%
CR1.3	Direct delivery cargo closure rate without in-flight refueling (AR). (APOE→FOB)	408.47	10.21%
CR1.4	Direct delivery closure rate with in-flight refueling (AR). (APOE→FOB)	433.03	10.83%
	OR		
	Passenger Closure Rates to FOB	**Average Passengers per day**	**Capability vs Baseline**
PR1.1	Passenger closure rate without in-flight refueling (AR). (APOE→APOD→FOB)	716	10.22%
PR1.2	Passenger closure rate with in-flight refueling (AR). (APOE→APOD→FOB)	753	10.76%
PR1.3	Direct delivery passenger closure rate without in-flight refueling (AR). (APOE→FOB)	817	11.67%
PR1.4	Direct delivery passenger closure rate with in-flight refueling (AR). (APOE→FOB)	866	12.37%

As shown above, a fleet of 30 C-17s can deliver approximately 357.82 STONs of cargo or 716 passengers to the APOD every day. If in-flight refueled (assumes overfly of en route stops), the fleet can deliver 376.53 STONs or 753 passengers per day (a 5 percent increase). Demonstrating direct delivery, the C-17 can deliver 408.47 STONs or 817 passengers without in-flight refueling (a 12 percent increase) and 433.03 STONs or 866 passengers with in-flight refueling (a 17 percent increase).

It is important to note that the above table assumes the C-17 fleet will deliver cargo or passengers (not both). While this is not necessarily operationally representative, this was done to simplify the demonstration of the AMEP and its ability to evaluate fleet aircraft capability—little additional effort would be required to modify the above table to accommodate cargo / passenger mixes. Performing similar calculations for the other airlift fleets and plotting them gives us the next two figures.

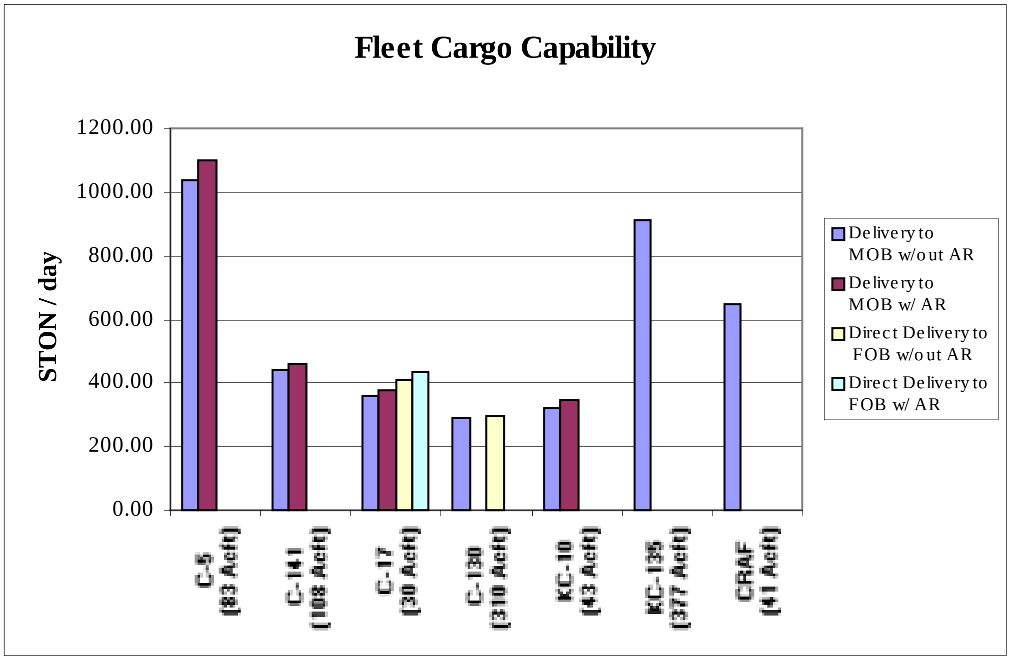


Figure 6. Fleet Cargo Capability Comparison

As shown in Figure 6, the 83 C-5s (61.3 STON planned payload per aircraft) can deliver the most amount of cargo to a theater MOB (or APOD) every day. But keep in mind the cargo must be transshipped from the MOB to forward areas, which will take some time before it gets to its final destination.

It is interesting that the KC-135 comes a close second to the C-5 in cargo delivery. But then, there are 377 KC-135s available and it is not likely that the theater will be able to support this many aircraft every day. Also, since the KC-135's planned payload per aircraft is only 13 STONs, and since it is unable to carry outsize or oversize cargo, it would not be a very good choice as a primary transporter. This is a good example of why just using tonnage delivered is problematic.

Instead, the CRAF with its planned payload of 78 STONs per aircraft would be a good transporter to use for bulk cargo as long as special MHE was available and theater threats were low enough to permit their use. By using the AMEP, these concerns and many others are addressed.

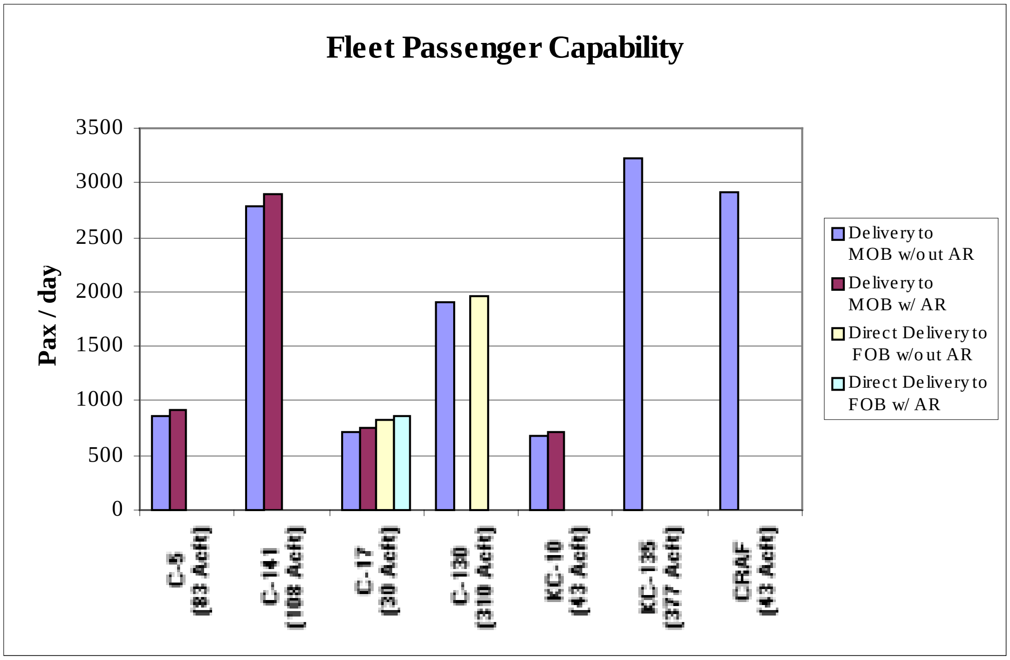


Figure 7. Fleet Passenger Capability Comparison

In Figure 7, it is readily apparent that the C-141 and CRAF are very capable aircraft to airlift passengers to theater MOBs (or APODs). But again, one must keep the whole scenario in mind. Neither aircraft can directly deliver their payload to small austere airfields nor do they have very high levels of resistance to chemical / biological agents.

If we wanted to airlift passengers directly to forward operating areas, then the C-17 and C-130 are the best aircraft to perform this mission. But what this figure does not show is the C-17s greater range, speed, and higher daily utilization rate. For example, if there were 100 C-17s available (instead of 30) we could directly deliver 2,723 passengers every day to FOBs whereas 310 C-130s can only deliver 1,962. The "Hump" and the Berlin Airlift taught us that fewer aircraft with greater payload capacity means less infrastructure requirements. But the AMEP shows that greater capacity is not the only issue—huge gains are achieved by the use of aircraft with greater overall capability.

To finish Level IV of the AMEP, the next two figures show fleet cargo and passenger capability as a percentage of baseline requirements.

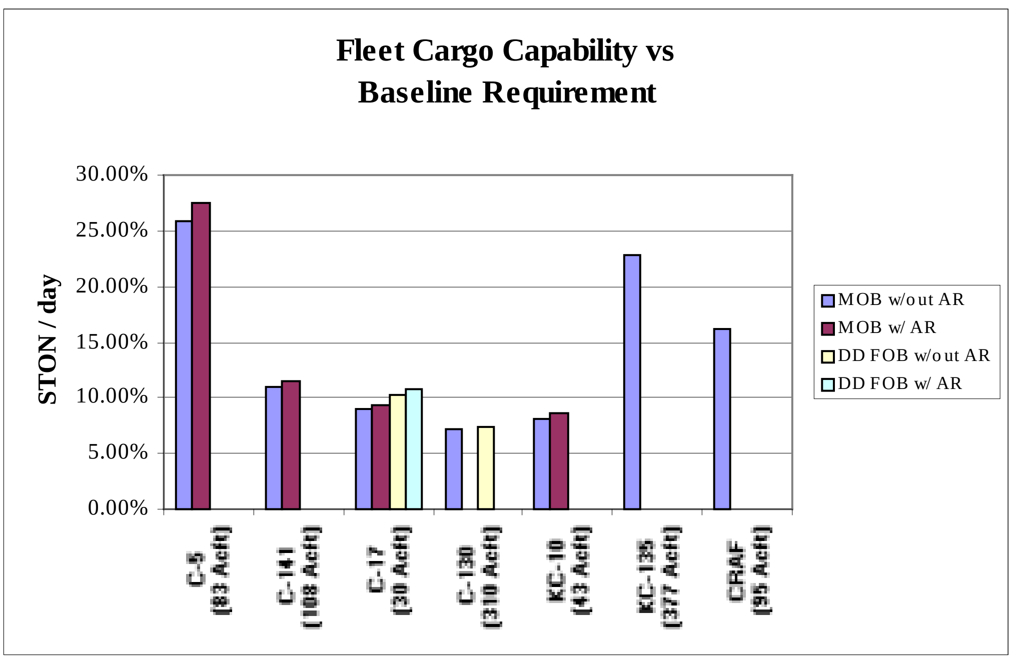


Figure 8. Fleet Cargo Capability vs Baseline Requirement

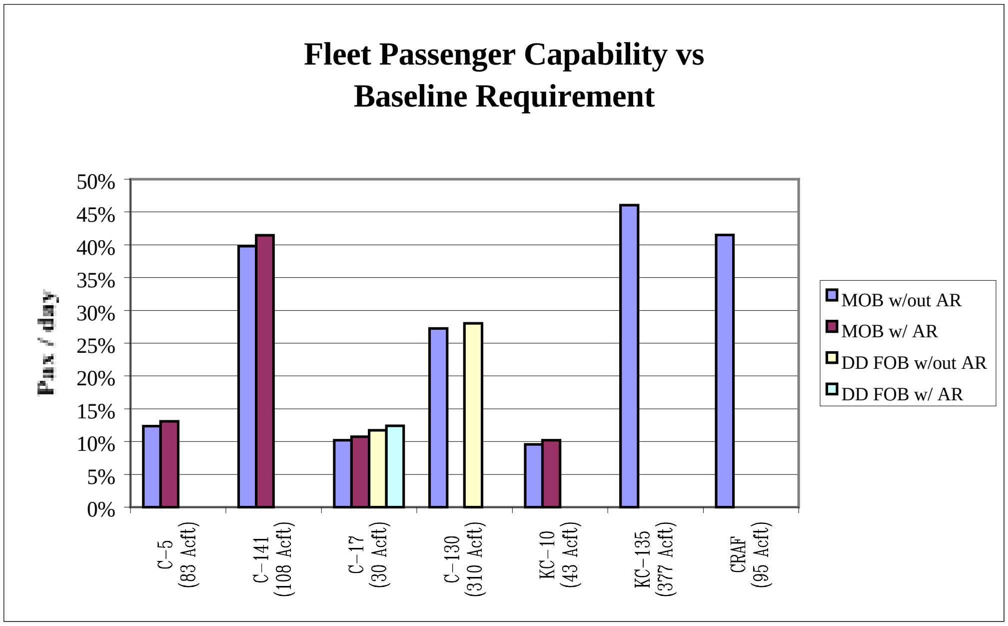


Figure 9. Fleet Passenger Capability vs Baseline Requirement

By now, the utility of the Air Mobility Evaluation Process (AMEP) presented in this paper should be readily apparent. By starting with a visual depiction of the AMVs for every type of airlifter, we get an overall picture of those aircraft that are best suited for the MTW scenario. By then displaying all the MOEs (corrected for weight) relative to the baseline requirements, we can easily determine where some aircraft clearly excel, and where others may lag behind. Finally, by plotting the fleet capabilities, we complete the picture.

Overall, the AMEP provides a methodology that is understandable, visually luminous, informative, and provides an “at a glance” depiction more revealing than other methodologies strictly based on tonnage delivered.

Other Uses

The AMEP methodology can be applied to the spectrum of conflict expected in the coming millennium. Changing the baseline MOEs for a scenario, or changing the baseline MOE requirement values and weights, can accommodate everything from humanitarian relief missions to major theater wars.

The AMEP will help planners and analysts consider those areas of airlift that are critical to successful mission accomplishment—not just tonnage delivered per day. Its open architecture and easily discernable parts provide an excellent way to brief senior military and civilian leadership on what airlift can do relative to what is required. The methodology can also educate those unfamiliar with the airlift system and provide a flexible tool for future plans and concepts.

Notes

[192] Matthews and Holt, iii.

[193] Reliability, maintainability, and availability (RM&A) are requirements imposed on systems to ensure they are operationally ready for use when needed, will successfully perform assigned functions, and can be economically operated and maintained within the scope of logistical concepts and policies. Reliability is the ability of a system and its parts to perform its mission without failure. Maintainability is the ability of an item to be retained in, or restored to, a specified condition when maintenance is performed. Availability is a measurement of the degree to which an item is in an operable state at the start of a mission. *Glossary of Defense Acquisition Acronyms & Terms*, 7 ed. (Fort Belvoir: Defense System Management College Press, October 1996), B-10, 70, 104, 105.

[194] While this scenario is greatly simplified due to limited space, I ask the reader to remember the exercise here is to demonstrate the methodology, not to develop an operations plan.

[195] While sealift is indeed one of the most economical forms of travel, it is also one of the slowest. It can take 4-6 weeks from when the first ship is loaded, departs the SPOE, and arrives at the SPOD. Then the equipment and supplies have to be hauled over land routes or airlifted to the forward operating locations. Such transshipments not only take longer, but there is a good chance that unit equipment can become separated from unit personnel for extended periods of time. This is one of the reasons why airlift is so

Notes

critical in the early stages of any conflict where expediency and maintaining unit integrity is of the utmost importance.

[196] User entries are not shaded. Calculated values are shaded.

[197] For this example, the travel time from the APOD to the FOB is used for traditional strategic airlift missions that first land at the APOD and then the cargo and passengers must be moved to forward locations via air, land, or water modes of travel. Direct delivery missions can bypass this transshipment process and deliver the cargo and personnel to the forward operating areas.

[198] See Appendix G for a full explanation of these factors.

[199] These values do not account for any other limitations such as MOG per day, maximum aircraft size and weight, etc. The overall average values are a gross planning factor and used as a demonstration of how AMEP could be used in lieu of MTM/d.

Chapter 7

Conclusions and Recommendations

> *If we do not build a transportation system that can meet our needs of tomorrow, then it doesn't matter what kind of force we have because we won't be able to get it there.*
>
> — General John M. Shalikashvili
> Chairman of the Joint Chiefs of Staff

Airlift was first used to any great extent during World War II. A combination of evolving technology, sparse doctrine, limited funds, and senior military leadership desire for bomber and fighter aircraft hindered development of military airlift until the war was well underway. But thanks to the relatively robust commercial aviation industry, when airlift was needed, it was available.

The one operation that truly demonstrated the efficacy of airlift was the "Hump" operation in the Far East. The massive airlift effort from India to China helped keep over one million Japanese troops occupied and helped the Allies pursue their strategy of establishing airfields from which they could carry the offensive fight against Japan. The "Hump" operation proved that a massive amount of cargo and whole battalions of troops could be moved solely by air.

Shortly after World War II, airlift again proved its utility and importance when it helped keep over two million Berlin citizens and Allied troops supplied for almost a year. By hauling everything from food to coal, Berlin not only survived but was able to keep a significant portion of its industry operating as well. When the Russians realized the Western Allies were not going to succumb to the blockade, they gave up and reopened the ground routes to the city. Airlift gave the West another alternative to countering force with force and presented a powerful score to the opening credits of the Cold War.

From the "Hump" operation and the Berlin crisis, tonnage delivered emerged as the primary measurement of airlift effectiveness. This metric was measured in terms of tonnage per month, tonnage per day, tonnage per year, and finally centered on today's metric of million ton-miles per day (MTM/d). But while this metric may have sufficed with the Cold War paradigm of "getting there the fastest with the mostest," the diverse nature of today's environment dictates the need for another way to measure airlift's effectiveness.

Since the demise of the Soviet Union, the world has changed. No longer are huge enclaves of military personnel forward-stationed. Budget cuts and force reductions have greatly reduced the size of the military and necessitated a change in the way the Air Force does business. To adapt to the changing world, the Air Force has elected to adopt an expeditionary posture. But with the increased reliance on rapid global mobility, small forward footprint, "reach back", and operating from austere locations, airlift has become even more important. For airlift to continue to best serve the United States, we must change the way we evaluate its effectiveness.

By using the aggregated mobility evaluation process (AMEP), we finally have a better way to capture the unique capabilities of airlift relative to a given scenario. By aggregating the measures of effectiveness (MOEs) for *range*, *payload*, *speed*, *operations*, and *cost* into an air mobility value (AMV), we can visually obtain an "at-a-glance" confirmation of the best aircraft to use. We can also easily compare each type of aircraft at the MOE level to determine why some airlifters are more suitable than others.

By including unique airlift capabilities such as in-flight refueling and direct delivery, the AMEP can also calculate cargo and personnel closure rates to theater main and forward operating bases—a primary concern of theater commanders.

By using the AMEP, we can readily prepare briefings for senior military and civilian leadership and comprehensively explain mathematically and graphically why some airlifters are better than others for a specified scenario.

Finally, by basing the MOEs on future requirements, the AMEP can be used to evaluate the efficacy of new airlift proposals.

With the battle-cry of the new expeditionary air force being “light, lean, and lethal,” the counter-cry of the airlift community should be “right place, right stuff, at the right time.” And the right place to start is to adopt a new methodology for determining airlift effectiveness.

Appendix A

The “Hump” Airlift During World War II

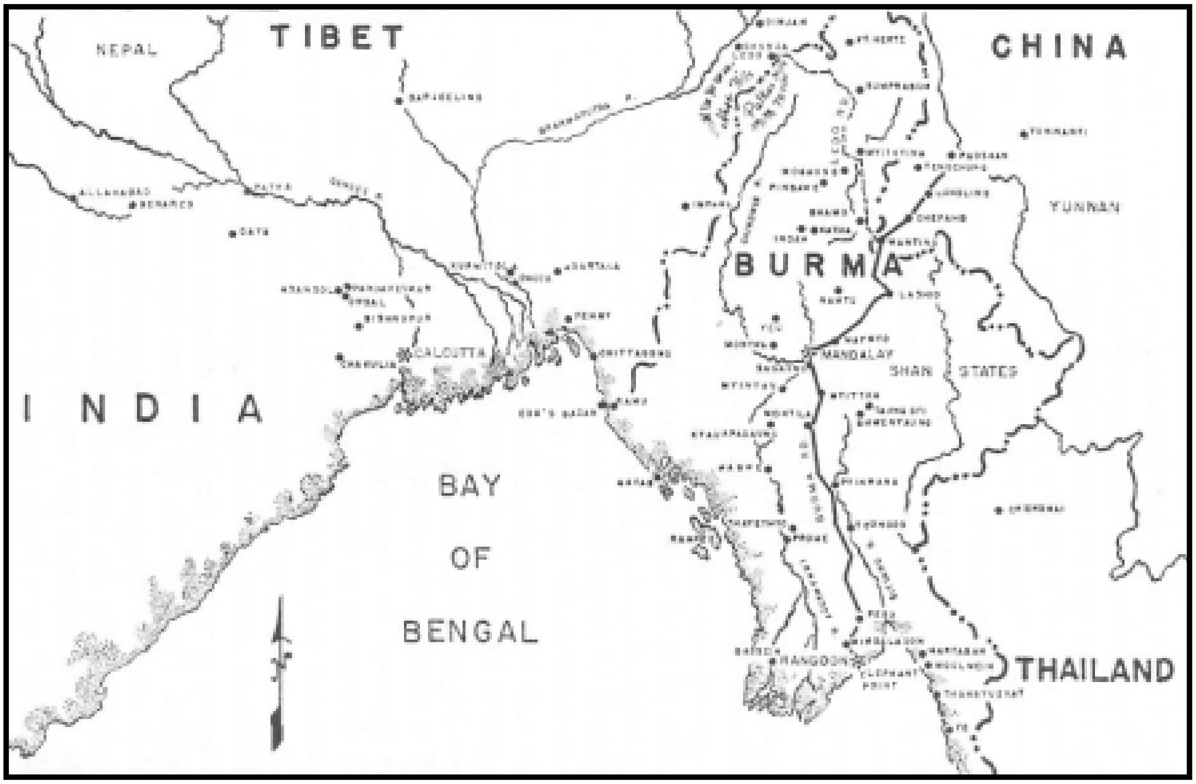


Figure 10. China-Burma-India (CBI) Theater. Craven and Cate, vol. 4, 462.

The “Hump” (so called due to the towering Himalaya mountain range that divided the route from India to China) was a very difficult route to fly during World War II. Heavily loaded transport aircraft lifted off from hot, muggy airfields in India’s eastern jungles, struggled up to the altitude needed to clear the towering Himalayas (16,000 to

20,000 feet), and flew almost four hours to reach China. Along the way, aircrews were subjected to freezing cockpit temperatures, horrendous weather, and enemy patrols. To bail out or crash land meant dealing with inhospitable terrain, carnivorous animal life, hostile natives, and Japanese patrols. Most that crashed had to walk several weeks to get to friendly territory and many did not survive the ordeal.[200]

Notes

[200] Bilstein, 38-43 and Tunner, 81.

Appendix B

Germany Divided After World War II

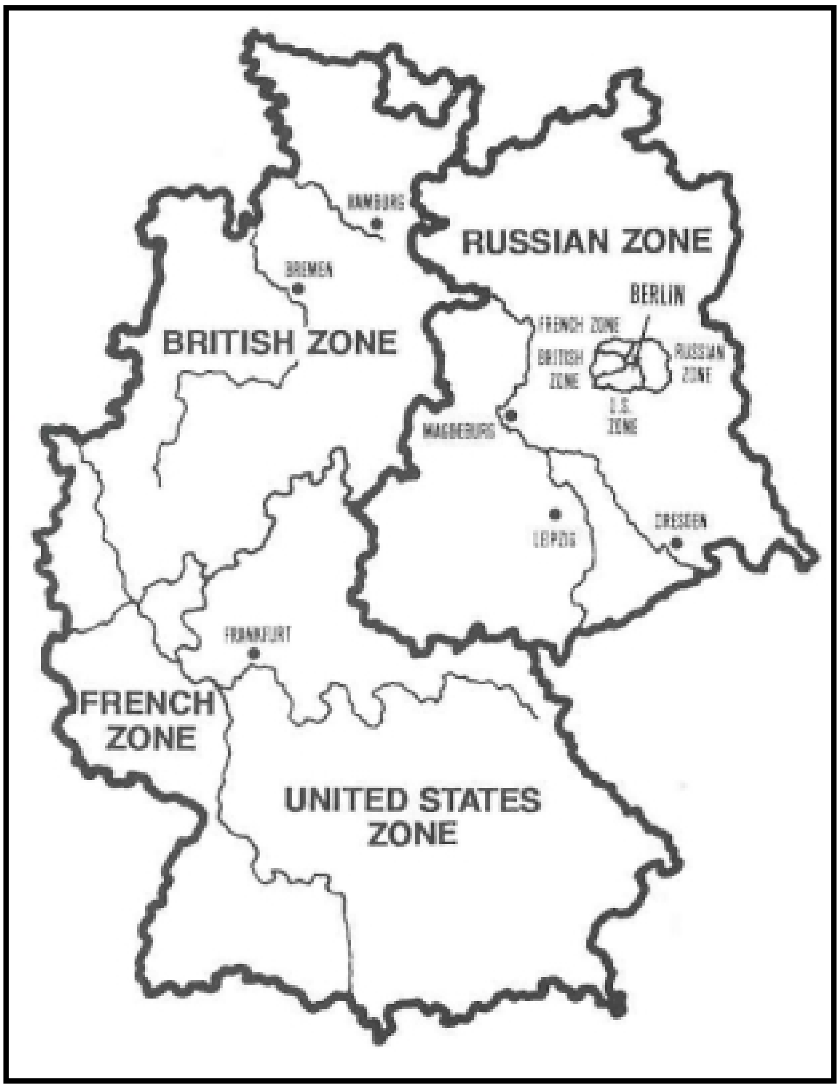


Figure 11. Allied Occupation Zones in Germany. Launius and Cross, 2.

To keep Germany from ever becoming an aggressor and instigator of war again, the Allies divided Germany into four zones of occupation after the end of World War II.

Appendix C

The Berlin Airlift Corridors

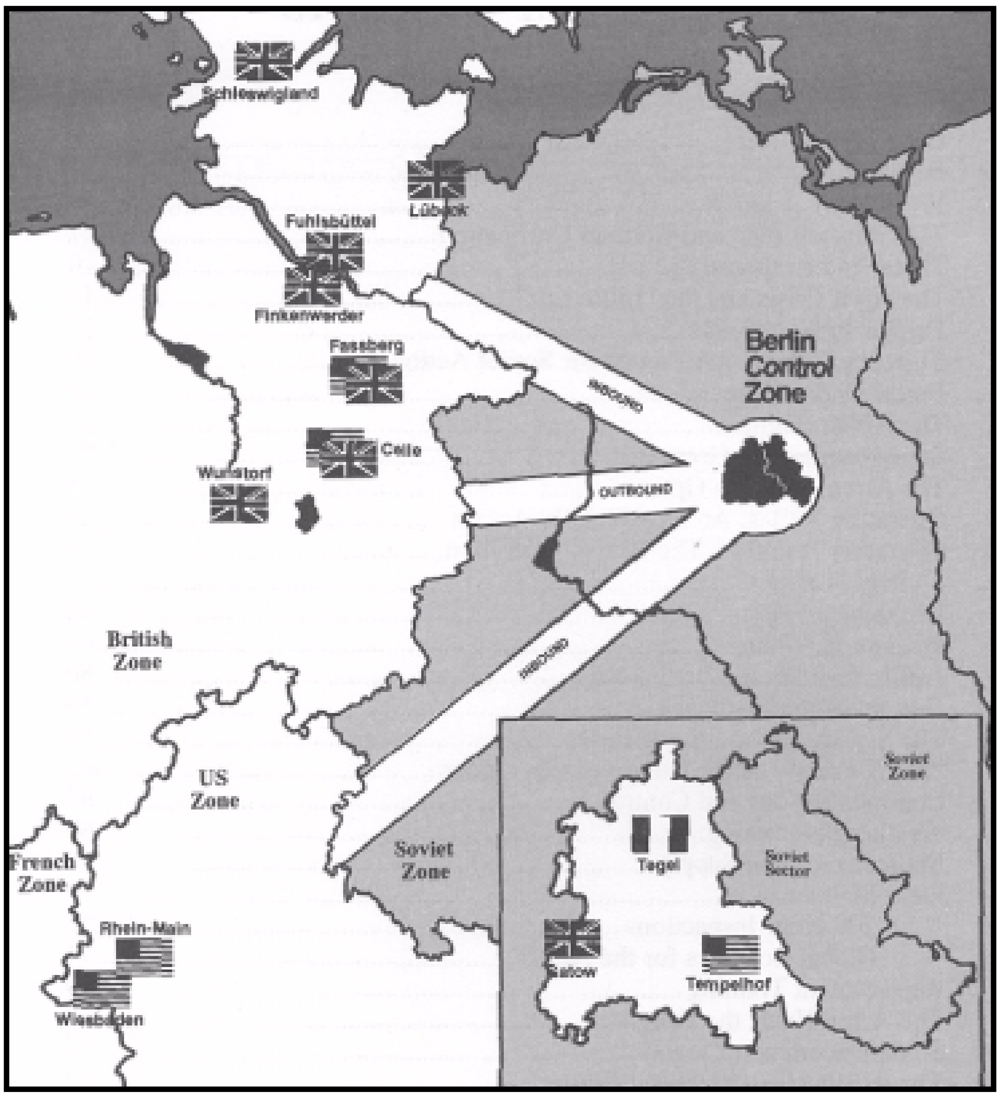


Figure 12. Air Corridors of the Berlin Airlift. Roger Miller, iv.

On 30 November 1945, all four World War II allies signed an agreement that provided for three air corridors between the western zones and Berlin.[201]

Notes

[201] Launius and Cross, 9.

Appendix D

Berlin Airlift Summary

Table 5. Summary Totals for Berlin Airlift. Data from Harrington, 109-110.

Tonnage Delivered[202] **26 June 1948 – 30 September 1949 (STON)**						
	American Tonnage	British Tonnage	Total Tonnage	US Flights	British Flights	Total Flights
Jun-48	1,199.0	205.0	1,404.0	474	26	500
Jul-48	39,971.0	29,034.7	69,005.7	7,550	5,978	13,528
Aug-48	73,658.1	45,344.5	119,002.6	9,770	8,372	18,142
Sep-48	101,846.7	37,776.2	139,622.9	12,904	6,825	19,729
Oct-48	115,792.2	31,788.6	147,580.8	12,135	6,100	18,235
Nov-48	87,979.3	25,608.6	113,587.9	9,047	4,305	13,352
Dec-48	114,567.2	26,870.9	141,438.1	11,660	4,832	16,492
Jan-49	139,218.8	32,740.4	171,959.2	14,095	5,397	19,492
Feb-49	120,394.6	31,846.1	152,240.7	12,043	5,043	17,086
Mar-49	154,475.0	41,685.7	196,160.7	15,530	6,633	22,163
Apr-49	189,957.2	45,406.5	235,363.7	19,130	6,896	26,026
May-49	192,271.4	58,547.1	250,818.5	19,366	8,352	27,718
Jun-49	182,722.9	57,602.1	240,325.0	18,451	8,094	26,545
Jul-49	201,532.2	51,557.8	253,090.0	20,488	7,104	27,592
Aug-49	55,940.0	21,818.6	77,758.6	5,886	3,098	8,984
Sep-49	12,047.1	4,104.1	16,151.2	1,434	551	1,985
Total	**1,783,572.7**	**541,936.9**	**2,325,509.6**	**189,963**	**87,606**	**277,569**

In-bound Cargo to Berlin				
	Food	Coal	Other	Total
US	296,319.3	1,421,118.8	66,134.6	1,783,572.7
UK	240,386.0	164,910.5	136,640.4	541,936.9
Total	**536,705.3**	**1,586,029.3**	**202,775.0**	**2,325,509.6**

Out-bound Cargo from Berlin		
US	UK	Total
45,887.7	**35,843.1**	**81,730.8**

Passengers Flown[203]			
	Inbound	Outbound	Total
US	25,263	37,486	62,749
UK	34,815	130,091	164,906
Total	**60,078**	**167,577**	**227,655**

Notes

[202] Does not include French delivery of 881.8 STONs in 424 flights (for garrison troops). Harrington, 109.

[203] Does not include the 10,000 passengers the French airlifted into and out of Berlin. Ibid., 110.

Appendix E

Strategic and Tactical Airlift

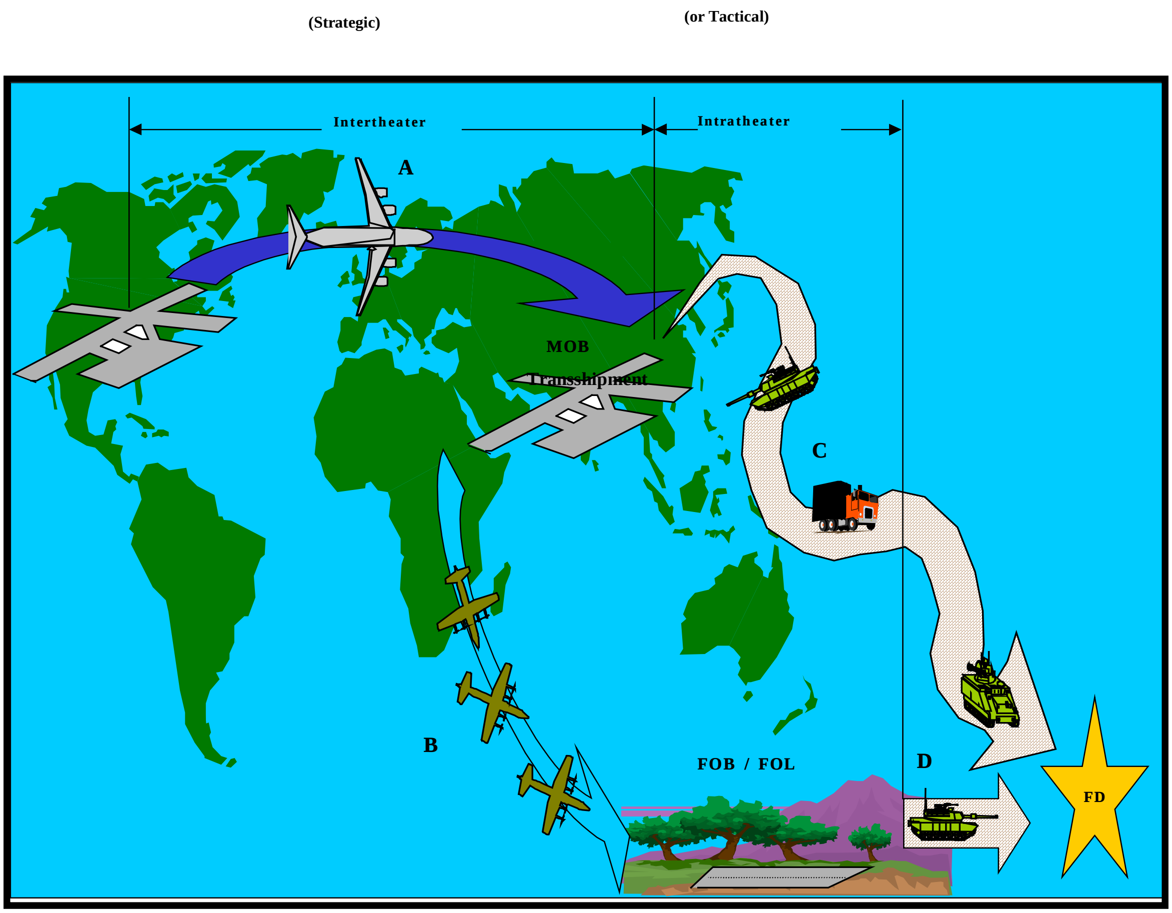


Figure 13. Traditional Strategic Airlift. Adapted from Lt Col Miller, 405.

Traditional strategic airlift delivers personnel and cargo from the CONUS or Aerial Point of Embarkation (APOE) to a theater main operating base (MOB) or Aerial Point of Debarkation (APOD)—route A. Once in theater, the personnel and cargo are airlifted using more tactically capable aircraft or moved via land / water routes (if transportation is available and can support the movement), to a forward operating base (FOB) or forward operating location (FOL)—route B and C. From the FOB or FOL, the personnel and cargo usually move over land to the final destination (although some smaller air assets, such as helicopters may be used)—route D. This method of airlift can cause delays from the MOB / APOD to the final destination, is problematic when "marrying up" troops with their equipment, and can cause a loss of in-transit visibility.

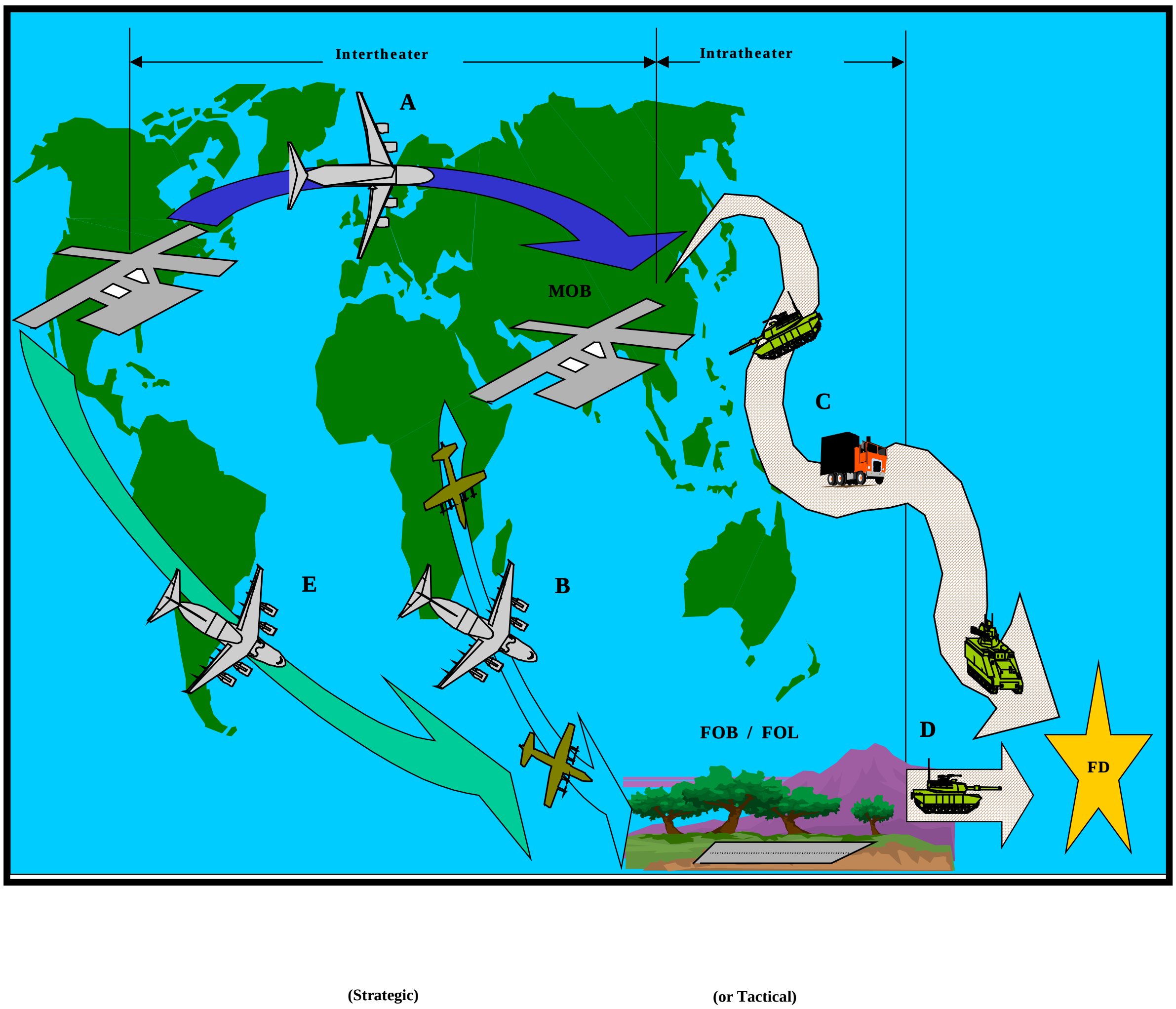


Figure 14. Direct Delivery Airlift. Adapted from Lt Col Miller, 406.

The direct delivery airlift method is usually more desirable, especially when time is critical. While the traditional strategic airlift method can still be used, direct delivery avoids theater airlift transshipments by delivering personnel and cargo directly from the CONUS or APOEs to FOBs or other forward areas (which are normally closer to the payload's final destination)—route E. Direct delivery shortens in-transit time, reduces congestion at MOBs, and enhances sustainment of forward forces.[204] But one must keep in mind that not all aircraft can accomplish direct delivery. Direct delivery aircraft must be able to fly intercontinental distance and may have to operate at airfields that have little or no support infrastructure (see note below). For example, since the C-5 is very large (it requires extensive runway and ramp space) and it lacks nimble ground agility (it has a wide turn radius and does not normally back up without a ground tug), it is restricted to MOBs.[205] The C-17 with its agile ground maneuverability and smaller footprint can bypass en route MOBs and deliver passengers and cargo from CONUS APOEs to the APODs or directly to austere theater FOBs.

There are many factors to consider when deciding to use the direct delivery option. Some of these include: [206]

1. Required closure time at the final destination and desire to reduce transshipment problems (such as lose of in-transit visibility and difficulty "marrying up" ground forces with their equipment).

2. Whether other transshipment modes (ground, sea, or air) are available to deliver the forces from the MOBs to the forward areas.

3. The proximity of the forward airfields to the final destination, any requirement to assemble ground forces before they come in contact with enemy elements, possible exposure to enemy threats, and potential for fratricide in forward areas.

4. The ground plan, capacity, and offload capability (to include any special MHE required) available at forward airfields.

5. The desire to reduce airspace and airfield congestion at MOBs.

Note: As the C-130J (with its greater range and speed than other C-130 models) enters the Air Force inventory, the air mobility community should investigate its use as a direct delivery platform from CONUS APOEs. At the time this thesis was written, there was very little published / operationally validated C-130J information available. Otherwise I would have included C-130J analysis in this paper.

Notes

[204] Joint Publication 4-01.1, *Joint Tactics, Techniques, and Procedures for Airlift Support to Joint Operations*, 20 July 1996, III-8.

[205] *1997 Air Mobility Master Plan*, 11 October 1996, 5-27.

[206] Joint Publication 3-17, *Joint Tactics, Techniques, and Procedures for Theater Airlift Operations*, 18 July 1995, VII-4.

Appendix F

Airlift Planning Factors[207]

Table 6. Summary of Airlift Planning Factors

Aircraft Type	UTE[d] Rate Surge (hrs)	UTE Rate Sustain (hrs)	Contin-gency USE Rate[e] (hrs)	Block-speed[f] (kts)	Cargo[g] (STON)		Passengers[g]		NEO Passen-gers[j]	Aeromedical (AE)		
					ACL[h]	Plan[i]	ACL[h]	Plan[i]		Normal Litter/ Ambul-atory[k]	Surge Litter/ Ambul-atory	AE Crews[l]
C-5A/B	10.0/11.4	8.4/8.4	5.8/7.5	409	89	61.3	73	51	73	-	-	-
C-141[a]	12.1	9.7	7.4	394	30	19	153	120	200/153	31/78	48/38	1.5
C-17	15.15	13.9	11.7	410	65	45	102	90	102	36/54	36/54	1.5
C-130	6.0	4.0	6.0	246	17	12	90	80	92/74	24/36	50/22	1
KC-10	12.5	10.0	7.9	434	60	32.6	75	68	75	-	-	-
KC-135	*10.0*	*10.0*	5.6	419	18	13	53	46	53	-	-	-
C-9[b]	8.0	8.0	8.0	414	-	-	40	32	40	9/30	40	1
CRAF[c]	10.0	10.0	10.0	465	See note h	78	See note h	335	390	87/33	87/33	2

Notes:

a. Normally UTE rate is a function of numerous factors to include scenario distance, infrastructure constraints, aircraft Reliability, Maintainability, and Availability (RM&A), ground times, crew availability, and total numbers of aircraft available. But, for this paper, UTE rate is based on aircraft RM&A and crew ratio. This is done so other critical factors that impact the mission can be "broken out" of the UTE rate and tracked separately via the AMEP methodology. As the C-141 fleet retires and more C-17s enter service, the UTE rate will change for both aircraft.

b. C-9 aircraft are primarily used for delivery of medical patients.

c. There are 7 aircraft primarily used for CRAF, B-747, B-757, B-767, DC-8, DC-10, L-1011, and MD-11. To facilitate planning, CRAF values are based on a mixed service average and are measured in B-747-100 equivalents.

d. Surge UTE rates are used for first 45 days of a crisis (C-130 surge rate is 30 days). Sustained rates used thereafter.

e. Contingency USE rates are used for operations other than war.

f. Blockspeed = (Total Flight Planned Distance from Point A to Point B) ÷ (Total Elapsed time from Brake Release on Takeoff to Block-In After Landing). Blockspeed includes Takeoff, Departure, En route, Approach, Landing, and Taxi-in. It does not include Engine Start, Taxi-out, or Pre-departure holding before Takeoff. CRAF blockspeed based on 3,500 nm leg distance. C-130 blockspeed based on 1,500 nm. All others based on 2,500 nm.

g. Cargo and passenger payloads (except C-5) are exclusive of one another. CRAF values based on B-747-100 equivalents.

h. Allowable cabin load (ACL) based on 3,200 nm leg except CRAF which is based on 3,500 nm leg. CRAF ACL for cargo varies from the highest of 100 STONS for B-747 to lowest of 38 STONS for the B-757 and DC-8. CRAF ACL for passengers varies from the highest of 335 for B-747 to the lowest of 110 for the B-757. For this paper, the planned values will be used for CRAF.

i. Planning payloads based on Desert Shield / Desert Storm historical averages. KC-10 and KC-135 payloads based on using these aircraft in cargo role (vice air refueling role).

j. For over water flights, the noncombatant evacuation operation (NEO) values for the C-130 and C-141 are lowered due to life raft limitations.

k. Litter patients are carried on and off the aircraft via a stretcher and patients normally remain on the stretcher for the flight. Ambulatory patients can enplane and deplane without assistance. Aircraft can usually be configured for various mixes of litter and ambulatory patients. Values shown are for planning only. CRAF values are based on specially modified and equipped B-767-200 aircraft.

l. 1.5 AE crews = 3 flight nurses and 4 technicians. 2.0 AE crews = 4 flight nurses and 6 technicians.

Aircraft Type	In-flight Refuel[m]	Number of Pallet Positions[n]	Oversize/ Outsized Cargo Capable[o]	Roll-on Roll-off Capable[p]	Special MHE[q]	Airdrop Capable / SBA Capable[r]	SOLL Capable[s]	Airborne Surviv-ability Level[t]	Resist / Decon-taminate WMD[u]	SAAF[v]
C-5A/B	Y	36	Y / Y	Y	N	Y / Y	Y	*M*	*L / T*	N
C-141	Y	13	Y / N	Y	N	Y / Y	Y	*M*	*L / T*	N
C-17	Y	18	Y / Y	Y	N	Y / Y	Y	*M*	*M / T*	Y
C-130	N	6	Y / N	Y	N	Y / N	Y	*M*	*L / T*	Y
KC-10	Y	25	Y / N	N	Y	N / N	N	*L*	*L / F*	N
KC-135	N	6	N / N	N	Y	N / N	N	*L*	*L / F*	N
C-9	N	-	N / N	N	N	N / N	N	*L*	*L / F*	N
CRAF	N	36	N / N	N	Y	N /N	N	*L*	*L / F*	N

Notes:

m. A small number of C-130s are in-flight refuelable, but for this paper, they are not considered.

n. CRAF pallet positions vary from the highest of 44 for B-747 to lowest of 15 for the B-757. For this paper, the average pallet positions for CRAF was based on B-747-100 equivalents.

o. The CRAF has limited oversize and no outsize capability. For this paper, this capability is not considered since there are many restrictions and limitations associated with the delivery of oversized cargo by the CRAF.

p. Roll-on / Roll-off capability implies an operator can drive the tracked or wheeled vehicle on / off the aircraft. Requires large cargo door and ramp.

q. Special MHE includes k-loaders and other devices that are required to on / offload aircraft that have cargo ramps high above the ground. This includes all civilian airlift, the KC-135, and the KC-10.

r. Airdrop capability varies greatly for each aircraft. Each airdrop capable aircraft can drop different mixes of paratroopers, heavy equipment (HE), and container delivery system (CDS). For this paper, delineation between different airdrop capabilities between aircraft is not made. If an operation requires more fidelity for airdrop, then additional MOEs should be added. Strategic Brigade Airdrop (SBA) is a specialized form of combat delivery that includes airdrop and airland insertions of a brigade-size compliment of equipment and combat personnel over great distances. Since the C-130 does not have the range, speed, or ability to fly at the higher altitudes flown by the C-5, C-17, and C-141, it is normally excluded from the SBA mission.

s. The Special operations low level (SOLL) mission is normally classified and no delineation between various aircraft capabilities is made in this paper. If more fidelity is needed for mission accomplishment, then additional MOEs should be added.

t. **Note: This section does not reflect true aircraft capability. It is used for demonstration purposes only.** Aircraft survivability pertains to conventional threats such as surface-to-air, surface-to-surface, air-to-air missiles and antiaircraft artillery (AAA). Low survivability indicates this aircraft has little or no protection against these threats. Medium applies to aircraft that have survivability designed into the airframe or added on (such as widely separated electronics and hydraulic systems and armor to protect the aircrew and vital aircraft systems) and some type of defensive system (such as chaff, flares, and electronic countermeasures) that automatically detects and deploys expendables / countermeasures to mitigate these threats. High applies to aircraft that have more active measures to counter threats such as decoy systems, and possibly stealth. The threat of nuclear weapons (electromagnetic pulse, fallout, etc.) is not covered in this paper. If there is such a threat, then planners could expand this area accordingly.

u. **Note: This section does not reflect true aircraft capability. It is used for demonstration purposes only.** Weapons of Mass Destruction (WMD) for this section pertains to chemical and biological agents. Nuclear threats are not considered (see above note). Low *resistance* implies the aircraft has little capability to prevent bio / chem agents from coming into the aircraft (beyond not opening aircraft doors). Medium *resistance* applies to aircraft that have some capability to prevent bio / chem agents from coming into the aircraft (such as a well-sealed fuselage, overpressure systems, air blowers, and / or split-type plastic curtains that permit cargo and people to move in or out of the aircraft but then swing back into place). High *resistance* applies to aircraft that have even more resistance such as interior coatings to counter chem / bio agents and possibly a cargo compartment that can be operated remotely from a sealed cockpit to on and offload cargo.

Formidable *decontamination* indicates that extensive work must be done to clear the aircraft of bio / chem agents before it can be returned to normal operational use. This may include extensive disassembly of the exterior and interior of the aircraft to get to crawl spaces and other nock and crannies to apply decontamination methods and cannot normally be done at forward locations due to highly specialized equipment required and several days to weeks to complete. Tough *decontamination* is used for those aircraft that require a moderate amount of work to clear the aircraft. Some disassembly may still be required, but it is not extensive and decontamination is facilitated by easy access to remote areas and proper sealing of areas not reachable without extensive disassembly. It can be done at forward areas but may require some additional equipment and a modicum of effort to complete the job within one day or less. Productive *decontamination* is used for those aircraft that require a minimum amount of work to the aircraft before it can return to operational (usually within hours). Little or no additional equipment is required since these aircraft have automatic decontamination systems installed such as infrared / ultraviolet lights, spray nozzles to disperse decontamination agents and foaming cleansing systems to automatically wash the contaminates from the aircraft.

v. Small austere airfields (SAAF) typically have runways only 3,000 ft, narrow taxiways, very limited ramp space, sparse maintenance support, and other limitations.

Aircraft Type	Ground Time[w] (minutes)			Minimum Runway and Taxiway (ft)[x]			Aircraft Classification Number (ACN)[y]	*Qualified Aircraft Weight*[z]	
	On-load	**En-route**	**Off-load**	**Min Rwy Length**	**Min Rwy Width**	**Min Taxiway Width**		**Maximum Aircraft Gross Weight (lbs)**	**Landing Gear Type**
C-5A/B	255	195	195	6,000	147	75	10 to 32	*XH*	
								840,000	TDT
C-141	135	135	135	6,000	98	50	18 to 58	*M*	
								343,000	TT
C-17	135	135	135	3,000	90	50	22 to 52	*H*	
								585,000	TRT
C-130	90	90	90	3,000	60	30	9 to 37	*ML*	
								175,000	ST
KC-10	255	195	195	7,000	148	75	13 to 57	*H*	
								593,000	SBTT
KC-135	210	150	210	7,000	147	75	8 to 45	*M*	
								322,500	TT
C-9	90	90	90	5,000	90	40	12 to 32	*L*	
								110,000	T
CRAF	210/300	150	120/180	6,600	90	75	17 to 55	*XH*	
								836,000	DDT

Notes:

w. Onload and offload times for CRAF are given as passengers / cargo for B-747-100.

x. Minimum runway lengths based on landing. While takeoff runway length can be much greater, it is assumed the aircraft will land, download its cargo and passengers, and then takeoff at a much lighter gross weight which normally will not require a longer runway than what was required to land. Although this is not always the case, since temperature, pressure altitude, runway conditions (wet, dry, type of surface etc.) can greatly impact engine performance and runway required to takeoff, and planners should take these factors into consideration for any operation. For this paper, these issues are not taken into consideration. AMC Director of Operations (DO) can waive minimum runway requirements on a case-by-case basis. For non-tactical assault operations, the minimum runway length for the C-130 is 5,000 ft and minimum runway width is 80 ft. CRAF minimum runway length for landing varies from 4,750 ft (B-757) to 7,300 ft (L-1011). For this paper, CRAF minimum runway length required is based on the B-747 (6,600 ft). CRAF minimum runway width varies from 90 ft (B-747) to 150 ft (B-767). CRAF minimum taxiway width varies from 50 ft (DC-8) to 75 ft (B-747). For this paper, CRAF minimum runway length and taxiway width is based on the B-747-100.

y. Pavement classification number (PCN) and aircraft classification number (ACN) are part of an international system used to determine if a runway can support the weight of a given aircraft. ACN relates aircraft weight characteristics to a runway's load bearing capability. ACNs are reported as a range of values for each aircraft version depending on the type of pavement the aircraft is expected to operate on (rigid or flexible) with four subgrades assigned to each type of pavement. For example, the C-130 has four ACN ranges for rigid pavement (high, medium, low, and ultra low) and four for flexible pavement (high, medium, low, ultra low). For this paper, only rigid pavement (medium) is used. For CRAF aircraft, the B-747-100 ACN for rigid pavement (medium) is used. If the ACN range is less than or equal to the PCN, then the aircraft can safely operate on that runway.

z. Another way to determine if runways, taxiways, and ramps can support an aircraft is to specify any restrictions based on the maximum aircraft gross weight for a particular landing gear system. For example, airfield managers may stipulate that aircraft greater than 500,000 lbs with twin-double-tandem (TDT) can only operate on the runway whereas aircraft less than 350,000 lbs with twin-tandem (TT) landing gear may operate on all runways, taxiways and ramps. For this paper, a *qualified aircraft weight* that combines maximum gross weight with the type of landing gear into an overall value is used. *Qualified aircraft weight* is specified as *extra-heavy (XH)*, *heavy (H)*, *medium (M)*, *medium-light (ML)*, *light (L)*, and *extra-light (XL)*.

Aircraft Type	*Qualified Aircraft Size*[aa]		*Qualified Ground Maneuverability*[bb]		Engine Running Onload & Offload[cc]	C-130 MOG Equiv-alency[dd]	SAAM Fly Cost[ee] (per hr)	PMAI[ff]	Crew Ratio[gg]
	Length (ft)	**Width (ft)**	**Backup Unassisted**	**Distance for 180° Turn (ft)**					
C-5A/B	*XL*		*C*		Y	*4.0*	$13,812	104	1.8 1.8 2.0
	247.8	222.7	N	147					
C-141	*L*		*D*		Y	*2.0*	$6,227	135	1.8 1.8 2.0
	168.4	160	Y	98					

C-17	*L*		*S*		Y	*2.26*	$7,418	37	3.0 2.0
	173.92	169.75	Y	90					
C-130	*MS*		A		Y	*1.0*	$5,669	388	2.0 1.75 1.75 1.75
	99.5	132.6	Y	60					
KC-10	*L*		*C*		N	*2.2*	$8,026	54	2.0 1.5
	181.6	165.3	N	148					
KC-135	*M*		*C*		N	*1.4*	$6,980	472	1.36 1.27
	136.25	130.85	N	147					
C-9	*MS*		*D*		N	*0.8*	$4,027	18	1.1 1.8
	119.3	93.4	Y	90					
CRAF	*XL*		*C*		N	*3.4*	See note ee	41/43 95/119 216/277	4.0
	231.83	195.67	N	90					

Notes:

aa. A *qualified aircraft size* combines length and width into an overall value. *Qualified aircraft size* is specified as *extra-large (XL), large (L), medium-large (ML), medium (M), medium-small (MS),* and *small (S)*.

bb. A *qualified ground maneuverability* is assigned to each aircraft based on its ability to backup unassisted, the distance required to turn 180 degrees, and the overall ground handling characteristics of the aircraft (responsiveness of engines, turning mechanisms, etc.), and the visibility from the cockpit (to avoid ground obstacles). *Qualified ground maneuverability* is specified as *Agile (A)*, S*pry (S)*, *Deft (D)*, and C*umbersome (C)*. While the C-141 can backup on its own, it is not routinely done. The C-17 can perform a three-point star turn in 90 ft.

cc. Engine running on / offload permits cargo and personnel to enplane / deplane the aircraft without having to shut down the engines.

dd. **M**aximum number of aircraft **O**n the **G**round (MOG) refers to the number of aircraft of a specific type (e.g. C-130) that can land, taxi-in, park, offload or onload cargo and / or passengers, refuel, be maintained and inspected by maintenance, change aircrews, obtain flight clearance, taxi-out, and takeoff at any given time. It is very dependent on the type of aircraft, ground resources available, and airfield physical characteristics (such as ramp space). For this paper, MOG is measured in C-130 equivalents.

ee. Since costs depend on numerous factors (depot repairs, maintenance, crew travel, civilian pay, logistics support, depreciation, acquisition, modernization, etc.), for simplicity purposes the cost shown is based on the special assignment airlift (SAAM) rate. A SAAM rate is the cost a user pays per hour to "borrow" a dedicated Air Mobility Command aircraft (and aircrew) to perform a mission. For CRAF, cost is 53.584 cents per ton-mile for cargo and 13.842 cents per seat-mile for passengers.

ff. Primary mission aircraft inventory (PMAI) reflects active and reserve component aircraft inventory, not apportionment. The C-9 is shown for aeromedical evacuation aircraft only. CRAF PMAI values shown from top to bottom for Stage I, Stage II, and Stage III. CRAF aircraft for each stage shown as cargo / passenger aircraft. As the C-141 retires and more C-17s come in service, the PMAI for both aircraft will change. In FY03, there will be no active duty C-141s, and the Reserve/Guard will have 40. In FY03, there should be 102 usable C-17s. By FY06, only 8 C-141s will be in service (Guard/Reserve) at which time, there should be a total of 135 C-17s.

gg. Crew ratio shown from top to bottom for Active Duty, Associate Reserve, and Unit Equipped (UE) Guard and Reserve (if applicable) except the C-130 and CRAF. The C-130 crew ratios from top to bottom are Active Duty (CONUS), Active Duty (OCONUS), Associate Reserve, and UE Guard and Reserve. CRAF crew ratio is normally contracted at 4 aircrew per aircraft.

These planning factors are for academic purposes only. They are a combination of actual planning and author created values and should not be used for "real world" analysis without HQ AMC review and approval.

Table 7. Range versus Payload (Cargo).

Chart derived from data provided by HQ AMC/XPY, 1 May 1999 (see note below).[208]

Distance (nm)	C-5A/B	C-141	C-17	C-130	KC-10	KC-135	B-747-400	B-747-100	DC-10	MD-11	Air Evac B-767	C-130J-30
0	291000	89000	172200	44000	169350	56000	243200	195000	178500	200000	131500	37300
250	291000	89000	172200	42700	169350	56000	243200	195000	178500	200000	131500	37300
500	291000	89000	172200	41400	169350	56000	243200	195000	178500	199000	131500	37300
750	291000	89000	172200	39500	169350	56000	243200	195000	178500	198000	131500	37300

1000	291000	89000	172200	38200	169350	56000	243200	195000	177500	197000	131500	37300
1250	275000	89000	172200	36150	169350	56000	243200	195000	176000	195500	131500	37300
1500	263000	89000	172200	34100	169350	56000	243200	195000	175500	194500	131500	37300
1750	251000	89000	172200	30500	169350	56000	243200	195000	174000	194000	131500	37300
2000	239000	89000	172200	26900	169350	56000	243200	195000	173500	193000	131500	37300
2250	227000	81500	161000	23600	169350	56000	243200	195000	172500	192000	131500	37300
2500	215000	74000	150000	20300	169350	56000	243200	195000	171500	191000	131500	36700
2750	203000	72000	139000	17250	169350	56000	243200	195000	171000	190000	131500	34100
3000	191000	66500	128000	14200	158000	56000	243200	195000	170000	189000	131500	32000
3250	179000	60500	110000	9000	150000	56000	243200	188000	169000	188000	130742	28700
3500	167000	53500	77000	3800	141000	56000	243200	176000	160000	187000	129984	18900
3750	154000	47000	53000	0	132000	56000	243200	163000	152000	179000	124281	10800
4000	142000	41500	29000		123000	56000	243200	151000	143000	171000	118577	4100
4250	130000	22000	10000		115000	56000	243200	138000	134000	162500	113042	0
4500	118000	0	0		107000	56000	243200	125000	126000	154000	107507	
4750	106000				98000	56000	234616	112000	117000	146000	102118	
5000	94000				90000	56000	226032	99000	108000	138500	96728	
5250	81000				82000	56000	215210	86000	97000	130000	91501	
5500	69000				74000	56000	204388	73000	81000	122000	86274	
5750	52000				66000	52000	192000	60000	64000	113000	81231	
6000	35000				58000	48000	180000	47000	49000	103000	76188	
6250	17000				50000	44500	173000	34000	32000	89000	68960	
6500	0				43000	41000	160000	21000	15000	73000	61732	
6750					36000	37500	151000	0	0	59000	49523	
7000					30000	34000	141000			44000	37313	
7250					24000	30500	132000			29000	26984	
7500					18000	27000	122000			14000	16654	
7750					13000	23500	103742			0	8327	
8000					6500	20000	80000				0	
8250					0	16500	60000					
8500						13000	40000					
8750						9500	24000					
9000						5000	7000					
9250						0	0					
9500												
9750												
10000												

Notes

[207] Values in italics are author derived / determined and not published in any other known documentation. All others were obtained from several different publications to include: Air Force Pamphlet (AFP) 10-1403, *Air Mobility Planning Factors*, 1 March 1998; AMC Instruction 65-602, *Transportation Working Capital Fund (TWCF) Budget Operations, Concepts and Accounts*, 24 October 1997; *1998 AMMP*; Briefing, Dave Merrill, HQ AMC/XPY, subject: The Algebra of Airlift, November 1998; Briefing, Maj Vic Del Moral, AMC Civil Air Division, subject: Civil Reserve Air Fleet, n.d.; USAF Aircraft Fact Sheets, on-line, Internet, 25 February 1999, available from http://www.af.mil/news/factsheets; and Boeing Aircraft Fact Sheets, on-line, Internet, 5 May 1999, available from http://www.boeing.com.

Notes

[208] Note: This chart is for academic purposes only. The range / payload values may not be accurate for "real world" missions since they do not include other fuel requirements dictated by command operating guidance, anticipated weather delays, degraded navigation, or fuel to divert to an alternate airfield. The values in this chart also reflect maximum cabin loads that are rarely achieved during "real world" operations. Frequently, an aircraft will reach its maximum volume (or floor space) before it gets to its maximum tonnage capacity ("bulk out" before "gross out").

Appendix G

Measures of Effectiveness (MOEs) Explained

Table 8. Baseline MOEs Explained

Range
What is the average distance from the APOD to the theater APOE? (nm) *This distance is from the aerial port of embarkation (APOE) to the aerial port of debarkation (APOD) or theater main operating bases (MOBs). The range for the aircraft is dependent on the average distance (not using in-flight refueling) the aircraft can fly carrying an average cargo load and is evaluated relative to this distance (not using in-flight refueling).*
Is in-flight refueling capability desired? (Y/N) *In-flight refueling extends the range of an aircraft and can reduce time to the final destination by minimizing or eliminating en route stops. In-flight refueling can also permit some aircraft to carry more tonnage by allowing them to take off with less fuel (and more cargo) and then refueling while airborne. This situation is encountered when an aircraft has a maximum ramp weight (on the ground) but a less restrictive weight when airborne.*
Payload
What is the planned average tonnage per acft? (STON) *While some may think this should always be set to the maximum tonnage possible, this is not necessarily true, especially since transport aircraft often "bulk out" before they "gross out." In other words, the aircraft fills up with cargo before the maximum allowable tonnage is reached. Frequently, airlifters will haul mixes of cargo (bulk, passengers, rolling stock, container, outsize, oversize, airdrop, etc.) which necessitates that we do not always plan for the maximum "tonnage" possible. To do so would frequently result in underestimating the number of aircraft required for an operation. To mitigate this issue, planners use a "planned" tonnage for each type of airlift aircraft.*
How many 463L pallets are planned per acft? *The same discussion listed for tonnage above applies here as well.*
Is oversized capability needed? (Y/N) ***While oversized cargo may not be needed for every aircraft, we must capture this critical capability if mission success depends on its delivery.***
Is outsized capability needed? (Y/N) ***Same discussion as oversized.***
What is the average passenger capacity expected per aircraft? *Again one may think this value would always be set as high as possible, but this is not always the case. Military airlift aircraft are primarily designed to carry cargo. If a large number of passengers must be moved, then either contract civilian aircraft will be utilized or the CRAF may be activated. But if there is a need to move people into a non-permissive area (i.e. closer to combat operations, threatened by terrorist activity, etc.), or to an airfield that cannot handle commercial aircraft (due to aircraft size or special ground equipment required) then a majority of the people will likely travel on military aircraft.*
Is Roll-on / Roll-off capability needed? (Y/N) *Rolling cargo is tracked and / or wheeled vehicles which can either be towed or driven onto or off from the aircraft. This capability is normally unique to military airlift aircraft that have cargo floors stressed for heavy vehicles and large cargo doors and an integrated ramp.*
Speed
What is the desired average en route blockspeed? (kts) *For this paper, the average blockspeed is based on a 3,500 nm leg for all aircraft except the C-130 which is based on a 1,500 nm leg distance. These distances reflect average cargo loads.*
Cost
What is the planned average flying cost? (per aircraft hour) *The cost of flying a specific aircraft should be a consideration when planning an operation (although it is not likely to be a primary consideration when vital national interests are at stake). Where this value is especially useful is for operations less than war and / or evaluating future airlift proposals.*

Aerial Operations
What is the desired aircraft utilization (UTE) rate? (hrs) *The average flying hours per day for an aircraft is given by UTE or USE rate. For this paper, UTE includes aircraft reliability (percentage of time aircraft can fly before maintenance down time), maintainability (ease of accomplishing repairs / scheduled maintenance), availability (aircraft are ready for when needed), and crew ratio. UTE rate normally only applies to long-term, large-scale operations such as the execution of an OPLAN. For smaller operations that involve less than the entire fleet, UTE rate is normally not used. Wartime objective surge UTE rate is the established flying hour goal for planning and programming to meet JCS directed wartime objectives in the first 45 days of the deployment. Surge UTE assumes deferred scheduled maintenance, support people working overtime, and full mobilization of both active / reserve forces and operating with fully funded / fully stocked spares. Wartime objective sustained UTE rate is usually less than surge UTE. Sustained UTE is based on normal duty days, 100% active and reserve participation, and accomplishment of maintenance activities deferred during the surge period. Contingency non-mobilized USE rate is normally less than UTE rates and is based on full active duty participation and 25% reserve volunteerism.*
Is airdrop capability needed? (Y/N) *Airdrop normally entails the aerial delivery of personnel (PER), heavy equipment (HE), and / or container delivery system (CDS). The amount of cargo and personnel that can be airdropped varies with different types of airlift aircraft. For this paper, these varied amounts are not specified. If more fidelity is needed depending on the scenario, then this MOE could be further subdivided to capture this information. Strategic Brigade Airdrop (SBA) is a specialized form of combat delivery that includes airdrop and airland insertions of a brigade-size compliment of equipment and combat personnel over great distances. SBA supports the JCS requirement to immediately deploy massed airborne forces anywhere in the world. SBA uses the direct delivery concept by inserting personnel, cargo, and equipment as close as practicable to the user's final destination which minimizes en route travel time and transshipments. SBA also allows the insertion of combat forces directly into the battle area or the immediate resupply in areas where forcible entry is required. It can also enable friendly ground forces to gain the initiative through surprise and maintain the initiative through mobility and mass.*
Is special operations low level (SOLL) planned? (Y/N) *SOLL missions require specially trained aircrew proficient in the use of night vision goggles and knowledgeable of the unique procedures required to conduct special operations (e.g. tactical onload / offload and airdrop of special forces equipment at night in a minimum illumination environment).*
Is aeromedical evacuation (AE) capability needed? (Y/N) *AE missions entail the delivery of ill or injured persons under medical supervision to appropriate medical care during peacetime or war. AE capable aircraft have special design characteristics (e.g. therapeutic oxygen connections and tie-down locations for litters) and different types of aircraft can carry varying levels of litter and ambulatory patients. For this paper, we will just capture the overall ability of an airlift aircraft to do the AE mission. If additional fidelity is needed, then this MOE could be further subdivided accordingly.*
What level of airborne survivability is needed? (None, Low, Med, High) *Since airlift operates across the spectrum of conflict, America is adverse to friendly casualties, and proliferation of weapons such as MANPADS will likely continue, the requirement for airlift aircraft with various levels of survivability will likely increase. Threat level for any theater is very difficult to assess, but intelligence and planners need to determine the potential threat conventional weapons pose to aircraft and decide the level of aircraft capability needed to survive / counter that threat. None indicates that aircraft not designed for a combat environment (e.g. B-7476) can be used. Low implies that aircraft must have at least some inherent survivability (e.g. dispersed hydraulic / electrical systems) and some passive measures (e.g. Identification Friend or Foe (IFF)) before they can be used in this AOR. Medium implies that aircraft with additional passive measures (e.g. aircrew / aircraft armor) and more active measures (e.g. flares, chaff, and electronic-counter measures) is needed. High implies that aircraft with stealth and / or decoy systems is required. Weapons of mass destruction (chemical / biological agents) is discussed under ground operations.*
Ground Operations
What level of aircraft resistance to chemical / biological weapons is needed? (None, Low, Med, High) *The proliferation of weapons of mass destruction (WMD), especially chemical and biological agents, and the increased chance of an adversary using asymmetrical warfare to counter friendly coalition advantages dictates that we consider WMD for most every scenario. While these weapons may threaten airborne aircraft (e.g. atomized vapors / aerosol sprays), the greatest threat of contamination is while operating on the ground. Resistance to chem / bio weapons is measured relative to an aircraft's capability. None indicates that no special aircraft resistance to chem / bio agents is required and any aircraft can be used. Low resistance implies that aircraft with little capability to prevent chem / bio agents from coming into the aircraft (beyond not opening aircraft doors) can be used. Medium resistance requires aircraft with more robust capability (such as a well-sealed fuselage, overpressure systems, air blowers, and / or split plastic curtains like the ones used for walk-in freezers that permit cargo and people to pass and then swing back into place) must be used. High resistance requires aircraft with the greatest resistance. Aircraft must be able to operate into a chem / bio environment with protective measures that resist these agents from coming onto the aircraft. Aircraft with this capability may automatic detection systems that deploy and defeat counter-agents immediately upon sensing them, interior coatings to counter the agents, and possibly a cargo compartment that can be remotely operated from a sealed cockpit.*
What level of aircraft decontamination is needed? (None, Formidable, Tough, Productive) *Resistance to chem / bio agents is just one half of the WMD issue. The ability to decontaminate an aircraft must also be considered. None indicates that no special aircraft decontamination capability is required and any aircraft can be used. Formidable decontamination indicates that extensive work must be done to clear the aircraft of chem / bio agents before it can be returned to normal*

operational use. This may include extensive disassembly of the exterior and interior of the aircraft to get to crawl spaces and other nock and crannies to apply decontamination methods and cannot normally be done at forward locations due to highly specialized equipment required and several days to weeks to complete. Tough decontamination is used for those aircraft that require a moderate amount of work to clear the aircraft. Some disassembly may still be required, but it is not extensive and decontamination is facilitated by easy access to remote areas and proper sealing of compartments not reachable without extensive disassembly. It can be done at forward areas but may require some additional equipment and a modicum of effort to complete the job within one day or less. Productive decontamination is used for those aircraft that require a minimum amount of work to the aircraft before it can return to operational use within hours. Little or no additional equipment is required since these aircraft have automatic decontamination systems installed such as infrared / ultraviolet lights, spray nozzles to disperse decontamination agents and foaming cleansing systems to automatically wash the contaminates from the aircraft.
What is the planned minimum ground time? (minutes) *Ground time is the amount of time from when an aircraft pulls into parking ("block in") to when it becomes airborne again. For operations where airfield throughput is a critical factor, then ground time should be as short as possible.*
Is any special materials handling equipment (MHE) available? (Y/N) *Special MHE pertains to k-loaders and other devices that are required to on- and offload aircraft with high cargo decks that are typical of large wide-body civilian aircraft. Frequently, this type of equipment is not available at austere locations or during the initial "surge" period of an operation.*
Is small austere airfield (SAAF) capability needed? (Y/N) *Austere bases typically have little or no navigational aids, narrow taxiways, limited ramp space, sparse maintenance, and limited ground support equipment (e.g. power carts, oxygen / nitrogen carts). Aircraft that can operate from these airfields provides a forward commander with many more options than having to depend on larger bases located further from the crisis. A small austere airfield (SAAF) has all of the previous characteristics plus a runway that is usually only 3,000 ft long.*
Is engine running onload / offload (ERO) capability desired? (Y/N) *ERO capable aircraft can on and offload cargo and personnel while the engines remain operating. This can greatly reduce ground times and minimize maintenance problems due to shutting down and then starting the aircraft up again. Aircraft must be designed to perform this function to include devices to divert engine exhaust over or around enplaning / deplaning passengers and ground crews.*
What is the largest aircraft the average airfield can support? (Small, Medium Small, Medium, Medium Large, Large, Extra Large) *APODs and MOBs can usually support aircraft up to extra large (XL), whereas FOBs can normally only support large (L) aircraft or smaller. For this paper, a qualified aircraft size (based on aircraft length and width) is used.*
What is the heaviest aircraft the average airfield can support? (Light, Medium Light, Medium, Medium Heavy, Heavy, Extra Heavy) *APODs and MOBs can usually support aircraft up to extra heavy (XH), whereas FOBs can normally only support heavy aircraft (H) or lighter. For this paper, a qualified aircraft weight (based on aircraft maximum gross weight and landing gear type) is used.*
What level of ground maneuverability is needed? (Agile, Spry, Deft, Cumbersome) *The ground maneuverability of an aircraft is especially important when operating into airfields that have very limited ramp space and little or no ground equipment (i.e. tugs) to push back aircraft out of parking locations. A qualified ground maneuverability level is based on the distance it takes an aircraft to turn 180 degrees, its ability to backup without ground assistance, visibility from the cockpit to avoid ground obstacles, and the overall handling characteristics of the aircraft while on the ground. Agile is the most maneuverable and Cumbersome the least.*
What is the maximum aircraft on the ground (MOG) that the average airfield can support per day? (C-130 equivalents) *Every airfield has a maximum number of aircraft on the ground (MOG) that they can support for a given 24-hour period. While MOG may refer to the number of parking spaces available, it can also be limited by ground refueling capability, maintenance, support equipment, aircrew billets available, and other factors. A higher MOG means more aircraft can simultaneously transit an airfield. MOG for this paper is based on the number of C-130 equivalents the average airfield can support (which is a function of premium parking locations). Theoretically, an airfield should be able to support more aircraft if their C-130 MOG equivalency is less than 1.0 (see Appendix F for each type of aircraft's C-130 MOG equivalency). For example, if an airfield has a C-130 MOG of 5, that should mean it can support 10 aircraft that have a C-130 MOG equivalency of 0.5 (the aircraft are one-half the size, so twice as many can fit on the airfield). But this may not always be true, especially if the MOG is based on something other than parking spots. For example, if an airfield has only 5 power carts, or 5 fuel trucks, then it may not be able to simultaneously support more than 5 aircraft. For this paper, I assume that if an aircraft's MOG equivalency is less than 1.0 the airfield will be able to support the increased number of aircraft. Similarly, if an aircraft's C-130 MOG equivalency is greater than 1.0, then the average airfield cannot support as many aircraft of that type.*

These MOEs are for academic purposes only. They are used to demonstrate the methodology presented in this paper, and although the author has tried to make them as realistic as possible, they should not be used for "real world" analysis without HQ AMC review and approval. The goal is to encourage analysts, planners, and those responsible for reporting airlift effectiveness to develop their own MOEs that best reflect the scenario and / or the capabilities of the aircraft being evaluated.

With that said, the MOEs developed should reflect the requirements for each major area (range, payload, speed, cost, aerial operations, and ground operations) and that they are mutually exclusive. This will ensure requirements or aircraft capabilities are not "counted" more than once. Otherwise, the accuracy of the evaluation is questionable.

Table 9. Fleet Planning Values Explained

Usable Aircraft
What percentage of the primary mission aircraft inventory (PMAI) will be used? *Rarely will every aircraft be available for any operation. Some aircraft are still needed for other missions and contingencies. A higher percentage of aircraft will likely be used for major theater wars, whereas a lower percentage of aircraft will likely be used for smaller operations. Frequently, allocation is by type of aircraft (e.g. 22 C-141s, 30 C-5s, etc.) depending on the scenario and various capabilities needed, but for simplicity purposes an overall percentage is used for this paper.*
What level of the CRAF will be activated? (None, Stage I, II, or III) *If the CRAF is activated to support an operation, then the number of cargo and personnel aircraft are designated by stages. While USTRANSCOM may elect not to use every CRAF aircraft activated by that stage, this is not accounted for in this paper.*
Total Tonnage & Passenger Theater Requirements
How many tons must be airlifted to the theater every day? (STON) *Theater cargo requirements are frequently expressed in total STONs per day.*
How many passengers must be airlifted to the theater every day? *Theater personnel requirements are frequently expressed in total passengers per day.*
Travel Distance and Time from APOE to FOB
What is the average aerial distance from the APOD to the FOB? (nm) *Since the previous distance was to the theater MOB, we also need the distance from the MOB to the FOB to calculate direct delivery time.*
What is the average travel time from the APOD to the FOB? (hr) *The average travel time can be via air, ground, or water modes of transportation. While the distance from the MOB to the FOB may be relatively short, the travel time may be fairly long depending on availability of transportation and additional time required to "marrying up" troops with their equipment before moving to the forward operating bases.*

Appendix H

Calculations Explained

Table 10. MOE Calculations Explained

	Range	Actual Aircaft Capability	Capability vs Baseline	x Weight Value
R1	What is this aircraft's average range with a planned cargo load? (nm)	Value Obtained from Appendix F	See Note 1	See Note 7
R2	Is this aircraft in-flight refuelable? (Y/N)	See Appendix F	See Note 2	See Note 7
	Payload			
P1	What is this aircraft's planned average tonnage? (STON)	See Appendix F	See Note 1	See Note 7
P2	How many 463L pallets can this aircraft carry?	See Appendix F	See Note 1	See Note 7
P3	Can this aircraft accommodate oversized cargo? (Y/N)	See Appendix F	See Note 2	See Note 7
P4	Can this aircraft accommodate outsized cargo? (Y/N)	See Appendix F	See Note 2	See Note 7
P5	What is the aircraft's planned passenger capacity?	See Appendix F	See Note 1	See Note 7
P6	Can this aircraft accommodate Roll-on / Roll-off cargo? (Y/N)	See Appendix F	See Note 2	See Note 7
	Speed			
S1	What is this aircraft's average blockspeed? (kts)	See Appendix F	See Note 1	See Note 7
	Cost			
C1	What is this aircraft's hourly flying cost?	See Appendix F	See Note 1	See Note 7
	Aerial Operations			
A1	What is this aircraft's "surge" utilization (UTE) rate? (hrs)	See Appendix F	See Note 1	See Note 7
A2	Can this aircraft perform the Strategic Brigade Airdrop (SBA) mission? (Y/N)	See Appendix F	See Note 2	See Note 7
A3	Can this aircraft perform Special Operations Low Level (SOLL)? (Y/N)	See Appendix F	See Note 2	See Note 7
A4	Is this aircraft aeromedical evacuation (AE) capable? (Y/N)	See Appendix F	See Note 2	See Note 7
A5	What is this aircraft's airborne survivability level? (N, L, M, H)	See Appendix F	See Note 4	See Note 7
	Ground Operations			
G1	What is this aircraft's resistance to chem / bio agents? (N, L, M, H)	See Appendix F	See Note 4	See Note 7
G2	What is this aircraft's level of decontamination? (F, T, P)	See Appendix F	See Note 3	See Note 7
G3	What is this aircraft's planned ground time? (minutes)	See Appendix F	See Note 1	See Note 7
G4	Is any special MHE required for this aircraft? (Y/N)	See Appendix F	See Note 2	See Note 7
G5	Is this aircraft small austere airfield (SAAF) capable? (Y/N)	See Appendix F	See Note 2	See Note 7
G6	Can this aircraft perform engine running on / offload? (Y/N)	See Appendix F	See Note 2	See Note 7
G7	What is this aircraft's qualified size? (S, MS, M, ML, L, XL)	See Appendix F	See Note 5	See Note 7

G8	What is this aircraft's qualified weight? (L, ML, M, MH, H, XH)	See Appendix F	See Note 5	See Note 7
G9	What is this aircraft's qualified ground maneuverability? (A, S, D, C)	See Appendix F	See Note 4	See Note 7
G10	What is this aircraft's MOG equivalency relative to the C-130?	See Appendix F	See Note 6	See Note 7
	Aggregate Mobility Value (AMV)			See Note 8

Notes: (User entered values are not shaded. Calculated values are shaded gray.)

1. The aircraft's actual capability is divided by the baseline requirement. If the resultant is greater than 1.0 (which indicates the aircraft's actual capability exceeds / beats the baseline) then the resultant entered is 1.0. Otherwise, the actual resultant of the division is placed here which provides a fractional aircraft capability relative to the baseline. In this fashion, no aircraft is given "extra credit" for exceeding the requirement. My reasoning for not awarding "extra credit" is that if the baseline requirement is not appropriate, then the user should set it at a more acceptable value. Aircraft that meet the requirement should receive the highest value for any given MOE—to award an aircraft a higher value for exceeding the requirement would actually penalize those that at least meet the requirement. If one wanted to give "extra credit" for exceeding the requirement, then it would be a simple matter to adjust the formulas accordingly.
2. For MOEs with a yes or no answer, a value of 1 is used if the aircraft capability meets the baseline requirement and a value of 0 is used if it does not meet the baseline.
3. For MOEs with three responses, if the aircraft's capability meets or exceeds the baseline requirement, a value of 1 is used (no "extra credit" for exceeding the requirement). If the aircraft does not meet the requirement, then a scaler value is used. A value of 0.5 is used if the aircraft is one level below the requirement, and a value of 0.0 is used if the aircraft is two levels below the requirement. For example, if the requirement for G2, Aircraft Decontamination Level, is Productive and the aircraft's capability is Tough, the value used is 0.5. If the aircraft's capability is Formidable, the value used is 0.0. This permits planners to still consider those aircraft that have a capability that is fairly close to that specified by the baseline.
4. For MOEs with four responses, if the aircraft's capability meets or exceeds the baseline requirement, a value of 1 is used (no "extra credit" for exceeding the requirement). If the aircraft does not meet the requirement, then a scaler value is used. A value of 0.7 is used if the aircraft is one level below the requirement, 0.4 for two levels, and 0.0 for three levels. For example, if the requirement for G1, Aircraft Resistance to chem / bio agents is High and the aircraft's capability is Medium, the value used is 0.7. If the aircraft's capability is Low, the value used is 0.4. If the aircraft's capability is None, the value used is 0.0. This permits planners to still consider aircraft that have a capability that is fairly close to that specified by the baseline.
5. For MOEs with six responses, if the aircraft's capability meets or exceeds the baseline requirement, a value of 1 is used (no "extra credit" for exceeding the requirement). If the aircraft does not meet the requirement, then a scaler value is used. A value of 0.8 is used if the aircraft is one level below the requirement, 0.6 for two levels, 0.4 for four levels, and 0.0 for five levels below the baseline requirement. For example, if the requirement for G7, Largest Aircraft the Average Airfield can Support is Small and the aircraft is Medium-Small, the value used is 0.8. If the aircraft is Medium, the value used is 0.6. If the aircraft is Medium-Large, the value used is 0.4. If the aircraft is Large or Extra-Large, the value used is 0.0. This permits planners to still consider aircraft that have a capability that is fairly close to that specified by the baseline.
6. The maximum aircraft on the ground (MOG) the average airfield can support per day (C-130 equivalents) is divided by each aircraft's C-130 MOG equivalency. The resultant value is then divided by the MOG the average airfield can support per day to keep the value between 0 and 1.0. Essentially, this calculation is the same as inverting each aircraft's C-130 MOG equivalency (i.e. dividing it into 1).
7. After the aircraft's "capability vs baseline" is determined, it is multiplied by the weight factor for that MOE.
8. All the values in the "x weight value" column are combined into an aggregate mobility value (AMV) by adding them together and then dividing the result by the total number of MOEs.

Table 11. Fleet Calculations Explained

Usable Aircraft		Total PMAI	Usable	
U1.1	What is the primary mission aircraft inventory (PMAI) for this airlifter?	See Appendix F	See Note 1	Not Used
Fleet Cargo Closure Rates		**Round Trip (Days)**	**Fleet Average Tons per day**	**Fleet Capability vs Baseline**
CR1.1	Cargo closure rate without in-flight refueling. (APOE→APOD→FOB)	See Note 2	See Note 6	See Note 8
CR1.2	Cargo closure rate with in-flight refueling. (APOE→APOD→FOB)	See Note 3	See Note 6	See Note 8
CR1.3	Direct delivery cargo closure rate without in-flight refueling. (APOE→FOB)	See Note 4	See Note 6	See Note 8
CR1.4	Direct delivery cargo closure rate with in-flight refueling. (APOE→FOB)	See Note 5	See Note 6	See Note 8
OR				
Fleet Passenger Delivery Rates		**Round Trip (Days)**	**Fleet Average Pax per day**	**Fleet Capability vs Baseline**
PR1.1	Passenger delivery closure rate without in-flight refueling. (APOE→APOD→FOB)	See Note 2	See Note 7	See Note 8
PR1.2	Passenger delivery closure rate with in-flight refueling. (APOE→APOD→FOB)	See Note 3	See Note 7	See Note 8
PR1.3	Direct delivery passenger closure without in-flight refueling. (APOE→FOB)	See Note 4	See Note 7	See Note 8
PR1.4	Direct delivery passenger closure rate with in-flight refueling. (APOE→FOB)	See Note 5	See Note 7	See Note 8

Notes: (User entered values are not shaded. Calculated values are shaded gray.)

1. The total PMAI is multiplied by the percentage allotted to get total usable aircraft for this scenario. For CRAF allocation, the total aircraft activated by stage becomes the usable aircraft.
2. Round trip time (days) without in-flight refueling assumes only one en route stop between the APOE and APOD. If additional stops are planned, then the second argument of the formula should be modified accordingly. The first two arguments in the round trip formula calculate the time (in days) it takes an aircraft to travel from the APOE to the APOD and then back to the APOE. Since the cargo and personnel are offloaded at the APOD, the last argument in the formula accounts for the time required to travel (either air, land, or water) from the APOD to the FOB. The formula used to calculate round trip time is:

$$RT = \frac{2 * \text{Avg Distance APOEs to APODs (nm)}}{\text{Blockspeed (nm/hr) X UTE Rate (hr/day)}} + \frac{4 * \text{Avg Ground Time (min)}}{60 \text{ (min/hr)} * 24 \text{ (hr/day)}} + \frac{\text{Avg Travel Time from APOD to FOB (hr)}}{24 \text{ (hr/day)}}$$

3. The round trip time with in-flight refueling assumes no en route stops between the APOE and APOD.

$$RT = \frac{2 * \text{Avg Distance APOEs to APODs (nm)}}{\text{Blockspeed (nm/hr) X UTE Rate (hr/day)}} + \frac{2 * \text{Avg Ground Time (min)}}{60 \text{ (min/hr)} * 24 \text{ (hr/day)}} + \frac{\text{Avg Travel Time from APOD to FOB (hr)}}{24 \text{ (hr/day)}}$$

4. The direct delivery round trip time without in-flight refueling assumes one en route stop each way, overflight of the APOD, and landing at the FOB.

$$RT = \frac{2 * [\text{Avg Distance APOEs to APODs (nm)} + \text{Avg Air Distance from APOD to FOB (nm)}]}{\text{Blockspeed (nm/hr) X UTE Rate (hr/day)}} + \frac{4 * \text{Avg Ground Time (min)}}{60 \text{ (min/hr)} * 24 \text{ (hr/day)}}$$

5. The direct delivery round trip with in-flight refueling assumes overflight of en route stops and the APOD and landing at the FOB.

$$RT = \frac{2 * [\text{Avg Distance APOEs to APODs (nm)} + \text{Avg Air Distance from APOD to FOB (nm)}]}{\text{Blockspeed (nm/hr) X UTE Rate (hr/day)}} + \frac{2 * \text{Avg Ground Time (min)}}{60 \text{ (min/hr)} * 24 \text{ (hr/day)}}$$

6. The fleet average tons per day is calculated using the following formula:

$$\text{Fleet Average Tonnage per Day} = \frac{\text{Acft Planned Average Cargo Load (STON)}}{\text{RT (days)}} * \text{Number of Usable Aircraft}$$

7. The fleet average personnel delivered per day is calculated using the following formula:

$$\text{Fleet Average Personnel per Day} = \frac{\text{Acft Planned Average Passenger Load}}{\text{RT (days)}} * \text{Number of Usable Aircraft}$$

8. Fleet capability versus baseline requirement per day is calculated by dividing the fleet average tons (or passengers) per day by the tons (or passengers) required per day.

Appendix I

Strategic Airlift Cargo Capability

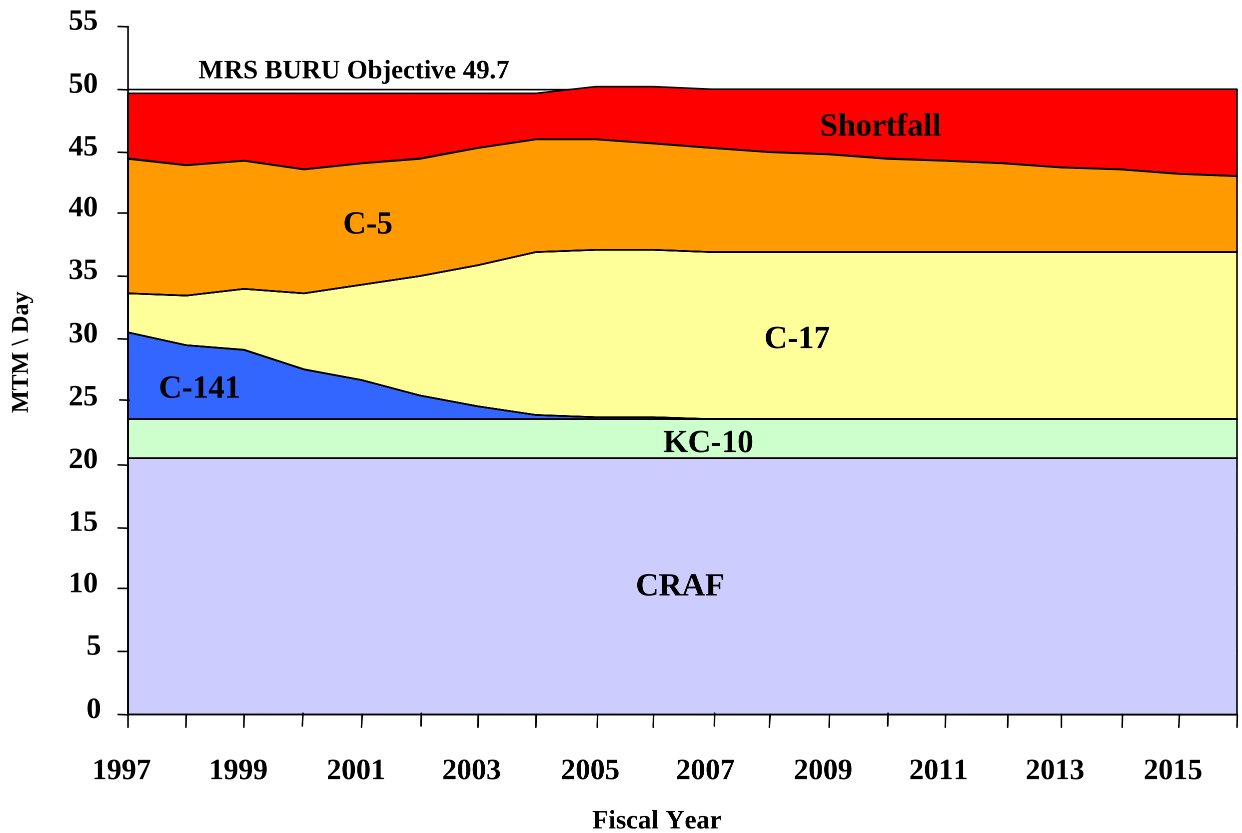


Figure 15. Projected Strategic Airlift MTM/d Capability.

Data obtained from briefing given at the Rapid Global Mobility Symposium, Robins AFB, GA, 28-30 January, 1999. General Charles T. Robertson, CINCTRANS, subject: Global Mobility: The Keystone of America's Defense Strategy.

Appendix J

AMV Calculations

Table 12. C-5 AMV for MTW Scenario

Range		Actual Aircaft Capability	Capability vs Baseline	x Weight Value
R1.1	What is the aircraft's average range with a planned cargo load? (nm)	3,500	0.39	3.11
R2.1	Is this aircraft in-flight refuelable? (Y/N)	Y	1.00	8.00
Payload				
P1.1	What is this aircraft's planned average tonnage? (STON)	61.3	1.00	8.00
P2.1	How many 463L pallets can this aircraft carry?	36	1.00	6.00
P3.1	Can this aircraft accommodate oversized cargo? (Y/N)	Y	1.00	10.00
P4.1	Can this aircraft accommodate outsized cargo? (Y/N)	Y	1.00	10.00
P5.1	What is the aircraft's planned passenger capacity?	51	0.26	2.30
P6.1	Can this aircraft accommodate Roll-on / Roll-off cargo? (Y/N)	Y	1.00	7.00
Speed				
S1.1	What is this aircraft's average blockspeed? (kts)	409	1.00	5.00
Cost				
C1.1	What is this aircraft's hourly flying cost?	$13,812	0.58	0.58
Aerial Operations				
A1.1	What is this aircraft's "surge" utilization (UTE) rate? (hrs)	11.4	0.95	7.60
A2.1	Can this aircraft perform the Strategic Brigade Airdrop (SBA) mission? (Y/N)	Y	1.00	10.00
A3.1	Can this aircraft perform Special Operations Low Level (SOLL)? (Y/N)	Y	1.00	5.00
A4.1	Is this aircraft aeromedical evacuation (AE) capable? (Y/N)	N	0.00	0.00
A5.1	What is this aircraft's airborne survivability level? (N, L, M, H)	M	1.00	9.00
Ground Operations				
G1.1	What is this aircraft's resistance to chemical & biological agents? (N, L, M, H)	L	0.70	4.90
G2.1	What is this aircraft's level of decontamination? (F, T, P)	T	1.00	7.00
G3.1	What is this aircraft's planned ground time? (minutes)	195	0.77	6.15
G4.1	Is any special MHE required for this aircraft? (Y/N)	N	1.00	7.00
G5.1	Is this aircraft small austere airfield (SAAF) capable? (Y/N)	N	0.00	0.00
G6.1	Can this aircraft perform engine running on / offload? (Y/N)	Y	1.00	7.00
G7.1	What is this aircraft's qualified size? (S, MS, M, ML, L, XL)	XL	0.80	7.20

G8.1	What is this aircraft's qualified weight? (L, ML, M, MH, H, XH)	XH	0.80	7.20
G9.1	What is this aircraft's qualified ground maneuverability? (A, S, D, C)	C	0.40	3.20
G10.1	What is this aircraft's MOG-equivalency relative to the C-130?	4.0	0.25	2.00
	C-5 Aggregate Mobility Value (AMV)			**5.7**

Table 13. C-141 AMV for MTW Scenario

Range		**Actual Aircaft Capability**	**Capability vs Baseline**	**x Weight Value**
R1.1	What is the aircraft's average range with a planned cargo load? (nm)	3,000	0.33	2.67
R2.1	Is this aircraft in-flight refuelable? (Y/N)	Y	1.00	8.00
Payload				
P1.1	What is this aircraft's planned average tonnage? (STON)	19	0.38	3.04
P2.1	How many 463L pallets can this aircraft carry?	13	0.87	5.20
P3.1	Can this aircraft accommodate oversized cargo? (Y/N)	Y	1.00	10.00
P4.1	Can this aircraft accommodate outsized cargo? (Y/N)	N	0.00	0.00
P5.1	What is the aircraft's planned passenger capacity?	120	0.60	5.40
P6.1	Can this aircraft accommodate Roll-on / Roll-off cargo? (Y/N)	Y	1.00	7.00
Speed				
S1.1	What is this aircraft's average blockspeed? (kts)	394	0.99	4.93
Cost				
C1.1	What is this aircraft's hourly flying cost?	$6,227	1.00	1.00
Aerial Operations				
A1.1	What is this aircraft's "surge" utilization (UTE) rate? (hrs)	12.1	1.00	8.00
A2.1	Can this aircraft perform the Strategic Brigade Airdrop (SBA) mission? (Y/N)	Y	1.00	10.00
A3.1	Can this aircraft perform Special Operations Low Level (SOLL)? (Y/N)	Y	1.00	5.00
A4.1	Is this aircraft aeromedical evacuation (AE) capable? (Y/N)	Y	1.00	8.00
A5.1	What is this aircraft's airborne survivability level? (N, L, M, H)	M	1.00	9.00
Ground Operations				
G1.1	What is this aircraft's resistance to chemical & biological agents? (N, L, M, H)	L	0.70	4.90
G2.1	What is this aircraft's level of decontamination? (F, T, P)	T	1.00	7.00
G3.1	What is this aircraft's planned ground time? (minutes)	135	1.00	8.00
G4.1	Is any special MHE required for this aircraft? (Y/N)	N	1.00	7.00
G5.1	Is this aircraft small austere airfield (SAAF) capable? (Y/N)	N	0.00	0.00
G6.1	Can this aircraft perform engine running on / offload? (Y/N)	Y	1.00	7.00
G7.1	What is this aircraft's qualified size? (S, MS, M, ML, L, XL)	L	1.00	9.00
G8.1	What is this aircraft's qualified weight? (L, ML, M, MH, H, XH)	M	1.00	9.00
G9.1	What is this aircraft's qualified ground maneuverability? (A, S, D, C)	D	0.70	5.60
G10.1	What is this aircraft's MOG-equivalency relative to the C-130?	2.0	0.50	4.00
	C-141 Aggregate Mobility Value (AMV)			**5.9**

Table 14. C-130 AMV for MTW Scenario

Range		Actual Aircraft Capability	Capability vs Baseline	x Weight Value
R1.1	What is the aircraft's average range with a planned cargo load? (nm)	1,500	0.17	1.33
R2.1	Is this aircraft in-flight refuelable? (Y/N)	N	0.00	0.00
Payload				
P1.1	What is this aircraft's planned average tonnage? (STON)	12	0.24	1.92
P2.1	How many 463L pallets can this aircraft carry?	6	0.40	2.40
P3.1	Can this aircraft accommodate oversized cargo? (Y/N)	Y	1.00	10.00
P4.1	Can this aircraft accommodate outsized cargo? (Y/N)	N	0.00	0.00
P5.1	What is the aircraft's planned passenger capacity?	80	0.40	3.60
P6.1	Can this aircraft accommodate Roll-on / Roll-off cargo? (Y/N)	Y	1.00	7.00
Speed				
S1.1	What is this aircraft's average blockspeed? (kts)	246	0.62	3.08
Cost				
C1.1	What is this aircraft's hourly flying cost?	$5,669	1.00	1.00
Aerial Operations				
A1.1	What is this aircraft's "surge" utilization (UTE) rate? (hrs)	6.0	0.50	4.00
A2.1	Can this aircraft perform the Strategic Brigade Airdrop (SBA) mission? (Y/N)	N	0.00	0.00
A3.1	Can this aircraft perform Special Operations Low Level (SOLL)? (Y/N)	Y	1.00	5.00
A4.1	Is this aircraft aeromedical evacuation (AE) capable? (Y/N)	Y	1.00	8.00
A5.1	What is this aircraft's airborne survivability level? (N, L, M, H)	M	1.00	9.00
Ground Operations				
G1.1	What is this aircraft's resistance to chemical & biological agents? (N, L, M, H)	L	0.70	4.90
G2.1	What is this aircraft's level of decontamination? (F, T, P)	T	1.00	7.00
G3.1	What is this aircraft's planned ground time? (minutes)	90	1.00	8.00
G4.1	Is any special MHE required for this aircraft? (Y/N)	N	1.00	7.00
G5.1	Is this aircraft small austere airfield (SAAF) capable? (Y/N)	Y	1.00	6.00
G6.1	Can this aircraft perform engine running on / offload? (Y/N)	Y	1.00	7.00
G7.1	What is this aircraft's qualified size? (S, MS, M, ML, L, XL)	MS	1.00	9.00
G8.1	What is this aircraft's qualified weight? (L, ML, M, MH, H, XH)	ML	1.00	9.00
G9.1	What is this aircraft's qualified ground maneuverability? (A, S, D, C)	A	1.00	8.00
G10.1	What is this aircraft's MOG-equivalency relative to the C-130?	1.0	1.00	8.00
C-130 Aggregate Mobility Value (AMV)				**5.2**

Table 15. KC-10 AMV for MTW Scenario

	Range	Actual Aircraft Capability	Capability vs Baseline	x Weight Value
R1.1	What is the aircraft's average range with a planned cargo load? (nm)	4,500	0.50	4.00
R2.1	Is this aircraft in-flight refuelable? (Y/N)	Y	1.00	8.00
	Payload			
P1.1	What is this aircraft's planned average tonnage? (STON)	32.6	0.65	5.22
P2.1	How many 463L pallets can this aircraft carry?	25	1.00	6.00
P3.1	Can this aircraft accommodate oversized cargo? (Y/N)	Y	1.00	10.00
P4.1	Can this aircraft accommodate outsized cargo? (Y/N)	N	0.00	0.00
P5.1	What is the aircraft's planned passenger capacity?	68	0.34	3.06
P6.1	Can this aircraft accommodate Roll-on / Roll-off cargo? (Y/N)	N	0.00	0.00
	Speed			
S1.1	What is this aircraft's average blockspeed? (kts)	434	1.00	5.00
	Cost			
C1.1	What is this aircraft's hourly flying cost?	$8,026	1.00	1.00
	Aerial Operations			
A1.1	What is this aircraft's "surge" utilization (UTE) rate? (hrs)	12.5	1.00	8.00
A2.1	Can this aircraft perform the Strategic Brigade Airdrop (SBA) mission? (Y/N)	N	0.00	0.00
A3.1	Can this aircraft perform Special Operations Low Level (SOLL)? (Y/N)	N	0.00	0.00
A4.1	Is this aircraft aeromedical evacuation (AE) capable? (Y/N)	N	0.00	0.00
A5.1	What is this aircraft's airborne survivability level? (N, L, M, H)	L	0.70	6.30
	Ground Operations			
G1.1	What is this aircraft's resistance to chemical & biological agents? (N, L, M, H)	L	0.70	4.90
G2.1	What is this aircraft's level of decontamination? (F, T, P)	F	0.50	3.50
G3.1	What is this aircraft's planned ground time? (minutes)	195	0.77	6.15
G4.1	Is any special MHE required for this aircraft? (Y/N)	Y	0.00	0.00
G5.1	Is this aircraft small austere airfield (SAAF) capable? (Y/N)	N	0.00	0.00
G6.1	Can this aircraft perform engine running on / offload? (Y/N)	N	0.00	0.00
G7.1	What is this aircraft's qualified size? (S, MS, M, ML, L, XL)	L	1.00	9.00
G8.1	What is this aircraft's qualified weight? (L, ML, M, MH, H, XH)	H	1.00	9.00
G9.1	What is this aircraft's qualified ground maneuverability? (A, S, D, C)	C	0.40	3.20
G10.1	What is this aircraft's MOG-equivalency relative to the C-130?	2.2	0.45	3.64
	KC-10 Aggregate Mobility Value (AMV)			**3.8**

Table 16. KC-135 AMV for MTW Scenario

	Range	Actual Aircraft Capability	Capability vs Baseline	x Weight Value
R1.1	What is the aircraft's average range with a planned cargo load? (nm)	5,500	0.61	4.89
R2.1	Is this aircraft in-flight refuelable? (Y/N)	N	0.00	0.00
	Payload			
P1.1	What is this aircraft's planned average tonnage? (STON)	13	0.26	2.08
P2.1	How many 463L pallets can this aircraft carry?	6	0.40	2.40
P3.1	Can this aircraft accommodate oversized cargo? (Y/N)	N	0.00	0.00
P4.1	Can this aircraft accommodate outsized cargo? (Y/N)	N	0.00	0.00
P5.1	What is the aircraft's planned passenger capacity?	46	0.23	2.07
P6.1	Can this aircraft accommodate Roll-on / Roll-off cargo? (Y/N)	N	0.00	0.00
	Speed			
S1.1	What is this aircraft's average blockspeed? (kts)	419	1.00	5.00
	Cost			
C1.1	What is this aircraft's hourly flying cost?	$6,980	1.00	1.00
	Aerial Operations			
A1.1	What is this aircraft's "surge" utilization (UTE) rate? (hrs)	10	0.83	6.67
A2.1	Can this aircraft perform the Strategic Brigade Airdrop (SBA) mission? (Y/N)	N	0.00	0.00
A3.1	Can this aircraft perform Special Operations Low Level (SOLL)? (Y/N)	N	0.00	0.00
A4.1	Is this aircraft aeromedical evacuation (AE) capable? (Y/N)	N	0.00	0.00
A5.1	What is this aircraft's airborne survivability level? (N, L, M, H)	L	0.70	6.30
	Ground Operations			
G1.1	What is this aircraft's resistance to chemical & biological agents? (N, L, M, H)	L	0.70	4.90
G2.1	What is this aircraft's level of decontamination? (F, T, P)	F	0.50	3.50
G3.1	What is this aircraft's planned ground time? (minutes)	210	0.71	5.71
G4.1	Is any special MHE required for this aircraft? (Y/N)	Y	0.00	0.00
G5.1	Is this aircraft small austere airfield (SAAF) capable? (Y/N)	N	0.00	0.00
G6.1	Can this aircraft perform engine running on / offload? (Y/N)	N	0.00	0.00
G7.1	What is this aircraft's qualified size? (S, MS, M, ML, L, XL)	M	1.00	9.00
G8.1	What is this aircraft's qualified weight? (L, ML, M, MH, H, XH)	M	1.00	9.00
G9.1	What is this aircraft's qualified ground maneuverability? (A, S, D, C)	C	0.40	3.20
G10.1	What is this aircraft's MOG-equivalency relative to the C-130?	1.4	0.71	5.71
	KC-135 Aggregate Mobility Value (AMV)			**2.9**

Table 17. CRAF AMV for MTW Scenario

Range		**Actual Aircraft Capability**	**Capability vs Baseline**	**x Weight Value**
R1.1	What is the aircraft's average range with a planned cargo load? (nm)	5,500	0.61	4.89
R2.1	Is this aircraft in-flight refuelable? (Y/N)	N	0.00	0.00
Payload				
P1.1	What is this aircraft's planned average tonnage? (STON)	78	1.00	8.00
P2.1	How many 463L pallets can this aircraft carry?	36	1.00	6.00
P3.1	Can this aircraft accommodate oversized cargo? (Y/N)	N	0.00	0.00
P4.1	Can this aircraft accommodate outsized cargo? (Y/N)	N	0.00	0.00
P5.1	What is the aircraft's planned passenger capacity?	335	1.00	9.00
P6.1	Can this aircraft accommodate Roll-on / Roll-off cargo? (Y/N)	N	0.00	0.00
Speed				
S1.1	What is this aircraft's average blockspeed? (kts)	465	1.00	5.00
Cost				
C1.1	What is this aircraft's hourly flying cost?	$18,807	0.43	0.43
Aerial Operations				
A1.1	What is this aircraft's "surge" utilization (UTE) rate? (hrs)	10.0	0.83	6.67
A2.1	Can this aircraft perform the Strategic Brigade Airdrop (SBA) mission? (Y/N)	N	0.00	0.00
A3.1	Can this aircraft perform Special Operations Low Level (SOLL)? (Y/N)	N	0.00	0.00
A4.1	Is this aircraft aeromedical evacuation (AE) capable? (Y/N)	Y	1.00	8.00
A5.1	What is this aircraft's airborne survivability level? (N, L, M, H)	L	0.70	6.30
Ground Operations				
G1.1	What is this aircraft's resistance to chemical & biological agents? (N, L, M, H)	L	0.70	4.90
G2.1	What is this aircraft's level of decontamination? (F, T, P)	F	0.50	3.50
G3.1	What is this aircraft's planned ground time? (minutes)	210	0.71	5.71
G4.1	Is any special MHE required for this aircraft? (Y/N)	Y	0.00	0.00
G5.1	Is this aircraft small austere airfield (SAAF) capable? (Y/N)	N	0.00	0.00
G6.1	Can this aircraft perform engine running on / offload? (Y/N)	N	0.00	0.00
G7.1	What is this aircraft's qualified size? (S, MS, M, ML, L, XL)	XL	0.80	7.20
G8.1	What is this aircraft's qualified weight? (L, ML, M, MH, H, XH)	XH	0.80	7.20
G9.1	What is this aircraft's qualified ground maneuverability? (A, S, D, C)	C	0.40	3.20
G10.1	What is this aircraft's MOG-equivalency relative to the C-130?	3.4	0.29	2.35
			CRAF Aggregate Mobility Value (AMV)	**3.5**

Appendix K

Fleet Airlift Calculations

Table 18. C-5 Fleet Calculations

Usable Aircraft		**Total PMAI**	**Usable**
U1.1	What is the primary mission aircraft inventory (PMAI) for this airlifter?	104	83
Cargo Closure Rates to FOB		**Average Tons per day**	**Capability vs Baseline**
CR1.1	Cargo closure rate without in-flight refueling. (APOE→APOD→FOB)	1037.89	25.95%
CR1.2	Cargo closure rate with in-flight refueling. (APOE→APOD→FOB)	1098.58	27.46%
CR1.3	Direct delivery cargo closure rate without in-flight refueling. (APOE→FOB)	N/A	N/A
CR1.4	Direct delivery closure rate with in-flight refueling. (APOE→FOB)	N/A	N/A
OR			
Passenger Closure Rates to FOB		**Average Passengers per day**	**Capability vs Baseline**
PR1.1	Passenger closure rate without in-flight refueling. (APOE→APOD→FOB)	863	12.34%
PR1.2	Passenger closure rate with in-flight refueling. (APOE→APOD→FOB)	914	13.06%
PR1.3	Direct delivery passenger closure rate without in-flight refueling. (APOE→FOB)	N/A	N/A
PR1.4	Direct delivery passenger closure rate with in-flight refueling. (APOE→FOB)	N/A	N/A

Table 19. C-141 Fleet Calculations

Usable Aircraft		Total PMAI	Usable
U1.1	What is the primary mission aircraft inventory (PMAI) for this airlifter?	135	108
Cargo Closure Rates to FOB		**Average Tons per day**	**Capability vs Baseline**
CR1.1	Cargo closure rate without in-flight refueling. (APOE→APOD→FOB)	441.23	11.03%
CR1.2	Cargo closure rate with in-flight refueling. (APOE→APOD→FOB)	459.77	11.49%
CR1.3	Direct delivery cargo closure rate without in-flight refueling. (APOE→FOB)	N/A	N/A
CR1.4	Direct delivery closure rate with in-flight refueling. (APOE→FOB)	N/A	N/A
OR			
Passenger Closure Rates to FOB		**Average Passengers per day**	**Capability vs Baseline**
PR1.1	Passenger closure rate without in-flight refueling. (APOE→APOD→FOB)	2,787	39.81%
PR1.2	Passenger closure rate with in-flight refueling. (APOE→APOD→FOB)	2,904	41.48%
PR1.3	Direct delivery passenger closure rate without in-flight refueling. (APOE→FOB)	N/A	N/A
PR1.4	Direct delivery passenger closure rate with in-flight refueling. (APOE→FOB)	N/A	N/A

Table 20. C-130 Fleet Calculations

Usable Aircraft		Total PMAI	Usable
U1.1	What is the primary mission aircraft inventory (PMAI) for this airlifter?	388	310
Cargo Closure Rates to FOB		**Average Tons per day**	**Capability vs Baseline**
CR1.1	Cargo closure rate without in-flight refueling. (APOE→APOD→FOB)	285.99	7.15%
CR1.2	Cargo closure rate with in-flight refueling. (APOE→APOD→FOB)	N/A	N/A
CR1.3	Direct delivery cargo closure rate without in-flight refueling. (APOE→FOB)	294.23	7.36%
CR1.4	Direct delivery closure rate with in-flight refueling. (APOE→FOB)	N/A	N/A
OR			
Passenger Closure Rates to FOB		**Average Passengers per day**	**Capability vs Baseline**
PR1.1	Passenger closure rate without in-flight refueling. (APOE→APOD→FOB)	1,907	27.24%
PR1.2	Passenger closure rate with in-flight refueling. (APOE→APOD→FOB)	N/A	N/A
PR1.3	Direct delivery passenger closure rate without in-flight refueling. (APOE→FOB)	1,962	28.02%
PR1.4	Direct delivery passenger closure rate with in-flight refueling. (APOE→FOB)	N/A	N/A

Table 21. KC-10 Fleet Calculations

Usable Aircraft		Total PMAI	Usable
U1.1	What is the primary mission aircraft inventory (PMAI) for this airlifter?	54	43
Bulk Cargo Closure Rates to FOB		**Average Tons per day**	**Capability vs Baseline**
CR1.1	Cargo closure rate without in-flight refueling. (APOE→APOD→FOB)	321.54	8.04%
CR1.2	Cargo closure rate with in-flight refueling. (APOE→APOD→FOB)	342.84	8.57%
CR1.3	Direct delivery cargo closure rate without in-flight refueling. (APOE→FOB)	N/A	N/A
CR1.4	Direct delivery closure rate with in-flight refueling. (APOE→FOB)	N/A	N/A
OR			
Passenger Closure Rates to FOB		**Average Passengers per day**	**Capability vs Baseline**
PR1.1	Passenger closure rate without in-flight refueling. (APOE→APOD→FOB)	671	9.58%
PR1.2	Passenger closure rate with in-flight refueling. (APOE→APOD→FOB)	715	10.22%
PR1.3	Direct delivery passenger closure rate without in-flight refueling. (APOE→FOB)	N/A	N/A
PR1.4	Direct delivery passenger closure rate with in-flight refueling. (APOE→FOB)	N/A	N/A

Table 22. KC-135 Fleet Calculations

Usable Aircraft		Total PMAI	Usable
U1.1	What is the primary mission aircraft inventory (PMAI) for this airlifter?	472	377
Bulk Cargo Closure Rates to FOB		**Average Tons per day**	**Capability vs Baseline**
CR1.1	Cargo closure rate without in-flight refueling. (APOE→APOD→FOB)	911.09	22.78%
CR1.2	Cargo closure rate with in-flight refueling. (APOE→APOD→FOB)	N/A	N/A
CR1.3	Direct delivery cargo closure rate without in-flight refueling. (APOE→FOB)	N/A	N/A
CR1.4	Direct delivery closure rate with in-flight refueling. (APOE→FOB)	N/A	N/A
OR			
Passenger Closure Rates to FOB		**Average Passengers per day**	**Capability vs Baseline**
PR1.1	Passenger closure rate without in-flight refueling. (APOE→APOD→FOB)	3,224	46.06%
PR1.2	Passenger closure rate with in-flight refueling. (APOE→APOD→FOB)	N/A	N/A
PR1.3	Direct delivery passenger closure rate without in-flight refueling. (APOE→FOB)	N/A	N/A
PR1.4	Direct delivery passenger closure rate with in-flight refueling. (APOE→FOB)	N/A	N/A

Table 23. CRAF Fleet Calculations

Usable Aircraft			Usable (Cargo / Pax)
U1.1	What level of the CRAF stage will be activated? (None, Stage I, II, or III)	I	41 / 43
Bulk Cargo Closure Rates to FOB		**Average Tons per day**	**Capability vs Baseline**
CR1.1	Cargo closure rate without in-flight refueling. (APOE→APOD→FOB)	645.50	16.14%
CR1.2	Cargo closure rate with in-flight refueling. (APOE→APOD→FOB)	N/A	N/A
CR1.3	Direct delivery cargo closure rate without in-flight refueling. (APOE→FOB)	N/A	N/A
CR1.4	Direct delivery closure rate with in-flight refueling. (APOE→FOB)	N/A	N/A
OR			
Passenger Closure Rates to FOB		**Average Passengers per day**	**Capability vs Baseline**
PR1.1	Passenger closure rate without in-flight refueling. (APOE→APOD→FOB)	2,908	41.54%
PR1.2	Passenger closure rate with in-flight refueling. (APOE→APOD→FOB)	N/A	N/A
PR1.3	Direct delivery passenger closure rate without in-flight refueling. (APOE→FOB)	N/A	N/A
PR1.4	Direct delivery passenger closure rate with in-flight refueling. (APOE→FOB)	N/A	N/A

Glossary

AMC	Air Mobility Command
ANSI	American National Standards Institute
AOR	Area of Responsibility
APOD	Aerial Port of Debarkation
APOE	Aerial Port of Embarkation
ATC	Air Transport Command
AU	Air University
AWC	Air War College
CINC	Commander in Chief
CONUS	Continental United States
CRAF	Civil Reserve Air Fleet
DOD	Department of Defense
DTS	Defense Transportation System
FOB	Forward Operating Base
FOL	Forward Operating Location
GTN	Global Transportation Network
ISO	International Standards Organization
ITV	In-transit Visibility
kts	knots (nm / hour)
MAC	Military Airlift Command
MATS	Military Air Transport Service
MHE	Materials Handling Equipment
MSC	Military Sealift Command
MTMC	Military Traffic Management Command
MOB	Main Operating Base
MOG	Maximum aircraft on the Ground
nm	nautical mile(s)
OSA	Operational Support Airlift

PAA	Primary Aircraft Authorization
PAI	Primary Aircraft Inventory
PMAI	Primary Mission Authorized Inventory
RDD	Required Delivery Date
SAAS	School of Advanced Airpower Studies
SAAM	Special Assignment Airlift Mission
SPOD	Sea Port of Debarkation
SPOE	Sea Port of Embarkation
STON	Short Ton
USAF	United States Air Force
USAFE	United States Air Force, Europe
USCINCTRANS	Commander in Chief, US Transportation Command
USTRANSCOM	United States Transportation Command

Definitions

Aerial Port. An airfield that has been designated for sustained air movement of personnel and material to serve as an authorized port of entrance or departure to or from the country where located. USTRANSCOM Handbook 24-2, GL-5.

Aerial Port of Debarkation (APOD). See Port of Debarkation.

Aerial Port of Embarkation (APOE). See Port of Embarkation.

Aeromedical Evacuation (AE). The airlift of medical patients from one place to another. *Litter* patients require assistance to enplane and deplane since they are confined to a stretcher. *Ambulatory* patients are not confined to a stretcher and enplane or deplane with little or no assistance. AFPAM 10-1403, 22.

Aggregate. For this paper, to combine measures of effectiveness (MOEs) in a meaningful fashion to formulate an overall depiction of the airlift system.

Airborne. In relation to *personnel*, these are troops that are trained to conduct an assault following transport by air; either by parachuting or by airland. In relation to *equipment*, this pertains to cargo that has been specially designed for use by airborne troops during or after an assault debarkation. JP 1-02, 14.

Airborne Operation. An operation involving the air movement into an objective area of combat forces and their logistic support for execution of a tactical or strategic mission. The means employed may be any combination of airborne units, air transportable units, and types of transport aircraft, depending on the mission and overall situation. JP 1-02, 15.

Airborne Troops. Those ground units whose primary mission is to make assault landings from the air. JP 1-02, 15.

Aircraft Parking Size. The ramp space a particular aircraft occupies. It is usually expressed in C-141 equivalents. But for this paper, it is expressed in C-130 equivalents. AFPAM 10-1403, 23.

Air Delivery Equipment. Special items of equipment, such as parachutes, air delivery containers, platforms, tie-downs, and related items used in air delivery of personnel, equipment, and supplies. JP 1-02, 20.

Air Direct Delivery. Air direct delivery avoids theater airlift transshipment common with traditional strategic airlift by delivering cargo and personnel to a forward operating base which is close to the payload's final destination. It avoids the traditional two-step strategic and theater airlift transshipment mission mix. It typically consists of moving personnel and cargo from an APOD to a location as close as practical to the customer's final destination. Air direct delivery shortens in-transit time, reduces congestion at main operating bases, and enhances sustainment of forward forces. JP 4-01.1, III-8.

Airdrop. The unloading of personnel or material from aircraft during flight. JP 1-02, 21.

Airfield. An area prepared to accommodate aircraft takeoffs and landings—includes any buildings, installations, and other equipment required to support aerial operations. JP 1-02, 21.

Airfield throughput capability. The number of passengers or amount of cargo that can be moved through an airfield per day via airlift depending on airfield capabilities and / or limitations (e.g. parking).

Airhead. A designated area in a hostile or threatened territory which when seized and held, ensures the continuous air landing of troops and material and provides the maneuver space necessary for projected operations. Normally it is the area seized during the assault phase of an airborne operation. It can also be a designated location in an area of operations used as a base for supply and evacuation by air. JP 1-02, 22.

Airland. Moved by air and disembarked or unloaded after the aircraft has landed or while a helicopter is hovering. JP 1-02, 23.

Airland Operation. An operation involving air movement in which personnel and cargo are air landed at a designated site for further deployment. JP 1-02, 23.

Airlift. Operations to transport and deliver forces and materiel through the air in support of strategic, operational, or tactical objectives. The type of mission performed dictates whether the type of airlift, not the type of aircraft. AFDD-1, 79.

Airlift Capability. The total capacity expressed in terms of number of passengers and/or weight/cubic displacement of cargo that can be carried at any one time to a given destination by available airlift. JP 1-02, 23. Can also indicate the various missions and airlift aircraft can perform (such as airdrop, air refueling, SAAF operations, etc.) and / or the inherent characteristics of the aircraft (such as "kneeling" like the C-5).

Airlift Requirement. The total number of passengers and/or weight/cubic displacement of cargo required to be carried by air for a specific task. JP 1-02, 24.

Air Logistic Support. Support by airland or airdrop. Includes aerial supply, movement of personnel, evacuation of casualties and enemy prisoners of war, and recovery of equipment and vehicles. JP 1-02, 24.

Air Mobility Command (AMC). The USTRANSCOM Air Force component command responsible for DOD strategic airlift and aerial refueling. JP 1-02, GL-5.

Air movement. Air transport of units, personnel, supplies, equipment, and materiel. JP 1-02, 24.

Air Movement Table. A table prepared by a ground force commander in coordination with an air force commander. This form, issued as an annex to the operation order: a. Indicates the allocation of aircraft space to elements of the ground units to be airlifted; b. Designates the number and type of aircraft in each serial; c. Specifies the departure area, time of loading, and takeoff. JP 1-02, 25.

Air Transportable Unit. A unit other than airborne, whose equipment is adapted for air movement. JP 1-02, 32.

Allowable cabin load (ACL). The maximum payload which can be carried on a mission. The ACL may be limited by the maximum takeoff gross weight, maximum landing gross weight, or by the maximum zero fuel weight. AFPAM 10-1403, 23.

Blockspeed. Is calculated in nautical miles per hour (kts) and is the average groundspeed from takeoff to parking at the destination.

Cargo. Supplies, materials, stores, baggage, or equipment transported by land, water, or air. JP 1-02, GL-5.

a. *Bulk.* Dry or liquid cargo (oil, coal, grain, ore, sulfur, or fertilizer) which is shipped unpackaged in large quantities. Also, air cargo that fits within the dimensions of a 463L pallet (108” by 88”) and the design height of 96”.

b. *Containerized.* Items which can be stowed or stuffed into a container closed SEAVAN or MILVAN.

c. *Non-containerized.* Items which cannot be stowed or stuffed into a SEAVAN or MILVAN (i.e. over-dimensional or overweight cargo).

d. *Oversize.* Air cargo which exceeds the dimensions of bulk cargo but is equal to or less than 1,090” in length, 117” in width, and 105” in height. This cargo is transportable on C-5, C-17, C-141, C-130, and KC-10.

e. *Outsize*. Air cargo which exceeds the dimensions of oversize cargo and requires the use of a C-5 or C-17 aircraft.

f. *Rolling Stock*. Equipment that can be driven or rolled directly into the cargo compartment.

g. *Source Stuffed Cargo.* Cargo which economically fills a container from a single point of origin.

h. *Special.* Items requiring specialized preparation and handling procedures such as space satellites or nuclear weapons.

Channel Airlift. Common-user airlift service provided on a recurring basis between two points. USTRANSCOM Handbook 24-2, GL-5.

Channel Traffic. Passengers and cargo moving over established worldwide routes served by either scheduled DOD aircraft under the control of AMC or commercial aircraft under contract to and scheduled by AMC. USTRANSCOM Handbook 24-2, GL-5.

Civil Reserve Air Fleet (CRAF). A program in which the DOD uses aircraft owned by a US entity or citizen. These aircraft are allocated by the Department of Transportation (DOT) to augment the military airlift capability of the DOD. These aircraft are allocated in accordance with DOD requirements, to route segments according to their capabilities such as, long-range international (LRI), short-range international (SRI), domestic, Alaskan, and others as mutually agreed upon by the DOD and DOT. The CRAF can be incrementally activated by the DOD in three stages in response to defense-oriented situations. Note: Recent revisions of the

CRAF program have limited the CRAF to just three segments: International, National, and Aeromedical Evacuation. AFPAM 10-1403, 23.

Closure. In transportation, it is the process of a unit arriving at a specified location. It begins when the first element arrives at a designated location (e.g. port of entry / port of departure, intermediate stops, or final destination) and ends when the last element also arrives at the designated location. AFPAM 10-1403, 24.

Common-user Lift. USTRANSCOM-controlled lift: The pool of strategic transportation assets either government-owned or chartered that are under the operational control of AMC, MSC, or MTMC for the purpose of providing common-user transportation to the DOD across the range of military operations. These assets range from common-user organic or the chartered pool of common-user assets available day-to-day to a larger pool of common-user assets phased in from other sources. USTRANSCOM Handbook 24-2, GL-5.

Container. A standardized, demountable receptacle for transporting cargo on a chassis, rail car, or vessel. JP 1-02, GL-6.

a. *Dromedary.* A container that can be mounted behind the power unit of a truck or carried on a flatbed trailer or in a van and which can be used to transport less-truckload shipments of classified or other sensitive material.

b. *Flat-rack*. Open sided and top International Standards Organization (ISO) containers with two removable / adjustable ends.

c. *Half-height*. Standard ISO container with one end door and a top.

d. *Military Van (MILVAN).* Military-owned demountable container that conforms to U.S. and international standards and operates in a centrally controlled fleet for movement of military cargo.

e. *Sealift Van (SEAVAN).* Commercial or government-owned (or leased) shipping containers which are moved via ocean transportation without bogey wheels attached.

Containerization. The use of containers to unitize cargo for transportation, supply, and storage. Containerization incorporates supply, transportation, packaging, storage, and security together with visibility of a container and its contents into a distribution system form source to user. USTRANSCOM Handbook 24-2, GL-6.

Continental United States (CONUS). Any one of the 48 contiguous United States and the District of Columbia. Alaska, Hawaii, Puerto Rico, and U.S. territories and possessions are normally considered overseas.

Defense Transportation System (DTS). That portion of the worldwide transportation infrastructure which supports DOD transportation needs in peace and war. The DTS consists of military and commercial assets, services and systems organic to, contracted for, or controlled by the Department of Defense. USTRANSCOM Handbook 24-2, GL-6.

Engine Running On / Offload (ERO). The onload or offload of cargo and / or personnel while the aircraft engines are still operating. Generally saves ground time since the aircrew does not have to accomplish engine shutdown and startup checks. Also mitigates some maintenance problems that may occur during the engine shutdown and startup sequence.

Fleet capability. The amount of cargo or passengers which can be moved into or out of a location or theater and is expressed in short tons (STON) or passengers per day.

Limitations include the number of aircraft in the operation, their USE rate, and the distance between onload and offload locations. AFPAM 10-1403, 24.

Forward Operating Base (FOB). An airfield used to support tactical operations without establishing full support facilities. The base may be used for an extended period of time. Support by a main operating base is required to provide backup support for the FOB.

Global Transportation Network (GTN). The automated command and control information system that will enable USTRANSCOM and its components to provide global transportation management. GTN will provide the integrated transportation data and systems necessary to accomplish global transportation planning, command and control, and in-transit visibility during peace and war. USTRANSCOM Handbook 24-2, GL-7.

Ground time. The planned amount of time expected for an aircraft to be on the ground at onload, en route, or offload locations. It varies depending on the type of aircraft used. AFPAM 10-1403, 24.

Intermodal. Type of cargo shipment system that permits transshipping among sea, highway, rail, and air modes of transportation through the use of ANSI / ISO standard containers, line-haul assets, and handling equipment. USTRANSCOM Handbook 24-2, GL-7.

Intertheater (strategic) Airlift. Intertheater airlift operates between theaters or the continental U.S. and other theaters. USTRANSCOM Handbook 24-2 p. GL-7. Intertheater forces remain under the command of USCINCTRANS. Due to the global ranges usually involved, intertheater airlift is normally composed of the heavy, longer range, intercontinental airlift assets, but may be augmented with shorter-range aircraft when required. JP 1-02, 277.

Intratheater (theater) Airlift. The delivery of personnel and cargo within a theater to meet specific theater objectives and requirements to include those forces directly engaged in combat. Delivery can be via airland, airdrop, extraction, or other delivery techniques. The airlift assets are either attached (temporary) or assigned (relatively permanent) to the geographical CINC utilizing them. AFDD-1, 55; USTRANSCOM Handbook 24-2, GL-7; JP 1-02, 539.

In-transit Visibility (ITV). The ability to track the identity, status, and locations of DOD unit and nonunit cargo (excluding bulk petroleum, oils, and lubricants) and passengers; medical patients; and personal property from origin to consignee or destination established by the CINCs, the Services, or DOD agencies during peace, contingencies, and war. USTRANSCOM Handbook 24-2, GL-7.

Knots (kts). Knots is a measurement of speed. It is an indication of the number of nautical miles flown per hour (e.g. 400 kts).

Line-haul. Transportation of cargo over carrier routes from point of origin to destination, excluding local pickup, delivery, local drayage, and switching services. USTRANSCOM Handbook 24-2, GL-8.

Loaded to Capacity. A conveyance loaded to its cube or weight-carrying capacity. Also, a conveyance loaded with that quantity of material which is so filled that no more like material, in the shipping form tendered, can be loaded in or on the conveyence. USTRANSCOM Handbook 24-2, GL-8.

Main Operating Base (MOB). A main operating base is an airfield usually located within close proximity to the contingency area. It can be in the CONUS or overseas. A MOB has an extensive support infrastructure to include robust maintenance facilities (although it does not usually have depot level repair capability). MOBs usually have spacious storage facilities, extensive ramp space, and a large operating runway with instrument approach capability.

Materiel Handling Equipment (MHE). Mechanical devices (K-loaders, forklifts etc.) for handling of supplies with greater ease and economy. USTRANSCOM Handbook 24-2, GL-8.

Maximum on Ground (MOG). This term literally refers to the maximum number of aircraft that an airfield can accommodate and usually reflects the amount of parking space available. It is sometimes used to refer to the working MOG (maximum number of aircraft simultaneously "worked" by maintenance, aerial port personnel, and others), the fuel MOG (maximum number of aircraft that can be simultaneously refueled) or on other factors. It is usually expressed in C-141 equivalents, but for this paper, it is expressed in C-130 equivalents. AFPAM 10-1403, 24.

Measure of Effectiveness (MOE). A measure of operational success that must be closely related to the objective of the mission or operation being evaluated. MOEs must be meaningful and measure to some degree how well the over all objective is achieved. For example, range, payload, or speed are individual MOEs that when combined can help determine whether a certain aircraft will meet the requirements for getting to a location in the fastest manner while carrying the maximum cargo possible. Realize that these three MOEs (range, payload, speed) may not tell the whole story. The goal is to choose those critical MOEs that when combined will portray the most accurate depiction within the constraints of the aircraft under study.

Metric. A measurement used to determine if actual performance is meeting expected / planned performance in order to help determine if an objective is met. *Organizational Theory*, 657. For this thesis, metric and MOE are used interchangeably.

Military Sealift Command (MSC). The USTRANSCOM Navy component with primary responsibility for providing sealift transportation service. USTRANSCOM Handbook 24-2, GL-8.

Military Operations Other Than War (MOOTW). Operations that encompass the use of military capabilities across the range of military operations short of war. These military actions can be applied to complement any combination of the other instruments of national power and occur before, during, and after war. An umbrella term encompassing a variety of military operations conducted by the DOD that normally complement the other instruments of national power. These military operations are as diverse as providing support and assistance (when consistent with US law) in a non-threatening environment, and conducting combat not associated with war. AFDD-1, 83.

Military Traffic Management Command (MTMC). The USTRANSCOM Army component that provides cargo, passenger, and personal property traffic management services to all DOD components. USTRANSCOM Handbook 24-2, GL-9.

Missions required. The number of airlift missions (by aircraft type) required to move a requirement from the onload to offload location. AFPAM 10-1403, 24.

Nautical Mile (nm). One nautical mile equals 6,076 feet. A statue mile (sm) equals 5,280 feet.

Noncombatant evacuation operation (NEO). Operations conducted to relocate threatened noncombatants from locations in a foreign country. The operations usually involve US citizens whose lives are in danger and may include foreign nationals. AFPAM 10-1403, 24.

Number of aircraft. The specific number of aircraft apportioned to any peacetime operation, contingency, or exercise, or the number apportioned in the Joint Strategic Capabilities Plan (JSCP) for tasked OPLANS. AFPAM 10-1403, 24.

Operational Support Airlift (OSA). Is airlift provided by assets that are an integral part of a specific Service, component, or major command (MAJCOM) and that primarily support the requirements of the organization to which they are assigned. These airlift assets are not common user use and normally only serve in that role by exception. OSA operations provide for the timely movement of limited numbers of critical personnel and cargo for the assigned user. AFDD-1, 56.

Organic Lift. Airlift provided by aircraft owned / operated by each Service. USTRANSCOM Handbook 24-2, GL-9.

Overseas. Any country or place beyond the limits of the 48 contiguous United States and the District of Columbia. Alaska, Hawaii, Puerto Rico, and U.S. territories and possessions are normally considered overseas. USTRANSCOM Handbook 24-2, GL-9.

Oversize Cargo. See cargo.

Outsize Cargo. See cargo.

Palletized Cargo. Cargo packaged or arranged on a pallet in a specific manner and securely strapped or fastened together so the whole is handled as a single unit.

Pavement / Aircraft classification number (PCN / ACN). The ICAO standard method of reporting pavement strengths. The PCN is established by and engineering assessment of the runway. The PCN is for use in conjunction with an ACN. ACN values relate an aircraft's characteristics to a runway's load bearing capability (which is PCN). An aircraft with an ACN equal to or less than the reported PCN can operate on the pavement subject to any limitations on tire pressure. PCN for airfields is provided in appropriate DOD Flight Information Publications. AFPAM 10-1403, 24.

Payload. The sum of the weight of passengers and cargo that an aircraft can carry. Cargo weight is normally expressed in STONS. AFPAM 10-1403, 25.

Planning payload. The payload expected on a fleet-wide basis and used by planners to make initial gross planning estimates. The size, shape, and density of most payloads, as well as passenger constraints (i.e. oxygen, life preservers, or life rafts available) rarely permit loading an aircraft to 100 percent capacity. Planning payload data, not maximum, should be used for operations / transportation planning. AFPAM 10-1403, 25.

Primary Authorized Aircraft (PAA). Aircraft authorized to a unit for performance of its operational mission. PMAI forms the basis for the allocation of operating resources to include manpower, support equipment, and flying hour funds. AFPAM 10-1403, 25.

Port of Debarkation (POD). The geographical point at which cargo or personnel are discharged—usually within an operating theater. May be a seaport (**SPOD**) or aerial port of debarkation (**APOD**). For unit requirements, it may or may not coincide with the final destination. USTRANSCOM Handbook 24-2, GL-9.

Port of Embarkation (POE). The geographical point in a routing scheme from which cargo or personnel depart. May be a seaport (**SPOE**) or aerial port (**APOE**) from which personnel and equipment flow to a port of debarkation. For unit and nonunit requirements, it may or may not coincide with the origin. USTRANSCOM Handbook 24-2, GL-9.

Reliability, Maintainability, and Availability (RM&A). RM&A are requirements imposed on acquisition systems to insure they are operationally ready for use when needed, will successfully perform assigned functions, and can be economically operated and maintained within the scope of logistical concepts and policies. Reliability is the ability of a system and its parts to perform its mission without failure. Maintainability is the ability of an item to be retained in, or restored to, a specified condition when maintenance is performed. Availability is a measurement of the degree to which an item is in an operable state at the start of a mission. *Glossary of Defense Acquisition Acronyms & Terms*, B-10, 70, 104, 105.

Required Delivery Date (RDD). The calendar date when material is required by the requisitioner, or the date when the supported CINC requires a unit to be at its destination. USTRANSCOM Handbook 24-2, GL-9.

Retrograde Cargo. Cargo moving in the reverse direction of the normal flow of material provided in support of the using theater. USTRANSCOM Handbook 24-2, GL-9.

Sea Port of Debarkation (SPOD). See Port of Debarkation.

Sea Port of Embarkation (SPOE). See Port of Embarkation.

Small Austere Airfield (SAAF). Unsophisticated airfield, usually with a short runway, that is limited in one or a combination of the following: taxiway systems, ramp space, security, materials handling equipment, aircraft servicing, maintenance, navigation aids, weather observing sensors, and communications. JP 1-02, 488.

Special Assignment Airlift Mission (SAAM). A mission performing special assignment airlift. SAAM is defined as airlift requirements for special pickup or delivery by AMC at points other than established AMC routes, and which require special consideration because of the number of passengers involved, the weight or size of the cargo, the urgency or sensitivity of movement, or other special factors. USTRANSCOM Handbook 24-2, GL-10.

Strategic Airlift (also called intertheater airlift). The airlift capability necessary to deploy and sustain military forces worldwide in support of national strategy. Typically strategic / intertheater airlift departs the CONUS or an APOE, flies intercontinental distances, and delivers personnel and cargo to an APOD or MOB. U.S. primary strategic airlifters are the C-5, C-141, and C-17, although the C-17 can also operate as a theater airlift platform as well. Strategic airlift assets remain in control of the Commander in Chief, US Transportation Command. USTRANSCOM Handbook 24-2, GL-10; AFDD-1, 55.

Strategic Mobility. The capability to deploy and sustain military forces worldwide in support of national strategy. USTRANSCOM Handbook 24-2, GL-10.

Strategic Transportation. Movement between theaters or between the CONUS and a theater. USTRANSCOM Handbook 24-2, GL-10.

Tactical Airlift. The delivery of cargo and personnel to support tactical operations. Delivery can be via airland, airdrop, extraction operations, or other techniques. Theater and tactical airlift are frequently interchanged, but where theater airlift can support operational or strategic objectives, tactical airlift supports tactical objectives.

Theater Airlift (also called intratheater airlift). Theater airlift provides rapid and direct transportation of personnel and cargo to forward operating locations. The C-130 is the primary theater airlift platform; however, all AMC airlift aircraft are capable of performing portions of this mission within their operational constraints. Theater airlift aircraft are frequently operationally controlled by the regional CINC responsible for the contingency within his area of operations.

Theater Assigned Transportation Assets. Transportation assets assigned for combatant command to a commander of a unified or specified command other than USCINCTRANS. USTRANSCOM Handbook 24-2, GL-10.

Ton. A Long Ton (LTON) equals 2,240 pounds, a Measurement Ton (MTON) equals 40 cu ft, a Metric Ton (MT) equals 2,204.6 pounds, and a Short Ton (STON) equals 2,000 pounds. USTRANSCOM Handbook 24-2, GL-10.

Transportation Priority. A number assigned to a shipment that establishes its movement precedence by air, land, or sea within the defense transportation system (DTS). USTRANSCOM Handbook 24-2, GL-11.

Transshipment Point. Point where the responsibility for an in-transit shipment is transferred from one mode or conveyance to another for further transportation to the consignee. USTRANSCOM Handbook 24-2, GL-11.

United States Transportation Command (USTRANSCOM). The unified command which is the DOD single manager for sea, land, and air transportation in both peace and war. USTRANSCOM controls all DOD transportation assets except those which are Service-unique or theater-assigned. USTRANSCOM Handbook 24-2, GL-11.

USE rate. The capability of a subset of PMAI aircraft to generate flying hours expressed in average flying hours per aircraft per day. It is computed only for those aircraft used for a specific mission. For example, consider an operation that has 2 C-141s available. If one aircraft flies 10 hours while the other is in maintenance, then one aircraft has 10 hours of USE rate and the other has 0 hours of USE rate. Together, these two aircraft generate 5.0 hrs/day of “USE.” AFPAM 10-1403, 26.

Utilization rate (UTE rate)—The capability of a fleet of aircraft to generate flying hours in a day, expressed in terms of per Primary Authorized Inventory (PAI). Normally only applies only to long-term, large-scale operations that have an OPLAN. For small operations involving less than the entire fleet, UTE rates are not normally a factor. AFPAM 10-1403, 25.

a. ***Wartime Objective “Surge” UTE Rate:*** A command established flying hour goal for planning and programming to meet JCS directed wartime objectives in the first 45 days of the most demanding wartime operations. AMC sets this rate as a target for planning and programming aircrews, maintenance, and aerial port manpower, active and reserve force mixes, and spare parts. This 45-day *surge* period assumes the deferral of scheduled maintenance, support people working overtime, and the full mobilization of both active and reserve forces with fully funded and fully stocked spares in supply.

b. ***Wartime Objective "Sustained" UTE Rate:*** Sustained UTE rates represent another Command goal for planning purposes. After the 45-day surge operation in wartime, the immediate demand for airlift decreases somewhat and a greater percentage of needed equipment arrives by ship. AMC plans to fly at a lower operational tempo known as a *sustained* UTE rate. This reduced rate is based upon normal duty days, 100% active and reserve participation, and the accomplishment of maintenance activities deferred in the *surge* period.

c. ***Contingency Non-Mobilized USE Rate:*** Sustained rate of flying hour activity based upon full active duty participation and 25% reserve volunteerism. (e.g. JUST CAUSE, RESTORE HOPE, PROVIDE COMFORT).

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