United States Air Force
Scientific Advisory Board

Report on

United States Air Force Expeditionary Forces

Volume 2: Appendices E - H

SAB-TR-97-01

February 1998

Authorized for Public Release

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ABSTRACT (Maximum 200 Words)

This study was produced by the Air Force Scientific Advisory Board (SAB). It was requested and approved by both the Secretary and Chief of Staff of the Air Force. It summarizes the deliberations and conclusions of the study committee on providing an overall picture of the SAB concept for Aerospace Expeditionary Forces.

Aerospace Expeditionary Forces (AEFs) are defined to be "tailorable and rapidly employable air and space assets that provide the National Command Authority and the theater commanders-in-chief with desired outcomes for a spectrum of missions ranging from humanitarian relief to joint or combined combat operations." Volume 1 presents an overall picture of the AEF concept. This volume, Volume 2, provides detailed deliberations and conclusions of the study panels on: Operational Context and Training; Command, Control and Information; Technology Thrusts; and Lean Logistics. Volume 3 details the deliberations and conclusions of the Environment panel.

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Aerospace Expeditionary Forces, Air Expeditionary Forces, AEF, Global Grid, MetaNet, JFACC, Lean Logistics, Command and Control, Regional Contingency Centers, Global Connectivity, Battlespace Awareness, Geospatial Position, Navigation, and Timing, Information Management, Small Bomb System, Light Weight Munitions.

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Foreword

In this 1997 Air Force Scientific Advisory Board (SAB) study on *United States Air Force Expeditionary Forces*, the Committee develops an enhanced Air Force capability to conduct expeditionary operations, the Aerospace Expeditionary Force. A combination of operational concepts, new systems, and technologies training and organizational changes are identified in the three volumes of this report. Volume 1 presents an overall picture of the AEF concept. Volumes 2 and 3 provide added detail and reference information. This volume details the deliberations and conclusions of the following study panels: Operational Context and Training; Command, Control, and Information (C^2I); Technology Thrusts; and Lean Sustainment.

The study results represent an outstanding collaboration between the scientific and operational communities and between government and industry. The Study Committee wishes to thank the many individuals who contributed to the deliberations and the report, as listed in Appendix B. In addition to Scientific Advisory Board members, many ad hoc members devoted their time. Industry also assisted and Air Force Major Command liaison officers were extremely helpful. The Air Force Academy provided critical technical writing assistance, and several executive officers from the Air Staff and Major Commands provided outstanding administrative and logistical support. We gratefully acknowledge the assistance of the UK Strike Command and DARPA. Senior leadership including General (Retired) Mike Carns, Lieutenant General George Muellner, Lieutenant General John Jumper, Mr. Ron Orr, Mr. Larry Lynn, and Mrs. Natalie Crawford improved the study greatly through contribution of both their people and their own personal time.

The Study Committee would also like to give special recognition to the SAB Secretariat and support staff, in particular Lieutenant Colonel Jim Berke, and the ANSER team, in particular Ms. Kristin Lynch, who provided invaluable administrative and logistical assistance in pulling together the myriad of inputs into this final report. Their efforts are greatly appreciated.

We believe the AEF will become the most frequently used Air Force capability and we are proud to have been part of the establishment of this capability. The men and women of the Air Force want to make the AEF happen and, with a little help, they can and will.

Finally, this report reflects the collective judgment of the SAB and hence is not to be viewed as the official position of the United States Air Force.

Dr. Ronald P. Fuchs
Study Director

February 1998

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Abstracts for Appendices E–H

This report consists of three Volumes. Volume 1 is the Summary Volume of the report. Volume 2 contains Appendices E–H and Volume 3 contains Appendix I. The Appendices are titled as follows:

Appendix E: Operational Context and Training

Appendix F: Command, Control, and Information

Appendix G: Technology Thrusts

Appendix H: Lean Sustainment

Appendix I: Environment (Biological, Chemical, and Force Protection)

A short summary of the contents of Appendices E through H follows.

Operations Context and Training: Volume 2, Appendix E

The purpose of the Operational Context and Training Panel was to set the stage and provide the background required by the other panels of the study for them to use as a basis for their work. This Appendix begins with a brief review of the need for an Aerospace Expeditionary Force (AEF). Such aspects as the motivation for an AEF, a definition of an AEF, a vision for an AEF, the fundamental building blocks of an AEF, and the likely missions for an AEF are reviewed. Next, the current and future operating environment in which an AEF might be employed is covered. Included in this section are constraints on future military resources and operations, the various current and future actors in the operating environment, and the implications for an AEF that result. With the foregoing as a basis, a representative spectrum of missions that an AEF might be expected to perform is presented. These missions range from full-scale conventional war to humanitarian relief operations. With the range of missions established, the needed operational capabilities and qualities of an AEF are put forward and explained in the context of the missions that an AEF might have to perform. The Appendix next makes comments on the organization and operation of USAF Battlelabs in support of making the AEF part of the Air Force culture and concludes with a detailed review of the training implications that result.

Overview of AEF Operational Context and Training

Section Number	Title
1.0	Introduction
2.0	The Need for an AEF
3.0	Likely Future AEF Missions
4.0	Needed AEF Capabilities
Annex	A Précis of Recent Global Trends

Command, Control, and Information: Volume 2, Appendix F

Appendix F provides a more extensive discussion of the improvements in Command, Control, and Information that are the foundation of the SAB Committee's vision for the AEF. Some of the text is identical to the Volume 1 sections on C^2I. The reader can review this appendix with the knowledge that all of the information in Volume 1 on C^2I is included in this appendix.

Overview of AEF Command, Control, and Information (C^2I)

Section Number	Title
1.0	Overview
2.0	Critical Enablers to C^2I in Future AEFs
3.0	New Operational Concepts Enabled by New Command and Control Capability
4.0	C^2I Transition Plan
5.0	Required Experiments and Demonstrations
6.0	Recommendations
7.0	Summary

Technology Thrusts: Volume 2, Appendix G

Volume 1 of this report addresses operations, training, and equipment that, if implemented, would make major improvements in the effectiveness of AEFs in the near- and mid-term time frames (through 2012). In the future, however, it may be possible to provide an even faster response with an even smaller footprint forward. Concepts and emerging technologies exist that if developed and employed could make paradigm-changing improvements to AEF operations mainly in the longer term, that is beyond 2012. These concepts and technologies, and a vision of their potential effect on AEF operations, are described in Appendix G.

Overview of AEF Technology Thrusts

Section Number	Title
1.0	Long-Term Vision of AEF
2.0	Advanced Technologies to Enable This AEF Vision
3.0	AEF Concepts and Technologies

Lean Sustainment: Volume 2, Appendix H

A primary theme of the study is reduction in deployment footprint and in the time required to prepare, deploy, and employ an AEF anywhere in the world. The Lean Sustainment Panel examined the full range of logistics functions associated with an AEF, including transportation, supply, munitions, fuel, maintenance, civil engineering, base operations, and personnel support services. Through interaction with experts in each of these areas, supported by modeling and analysis, the Lean Sustainment Panel has estimated the minimum feasible package of personnel and materiel required to set up a combat AEF at an austere forward base and the minimum feasible time from receipt of an execution order to delivery of a military effect. The Panel identified the primary limiting factors and made recommendations to move the Air Force closer to the goal of rapid, global response across the spectrum of operations.

The Panel found that significant improvements in planning and execution monitoring processes are essential to the AEF concept. Logistics planning must be based on required operational outputs and must switch from traditional “supply push” to responsive “demand pull.” Crisis action planning must be faster, better integrated across functional areas, and based on modern information systems. The Panel also found that AEF-eligible wings should be trained, organized, and equipped to deploy sub-squadron sized “slices” that can be aggregated as required to tailor a force to a specific mission. Minimum response times depend on posturing mobility forces (tankers and transports) for rapid movement of deploying forces and may require some level of alert status for units designated as primary for AEF tasking.

Important infrastructure improvements include establishment of Regional Contingency Centers as in-theater support sites to reduce required airlift and establishment of bomber main operating bases to allow global bomber operations. Focused investments in reliability and maintainability improvements in airlift and in regional mission support assets would have major benefits, especially with reduced force structure. Full implementation of the Lean Logistics initiative is essential to minimizing AEF logistics footprint. Similarly, we have defined a “Minimum Flight-Essential Maintenance” concept for forward-deployed forces. A number of technologies, notably advanced munitions like Small, Smart Bomb and enhanced engine durability, offer significant payoffs for deployed operations.

Overview of AEF Lean Sustainment

Section Number	Title
1.0	Introduction
2.0	Deployment Processes and Timelines
3.0	Tools for Employment-Driven Crisis Action Planning
4.0	Minimum Bare-Base AEF Package
5.0	Infrastructure Considerations
6.0	Airlift
7.0	Deployment Base Operability
8.0	Reliability and Supportability Issues
9.0	Cost Estimates
10.0	Findings
11.0	Recommendations
Annex	Logistics Abbreviations

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Appendix E

Operational Context and Training

1.0 Introduction

This appendix reports on the work of the Operational Context and Training Panel. The purpose of this Panel was to set the background and provide the operational basis for the other panels' work and the summary volume of the Aerospace Expeditionary Force (AEF) report. This appendix documents the individual work of the Operational Context and Training Panel members.

The appendix is organized as follows:

- Section 2 examines the factors that have created a need for an AEF.
- Section 3 describes likely missions for AEFs.
- Section 4 suggests needed capabilities and provides the Panel's observations on Battlelabs and the experiments necessary to test the AEF concept.
- Section 5 covers AEF training considerations and recommendations.

1.1 Operational Context and Training Panel Membership

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2.0 The Need for an AEF

2.1 Motivations for an AEF

The immortal words of Stonewall Jackson, who said, "Get there fustest with the mostest," ring truer than ever. The U.S. National Command Authority (NCA) and the warfighting Field Commanders of the U.S. Military (Commanders-in-Chief — CINCs) require fast, flexible, precise, lethal/effective, and sustainable military capability that can be applied in a joint and combined manner.[1] These forces are needed to meet the wide range of contingencies that may require immediate action, including deterring or defeating threatened use of weapons of mass destruction (WMD) or ballistic and cruise missiles; deterring or halting invading armies before they achieve objectives that will be costly or otherwise difficult for U.S. forces to recover; and acute natural and technological disasters ranging from earthquakes, droughts, or epidemics to incidents such as Chernobyl and Bhopal, which require urgent action to minimize casualties and far-ranging damage.

In addition, reductions to budgets and forward-deployed forces mean that more and more forces will come from the continental United States (CONUS). These considerations dictate the need for wide-ranging airpower capabilities that can be employed on short warning from the United States or other (often austere) bases. The wave of the future will be CONUS to CONUS, and CONUS to target to forward deployment base. The Air Force's response is the AEF.

2.2 Definition

AEFs are tailorable and rapidly employable air and space assets that provide the NCA and the CINC with desired outcomes for a spectrum of missions ranging from humanitarian relief to joint or combined combat operations.

2.3 Vision of the AEF

We imagine the AEF as a "slice" of capability that could be used alone or combined with more slices as the situation warrants (see Figure E-1).

The area at the bottom of the chart in Figure E-1 represents the three basic capability components for the AEF. Any execution will require at least one and normally two (the "info" capability will almost always be executed regardless of the kind of operation) .

"Food" is the symbol for an AEF disaster relief capability. The humanitarian AEF is capable of putting directly into the hands of 1,000 people enough food, self-administerable medicine, water, and emergency shelter to allow them to function with minimum ill effects for 10 days (which may mean daily delivery or one delivery). Key is the "point of use" concept as we assume a natural or human-induced breakdown in the distribution network. (If the distribution network is undamaged, the task will be relatively low stress:

[1]CINCs Integrated Priority List.

deliver so many tons of sustenance to an airfield from which it will pass into the normal delivery network.) Assume that the nearest airfields are at least 500 miles away and that there will be a requirement for light security (no organized terrorism expected). Today, our means of delivery would be cargo aircraft; conceptually, however, a fighter that can deliver an antipersonnel cluster bomb unit could also deliver an equivalent amount of “good” energy.

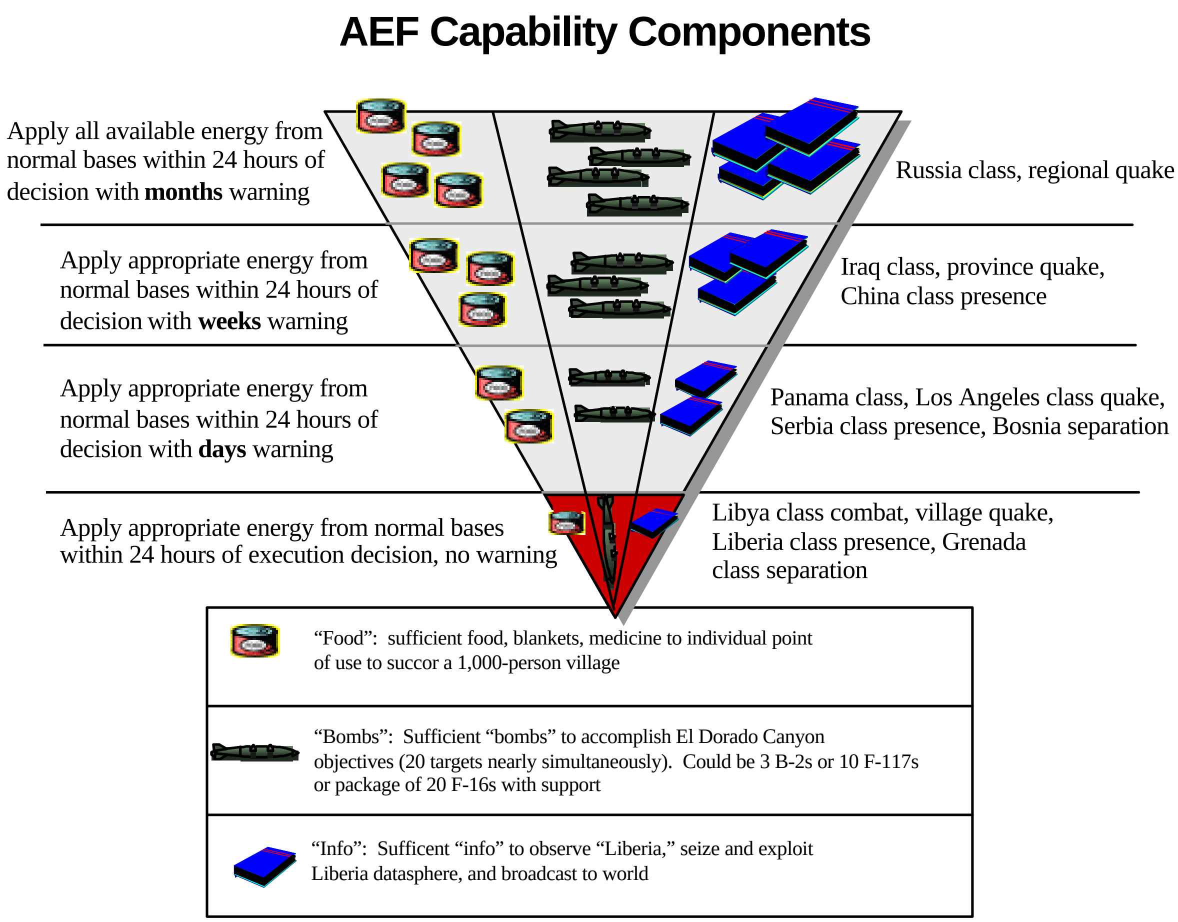

Figure E-1. *Capability Components of an AEF*

“Bombs” is shorthand for harm to the enemy; it could be induced with bombs, rays, or something else. Conceptually, an AEF bomb unit could solve an El Dorado Canyon class problem less than a day after the execution decision with no need for deployment prior to the operation. This class of problem requires precise effect on 20 moderately hard (on average, 3 feet of reinforced concrete) targets, which include the following types: leadership, communications, energy, infrastructure, and military headquarters, including air defense facilities. The target country has 1991 Iraq class air defense capabilities. Possible forces include 3 B-2s (assumes each can target at least seven separate targets in the course of a sortie) and appropriate tankers; 12 F-117s (assumes each can attack two separate targets with two available for catch-up or for targets that need more than one bomb) and appropriate tankers; 24 F-16s with 6 F-15Cs for air escort, 4 F-4G equivalent aircraft, 2 EF-111 equivalent aircraft, and appropriate tankers. (Note: The above illustrates a range of possibilities; clearly other combinations within this range are possible.) If the aircraft must be deployed prior to attack (undesirable) or recovered in the vicinity, assume bare bases with good concrete in a moderate ground threat, which includes terrorists with light chemical and biological capability.

"Info" is shorthand for an informational effect on the opponent; it requires observation of a Liberia-size country, seizure of its internal communications so that they cannot be used by the local government without our permission, broadcast of television and radio to the entire country, and broadcast of pertinent information to worldwide commercial networks such as CNN. Assume a bare base at least 500 miles distant with light to moderate ground threat (no air threat), and the need to operate continuously for at least 10 days after initial operations begin — which should not require prior deployment.

The basic units should be able to manage the problem described on the right of the triangle at the first level. At the next level, the same types of capabilities will be needed but the numbers go up as the number of targets increases. The second level has roughly the following parameters: Food for about 10,000 people over the same period, bombs for about 200 targets, and info about 10 times the Liberia class requirement. Threats remain about the same. At the third level up, assume food for 100,000 people, bombs for about 2,000 targets, and info 100 times the Liberia class requirement. Threats to forward bases (if used) increase to include moderate aircraft, cruise missile, and short-range ballistic missile (SRBM) attack, which may include moderate chemical and biological agents, determined commando-type raids, and extensive covert sabotage attempts against bases and supporting infrastructure. At the fourth and highest level, assume food for 1,000,000 people, bombs for 5,000 targets, and info 1,000 times the Liberia class requirement. Threats become ubiquitous and include the possibility of covert attack on CONUS installations and perhaps some direct attack.

Timetable: The Air Force should be able to execute the basic food, bomb, and info AEFs within 24 hours of execution order by the end of 1998, and should be able to execute Level 2 (Panama class) by the end of 2000. Third and fourth levels may depend on new technologies, but the Air Force should strive to be able to provide the NCA with these full capabilities by the end of 2014.

Defined this way, the emergence of AEFs can have dramatic consequences for the entire Air Force, potentially resulting in revolutionary changes throughout the institution, including doctrine, organization, training, equipment, alert status, and operational tempo.

2.4 Key Characteristics of the AEF

AEFs must be rapid, aware, precise, secure, light, and evolvable, resulting in the following attributes:

- **Operational Effectiveness.** AEFs, with their speed, precision, and lethality, are capable of leveraging global air and space power.
- **Minimum Forward Presence.** AEFs rely extensively on reachback.
- **Global Employability.** AEFs are fully capable of operating from preplanned or austere basing.
- **Rapid Response.** AEFs are capable of having an impact within 24 hours (at most) of receiving an order from the NCA.
- **Agility.** AEFs consist of force packages that are responsive to a full spectrum of missions.
- **Evolvability.** AEFs can adapt to the situation from the initial contact through sustained operations.

3.0 Likely Future AEF Missions

Likely future AEF missions may be understood in the context of the continuum of U.S. national security strategy, the current and future operating environments, and the historical pattern of Air Force employments.

3.1 The Air Force Role in Promoting the National Security Strategy

Since its creation in 1947, presidents have called upon the Air Force to provide unique airpower capabilities to promote the nation's interests and values at home and abroad. During this period, the Air Force has made major contributions to the U.S. joint warfighting effort in three major theater wars (MTWs): Korea, Vietnam, and the Gulf War; to a host of smaller-scale contingencies, including operations in Grenada, Libya, Panama, and Bosnia; to an even larger number of crisis deployments that were aimed to deter, assure, or coerce; and to a still larger number of noncombat operations, including hundreds of humanitarian operations.[2]

Between now and 2010, employment of U.S. military forces — including the AEF — will be greatly influenced by the same criteria that have guided past presidents in their decisions to use force.

3.1.1 Elements of Continuity in U.S. National Security Strategy

The ends of U.S. foreign policy — national survival, the preservation of our basic liberties and institutions, and the promotion of economic well-being — will continue to guide future presidents. The current national security strategy puts it this way:

> Since the founding of the nation, certain requirements have remained constant. We must protect the lives and personal safety of Americans, both at home and abroad. We must maintain the sovereignty, political freedom and independence of the United States, with its values, institutions and territory intact. And, we must provide for the well-being and prosperity of the nation and its people.[3]

Generally speaking, the level of U.S. military involvement — from modest commitments of U.S. military personnel for humanitarian operations in an unopposed environment to large commitments of force for combat operations — has been commensurate with the president's perceptions of the importance of the national interests engendered in the situation. Put simply, the level of U.S. involvement and commitment has reflected presidential judgments that (1) a particular set of conditions was likely to have a significant impact on important U.S. interests; (2) the behavior of the United States could significantly affect these conditions; and (3) the expected benefits from a particular course of action were worth its expected costs. This logic dictates that presidents commit U.S. forces to combat operations only when particularly important interests are at stake and the use of force is likely to lead to the desired result. Otherwise, they generally seek to avoid use of force.

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[2] Three data sources were used: the Global Reach–Global Power database of over 600 Air Force operations from 1947 to 1992; the database of Air Force presence operations from 1981 to 1995 developed by Defense Forecasts International (DFI, 1995), a defense consulting company in the Washington, DC, area; and a database of Air Force military operations other than war (MOOTW), covering operations from 1916 to 1996 (the period before 1947 under the U.S. Army).

[3] President Clinton, *A National Security Strategy for a New Century*, the White House, May 1997.

3.2 The Current and Future Operating Environment

Key features of the operating environment will set the context for accomplishing the missions described above.

3.2.1 The Current Operating Environment[4]

For the foreseeable future, the United States will remain the only multidimensional (political, economic, military, cultural, information, etc.) superpower. The rest of the world will be nonpolar but will involve multiple players in the security domain while being loosely multipolar in the economic domain. Put another way, the world will be characterized by the formation and dissolution of ad hoc coalitions to meet threats to security, but will exhibit more consistency in trade relations, investment, and other economic activities.

3.2.2 The Future Operating Environment

By 2010, there will still be no clear *global* challenge to the United States. Nevertheless, there will be a number of emerging regional economic giants, potentially including China, Russia, India, Brazil, Indonesia, and Iran. In some cases, these countries also will be aspiring to regional military hegemonies, and may use their growing wealth to improve their military capabilities. Nonproliferation efforts are likely to be only partly successful, as other countries, especially rogue nations, acquire medium-range ballistic missiles (i.e., capable of Persian Gulf–to–Europe trajectories) and some WMD capabilities.

The United States will continue to find the greatest common ground with the Western-style market democracies of Western Europe and the Far East regional trading blocs. Because of divergent interests and threat perceptions, however, the United States is likely to encounter difficulty in constructing coalitions with these nations. The United States often may face the choice of acting in restrictive coalition or acting alone, since base access may be either unavailable or contingent on providing reliable theater missile defenses to regional allies.

Populations affected by disasters also may be larger as a result of population growth and urbanization, resulting in the need for humanitarian operations of unprecedented scale.

3.2.3 Constraints on the AEF

3.2.3.1 Constraints on Resources

The first constraint will be that the Air Force will need to do more with less. In the past, the defense share of national resources has risen and fallen on the basis of many factors, both external and internal. As Kaufmann and Korb (1989, pp. 50-51) note, "The funds made available to defense in the last forty-five years have resulted from a combination of factors: the magnitude of the perceived threat, the international environment, and the internal political and economic situation." In the post–Cold War world, the threat perceived by the general public has diminished and the United States has focused more on domestic issues, including the national debt. Until these factors change, it is unlikely that defense spending will increase, and most likely that it will continue to decrease. Weidenbaum (1991) also points to the interaction between international and domestic factors in determining defense resourcing:

> *[D]ecisions affecting war, peace, and the host of in-between positions cannot be made in isolation from domestic and international political, economic, and social factors. Both the willingness and the ability of a nation to support a given level of military preparedness are determined by complex interactions of these related dimensions.*

[4] The annex to this appendix provides a précis of current trends in the international environment that often are drivers of Air Force operations.

As shown in Figure E-2, the changing share of resources allocated to defense has in fact been responsive to both international and domestic conditions: increased defense spending can be seen at the onset of the Spanish-American War (1898), World War I (1917), World War II (1941), the Korean War (1950), and the Vietnam War (1965). The Cold War level of funding — especially during the 1953 to 1968 period — can be seen as something of an anomaly, historically speaking. And the current level of spending — somewhere between the interwar levels and those of the Cold War — has tapered off.

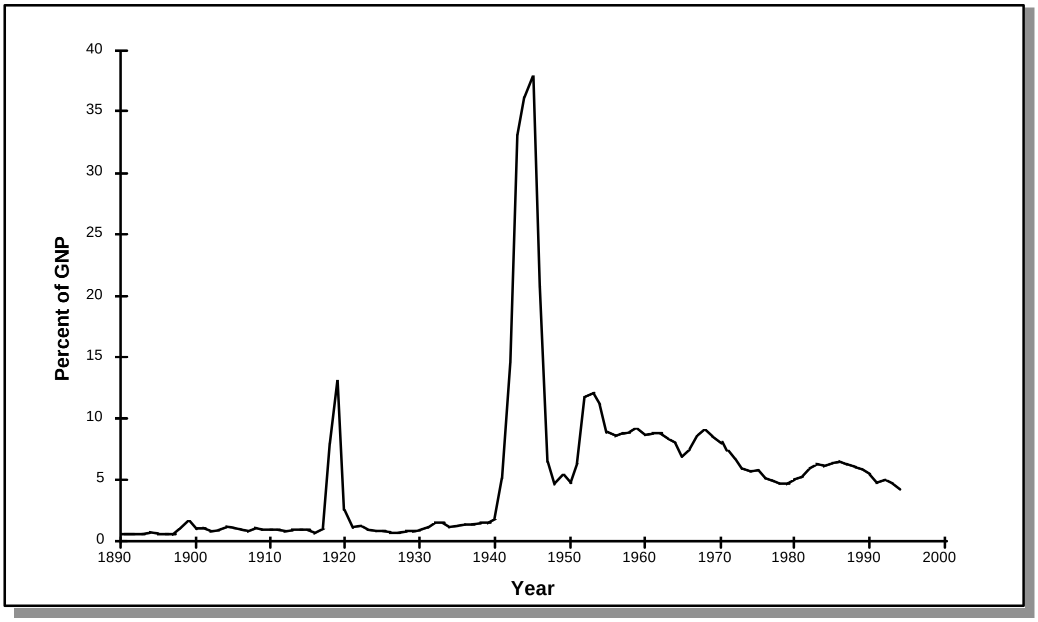

Figure E-2. *National Defense Outlays as a Percent of Gross National Product (GNP), 1890–1995*

Absent a change in threat, it seems unlikely that defense budgets will grow. And in spite of the remarkable macroeconomic performance of the country over the past 5 years, problems with Medicare and Social Security funding may cause defense spending to come under increasing pressure.

3.2.3.2 Constraints on Military Operations

For the foreseeable future, important external and domestic considerations will constrain U.S. military operations. A number of these constraints will arise from the international environment. As a result of consensus-building in coalitions based upon decisions by the United Nations or other alliances, lowest-common-denominator concerns often will determine the objectives to be achieved, the strategy pursued, the forces assigned to different missions, and other aspects of the conduct of military operations. Because different coalition members will have different stakes in the outcome, the least-committed members may be particularly sensitive to the costs and benefits of coalition membership.

In the domestic sphere, constraints also will be imposed as a result of such factors as

- Broad differences among leaders over the nation's foreign policy goals and the appropriate circumstances for the use of force
- The gravity of particular situations
- The benefits and prospects for success of specific uses of force
- The scrutiny of the conduct of military operations as a result of real-time news coverage

Among the more important of these constraints are minimization of casualties, collateral damage, and the duration of combat operations.[5]

The future will bring with it new constraints. Outside of the core regions of interest to the nation (i.e., Western Europe, the Far East, and the Persian Gulf), military intervention typically will be considered optional. This is because the nation's stakes will be small in most situations, military operations will meet with congressional and public ambivalence, and severe constraints on casualties, collateral damage, duration, or other dimensions frequently will be imposed on future U.S. military operations. The president most often will choose *not* to employ combat forces because of the perceived low benefit-risk ratio; the severity of constraints (e.g., on casualties) imposed by the NCA will be inversely proportional to the stakes. In addition, political sensitivity to and the viability of many operations will continue to hinge on the accomplishment of objectives within these constraints. We can expect that CNN and other media effects will be most prevalent when leaders are divided over the merits of an operation. In some cases, these constraints may make it exceedingly difficult to accomplish the missions.

In those few cases in which presidents see sufficient interests to engage in combat operations outside the core regions, they will seek to conclude them quickly and with low casualties to avoid political liability (e.g., the operations in Grenada and Panama). In other cases, when the interests are insufficient to justify any casualties, presidents will rely on noncombat capabilities (e.g., humanitarian and peacekeeping operations), and operations will continue only as long as the environment remains relatively benign. Only when convinced that the costs will be modest will the president commit forces to peace enforcement, the promotion of democracy, humanitarian causes, and other core values. Presidents, in virtually all cases, will place stringent constraints on these operations.

3.2.4 Actors in the Operating Environment

The missions assigned to AEFs typically will involve one of three types of international actors: high-end competitors, rogue nations, and failing or failed states.

3.2.4.1 High-End Competitors

Status. High-end competitors will approach parity with the United States in the size of their economies, but not in the wealth of their societies. That is, while their economies may be very large, given their large populations, wealth on a per capita basis will lag behind that of the United States. Thus, these countries are likely to be followers (rather than leaders) in technology. As a consequence, these countries will seek to acquire technology from abroad through espionage, arms transfers, co-production agreements, and other arrangements. Although such competitors appear unlikely in the next 15 to 20 years, the most obvious candidates for future high-end competitors appear to be Russia and China, which have very large populations, tremendous national resources, and sizable military establishments.

Goals. The goals of high-end competitors will be increased regional influence and, in some cases, even regional hegemony. These nations will seek to deny U.S. influence in their regions by using a host of strategems to weaken or break up U.S. alliances or coalitions formed to oppose them, and to weaken the resolve or sense of security of U.S. friends in the region.

Weapons. High-end competitors will acquire fifth-generation fighters, advanced Integrated Air Defense Systems (IADS), and cruise and ballistic missiles. They also may acquire limited numbers of aircraft carriers, antisatellite capabilities, precision-guided munitions (PGMs), information warfare, and WMDs.

[5]The desirability of avoiding losses also arises from a smaller force structure and diminished capacity to replenish capital stocks (e.g., of high-performance aircraft).

Perhaps more important, as with many other nations, high-end competitors will attempt to engage in asymmetric strategies to avoid head-on technological competition with the United States; they will attempt to affect the United States' will by stressing the potential costs of military conflict, and develop strategies whose success or failure will be determined only in the very long term (well beyond the United States' short attention span).

U.S. Strategy. The U.S. strategy with high-end competitors is to deter or prevent *faits accompli* to the United States' disadvantage, e.g., the seizure of key objectives that will be more costly to recover than to protect. The United States also will seek to minimize friendly casualties but, with the higher stakes, domestic audiences may be willing to accept more casualties than in other cases. Finally, the United States will seek to act in "coalitions of the willing," frequently constructed under the rubric of the United Nations, the North Atlantic Treaty Organization (NATO), or another formal body.

3.2.4.2 Rogue States

Status. Rogue states generally will be developing states with leaders who believe the possession of threatening military capabilities (especially WMDs and delivery means such as ballistic or cruise missiles) will provide them with political influence well beyond what they would have without these capabilities.

Goals. Like the high-end regional competitors, rogue states will seek increased regional influence, although this influence will stem from the coercive ability they derive from their military capabilities. Rogue states also will attempt to weaken or deny U.S. influence and to complicate the United States' ability to build coalitions in their region.

Weapons. Less capable than high-end regional competitors, rogue states may have fourth-generation fighters, cruise/ballistic missiles, PGMs, and WMDs, especially chemical and biological weapons. They also may sponsor terrorism.

U.S. Strategy. The typical U.S. strategy for dealing with rogue states will be to deter or deny coercive actions by these states, to contain the damage that these states can do, and to punish them for their actions. As in the case of Libya, the United States will likely rely upon highly selective strike operations to neutralize capability while minimizing friendly and noncombatant capabilities.

3.2.4.3 Failing and Failed States

Status. Failing and failed states face political, economic, or social breakdown, and may be incapable of providing either a secure environment for their populations or basic human needs such as food, water, shelter, and medicine.

Goals. While some failing and failed states may aspire to economic self-sufficiency, free markets, or democracy, many — perhaps most — will be incapable of formulating any goals other than resisting outside intervention in their affairs.

Weapons. The populations of failing and failed states will have access to relatively cheap and low-technology weapons such as small arms, mortars, land mines, shoulder-launched surface-to-air missiles (SAMs), and other, similar systems.

U.S. Strategy. The U.S. interest in these states typically will be humanitarian only, although in some cases limited national interests also may be involved.[6] The U.S. strategy accordingly will be to provide humanitarian relief to mitigate suffering and — as a last resort — to use coercive diplomacy (including

[6] For example, one motivation for the U.S. intervention in Haiti was to stop the undesirable refugee flow to Florida.

airpower) to shape the political-military environment. Because the U.S. stakes in these situations will be so much lower than in the other cases, military forces will need to accomplish their objectives with absolutely no casualties, and to deter or avoid engagement wherever possible.

3.2.4.4 Other States

Other states — perhaps the great majority — can be considered neutrals, economic partners, or competitors, although the roles they play are likely to change from issue to issue. Unless their interests are substantially engaged, these nations are unlikely either to assist or to impede U.S. actions, and will remain neutral or fence-sitters. In other cases, the role they assume — whether in support of or opposition to U.S. actions — will be tied to their perceptions of the correlation between their own national interests and those of the United States in the situation at hand. Most of the Western European states can be expected to remain, by virtue of their membership in NATO, allies of the United States and major trading partners. The same can be said for Japan and South Korea in the Far East. Despite these ties, most of these countries can be expected to compete actively with the United States in the economic domain. Absent a compelling threat, however, these alliance ties seem likely to weaken, making it difficult for the United States to build coalitions. The goals of these states are likely to vary from situation to situation, and their weapons will be tied closely to their level of economic and technological development. The U.S. strategy with these states will be to bring them on board as coalition partners and to prevent them from providing aid and comfort to U.S. adversaries.

3.2.5 Implications for AEFs

When the basic ends of U.S. foreign policy are threatened, presidents will be willing to commit the nation to combat operations. Absent direct threats to these basic ends, future U.S. presidents will likely continue to espouse a general policy of nonintervention with combat forces, except in specific, narrowly defined circumstances. In some cases, presidents may commit combat forces, especially when there are threats to American citizens abroad, threats to allies to whom the U.S. has obligations codified in preexisting treaties, and United Nations–sponsored operations that promote important U.S. goals.

More specifically, future presidents probably will continue to differentiate between core regions of vital interest to the nation — places where important U.S. allies and friends can be found — and secondary regions that engage only American values (e.g., aspirations for the spread of democracy, humanitarian desires to eliminate starvation). In the core regions of the Western Hemisphere, Europe, the Far East and the Persian Gulf, U.S. leaders will be willing to use force to secure important strategic and economic interests. When select allies are threatened, the United States will provide military assistance calibrated to the nature of the interests engaged. In the secondary regions of Africa, other parts of Asia, and the Pacific, the level of involvement and cost-acceptance will be even more acutely sensitive to the interests engaged. In these regions, the United States generally will avoid interventions involving combat (and commitment of ground combat forces) unless American citizens must be protected or evacuated. Humanitarian and other noncombat operations in an unopposed environment will be routine; less often will the United States undertake these operations in an opposed environment.

Future U.S. national security strategy will continue to focus on emerging threats to the core regions, while responding to and attempting to shape developments in the other regions without incurring costs beyond relatively modest commitments of political, diplomatic, and economic capital.

The premise of national security strategy will continue to be that defense planning should focus on major combat operations in defense of the core regions. Nevertheless, the United States is likely to become increasingly attentive and responsive to the needs that arise from noncombat operations in the other regions, and the trade-offs between preparations for war and peace operations.

This current and likely future operating environment has a number of major consequences:

- **The Need for a Spectrum of Capabilities.** AEFs must be able to participate in a wide array of missions, although the nature of Air Force involvement in any particular situation will be tied to the stakes involved. In some cases, those stakes will be sufficiently high to warrant the employment of Air Force combat capabilities, but in many situations, noncombat capabilities such as command, control, communications, and computers, intelligence, surveillance, and reconnaissance (C^4ISR) and airlift may be all that is warranted. This variability requires a full spectrum of capabilities, ranging from noncombat to major combat capabilities.
- **Joint Operations.** While the Air Force will be called upon to provide airpower, it most often will operate in a joint context alongside its sister Services, which bring to the table capabilities of their own.
- **Coalition Operations.** There will be, for the foreseeable future, a greater emphasis on coalition operations. U.S. involvement frequently will be the catalyst for constructing coalitions, although the composition of the coalitions may vary by region and issue.
- **Force Protection.** The protection of forces will become increasing important. Force protection means assuring high survivability and low vulnerability to loss or capture, as well as detecting and preventing WMD, terrorist, or other unconventional threats to forces.

3.3 Representative AEF Missions

Planning for AEFs needs to focus on the unique contributions AEFs can make to the full range of Air Force missions, ranging from deterring or fighting the early stages of MTWs to undertaking noncombat operations such as humanitarian relief. To better understand the potential role of AEFs, we will review the historical record of how the Air Force has been employed in the past.

3.3.1 The Recent Historical Record of Air Force Employment

While it is impossible to forecast specific demands that may be levied, data on past operations (especially those in the recent past) can help us understand how the present differs from the past, the variability in the demand for different types of operations, and the range of Air Force contributions to these missions. It also can help us to assess the evidence that the Air Force has engaged in more operations since the end of the Cold War than it did during the Cold War.

3.3.1.1 The Number of Annual Operations Has Declined

To set the context for understanding the shape of future demands on AEFs, we first can explore the frequency of Air Force operations. Figure E-3 provides about 15 years of data from two sources on the annual number of Air Force operations (each source uses slightly different inclusion criteria).

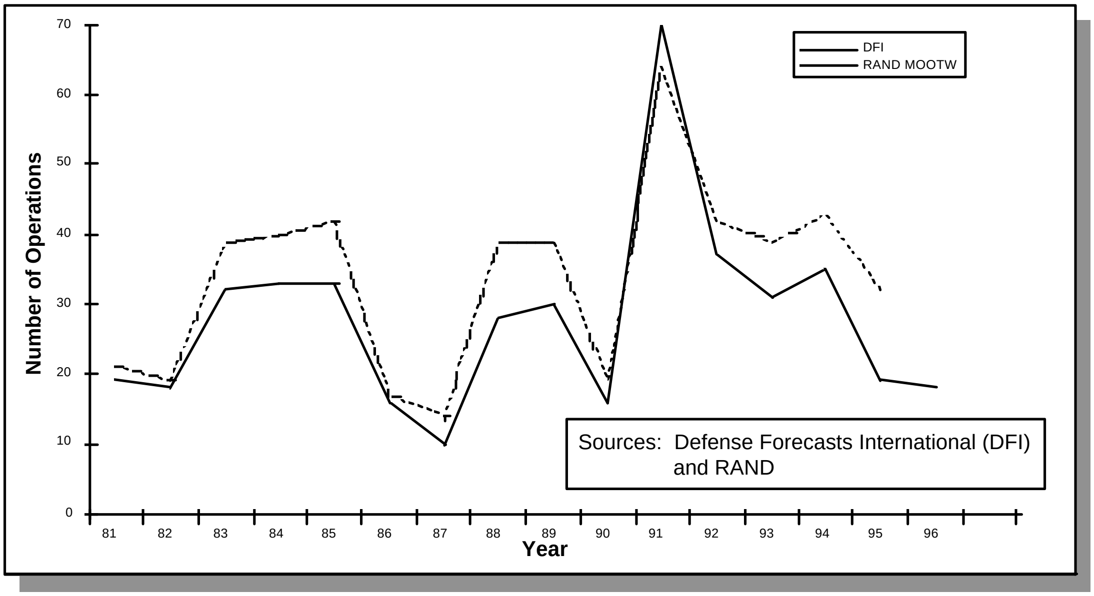

Figure E-3. *Frequency of Air Force Employment Has Been Declining Toward 15-Year Low*[7]

Both series show variability in the annual number of operations undertaken by the Air Force, with higher levels of activity in 1983 to 1985, 1988 to 1989, 1991, and 1994. Both also show a sharp decline in the annual number of Air Force operations since 1991. Since the two sources track well with one another, we should be able to trust these conclusions. These data strongly suggest that the number of Air Force operations has decreased since the end of the Cold War. But that is not the whole story.

3.3.1.2 The Level of Effort in Air Force Operations Has Increased

In spite of the decline since 1991 in the annual number of operations, the average level of effort involved in recent operations is higher than in the past. Figure E-4 presents data on the average duration and number of missions flown in Air Force operations begun in each year from 1981 to 1994.

Figure E-4 shows that the average duration and missions flown in Air Force operations has increased over the levels in the 1980s. To interpret these data, however, we need to understand that these results are dominated by the very large, lengthy deployments to Southwest Asia, Somalia, and Bosnia. Put another way, a few large operations have been driving the increased level of effort.

[7] The data from RAND are the annual frequency of Air Force participation in MOOTW. The data from DFI are the annual number of presence missions, broadly defined, minus participation in exercises.

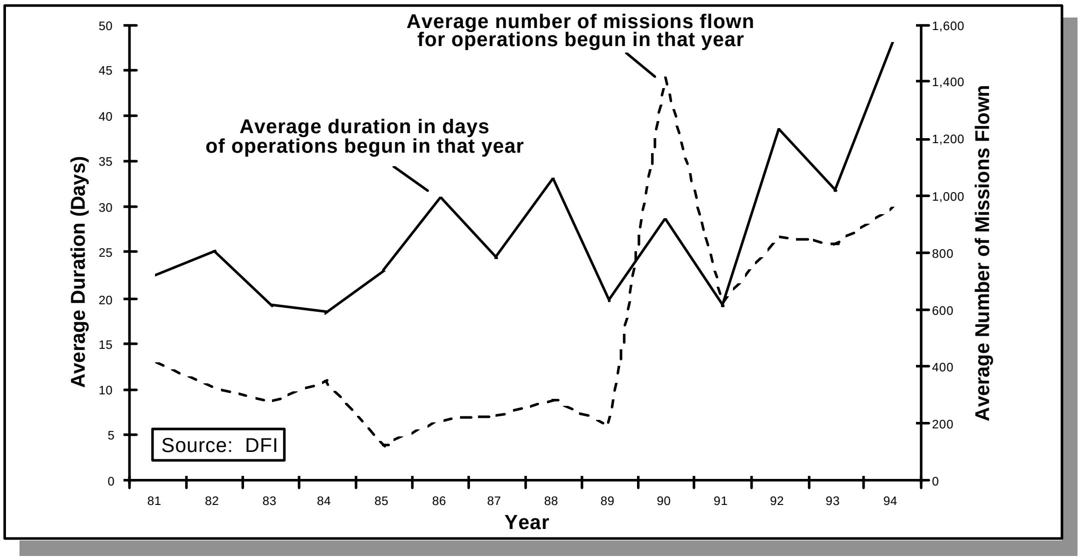

Figure E-4. *Operations Have Become Longer and More Demanding*

3.3.2 The Range of AEF Missions Supporting U.S. National Security Strategy

Table E-1 provides an illustrative list of the possible AEF missions.

Of these missions, the Operational Context and Training Panel has chosen six that span the range of plausible AEF missions and that should provide insights into the possible challenges to designing AEFs: (1) combat operations, (2) counterproliferation operations, (3) presence/show-of-force/demonstration operations, (4) peace enforcement operations, (5) global awareness and illumination operations, and (6) humanitarian operations.

Table E-1. *Illustrative Missions for the AEF*

Protection of the homeland	Counterterrorism
Protection of Americans abroad	Security of legitimate regimes
Prevention/halting aggression	Advancement of democratization
Peace enforcement (neutralizing/separating combatants)	Enhancement of global awareness
Counterinsurgency operations	Peace operations
Counterproliferation operations	Humanitarian assistance
Support of allies/pro-democracy insurgents	Assisting other U.S. authorities (e.g., counterdrug, border control)
	Space control

3.3.2.1 Combat Operations

Combat operations are rather rare events. For example, when we consider MTWs or larger wars, in the past 100 years we have experienced one in each generation:

- Spanish-American War (1898)
- World War I (1917), nearly 20 years after the onset of the Spanish-American War
- World War II (1941), 24 years intervening
- Korean War (1950), 9 years intervening
- Vietnam War (1965), 15 years intervening
- Gulf War (1991), 26 years intervening

While smaller combat operations (including activities ranging from strikes and raids to *coups de main* such as those in Grenada and Panama) are more common than large wars, they are not all that common, especially those involving ground troops. Examples of these cases found in the Global Reach–Global Power and Defense Forecasts International (DFI) datasets of Air Force operations include

- Grenada (1983)
- Libya (1986)
- Panama (1989)
- Strikes during Persian Gulf reflagging and escort operations (1987)
- Strikes against Iraq since the end of the Gulf War (1991 to present)

3.3.2.2 Counterproliferation Operations

A unique subset of combat operations is counterproliferation operations aimed at denying an adversary its WMD capability. There are only a few examples of this sort of operation, including the Israeli strike on Iraq's Osirak nuclear reactor, U.S. strikes against Iraqi WMD sites during Operation Desert Storm, and apparent preparations for potential strikes against North Korean nuclear facilities prior to the agreement on the disposition of their nuclear capabilities.

3.3.2.3 Presence/Show-of-Force/Demonstration Operations

Only somewhat more common are operations short of combat aimed at accomplishing discrete political objectives. Presence operations, shows of force, and demonstrations fit into this category and remain a tool for deterring or coercing when other means have failed.[8] According to the Global Reach–Global Power data set of Air Force operations, from 1981 to 1992, there were 168 operations, of which 25 (fewer than one-sixth) were presence/show-of-force operations. Examples included deployments to the Persian Gulf, Korea, Panama, and the Philippines. According to the DFI dataset of 1,052 Air Force presence operations from 1981 to 1995, five operations were classified as combat deployments and four as national shows of force.

[8] Although they may accomplish the same goals, permanently stationed forward-deployed forces and exercises are not included in the category of presence/show-of-force/demonstration operations. The emphasis here is on deployments that are undertaken to deter, reassure, or coerce.

3.3.2.4 Peace Enforcement Operations

Peace enforcement/neutralization operations — in which combat air patrols, strikes, or other operations may be used to separate combatants in an internal conflict — also have been quite rare.[9] Examples include

- Dominican Republic (1965)
- Lebanon (1982 to 1984)
- Somalia (summer to fall 1993)
- Bosnia (no-fly zones and strikes prior to negotiations on the Dayton accords)

These operations can be difficult to accomplish and typically involve larger commitments of ground forces than do peacekeeping operations (see Figure E-5). To the extent that these more ambitious operations can be successfully accomplished by AEFs at a smaller cost and footprint, there is an opportunity to develop concepts of operation (CONOPS) for this type of mission.

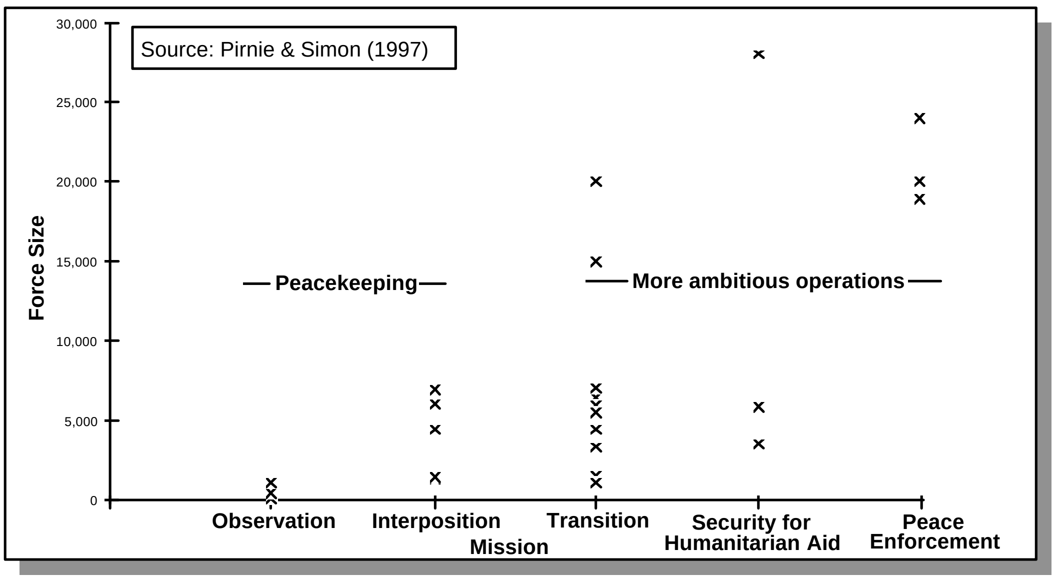

Figure E-5. *Manpower Level of Effort for Various Peace Operations*

Further evidence indicates that presidents have shown less commitment to peace enforcement operations.[10] For example, presidents often have chosen not to commit air or ground combat forces to deal with civil wars.[11] In other cases, they have shown a willingness to withdraw when costs became unacceptable; indeed, many past examples (e.g., Lebanon [1982-84] and Somalia [1992-1994]) are cautionary ones.

[9] We include in this category such activities as establishment of no-fly zones and safe havens, and coercive strikes to separate combatants.

[10] There also is evidence that members of the public are much less likely to support the use of U.S. military forces for interventions in the internal affairs of other countries than in the case of interstate wars where a U.S. friend has been attacked.

[11] Such cases include the civil wars in China (1945 to 1949), Greece (1947) and Palestine (1947 to 1948), Vietnam (at Dien Bien Phu, 1954), and most recently in Rwanda, Zaire, and Cambodia.

These data together suggest that involvement in these sorts of operations will continue to be infrequent, and when the U.S. *does* engage in these operations, the government will prefer airpower in order to avoid the commitment of more vulnerable ground forces.

3.3.2.5 Global Awareness/Illumination Operations

The mission of global awareness and illumination operations is to collect, fuse, and disseminate information. These operations are far more common than combat operations. Past operations with a primary focus of global awareness and illumination have included

- Creek Sentry — Airborne Warning and Control System (AWACS) deployment to Poland
- Elf One — AWACS deployment to Saudi Arabia
- Counterdrug operations in the Western Hemisphere
- Support to peace negotiations in the Balkans

In fact, of the 1,050 operations between 1981 and 1994

- 189 involved surveillance assets (e.g., AWACS, RC-135)
- 135 were in combination with fighters or bombers (54 involved C^4ISR in a primary role)
- Most were used in exercises, military operations other than war (MOOTW), or counternarcotics operations

Figure E-6 shows that the number of these operations has declined, largely due to the great reduction in exercises.

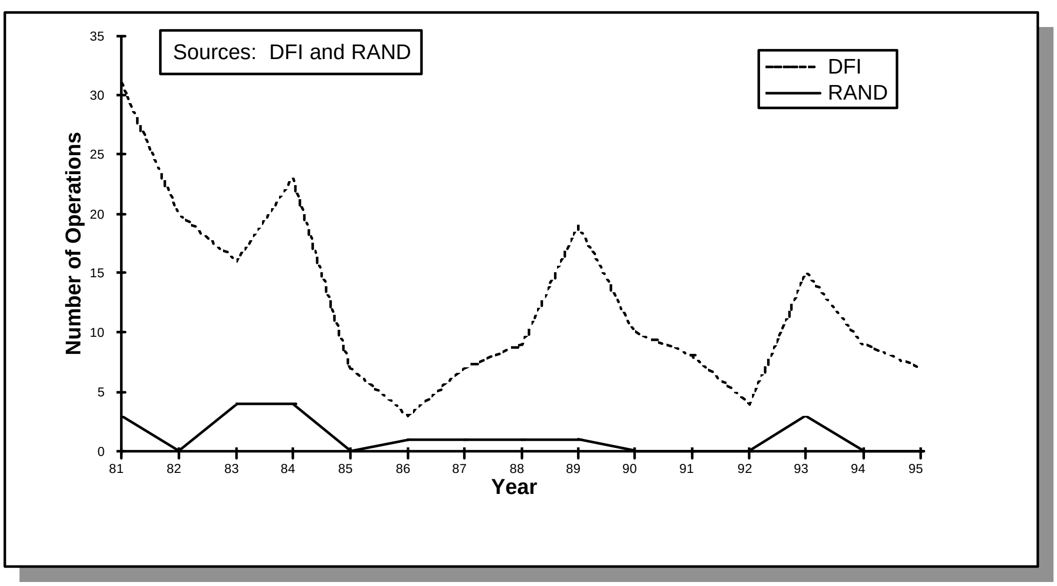

Figure E-6. *Frequency of Global Awareness Operations*

Figure E-7 suggests that the average level of effort of these missions increased at the end of the Cold War and subsequently declined.

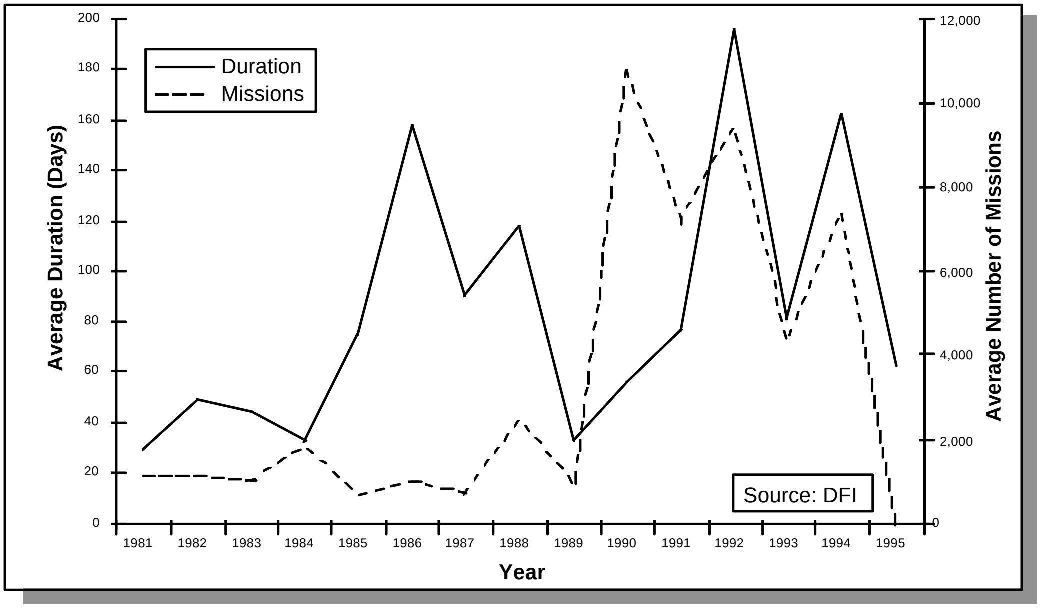

Figure E-7. *Average Level of Effort in Global Awareness Operations*

3.3.2.6 Humanitarian Operations

Humanitarian operations are the most common operations undertaken by the Air Force. They involve assessing and mitigating natural and technological disasters,[12] providing humanitarian relief, medical evacuation (medevac), and other humanitarian actions. Past humanitarian operations include

- Famine relief operations in Ethiopia, Somalia, Bosnia, and many other locations
- Earthquake relief in Armenia and the Philippines
- Flood relief in India and Bangladesh

According to the Global Reach–Global Power database of Air Force operations, of the more than 620 operations undertaken by the Air Force between 1947 and 1992

- 387 (62 percent) were humanitarian operations.
  - 329 of these were disaster relief operations.
  - 16 were medevac operations.
  - 42 were other miscellaneous humanitarian operations.

According to data from DFI, 216 of the nearly 1,050 operations undertaken between 1981 and 1994 (more than 20 percent) were humanitarian operations; this constitutes 40 percent of the nearly 530 operations that were not exercises.

Figure E-8 shows that the annual number of Air Force humanitarian operations peaked in 1991 and has declined since then.

[12]Natural disasters include earthquakes, volcano eruptions, and floods; technological disasters include Chernobyl and Bhopal.

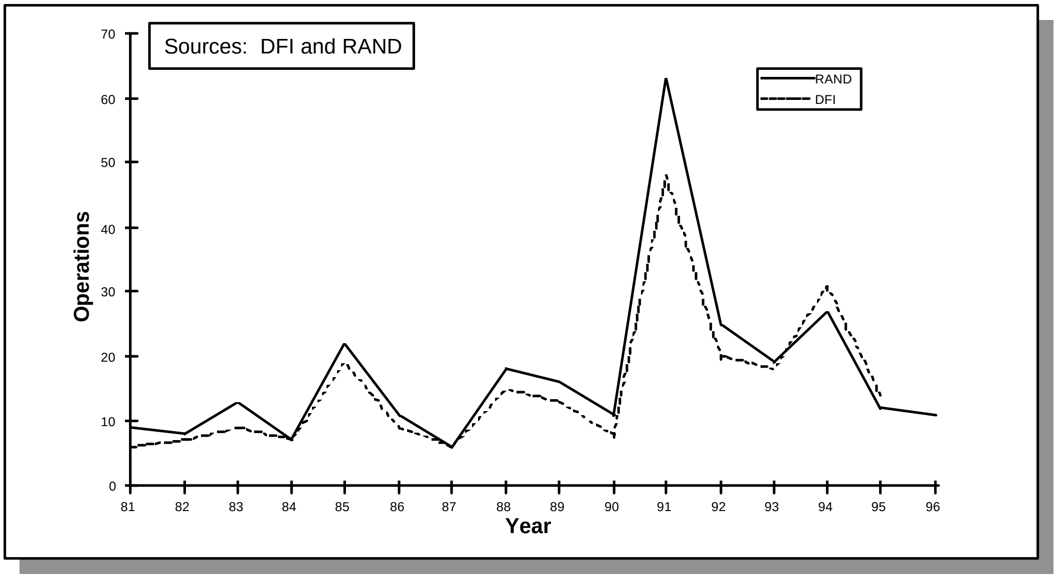

Figure E-8. *The Frequency of Humanitarian Operations Has Declined to Past Levels*

As suggested by Figure E-9, the average duration of these operations has greatly increased over the past several years but the average number of missions has declined, probably due to the resource constraints imposed by the very large and long-duration humanitarian operations in Southwest Asia and Bosnia.

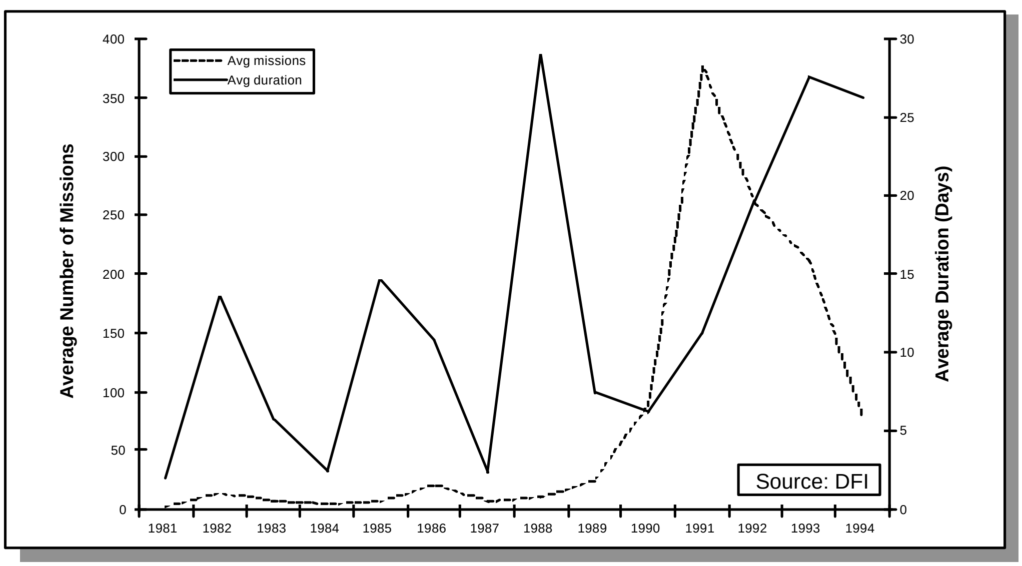

Figure E-9. *The Average Level of Effort for Humanitarian Operations Has Increased*

3.4 Summary and Conclusions

The Air Force needs to plan for a balanced force that can quickly generate AEFs capable of meeting the demands of a wide range of missions. To do this, the Air Force will need

- Enough ready combat-capable platforms to handle MTWs *and other* combat operations at short notice
- Enough ready support platforms for other (i.e., noncombat) missions
- Enough supporting capabilities to ensure success

The best approach is to examine time/impact/cost outcomes in a multidimensional matrix populated by vignettes that capture

- A distinct mission
- The area/context of the mission
  - Stakes/constraints
  - Environment (e.g., unopposed vs. opposed)
  - Different levels of HNS, infrastructure, etc.

The next section will identify the key capabilities needed by AEFs to undertake the six illustrative missions, and measures of effectiveness for determining the success or failure of the AEF.

4.0 Needed AEF Capabilities

Significant changes in the geopolitical situation coupled with new technologies make possible a new, powerful concept of air operations. In today's world, and in the world of the next quarter century or so, the United States will face a variety of threats that are not predictable in time, place, or specifics. The unpredictability of the future threat requires the development of a capability (including humanitarian relief) to solve military problems quickly to minimize the damage an aggressor might inflict or to minimize human suffering following a disaster. The timeline for disaster relief always has been short (help should arrive within 24 hours). The timeline for reaction, preemption, and prevention of military problems has shrunk from years and months early in this century to days at its close. We must anticipate that the time allowed will continue to shrink as faster and more effective means of aggression appear.

The advent of high bandwidth for communications, of computer processing and analysis of large amounts of information, and of precision that makes hitting a target a high-probability event have combined to make it possible to bring many enemy strategic, operational, and tactical targets under attack quickly and in parallel with a different effect than bringing those same targets under attack serially, as older technology demanded. The more parallel the attacks become, the faster the enemy's total energy is reduced. As the enemy's total energy is reduced, his ability to carry out his own operations, to react to attack, to learn, and to repair falls (see Figure E-10).

The faster we reduce our opponent's energy levels, the higher the probability we will succeed in achieving our objectives. The same concept prevails in humanitarian relief, except that our goal becomes adding energy to the system in the form of water, food, medicine, shelter, guidance, and communication.

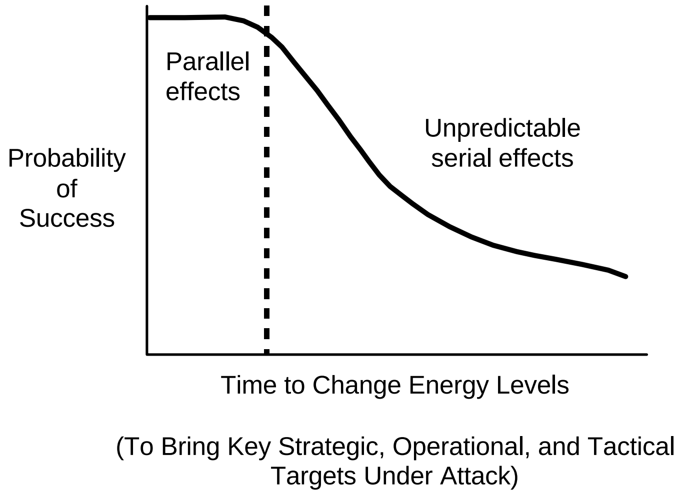

Figure E-10. *Probability of Success and Changing Energy Levels*

In the old serial world, our emphasis was on positioning forces that could make moves and counter those of the opponent. Numbers had to be large to make up for the inherent inaccuracy of weapons and the low probability of success on any given move. It is now, however, possible — and necessary — to think in terms of the effect we wish to impose on the opponent as a system (an enemy or a disaster environment). Our goal, then, becomes one of imposing our desired end on the opponent as quickly as possible. When weapons were highly inaccurate (as they have been up to almost the present day), affecting a large number of targets was a difficult and time-consuming task. For example, in World War II, B-17s had to drop over 9,000 bombs to have a 90 percent probability that one would fall into a target about a third the size of a football field; in the Gulf War, the number of bombs required to achieve the same probability of a hit was *one* if dropped by a precision-capable aircraft such as the F-117. Not only is it now possible to hit something with high probability, it also has become clear that there are not many strategic, operational, and tactical targets that must be hit in order to produce system failure. In addition, we can know roughly the target numbers we are likely to face in the future because the number of targets does not vary much and the numbers are quite low even for a large country and large military (see Figure E-11).

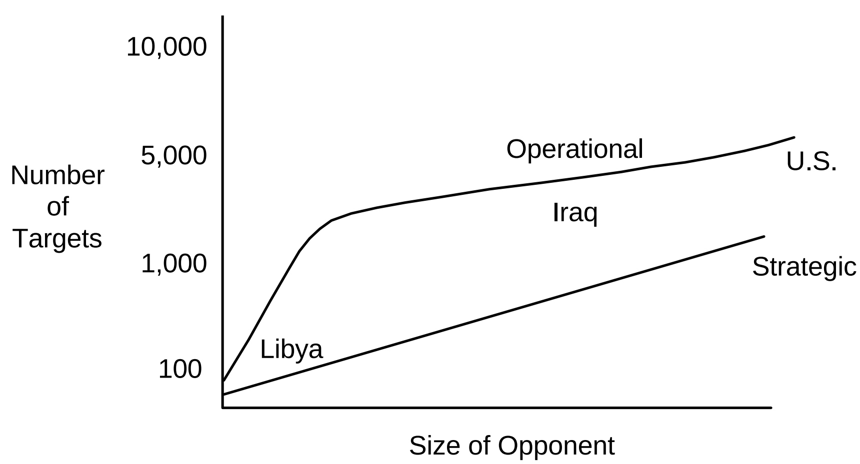

Figure E-11. *Numbers of Strategic and Operational Targets*

With new geopolitical and technological conditions, it is useful to consider encompassing descriptions of the outcomes realizable with military operations and to derive principles that apply across the board. The principles suggest a general mode of operation and also a way to measure our success in preparing for execution and for the execution itself. Overlying these principles is the need to bring the situation to fruition as quickly as can be managed politically; that is, slowness of military operations should never hinder political processes.

4.1 The Six General Outcomes for U.S. Military Forces and Accompanying Precepts

- **Illumination.** Collect and disseminate information, control information, and exploit information.
- **Denying the fruits of aggression.** Paralyze, deenergize, reverse, or halt an aggressor.
- **Separation of combatants.** Prevent third parties from damaging each other.
- **Intimidation.** Impress a potential opponent to do things or not do things it would do absent an AEF operation.
- **Inhibition of WMD use.** Make it difficult or impossible for a targeted organization to employ unusual and dangerous weapons.
- **Disaster relief.** Relieve starvation, stave off disease, and protect disaster victims from the elements.

To ensure maximum potential to attain these outcomes, the AEF should

- Focus on achieving the desired effects on enemy function and base all organization, planning, and operations on those desired effects.
- Produce an effect on the opponent as soon as the political decision to do so is made. In the short term, the opponent should be affected significantly within 24 hours of the political direction to execute; in the long term, the time should fall by at least an order of magnitude.
- Suffer few to no casualties to avoid creating a political liability.
- Plan for and use reserves and Guard forces appropriately.

4.2 Operational Concepts and Measures of Merit

4.2.1 Using These Concepts and the Accompanying Curves

Our objective is to become highly competent in each of these concept areas as quickly as possible and across as much of the AEF structure as possible. To measure our success, we have identified the capabilities an AEF must possess and have provided accompanying curves that demonstrate the effect the attribute (speed, precision, parallel targeting, etc.) has on the success of the mission. To use the curves, we must estimate where the AEF currently lies on each curve, then decide whether any given new technology, concept, or organization will move the AEF in the right direction on the curve.

To achieve its goals an AEF must

- Move very fast
- Affect the enemy system through parallel operations
- Exploit information rapidly

- Be precise
- Confound the opponent
- Cover enough targets rapidly enough to affect the opponent at a systems level
- Keep supporting functions to a minimum
- Survive to succeed and suffer few to no casualties
- Be capable of operating in a joint or combined environment
- Be technologically superior to the enemy to minimize casualties
- Innovate constantly
- Be realistic about future personnel resources[13]

4.2.2 Move Very Fast

An AEF that is very fast (with emphasis on speed of employment) can impose damage faster than an enemy can cope with it (parallel effects) or defend against it, and can do so with little risk. Conversely, a very slow AEF gives the enemy ample opportunity to devise counters and to impose military or political costs on the slow attacker. A fast AEF has significant political advantages in that it accomplishes its objectives before the external environment can adapt to thwart its effectiveness. Sufficiently high velocity also can substitute for numbers (in theory, a small number of units, if they were very fast, could strike all relevant operational and strategic targets before the enemy could react). Finally, the return on increased velocity of an AEF is very high (it approaches the square of the increase). However, speeds that were satisfactory yesterday are unsatisfactory today and the trend appears to be accelerating.

4.2.3 Affect the Enemy System Through Parallel Operations

All opponents (e.g., enemy nations, enemy armies, third-party combatants, and post-disaster environments) are systems. The objective in conducting operations against these systems is not primarily to destroy things, but rather to put the entire system into a position that forces it to conform to our objectives. We change the system by changing its energy levels (e.g., take out energy for a traditional war situation and put in energy for a disaster situation; see Figure E-12). The faster we affect key functions and entities, the more likely we are to succeed. We affect system functions by hitting key strategic, operational, and tactical targets with physical or information energy. When we are very fast, we shut down so many enemy functions (e.g., leadership, energy conversion systems, communications, mobility, support, and combat units) so quickly that the system simply cannot deal with what has happened to it; it goes into shock and suffers some degree of paralysis. The first principle of operations then, and the first metric, for an AEF is the rapidity with which it can create a shock effect on whatever system or subsystem is assigned to it. Since we know the range in numbers of potential targets (even though we don't know whom we might fight), we can base our assessment of the AEF on how many targets it can affect over a given period of time.

[13]We will map these attributes to the range of AEF operations in Chapter 5, where we define six missions and assess AEF capabilities to fulfill them.

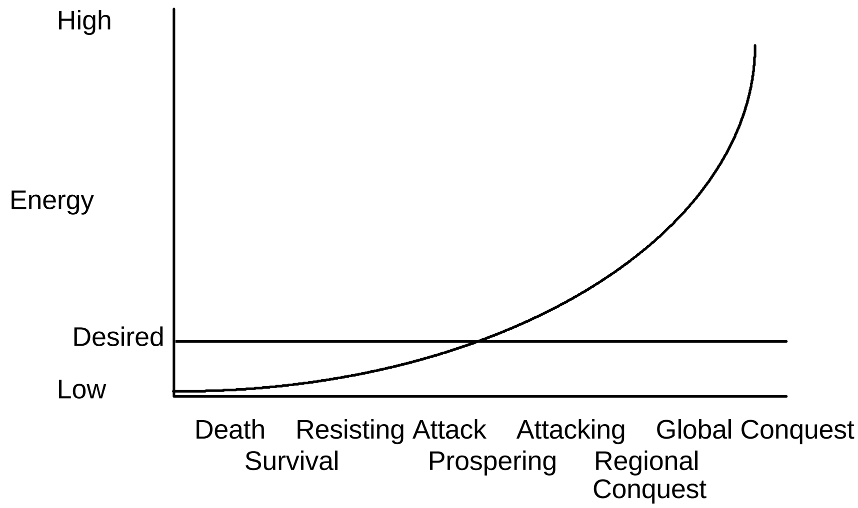

Figure E-12. *Energy Levels Should Be Driven Toward a Stable Situation*

4.2.4 Exploit Information Rapidly

In today's world, information is difficult to keep secret and rapidly loses its value. Success, then, is heavily dependent upon an organization's ability to gather, analyze, and use information faster than an opponent (see Figure E-13). Fast information exploitation depends on technological, organizational, and cultural factors.

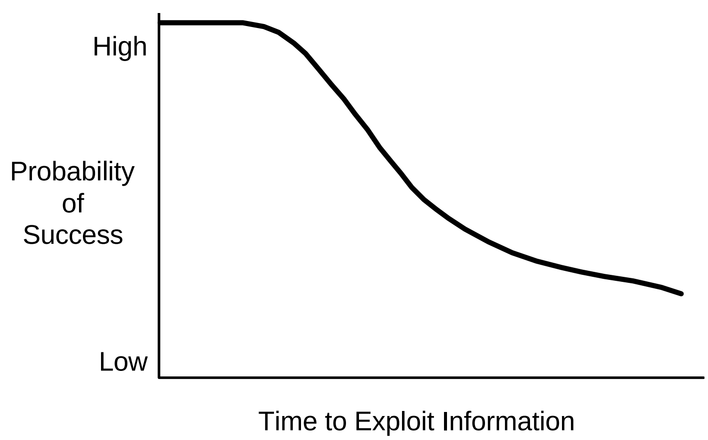

Figure E-13. *Exploitation of the Information*

4.2.5 Be Precise

When time is of the essence (as it always is), when resources are limited (as they always are), and when errors and collateral damage invoke a heavy political cost (as they normally do), it is imperative to be precise. Being precise means hitting the right targets as well as hitting them accurately. As Figure E-14 shows, greater precision reduces personnel requirements, the number of delivery platforms, collateral damage, casualties, and the time required to defeat the chosen targets.

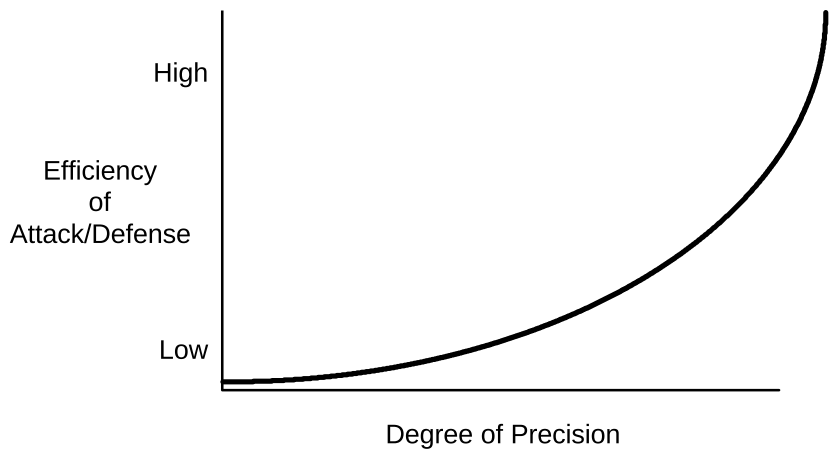

Figure E-14. *Precision and Effectiveness*

4.2.6 Confound the Opponent

An opponent can most easily manage an attack coming from a single direction and composed of only one attack element. As the number of attack elements goes up, the enemy rapidly loses the ability to deal effectively with more than one or two — and perhaps with any. The ideal AEF is one that confronts the enemy with multiple elements, composed of different technologies and different operating approaches (see Figure E-15). This may mean simultaneous attacks from the air, from space, and from the infosphere with platforms ranging from very fast (hypersonic) to very slow and from obvious to nearly invisible.

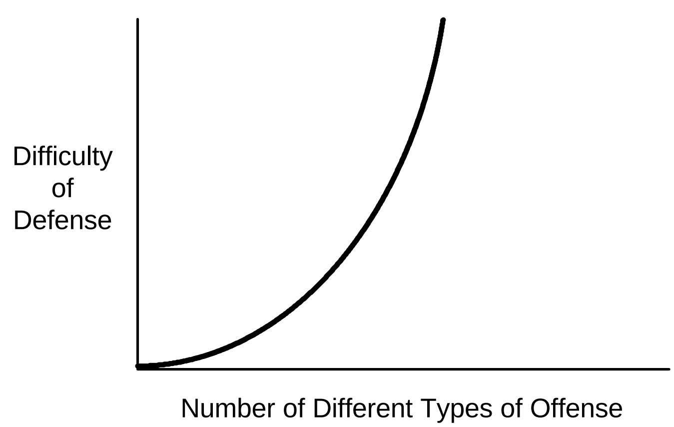

Figure E-15. *Confounding the Enemy*

4.2.7 Cover Enough Targets Rapidly Enough to Affect the Opponent at a Systems Level

Hitting targets sequentially gives the opponent time to react, recover, repair, and counter. An AEF should be able to impose rapid system effects. The number of destroyed targets (strategic, operational, and tactical) needed to paralyze or destroy an opponent is small regardless of the opponent's size (see Figure E-16). A key measure of a force structure is the time required to hit these targets. A slow force structure without precision would require a very long time regardless of size, while a fast, precision-capable force structure could hit all significant targets within a very short period even if the force itself is small in numbers. The reason is straightforward: Although each enemy soldier constitutes a potential target, the individual soldier is of little concern if he is not operating as part of a system that guides him, sustains him, and provides him with tools to multiply his individual physical capability. As an example, General Schwarzkopf correctly predicted that the Iraqi army in Kuwait would lose all its operational effectiveness if it lost the majority of its command, control, and sustenance, and about 50 percent of its major weapons (tanks, artillery, etc.). To impose these losses on the Iraqis, who had deployed the largest army since the Korean War, meant hitting just 4,000 targets.

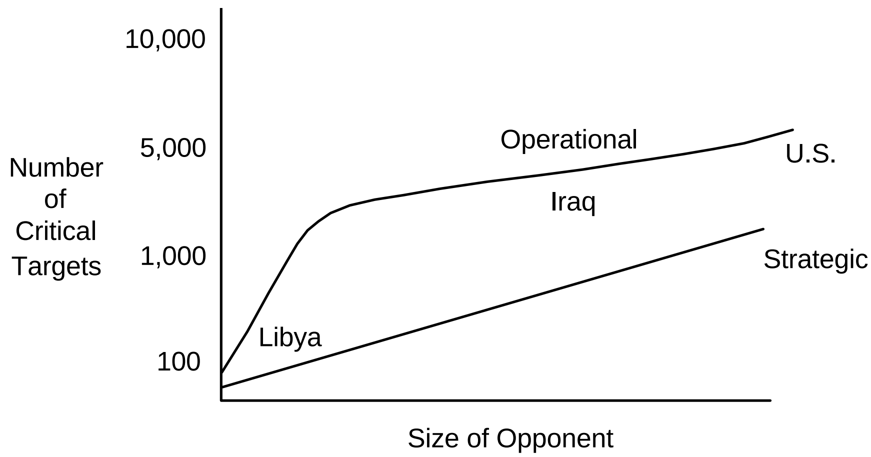

Figure E-16. *Target Coverage Requirement*

4.2.8 Keep Supporting Functions to a Minimum

Figure E-17 shows that complexity, cost, and risk rise rapidly as weapon delivery platforms (e.g., aircraft, tanks, and ships) require supporting platforms and personnel (e.g., aerial refueling, carrier battle group defense, and combined arms). The ideal force structure has delivery elements that can execute independently. The AEF command structure should focus on imposing the right effect on the opponent as quickly as possible. Every second spent solving support issues (e.g., escort, tankers, packaging, food, and bombs) is a second not spent on the real issue — affecting the opponent quickly. In addition, support operations, by definition, require time to execute, stretching the time required to affect the opponent. They slow operations and increase visibility.

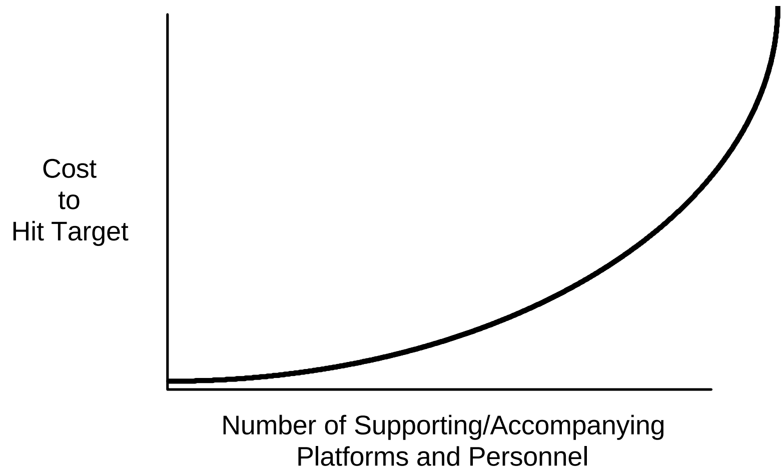

Figure E-17. *Support Personnel and Platforms*

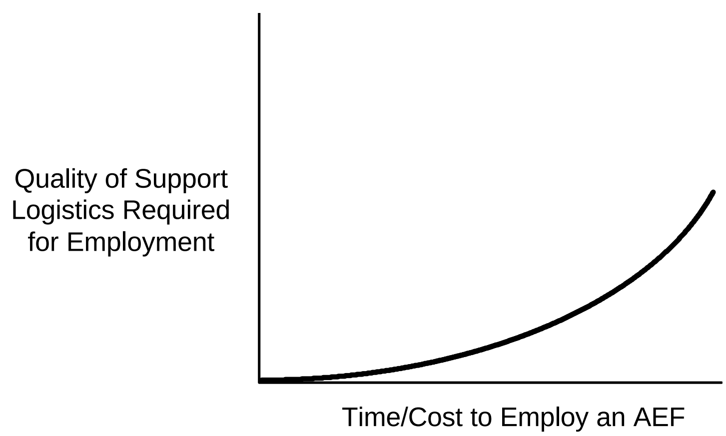

Figure E-18. *Logistics Support vs. Employment Force*

Maintaining forward logistics or moving logistics forward to support combat operations is costly, time consuming, and dangerous. A key measure of merit for a force that must leave its home territory to fight is its independence from logistical constraints. The ideal force structure consists of elements that need no preemployment logistics support (see Figure E-18).

4.2.9 Survive to Succeed and Suffer Few to No Casualties

In serial and attrition war, it was almost a given that both sides would suffer extensive losses; the winner was frequently whoever suffered least. In the parallel world, there is no reason to accept losses as a given if one has technological superiority/supremacy. In fact, losses represent errors in preparation and execution, which should be reduced drastically compared to earlier operations. Remember, too, that the likelihood of American casualties is a significant factor in making a political decision to intervene;

casualties after intervention affect decisions on the course of operations. Casualties are minimized and survival maximized by reducing visibility, increasing speed, reducing the number of personnel exposed, and operating out of reach of enemy attack. Hitting something that is moving very fast or that is invisible is difficult. The ideal AEF is very fast and as close as possible to being invisible individually and in mass (see Figure E-19).

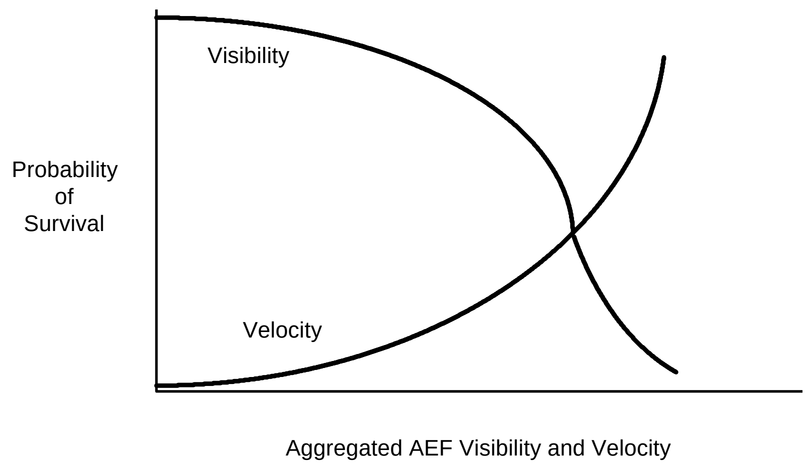

Figure E-19. *Visibility and Velocity vs. Survival*

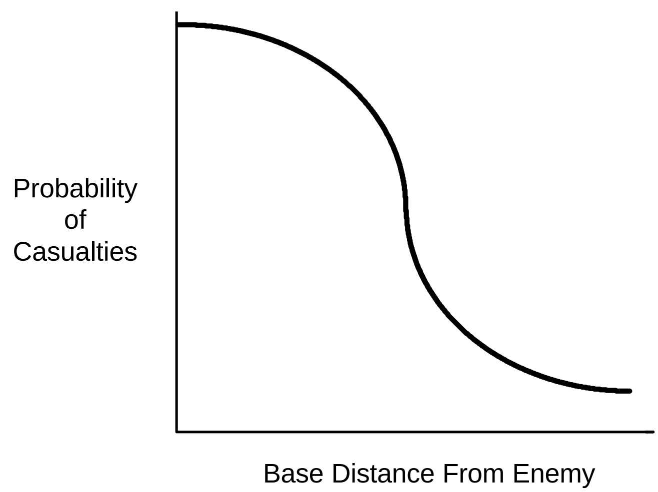

Figure E-20. *Effects of Staging for Opponent*

Support forces tend to be densely concentrated in small areas and less hard than combat forces. Dense masses make excellent targets, especially if the enemy's goal is to inflict casualties. An ideal force structure puts no support forces within easy range of enemy weapons (see Figure E-20).

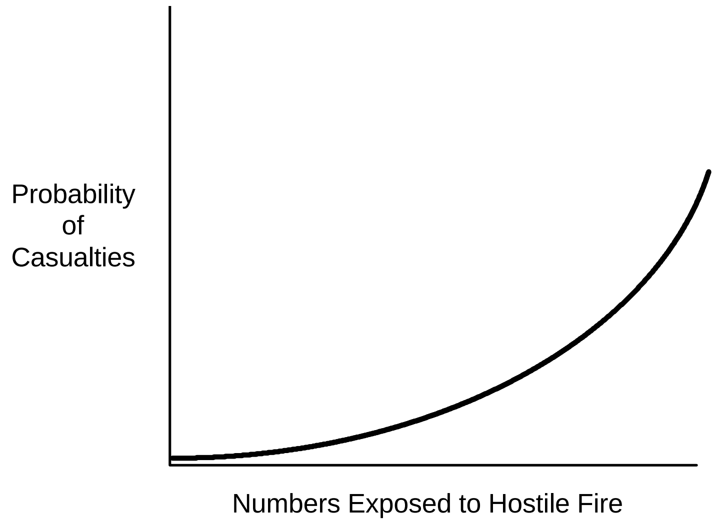

Figure E-21. *Exposure vs. Casualties*

If no one is exposed to hostile fire, the probability of casualties is zero. As the number exposed rises from zero, the probability that people will be hit goes up rapidly (see Figure E-21). The ideal force structure accomplishes its mission with very few exposed to enemy fire.

4.2.10 Be Capable of Operating in a Joint or Combined Environment

In many cases, the political situation will dictate the need to include other countries' forces in operations. The AEF must be able to accept these other forces without undue adverse effect on its own operations. In many instances, there also will be operations under way by non-AEF U.S. military forces. The AEF must be able to fit into the proper command relationship and to be supported by these other forces or to support them.

4.2.11 Be Technologically Superior to the Enemy

There is no way to predict the who, what, or why of future enemies beyond a logical assumption that someone will figure out a way to use new technology for purposes inimical to the United States; therefore, it is imperative that the AEF be as close to state of the art as possible. A rough approximation of what "state of the art" means can be derived by assuming that the potential for new technology is increasing roughly in proportion to Moore's Law. However, it is not appropriate to judge our technological or organizational progress against our past performance or against other militaries. The only acceptable measure is to compare our progress against that of the best in the commercial world. Whether being state of the art costs more or costs too much is not the immediate question; rather, it is, How far away are we from what we know to be physically possible? The AEF needs advanced technologies not only to maintain air superiority in an ever-more-threatening world, but also to allow us to complete missions faster and with a smaller footprint. Such advanced technologies include communications systems that allow for reachback, highly accurate missile systems that could be launched from farther away, planes that require less maintenance, and force protection sensors that could reduce the number of people required to patrol an area (see Figure E-22).

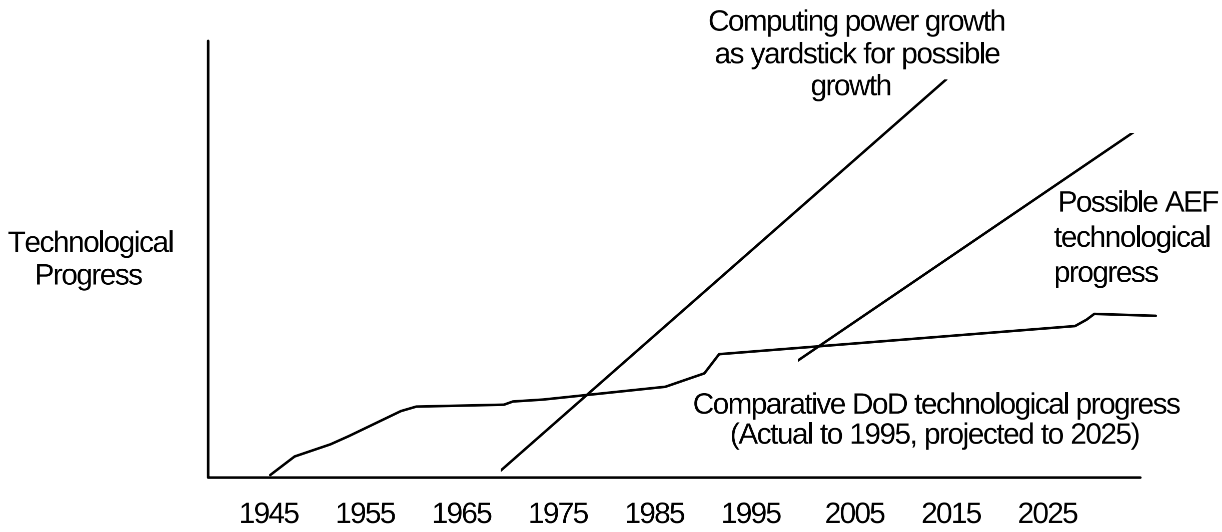

Figure E-22. *Exploitation of Technological Potential*

4.2.12 Innovate Constantly

If the AEF is to be always ahead of all competition (as it must be), then it must constantly and rapidly improve its technology and its CONOPS. If either or both stagnate, the impact and success of the AEF will fall dramatically and the cost of operations in human terms will go up. Note that today a new technology or concept of operation is likely to have a much shorter effective life than did new technologies or concepts in the past.

4.2.13 Be Realistic About Future Personnel Resources

The rapid expansion in world trade and wealth is creating jobs for "smart" people (the kind who currently serve in the Air Force at all levels) at a rate that exceeds the availability of people to fill these positions. The organization that today requires a certain number of smart people to accomplish its mission must, in just a few years, be prepared to do that same mission with substantially fewer people or be prepared to pay far more for their services than it currently pays.

Job creation worldwide, especially in the United States, is likely to continue. Every individual will have more and better job choices. Especially in demand will be "smart" people, including those upon whom the United States depends for the officer and enlisted corps. To compensate for the drop in availability, the AEF must either become more productive (capital intensive) or be willing to pay far more for its personnel — and it may not be able to pay enough.

4.3 Mission-Specific AEF Capabilities Needed

This section describes our methodology for assessing the AEF concept. We first present scenarios that illuminate the key characteristics of the six missions and identify the range of capabilities the AEF needs to accomplish each mission. We then present each study Panel's options for providing the needed capabilities. Each Panel has assessed the degree to which these options actually meet the required capabilities.

- Combat operations. We present three scenarios: (1) retaliate for a terrorist attack, (2) preempt an aggressor's missile attack, and (3) paralyze, halt, or deenergize an attacker (the leading edge of a major combat operation).
- Counterproliferation operations. Counter WMD development or use.
- Presence/show-of-force/demonstration operations. Deter, coerce, or otherwise impress a potential opponent.
- Peace enforcement to neutralize or separate combatants. Separate opposing forces.
- Global awareness and illumination. We present two scenarios: (1) conduct information warfare to mitigate unrest, and (2) investigate, document, and publicize genocide.
- Humanitarian relief. We present two scenarios: (1) provide disaster relief from mud slides, and (2) provide disaster relief from earthquakes.

To help develop specific technologies and concepts for the AEF within the general guidelines posed above, we should have a framework of hypothetical problems. The following vignettes illustrate the kinds of problems the AEF will face.

4.3.1 Combat Operations

There are three scenarios for combat operations.

Scenario 1.1: Counterterrorist Retaliation Against Small Country (Libya Equivalent)

> Intelligence and forensic evidence have determined that a small rogue nation in the Middle East was responsible for a terrorist attack that killed a large number of U.S. citizens. The president has authorized a strike against key command and control (C^2), intelligence, and training sites with ties to the terrorist group. Collateral damage to surrounding neighborhoods must be minimized.
>
> The objective is to strike about 20 targets in a very short period (minutes to hours) direct from CONUS without forward basing. Affect and exploit the rogue nation's datasphere. If absolutely essential, recover to a base outside CONUS (not desirable).

Scenario 1.2: Large Country (Iraq Equivalent) Missile Threat Against Neighbor

> An aggressor nation threatens to deliver a massive missile attack against a U.S. friend if the friend fails to make concessions that would be inimical to U.S. interests. The aggressor threatens the friend with unacceptable damage within 24 hours and says that the United States will not and cannot help. The aggressor claims that it is ready to suffer severe retaliatory damage from the United States, but that U.S. actions will be of no value to the friend and, in any event, the aggressor doesn't think the United States will launch a destructive attack after the fact. *AEF mission:* Preempt the aggressor's planned attack in such a way that few missiles are fired effectively against the friend. Presume the need for secrecy and surprise operations. Possible solutions may include robust defense or paralysis of execution.

The objective is to conduct parallel operations to affect about 1,000 targets directly associated with the aggressor's deployed land force, with the aim of imposing enough damage and disruption that it is unable to move forward. Focus on command targets, communications, fuel, supplies, key infrastructure such as bridges, and major weapons such as artillery and tanks. Operations should be successful within about 24 hours. Initial employment should be from CONUS- and space-based forces, with subsequent sorties flown from forward operating locations as distant as practicable from the opponent. Conduct aggressive information operations.

Scenario 1.3: Large Country Threatens Land Invasion of Neighbor

An aggressor assembles significant forces on a U.S. friend's border and threatens to attack rapidly unless the friend acquiesces. The U.S. president requests preemptive disablement of the attacking force with minimum fuss and human losses on the aggressor's side. The friend is unwilling to grant basing rights for fear that doing so will precipitate a war. A U.S. collaborator, located 2,000 miles from the friend, will allow use of its undeveloped concrete strip fields located in a remote region.

The objective is to conduct parallel operations to affect about 2,000 targets in as short a period as possible (preferably in less than 24 hours). Initial employment should be from CONUS and space-based forces with subsequent sorties flown from forward operating locations as distant as practicable from the opponent. Conduct aggressive information operations to shut down aggressor's internal communications, substitute appropriate programming for the aggressor's TV and radio audiences, and provide world news about the aggressor's deeds and the care with which attacks are conducted. Prepare to provide humanitarian relief as required.

Needed Capabilities for AEF Combat Operations

To successfully prosecute combat missions, AEFs must be able to

- Rapidly employ/deploy the AEF to the theater of operation, forcing entry if necessary, and begin offensive operations within 24 hours
- Provide location and target information to support strikes
- Strike targets with precision and with minimal collateral damage
- Counter opposing weapons of mass destruction
- Counter opposing ballistic and cruise missiles
- Provide force protection and minimize casualties
- Provide combat search-and-rescue at the earliest practical time
- Dominate opposing operations in the air, on land, and at sea, and operate at will
- Counter opposing IADS
- Dominate the information environment
- Degrade opposing C^2
- Degrade opposing stocks and infrastructure
- Establish minimal infrastructure necessary to support AEF operations
- Provide for lean sustainment of the AEF for the duration of its assignment
- Operate in a joint or combined environment

- Complement the capabilities of U.S. friends, allies, and coalition members

4.3.2 Counterproliferation Operations

Scenario 2.1: Rogue State Threatens Use of Chemical Weapons

A North Korea–sized state has surreptitiously completed a chemical weapons program and has built 100 VX warheads, which it threatens to use against a U.S. friend in 72 hours regardless of consequences. The President of the United States has decided that the rogue nation cannot be allowed to have missiles equipped with chemical weapons (CW) or CW production facilities and that the rogue must not attack the friend. Since the rogue nation has close relations with a significant regional power, the President wants to remove its CW facilities and weapons as quickly and surreptitiously as possible, with minimum damage to the rogue state. One concrete runway without facilities is available in a remote part of the friendly nation. The President insists on minimal collateral damage, especially chemical spillout.

The objective is to conduct operations against key parts of the rogue's reactor program (ostensibly a power research facility), to find and destroy the weapons, and to preclude their use in the process. Ensure that proper information operations are undertaken to support the strike and to communicate to the rogue's leadership exactly what is happening and why the rogue should not react.

Needed Capabilities for AEF Counterproliferation Operations

To successfully accomplish counterproliferation strike operations, AEFs must be able to

- Rapidly employ/deploy the AEF to the theater of operation, forcing entry if necessary, and begin offensive combat operations within 24 hours
- Provide location and target information to support strikes against WMD sites
- Strike targets with precision and with minimal collateral damage
- Provide force protection and minimize casualties
- Provide combat search-and-rescue at the earliest practical time
- Dominate opposing operations in the air, on land, and at sea, and operate at will
- Counter opposing air defenses
- Dominate the information environment
- Degrade opposing C^2
- Establish minimal infrastructure necessary to support AEF operations
- Provide for lean sustainment of the AEF for the duration of its assignment
- Operate in a joint or combined environment
- Complement the capabilities of U.S. friends, allies, and coalition members

4.3.3 Presence/Show-of-Force/Demonstration Operations

Scenario 3.1: Threat Against a Friendly Nation 200 Miles Offshore

A large aggressor threatens an attack on a U.S.-friendly island nation some 200 miles off the aggressor's shores. The aggressor is known to have very sophisticated antiship missiles with 1,000-mile range and has openly expressed its contempt for naval forces. It believes it can cross the water to get at the island nation if it has air superiority over the sea. It reportedly is ready to move within 36 hours. The island nation's intelligence has information indicating that the aggressor will not begin its attack if the United States makes a visible and credible show of force. It also believes that significant disagreement exists in the aggressor's government about its foreign policy and that the right U.S. response properly publicized may lead to the fall of the ruling party. No basing exists on the island, and the nearest available land bases are 1,000 miles or more away. It is possible that the AEF may need to stay for a long time or to pass responsibility to a non-AEF entity.

The aggressor will back down only if the United States deploys forces that clearly can do serious damage to the aggressor. The operation will require a clear demonstration of the United States' ability to fly against the aggressor with relative impunity and to defeat the aggressor air forces while providing reasonable defense for the island from missile and air attack. It also will be necessary to ensure that dissident elements within the aggressor understand what is occurring and that the world at large is convinced of its imminent aggression. Success demands a synergistic combination of force and information AEFs.

Needed Capabilities for AEF Presence/Show-of-Force/Demonstration Operations

The capabilities needed for presence/show-of-force/demonstration operations are essentially the same as those for combat operations. To successfully accomplish these missions, we must make the adversary believe that a credible capability exists for thwarting an anticipated course of action or making it too costly.

4.3.4 Peace Enforcement

Scenario 4.1: Separation of Rival Factions in Internal Conflict

Rival factions in a less developed country are attacking each other's forces and civilian supporters. The U.S. President wants to end the fighting rapidly with little to no risk to U.S. personnel. Unimproved concrete airstrips are available for operations in a remote area of a third country 800 miles from the warring country. The President believes he can maintain congressional support only for a week. The opposing forces number about 5,000 each, and each has about a hundred pieces of self-propelled artillery and tanks, and a handful of MiG-21 class aircraft. Weather is marginal, and the country has rough terrain. The President is amenable to destruction or incapacitation of equipment on both sides, but wants little or no damage to civilian property and essential services; likewise he does not want to kill combatants on either side.

The objective is to halt movement of military forces from both sides, preferably with nonlethal weapons. Take control of the country's datasphere to ensure that true information about both sides is seen by everyone internally and externally. Conduct food relief operations to groups on both sides as required. Extract U.S. and other nationals in untenable positions.

Needed Capabilities for AEF Peace Enforcement Operations

For successful peace enforcement operations, AEFs need capabilities to

- Rapidly employ/deploy the AEF to the theater of operation, forcing entry if necessary, and begin operations within 24 hours
- Provide location and target information to support strikes against combatants and supporting infrastructure
- Strike targets with precision and with minimal collateral damage
- Minimize friendly casualties
- Provide combat search-and-rescue at the earliest practical time
- Counter opposing air defense capabilities
- Dominate the information environment
- Degrade opposing C^2
- Degrade opposing stocks and infrastructure, as necessary
- Establish minimal infrastructure necessary to support AEF operations
- Provide for lean sustainment of the AEF for the duration of its assignment
- Operate in a joint or combined environment
- Complement the capabilities of U.S. friends, allies, and coalition members

4.3.5 Global Awareness and Illumination

There are two scenarios for global awareness and illumination.

Scenario 5.1: Information Warfare to Mitigate Unrest in a Small Undeveloped (Liberia-like) Country

A small West African country has deteriorated into chaos, with roving bands of armed brigands fighting in the streets, looting, and burning. The President wants to follow the situation closely to assure the safety of Americans and other noncombatants, and wants to use propaganda and information warfare capabilities to take over broadcast media in order to broadcast messages to reduce the violence.

The objective is to take over the country's datasphere, including all official internal traffic. Inject messages that will ameliorate tensions. Use air- and space-based capabilities.

Scenario 5.2: Investigate, Document, and Publicize Genocide

Strong rumors arise that a small, less developed country is committing genocide and may be on the verge of crossing borders into neighboring states. U.S. political leadership is troubled but needs more confirmation than is available from refugees and satellites. If the rumors are confirmed, the President believes that we must make the world aware of the situation as soon as possible. Although direct intervention is not feasible, the President believes that blocking the country's ability to use internal TV and radio and then substituting information showing the country's citizenry what is occurring will be highly useful. He needs a fast response (within days) in order to stave off attacks from the country's nationals in the United States demanding intervention, which is not feasible. Multiple bases are available in neighboring states.

Needed Capabilities for AEF Global Awareness/Illumination Operations

For successful global awareness/illumination operations, AEFs must be able to

- Rapidly employ/deploy the AEF to the theater of operation and begin operations within 24 hours
- Provide necessary location and target information
- Provide force protection and minimize casualties
- Provide combat search-and-rescue at the earliest practical time
- Dominate the information environment
- Degrade opposing C^2 or political control through information operations[14]
- Establish minimal infrastructure necessary to support AEF operations
- Provide for lean sustainment of the AEF for the duration of its assignment
- Operate in a joint or combined environment
- Complement the capabilities of U.S. friends, allies, and coalition members

4.3.6 Humanitarian Relief

There are two scenarios for humanitarian relief.

Scenario 6.1: Mud Slides in South America

> Following prolonged rains from a hurricane, mud slides have buried a small city in a medium-sized South American country, killing hundreds and injuring thousands. There is an austere airfield normally used under visual flight conditions, but its use is limited at this time due to inclement weather. Air traffic control (ATC) must be provided by the AEF.

Scenario 6.2: Huge Earthquake in Northeast Turkey Cuts Off Tens of Thousands From Outside Supply

> Many people have been killed and injured. There is a dire need for food, medicine, and shelter. There is no land access, and all existing runways and highways appear to have suffered earthquake damage. Winter conditions require rapid aid to widely dispersed and isolated people numbering over 100,000. They need food, medicine, and shelter fast. The nearest functioning bases are 500 miles from the catastrophe area.

Needed Capabilities for AEF Humanitarian Relief Operations

To successfully accomplish humanitarian operations, an AEF must be able to

- Rapidly employ/deploy the AEF to the theater of operation and begin operations within 24 hours
- Locate the affected population
- Provide point-of-use delivery of food, water, medicine, and other relief
- Minimize friendly casualties

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[14] Since this is an act of war, this probably is not a frequently needed outcome, outside of combat operations.

- Provide search-and-rescue at the earliest practical time
- Establish minimal infrastructure necessary to support AEF operations
- Provide lean sustainment of the AEF for the duration of its assignment
- Complement the capabilities of U.S. friends, allies, and coalition members

4.4 Battlelabs and the Development and Testing of AEF Capabilities

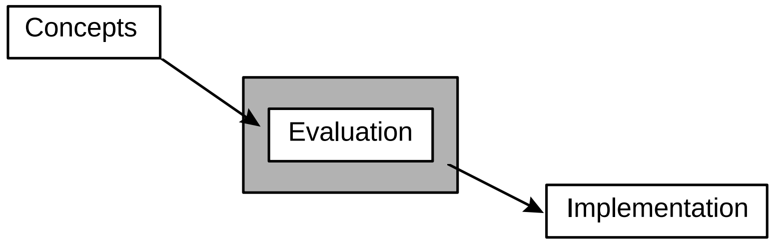
4.4.1 Introduction

The Air Force recently has implemented a new system of evaluating, testing, and implementing concepts that come from the field and that may improve operations. We see these "Battlelabs" as an ideal environment for testing potential improvements that may make implementing AEF operational concepts easier and more effective.

The Air Force Battlelabs were founded on the basis of a vision to "create an environment in which innovative concepts can be harvested, rapidly evaluated, and, when proven, quickly fielded." The key to this vision is that the labs serve as a vehicle to harvest ideas by taking concepts that may be generated anywhere — in operational units, in the laboratories, by staffs, by major commands, and by the Air Staff — and provide a forum for evaluating them objectively. The evaluation of a new concept involves determining whether it provides value in moving the Air Force toward its vision for the future in either the near term or far term (inherent in this evaluation is a focus on the military needs of the Air Force and the nation). The concept then is rigorously tested to improve it and to discover what would be required to field it. Finally, concepts are fielded or implemented by convincing others — the major commands, the Air Staff, and organizations external to the Air Force — that the concept provides either a significant capability improvement or cost savings. The concept then becomes a part of the Mission Area Plans (MAPs) and Program Objective Memorandum (POM) process. The Battlelabs and especially the AEF Battlelab are crucial to the success of the AEF because they can act as crucibles to test the AEF's current capabilities, its shortcomings, and ways to improve the AEF concept. In addition, the Battlelabs provide an Air Force–wide forum to demonstrate the capabilities of an AEF and measure an AEF's contribution to the Air Force's mission. This is important because the Battlelab's work provides a basis both inside and outside the Air Force for justifying the organizational and force structure changes required to make the AEF work.

4.4.2 The Battlelab Process

Figure E-23 depicts the Battlelab process. A number of issues revolve around the fact that Battlelab tasks and responsibilities cut across organizational lines. The current structure of the Battlelabs has them organized under the major commands in conjunction with the respective warfare centers. This type of organization makes it very difficult if not impossible to resolve the issues outlined in Figure E-23. In addition, as currently organized, the Battlelabs are hampered by too many layers of approval and do not have enough authority to execute their mission.



Major organizational issues revolve around the fact that Battlelab tasks and responsibilities cut across organizational lines:

- Who takes ownership and champions the process?
- How are interactions between Battlelabs fostered?
- How is the four-way link among labs, operators, acquisition staff, and programmers fostered?
- How does implementation occur?

Figure E-23. *The Battlelab Process*

The Battlelabs are organizations for examining change; in order to do this they must be sheltered from the institution they are trying to change. The labs need to be linked to power — and that means people and money. The Battlelabs should control their own resources and have enough resources — people, money, and things — to get their jobs done. This would clearly lay responsibility on the Battlelabs for producing concepts that would improve the Air Force's capability to perform its mission. Within this construct the corporate Air Force has to be willing to let the Battlelabs try experiments without having to ask permission and must accept the fact that some concepts will fail.

The fundamental question facing the Air Force is "What institutional incentives will allow the Battlelabs to survive over time?" There are two perspectives to the problem, one from the Battlelabs themselves and the other from the Air Force hierarchy. First, in order to survive, the Battlelabs must produce innovative and leading-edge solutions to either current problems or the Air Force's vision for the future. The first results have to become evident within a POM cycle of the lab's inception, or the Battlelabs will be viewed as another nonproductive attempt at innovation. Second, to assure the Battlelabs' durability, the Air Force has to structure the Battlelab process so that it is maximized for success.

The Battlelabs have to be owned and championed at the highest levels within the Air Force — the level of the Chief or Vice Chief of Staff. The Battlelabs' charter and tasks cut across all organizational lines within the Air Force, from major commands to the staffs to the laboratories and research institutions. The only way that the Battlelabs will be able to successfully work across these organizations is by being protected from them. In addition, the Battlelabs need to be protected from organizations that view them as threats or are resistant to change. Finally, the Battlelabs need to be integrated so that they do not produce "stovepiped" solutions. That integration can be brought about only through common ownership.

The Battlelabs must have the power to accomplish their missions, and that requires funding and resources. Initial funding should provide the Battlelabs with the capability to execute at least one major experiment this fiscal year. Adequate funding from a central source will ensure that the Battlelabs objectively evaluate concepts and squarely put the responsibility for producing results in their laps.

4.4.3 The AEF Battlelab

The Battlelabs must involve operators, the labs, acquisition organizations, and programmers in their process from the beginning. The focus for this process should be the Air Force Long-Range Plan and Vision. Battlelabs develop concepts to help fulfill the vision and implement those concepts by inserting them into the MAPs.

Whereas the other Battlelabs can work at any level from systems to employment, the AEF Battlelab was formed to address a single, immediate, Air Force–wide issue — the AEF. Specifically, how does the Air Force implement an AEF both today and in the future? In the near term, the AEF Battlelab must focus on the Air Force's requirement to rapidly build a power-projection AEF capability. It can accomplish this by analyzing and taking advantage of AEF experiments that already have occurred, designing new experiments to further mature AEF concepts, and interacting with the other Battlelabs and warfare centers. In the far term, the AEF Battlelab should extend the concept of an AEF from power projection to all facets of the Air Force's core competencies.

4.4.4 Experiments

The design of a Battlelab experiment can be modeled after a classic scientific experiment: Develop a hypothesis, test it, and analyze the results. First, we have to understand the question. The steps are as follows:

- Frame the hypothesis: What question are we asking?
- Develop and run the experimental protocol: How will we test the question?
- Capture and analyze the results: What are the metrics?
- Recommend, modify, or reject the concept: Did the concept improve capability?

The question should be based on the effects we want to achieve; in the case of the AEF Battlelab experiment, for example, the question could be "How do we destroy 45 targets in 48 hours or deliver 50 tons of humanitarian relief supplies within 24 hours?" After figuring out how the question will be tested, the lab should develop metrics to determine whether the concept would improve our capability or cost less than other approaches. The metrics are critical and play a fundamental role in our being able to support a decision to implement a concept in the future. Finally, this methodology has to be rigorously applied but still must not stifle innovation. The sciences have used this type of approach for centuries and produced amazing innovations.

Experiments can be executed at any level or at all of the levels outlined in Figure E-24. The initial look at a series of concepts might be at the tabletop level. In this situation, the concepts are subjected to a logical analysis of their ability to provide a desired capability or effect that fits into the Air Force Long-Range Plan and Vision. The next level is a test of the concept(s) using modeling and simulation. This approach allows the Battlelab to further scope the concept and submit it to tests that might not be possible to execute in the field. The third method for performing an experiment is to conduct an actual field trial. The goal of this type of experiment is to conduct a hands-on test of the concept and determine potential capabilities and deficiencies. These tools do not have to be used in a prescribed order and the result of one, some, or all of these methods should be a concept that can be implemented or inserted into the MAPs.

Experiment	Tools
Tabletop	Logical analysis
Modeling and simulation	Computers
Field	Live test

Implementable results

Figure E-24. *Levels of Experiments*

4.4.5 Example Experiment

There are six representative missions for the AEF: (1) combat operations, (2) counterproliferation operations, (3) presence/show-of-force/demonstration operations, (4) peace enforcement operations, (5) global awareness and illumination operations, and (6) humanitarian operations. An example experiment for a combat operation could be based on the question "How does the Air Force apply combat power to a situation in which it is tasked by the NCA to destroy a set of targets within 24 hours?" The secondary questions for this experiment are "What combat power do we apply?"; "How do we apply it within 24 hours?"; "How long will it take the Air Force to destroy the target set?"; "What are the political and legal constraints?"; and "What support is required?"

Once we have framed the question, the next step is to determine how to test the question. Figure E-25 illustrates the types of considerations that have to be addressed when performing a Battlelab experiment.

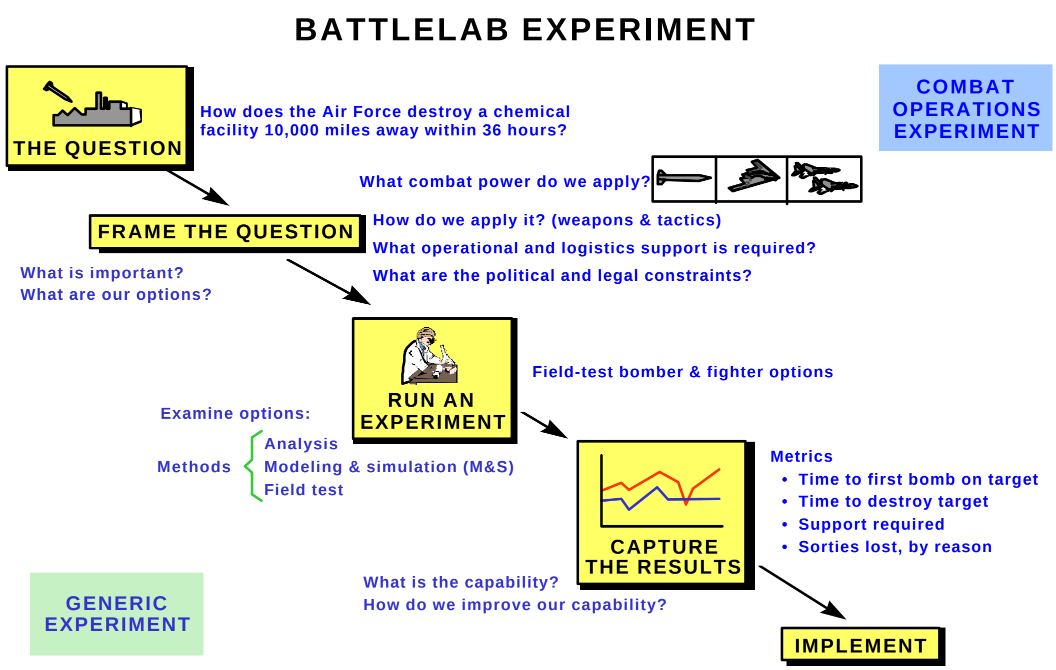


Figure E-25. *Example Experiment*

For this question, the scenario should be designed around either destroying a nuclear, chemical, or biological weapons site or stopping an invading army. Next, the Battlelab needs to find a test site. The experiment could be accomplished in conjunction with an exercise or at an Air National Guard (ANG) field training site. The advantage of an ANG field training site is that it provides a complete set of facilities, including an airfield, base infrastructure, and practice ranges. The operations plan (OPLAN) for the test outlines the infrastructure for the experiment and delineates support requirements. The final part of the experiment design is the decision to evaluate various options for answering the questions. This could be part of the actual test but also could be accomplished in a tabletop analysis or using modeling and simulation. The important thing is that the evaluation cover the range of reasonable options for accomplishing the task, including not just the attack option but also how we accomplish force protection, logistics, or movement.

How Do We Test the Question?

• Develop scenarios	Nuclear, biological, and chemical (NBC) target set and/or attack/slow/halt invading forces
• Determine test site	In conjunction with major exercise or ANG field training site
• Build OPLAN	Infrastructure for the experiment (personnel, ranges, C^2, etc.)
• Design options	Bombers vs. fighters Basing questions Force protection Others

Figure E-26. *Example Process for Testing the Question*

The next step is to develop metrics to measure the outcome of the test (see Figure E-26). They should be determined as a part of the OPLAN and should clearly address the question being asked — focusing on providing a means of measuring improvement over current capabilities. In our example experiment, some metrics would be

- Time to first bomb on target

  Time to destroy the target set

    Sorties generated per day
    Targets destroyed per day

  Lift required to accomplish the mission

  Combat support required to accomplish the mission

- Sorties lost because of inadequate force protection

It is absolutely critical that the metrics be established and collected during the test. These form the basis for evaluating the concept and implementing it later.

The final step after understanding whether the concept would improve our capability is to determine whether to recommend, modify, or reject the concept. Would we accomplish the tasking faster, better, or more cheaply than we could have today? If the concept would not improve our capability, can the concept be modified or improved to make it better? One possibility is to return the concept to the developer for additional work. If the concept would result in a new or improved capability, then the Battlelab should move the concept to the MAP process to compete for funding.

4.4.6 Candidate Experiments

The following are recommended high-level experiments that the AEF Battlelab should accomplish. The experiments are built around the five AEF missions:

- Leading Edge of Major Combat Operations
  - As described in the previous section
- Peace Operations/Neutralize Combatants
  - Begin air and space operations over a country within 24 hours
- Global Awareness
  - Provide detailed data to a country on a significant activity such as movement of the president within one hour of its happening
- Show of Force
  - Deploy a force, 6 to 30 aircraft, to a trouble spot within 24 hours and begin presence operations, flying sorties, within 36 hours
- Humanitarian Relief
  - Demonstrate precision airlift/airdrop of relief supplies within 24 hours to a small undeveloped country

4.4.7 Battlelab Conclusions

The keys to the success of the Battlelabs are (1) capable people willing to challenge the “old” way of doing things, (2) common ownership of the labs at the highest level of the Air Force, (3) access to senior Air Force leaders to capture their support and imaginations and to preclude layers of bureaucy from stifling the innovations and agile capability fielding, (4) funding to accomplish tests and validation of concepts, and (5) a rigorous methodology that provides not only an evaluation of the concept but also the basis for future advocacy of the concept inside and outside the Air Force.

To realize the potential of Aerospace Expeditionary Forces, the Air Force needs to plan for a balanced force that can quickly generate AEFs to meet the demands of a wide range of missions. The Air Force Battlelabs in general and the AEF Battlelab in particular can play a major role in creating such a balanced force.

4.5 Training

4.5.1 Overview

The Operational Context Panel examined training issues for each AEF study area to identify critical issues and promising approaches/technologies. Training includes instruction, which focuses on new knowledge; practice, which is the process of translating knowledge into skills; and rehearsal, which focuses on real-world practice of the operational scenarios soon to be executed.

AEF missions dictate unique operations training requirements. Geographical separation of organizations prior to deployment implies a need for distributed training to allow crews to learn in advance how to coordinate with their supporting forces and functions. Some training functions may have to deploy with the AEF, e.g., mission planning, intelligence, targeting, and electronic warfare/suppression of enemy air defenses (EW/SEAD) planning and employment. AEF missions are likely to have to provide their own capabilities in these areas.

The lack of existing Operations Plans will create the need for C^2 training focused on real-time integration of plan modules. The distributed nature of organizations also will create unique C^2 training needs. En route mission planning dictates capabilities for in-the-cockpit rehearsals to complement predeployment instruction and practice. This will require crews to use normal aircraft cockpit displays — for both flight and systems — as planning and rehearsal tools.

The lack of existing plans also will result in logistics planning being performed by the deploying organization and tailored using plan modules. Operations with minimal maintenance (e.g., flights servicing, no scheduled maintenance, and minimum flight-essential repair) imply important changes for training. To support a wide variety of deployed systems, training also should consider personnel and career policies.

AEF missions present considerable challenges for force protection because of the likely lack of infrastructure for forces inherently on the perimeter. There is a need for training — before and during deployment — to ensure that deployed forces can meet their own protection needs. Cross-training will be needed to assure acceptable levels of necessary skills, e.g., training at least one member of each deployable air and ground crew in chemical, biological, and laser protection.

4.5.2 Meeting the AEF Training Needs

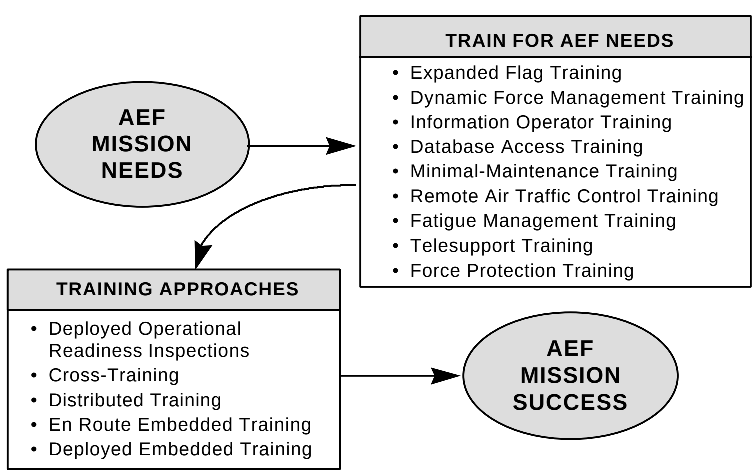


Figure E-27. *Air Force Training Needs to Reflect AEF Operations*

4.5.2.1 Overriding Training Needs

AEF missions will impose a variety of new demands. Thus, an overriding issue concerns the substantial risk that current training will leave the Air Force unprepared. For example, AEF missions will routinely use reachback communications during daily operations and must be trained to operate in this manner. As another example, AEF missions often will be conducted as joint/coalition operations. Training should reflect these conditions and be harmonized with the appropriate joint/coalition organizations. Air Force training should be systematically assessed, at all levels, to ensure that people "train as they plan to fight" for AEF missions.

4.5.2.2 Specific AEF Training Needs

Flag training exercises currently are oriented solely toward massive force-on-force missions. This narrow focus will leave people ill prepared for the wide spectrum of AEF missions, e.g., global awareness. Flag exercises should reflect all AEF scenarios, with scenarios and instructions changed accordingly to enable practice of AEF missions.

AEF mission characteristics often preclude having off-the-shelf operations plans. Response time requirements of AEF missions will preclude planning before execution. These two factors dictate dynamic force management. Training should include parallel planning and execution, including instruction and practice in use of the relevant information tools and decision processes.

Information may be a weapon in future operations. Multiple career fields relate to information, but a "big picture" approach to information as a warfighting tool is missing. Communications, intelligence, weapons controller, and ATC career fields should be merged into an "information operator" career field, with training designed accordingly.

AEF missions will require rapid access to a wide range of DoD, other Government, and commercial databases. Training in the use of standard tools for transparent access and utilization of the National Imagery and Mapping Agency (NIMA), the National Security Agency (NSA), and other Government and commercial databases should be developed and used.

AEF missions may be premised on minimal maintenance (i.e., flights servicing, no scheduled maintenance, and minimum flight-essential repair). Maintenance personnel should be trained to perform in this environment, including training to assess usability of degraded systems.

AEF missions will require remote ATC operations. Training should be developed to support this capability.

AEF missions will require people to work for long periods of time, in part to meet the tight response requirements and in part because of lean staffing. Training in fatigue management is required, both for countermeasures and for the ability to recognize unacceptable performance degradation.

The smaller AEF footprint depends on reachback communications for needs such as diagnostics, repair, supply, and telemedicine. The Air Force should develop instructions and practices for working with these "telesupport" systems, including use of the communications functions underlying these systems.

Force protection capabilities will be limited during many AEF missions, and personnel will have to compensate for this lack. The Air Force should routinely conduct predeployment training of air and ground personnel in self-protection, including use of chemical and biological gear, laser protection, and small arms, with at least one member of each air and ground crew trained to be a resource person in these areas.

4.5.2.3 Training Approaches/Technologies

The training needs just outlined can be met using several training approaches/technologies. While some of these approaches/technologies are readily available, the content needed to use them for effective training may require substantial research and development. In particular, all of these training approaches/technologies should include mechanisms for measurement, feedback, and adaptation of training to trainees' performance as well as to their individual characteristics.

AEF organizations will be much leaner than traditional Air Force organizations and many specialties will not be available, e.g., personnel with specialization in various aspects of force protection. Increase the breadth of training and the use of cross-training to ensure that required skill mixes are available, including provision of refresher training and reachback for data unavailable at the point of deployment.

AEF organizations will lack traditional training infrastructure (study materials, training systems, etc.) both en route and during deployment, and in some cases prior to deployment. Intelligent computer-aided instruction (ICAI) should be used to supplement training of C^2, air, and ground personnel throughout Air Force training programs.

AEF organizations will be assembled from many standing organizations. Consequently, AEF air and ground teams may not have had opportunities to develop team skills. Distributed training technologies that can be employed to provide practice and rehearsal of mission planning and operations both before and during AEF deployments should be developed and used.

A large proportion of the time available for planning and preparing for AEF missions will be en route. While some of this time may be used for sleep, much of the time could profitably be used for training. Embedded training technologies (e.g., simulation and intelligent computer-aided instruction) to be used to provide en route training for C^2, air, and ground personnel should be developed and used.

Proficiency tends to degrade during deployment because of the lack of the practice components of training. In addition, promotions of enlisted personnel may be at risk because the personnel are not prepared for tests. Embedded training technologies (e.g., simulation and ICAI) that can be used to provide ongoing training both before and during deployment for C^2, air, and ground personnel should be developed and used.

Annex 1 to Appendix E

A Précis of Recent Global Trends

Proliferation

One of the most lethal threats facing the country in the current environment is that of WMD, including ballistic and cruise missiles.

Table A-1. *Iraqi Missiles in Design or Research and Development (R&D) Before Operation Desert Storm*[15]

Al Fahd 300	Intended range of 300 kilometers (km). Based on coverting the Russian SA-2 SAM into a ballistic missile. Abandoned in R&D.
Al Fahd 500	Indended range of 500 km. A mock-up for a disinformation campaign was displayed at the 1989 Baghdad Arms Exposition. Never reached the design phase.
Al Abbas	Claimed range of 950 km. Longer in length and carried a lighter payload than the Al Husayn. Abandoned during R&D.
Badr 2000	Indended range 750–1,000 km. Solid-propellant, two-stage. Based on Argentine Condor missile. Facilities constructed to support missile production. Under R&D.
Tammouz I	Claimed range of 2,000 km. Based on SCUD technology with SA-2 SAM sustainer for second stage. In design stage, but not developed further for R&D.
Al Abid	A three-stage space launch vehicle. First stage consisted of five Al Abbas airframes. Test launch of first stage in December 1989.

Regional Conflicts

As shown in Figure A-1, conflicts are in decline worldwide as those that emerged with the breakup of the Soviet Union and the Balkans are resolved.

Contrary to the conventional wisdom, the post–Cold War world has not seen a particularly striking outbreak of ethnic and other conflicts. In fact, the number of armed conflicts worldwide has declined since its peak of 55 in 1992, and the number of "major armed conflicts" — involving the battle-related deaths of at least 1,000 people during the entire conflict — have been in decline since 1989.

[15]Office of the Secretary of Defense, April 1996.

While the reasons for the contrary belief are understandable — violence in what was formerly a relatively stable Europe came as quite a shock — the fact remains that conflict has been in decline, and not in ascendancy.

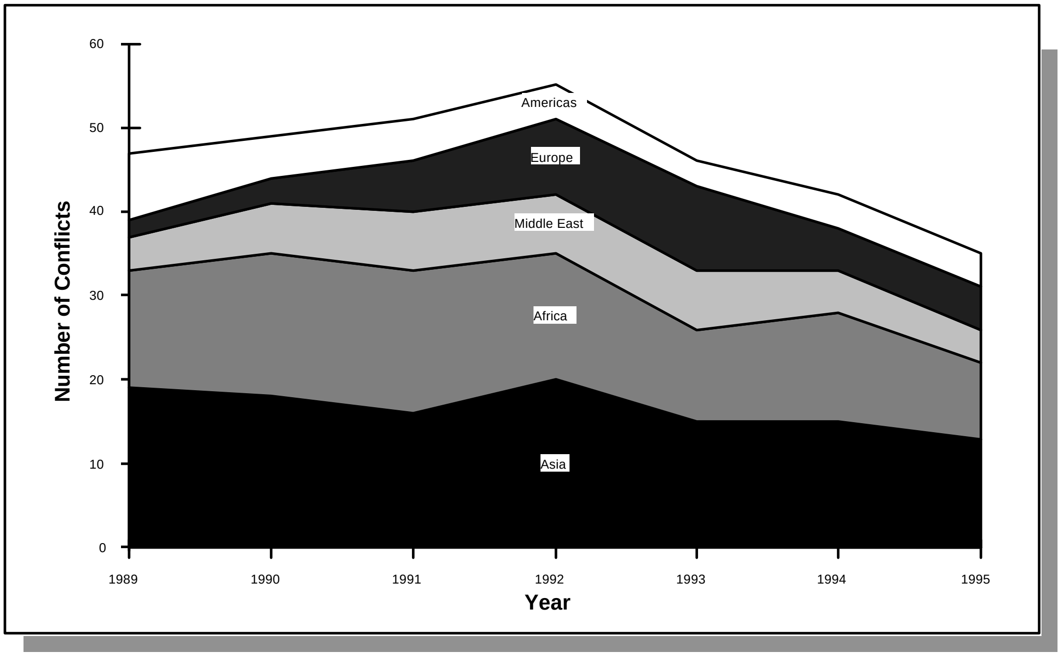


Figure A-1. *Regional Conflicts, 1989–1995*

Should this trend continue, one of the potential drivers of U.S. military operations — and AEF employments — may diminish in importance.

Military Expenditures

As Figure A-2 shows, military expenditures worldwide also are declining, with the possible exception of those in Asia.

Just as war has been in decline, so too have preparations for war in most parts of the world, including the volatile Middle East. In fact, between 1984 and 1994, military expenditures as a percentage of GNP have declined —

- From 5.5 to 3.0 percent for the world as a whole, from 5.4 to 3.1 percent for the developed world, and from 6.1 to 2.6 percent for the developing world
- From 6.6 to 3.2 percent for Europe, from 2.5 to 1.8 percent for East Asia, and from 17.9 to 7.7 percent for the Middle East
- From 5.8 to 2.4 percent for China
- From 16.3 to 12.4 percent from 1992 to 1994 for Russia

Should this trend continue, one implication is that in most parts of the world military capital stocks will erode and the capabilities of potential adversaries will decline. The United States' combat edge can be expected to widen, especially in the more expensive technologies such as advanced combat aircraft.

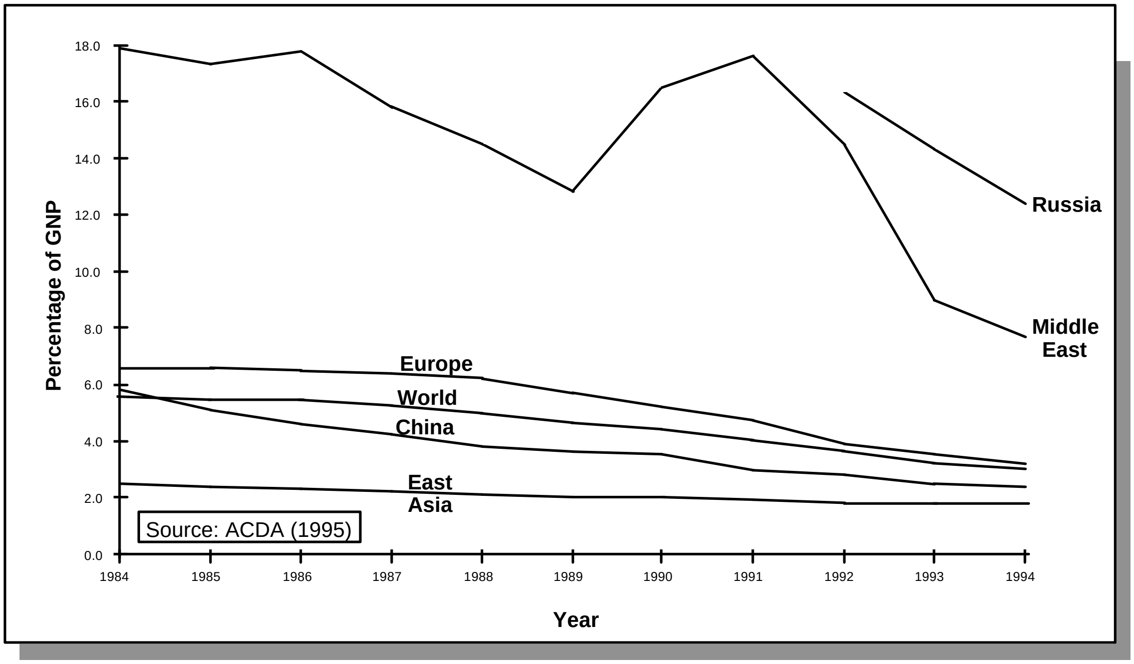


Figure A-2. *Military Expenditures as a Percentage of the GNP*

Another implication is that, with few willing to accept the risks of challenging U.S. military prowess, noncombat operations such as humanitarian relief operations may become an increasingly large share of the Air Force's day-to-day operations.

Finally, among those who do aspire to challenge the United States, there will be a preference for pursuing asymmetric strategies that seek to exploit the United States' lower tolerance for costs, casualties, or delayed success.

Terrorism

The level of terrorism abroad has declined since its peak in 1987, as shown in Figure A-3. According to data from the Department of State's (DoS's) *Patterns of Global Terrorism, 1996*, the number of acts of international terrorism declined from 665 in 1987 to 296 in 1996, a 25-year low. These incidents have become more lethal, however. The number of casualties reached a near-record 311 dead and 2,652 wounded. By contrast, there were 314 fatalities in 1994 and 165 in 1995. In addition, 132 terrorist acts were directed against Americans in 1996, a decline from the peak of 187 in 1987, but an increase over the past 2 years: there were 66 attacks against Americans in 1994 and 99 in 1995. All told, 24 Americans died and 250 were wounded in terrorist incidents in 1996, an increase from the six Americans killed in 1994 and the 10 killed in 1995. DoS has identified Iran as the chief state sponsor of terrorism.

There are two principal implications for the Air Force. First, because terrorism sponsors will seek plausible deniability, there are likely to be few instances in which the sponsoring state will be clearly identified and the Air Force called upon to conduct strike operations. Second, as was seen in the recent bombing in Saudi Arabia, there will be a continued need for close attention to force protection issues, particularly in regions like the Persian Gulf.

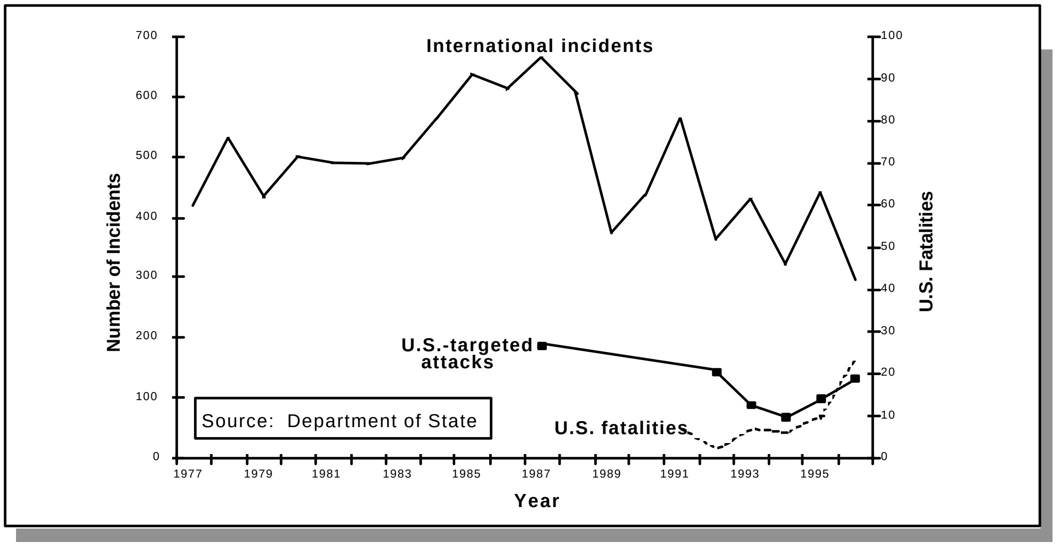


Figure A-3. *Trends in Terrorism*

Disasters

Another driver of Air Force operations is disasters, which frequently lead to humanitarian relief operations.[16] Natural disasters include earthquakes, droughts, famines, floods, high winds (cyclones, hurricanes, and typhoons), landslides, volcano eruptions, avalanches, cold and heat waves, insect infestations, and tsunamis; non-natural disasters include nontechnological accidents (including transport accidents), technological accidents, and fires.

Figure A-4 shows that natural and other disasters fall unevenly on the different countries of the world, but that most of the victims are found in the less developed world, primarily Africa and Asia. There is little doubt that the poverty of many of these countries, leading to poor construction techniques and inadequate infrastructure, contributes to the size of the affected populations. The implication is that the most dangerous disasters are associated with particular regions and therefore are somewhat predictable. AEFs can expect to be called upon to render humanitarian and disaster relief most often in these regions.

Furthermore, although we cannot predict disasters, the overall pattern or probability of certain types in certain regions is relatively consistent and, therefore, somewhat predictable. Deaths due to natural disasters in Africa are due primarily to the droughts and famines that periodically have occurred in such places as Biafra, Ethiopia, Somalia, and the Sudan. Deaths in South Asia, on the other hand, are due primarily to typhoons and hurricanes, which have created massive losses of life in such places as Bangladesh and India, and to the resulting food shortages, cholera epidemics, and other consequences.

In short, although the Air Force may not know in advance precisely when it will have to respond to a certain type of disaster, it has strong evidence that it will, over time, be responding to specific types of disasters in particular parts of the world. AEFs may need to be configured for response to these types of disasters.

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[16] Data are from the International Federation of Red Cross and Red Crescent Societies' annual *World Disaster Report.*

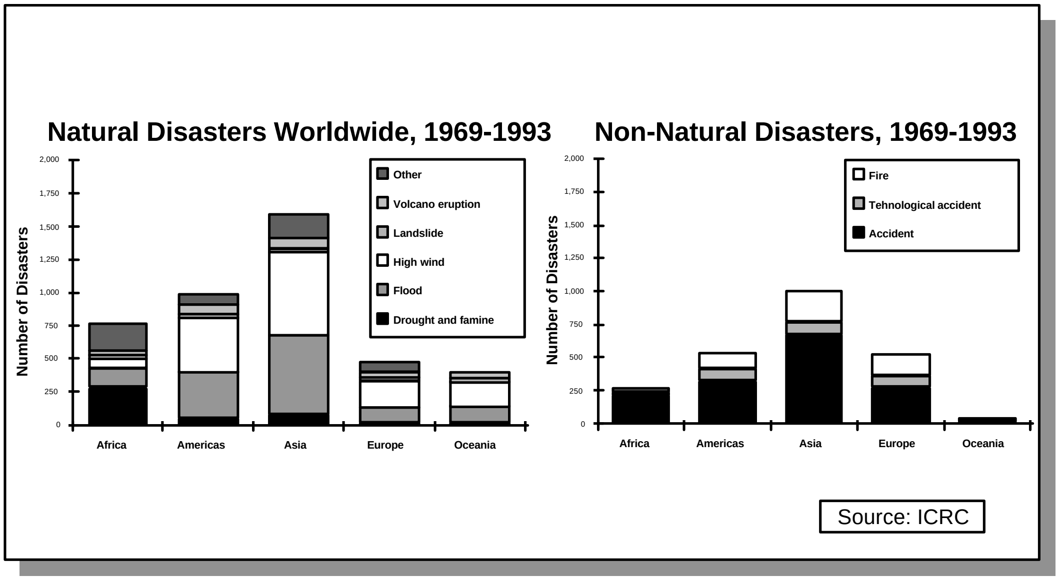

Figure A-4. *Disasters by Region*

Refugees

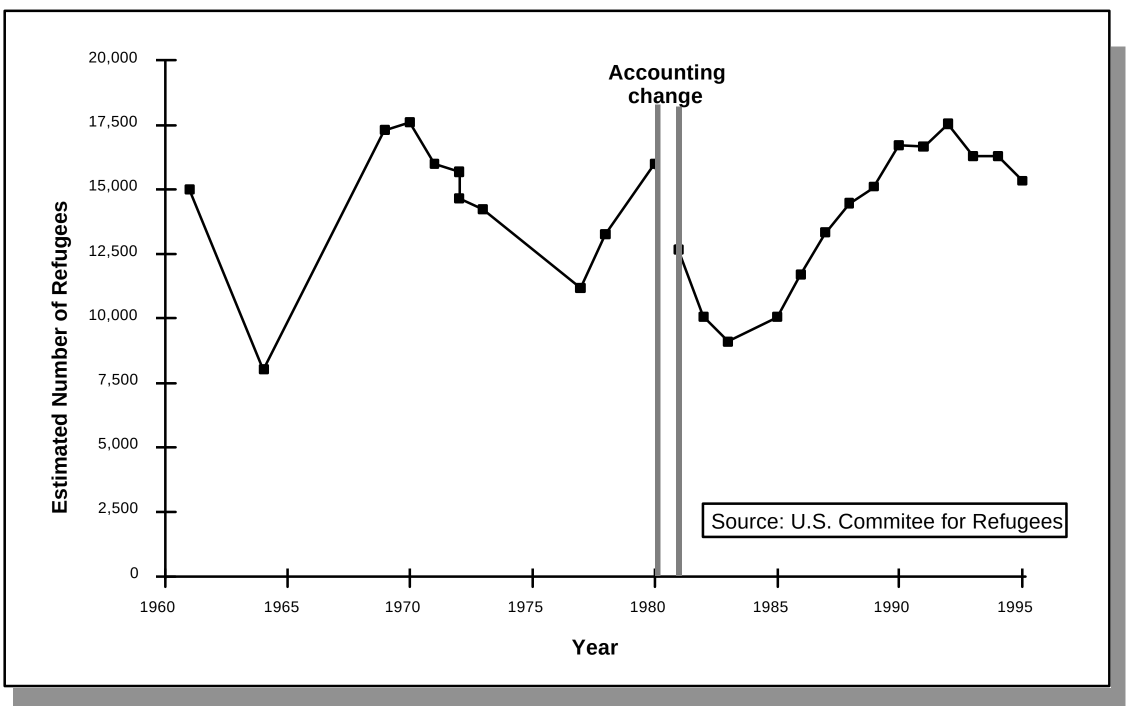

Figure A-5. *Refugees*

One perennial problem in the contemporary world is the plight of refugees, which has driven many humanitarian relief and assistance operations. As shown in Figure A-5, the number of refugees appears to be in the decline phase of its cycle.

Refugee movements can be the result of conflicts that drive populations from their homes, of governmental policies, or of disasters. Refugee movements can increase tensions between neighbors and ignite longstanding disputes over borders or over the protection of minorities.

If one were to look only at the data for the past 10 years, one would think that the number of refugees was climbing to unprecedented levels, but, as the figure clearly shows, the number of refugees worldwide has waxed and waned over time, with peaks roughly every 10 years (corresponding to new conflicts and emerging nations) and troughs between. The peaks are in part due to the ebb and flow of intrastate and interstate conflicts, and partly due to unpredictable disasters. Barring the eruption of major war or disaster, the figure suggests that the number of refugees worldwide may decline further, as disputes that emerged at the end of the Cold War are resolved and other longstanding disputes (e.g., the conflict in the Balkans and the dispute over Palestinian self-rule) creep toward a resolution.

Urbanization

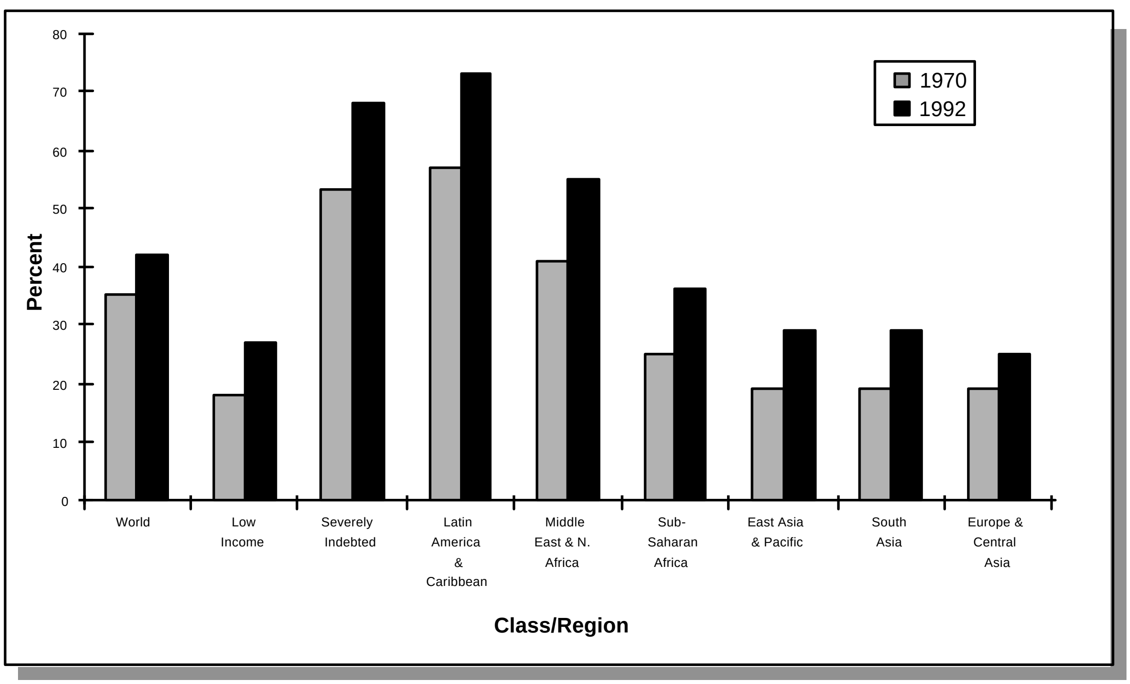

Figure A-6. *Urbanization, 1970 and 1992*

Figure A-6 shows the increase in urbanization for different classes and regions of the world. Although the number of wars and disasters is unpredictable, it seems likely that the combination of high population growth and growing density and urbanization in many of the regions most often afflicted by disasters, coupled with economic growth rates that fall short of being able to dramatically improve infrastructure, housing, and other features, will create larger disasters in the future. As the density and level of urbanization in many of these countries increase over time while building codes fail to improve, the Air

Force should expect the size of affected populations to grow. This means that the scale and scope of Air Force humanitarian operations, with the need for food, medical care, potable water, and other assistance, may increase for some regions.

Democracy

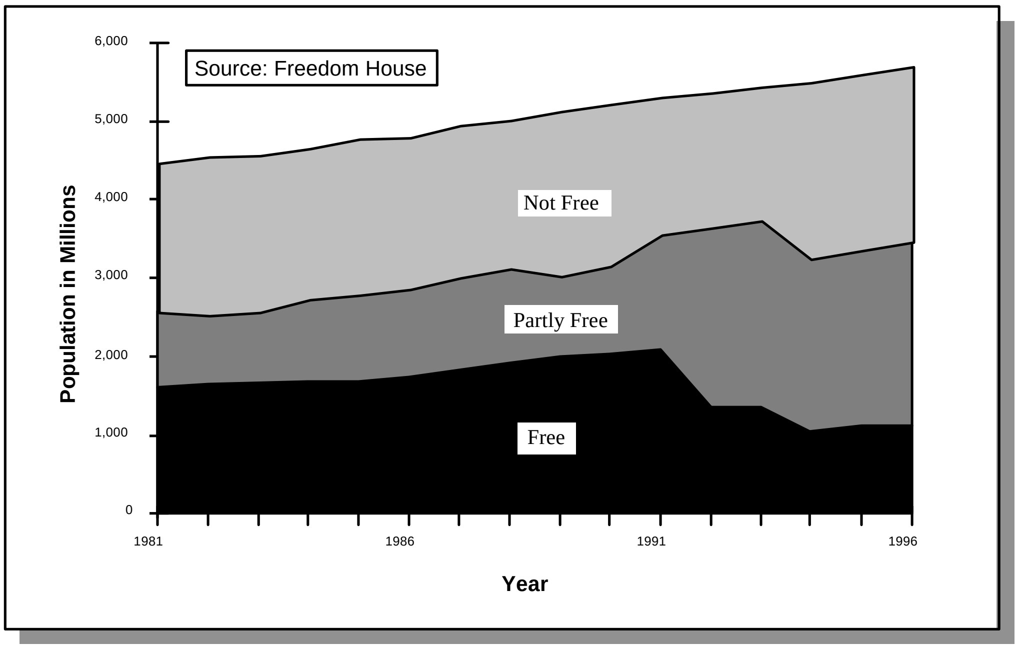

Figure A-7. *Population by Level of Freedom*

Market economies continue to advance, while democracy spreads more slowly and unsurely, based largely on indigenous factors. Figure A-7 presents data on the size of the world's population experiencing various levels of freedom, based upon the most commonly used source for such data — Freedom House, a human rights organization that annually categorizes countries in terms of the level of freedom enjoyed by their citizens.[17]

The data suggest that we can expect the development and spread of democracy in the future to be uneven at best. Since 1991, the number of the world's people living in countries that exhibit the most desirable attributes of Western-style democracy actually has declined, in large measure due to India's increased restrictions on press and personal freedoms.[18] The spread of democracy will continue to be fostered primarily by local political and economic factors, and less by external interventions aimed at promoting democracy. Although it is fashionable to note that democracies don't fight democracies, states in transition to democracy show a higher propensity for war than stable democracies. Put another way, the movement to democracy can be a bumpy and dangerous one.

[17] Freedom House reaches a summary judgment based upon a rather exhaustive list of indicators regarding elections, press freedom, and the like. It generally is considered to be the most consistent and reliable indicator of how freedom and democracy are faring.

[18] Most recently (in July 1997), the coup in Cambodia led by Hun Sen represented the loss of a country that appeared to have been making good progress toward democracy.

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Annex 2 to Appendix E

Acronyms and Abbreviations

ACC	Air Combat Command
AEF	Aerospace Expeditionary Force
ANG	Air National Guard
ATC	Air Traffic Control
AWACS	Airborne Warning and Control System
C^2	Command and Control
C^4ISR	Command, Control, Communications, and Computers, Intelligence, Surveillance, and Reconnaissance
CINC	Commander–in–Chief
CONOPS	Concept of Operations
CONUS	Continental United States
CW	Chemical Weapons
DFI	Defense Forecasts International
DoS	Department of State
EW	Electronic Warfare
GNP	Gross National Product
IADS	Integrated Air Defense Systems
ICAI	Intelligent Computer-Aided Instruction
km	Kilometer
M&S	Modeling and Simulation
MAP	Mission Area Plans
MOOTW	Military Operations Other Than War
MTW	Major Theater War
NATO	the North Atlantic Treaty Organization
NBC	Nuclear, Biological, and Chemical
NCA	National Command Authority
NIMA	National Imagery and Mapping Agency
NSA	National Security Agency
OPLAN	Operations Plan
PGM	Precision-Guided Munitions
POM	Program Objective Memorandum
R&D	Research and Development
SAM	Surface-to-Air Missile
SEAD	Suppression of Enemy Air Defenses
SRBM	Short-Range Ballistic Missile
USAFA	U.S. Air Force Academy
WMD	Weapons of Mass Destruction

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Appendix F

Command, Control, and Information (C^2I)

1.0 Overview

This appendix elaborates upon and further develops the concepts and recommendations addressed in Section 3.2 of Volume 1 of this report. This appendix should be read in tandem with Section 3.2 in order to fully understand the challenges of and potential opportunities for Command, Control, and Information in Aerospace Expeditionary Force (AEF) operations.

1.1 C^2I Panel Membership

General (Ret) James P. McCarthy, Chair
Olin Professor of National Security
United States Air Force Academy

Maj Gen (Ret) Robert A. Rosenberg, Deputy Chair
Executive Vice President and General Manager, Washington Operations
SAIC

Dr. Curtis R. Carlson
Executive Vice President, Interactive Systems Division
David Sarnoff Research Center

Mr. Charles L. Gandy
Private Consultant

Dr. Barry M. Leiner
Vice President
Microelectronics and Computer Technology Corporation

Dr. Donald L. Nielson
Director, Computing and Engineering Sciences Division
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Mr. Vincent Vitto
President and Chief Executive Officer
Charles Stark Draper Laboratory

Lt Gen (Ret) John Fairfield, USAF
Vice President, Air Force Programs
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Advisor: Colonel Bernhard S. Hoenle, AFCIC
Executive Officer: Major James F. Geurts, SAF/AQID
Technical Writer: Capt Anthony J. DelGenis, USAFA

1.2 C²I Panel Charter

The C²I Panel was charged with the following tasks:

- Examine ways to modify and strengthen current Air Force command and control practices to increase the effectiveness of future AEF deployments.
- Describe the value of C²I across the range of AEF operations, from combat operations to humanitarian relief.
- Evaluate global connectivity technologies essential for successful AEF operations.
- Address global awareness capability and the best means for achieving this critical AEF enabler.
- Study information management concepts that will allow observation and enable meaningful analysis of myriad simultaneous activities in the area of interest in real-time or near real-time.
- Emphasize system assurance principles that will allow AEF commanders maximum flexibility in their use of technology, while denying potential enemies the ability to breach our systems or deny their effectiveness.
- Underscore the importance of geospatial position, navigation, and timing services for AEF operations, especially those involving the planned or potential use of Air Force aircraft.
- Recommend new command and control concepts that should be pursued in order to maximize the effectiveness of AEF operations.
- Recommend new operational concepts that are enabled by information technology.

2.0 Critical Enablers to Robust C²I in Future AEFs

What a New C²I Offers an AEF

The AEF as defined in this study requires an expanded vision that embraces the totality of commercial and military capabilities to achieve mission success. A set of system-level enablers, developed below, will capitalize on these capabilities and lead to new operational concepts. A distributed Joint Force Air Component Commander (JFACC), implemented as a virtual assemblage of staff, permits only a fraction of that resource to be forward deployed. An ability to observe, plan, and execute far faster than the opposition leaves the enemy in a continual state of surprise. These new system-level enablers make the AEF a powerful new element of joint and combined operations by providing a global capability for battlespace awareness. Other new and valuable operational concepts are enabled. Dynamic air interdiction will replace preplanned missions for interrupting ground lines of communications, and close air support will become an all-weather, anytime aid to ground forces. We also will enjoy the efficiencies of precise location of our resources, which offers bare-base air traffic control (ATC), an ability to adaptively engage the most vital of the in-flight resources, and far more efficient logistics movement. All participants will have a greater common battlespace awareness and thus will be able to act effectively with less detailed tasking. Moreover, the envisioned AEF will be affected by new organizational structures, new systems and technologies, and new operating concepts. New training approaches will allow the AEF to control the operating tempo of the battlespace, preparing the battlespace for operations, and inflicting surprise and shock on the enemy. This will result in faster, more efficient achievement of AEF objectives with fewer casualties. Advances in total global and battlespace awareness will permit C²I capabilities that will lead to new operational concepts and greatly enhance operational effectiveness. These capabilities will permit common, timely, and accurate assessment of the threat. Reachback for distributed C^2 will be enabled; this reachback will permit the forward-deployed footprint to be reduced.

AEF C^2I Enablers

Any military operation with the attributes of an AEF will place significant reliance on C^2I. Rapid response, dynamic en route planning, and accurate battlespace awareness all depend on the presence of timely information, properly disseminated and used. To obtain and use such information, the Air Force, along with its joint and coalition partners, must upgrade both its equipment and procedures. Here, the Panel will address the necessary enablers, specifically those system-level concepts necessary for an information-intensive operation to succeed.

The Air Force can achieve the following required innovations in the next 5 to 10 years: first is the innovation in information technology, dominated by the commercial sector but also from continuing military research and development (R&D). To benefit, the Air Force must aim at assimilation, certainly more so than its prospective enemies do. Second is the likely air superiority the Air Force will have over its adversaries. This advantage will provide freedom in the use of unmanned aerial vehicles (UAVs) to supplement more conventional means of surveillance or communications, both from the military and commercial sector. Third is the comparative strength of U.S. information and intelligence gathering resources, and fourth is the comparative advantage of the U.S. technology base, such as the capability to field new and precise Global Positioning System (GPS)-enabled weapons.

The Air Force must use its own developmental resources to gain military capabilities and practices beyond what the commercial marketplace can provide to everyone else. The two capabilities that form the foundation of AEF operations are the precision and completeness of our battlespace awareness and the ability to move information where and when needed. These are enabled by the following:

- **Global Connectivity.** Any effort that relies on information must clearly have a means to convey it. Every platform that can potentially participate in an AEF must have some means of assured connectivity. This applies to not only Air Force platforms but those of Joint and Coalition forces as well.
- **Information Management.** Extensive information has no value if not properly managed. Systems must not only ease the interaction of staff with machines but also assist and guide the user community in the gathering, processing, and dissemination of information. This need becomes paramount under the time and spatially distributed pressures of an AEF.
- **Battlespace Awareness.** Awareness in this context means a global capability to precisely, comprehensively, and continuously define the battlespace. This includes the location status of both friendly and enemy forces. This database should be interpretable at several levels of abstraction.
- **Geospatial Position, Navigation, and Timing (PNT).** The accuracy already delivered by GPS has whetted the imagination of both users and developers. For example, the present system needs the ability to conduct remote operations with precision while creating high platform and weapon efficiency. This capability will also enable near-term unambiguous fusing of various sources of information.
- **System Assurance.** An operation that relies on the use of information must therefore secure that capability. More specifically, the connectivity grid and precise location must have extremely high availability because the operation depends on them. Additionally, systems must be designed to degrade gracefully. The loss of such detail, however, should not disable all operations. All AEF command support systems must default to a minimal but adequate C^2I functionality.

In addition to the C2I enablers listed above, the Pentagon's recently released list of 17 candidate Advanced Concept Technology Demonstrations (ACTD) for FY 98 leans heavily toward command, control, communications, computers, and intelligence (C4I) capabilities, including such promising programs as C4I for Coalition Warfare, the Joint Continuous Strike Environment, Space-Based Space Surveillance Systems, and Theater Precision Strike Operations. The Air Force leadership can make a strong statement in leveraging the future of AEF deployments by funding promising programs, such as these ACTDs, at a level sufficient for continued development and evolution.

2.1 Global Connectivity

Achieving the concepts of the AEF requires high-bandwidth connectivity to the various elements of the AEF, including forward deployed, en route, and reachback support elements. Today, such requirements range from voice connectivity and relatively low-bandwidth electronic mail to maps and other graphics data. Future capacity requirements will grow significantly, driven by concepts such as real-time imagery, video, and telemedicine. For example, digital high-definition video, which will become common over the next 5 years, requires a bandwidth of at least 18 megabits per second (Mbps).

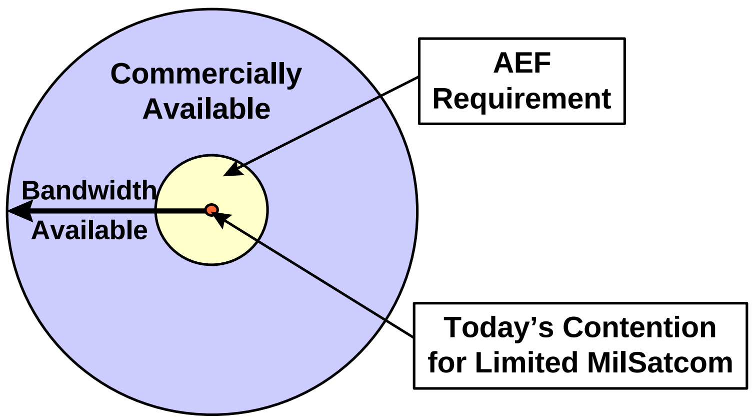
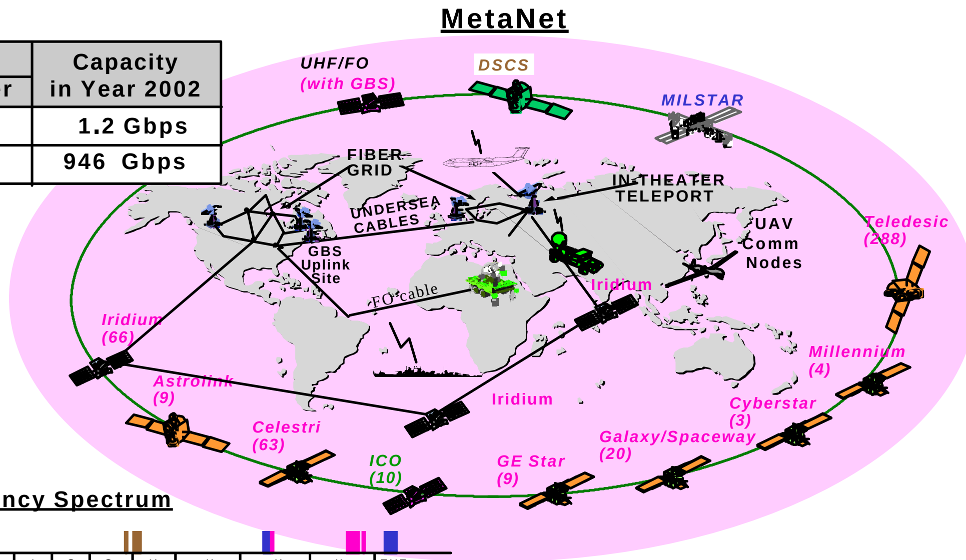


Figure F-1. *Military Satellite Communications Assets Require Augmentation to Meet the Needs of the AEF*

By contrast, current communications to en route aircraft elements typically operate at 4.8 kbps, provided by ultra high frequency (UHF) satellite communications (SATCOM). This capacity does not come close to meeting the operational requirements of even near-term AEF missions. Significant contention for communication resources results, with the highest priority users not being served adequately and lowest priority users not being served at all (see Figure F-1).

Satellites		Capacity
Type	**Number**	**in Year 2002**
Military	31	1.2 Gbps
Commercial	408	946 Gbps



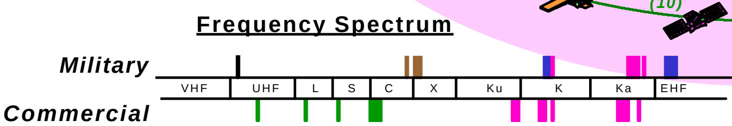


Figure F-2. *Satellite Capacity in 2002*

Commercial systems planned for future deployment will provide bandwidth to the end user of 155 Mbps or more, with a total capacity of satellite systems of about 950 gigabits per second (Gbps) by 2002 (see Figure F-2). Several commercial systems are designed for a local service area. Exploiting all possible communications assets, both military and commercial, can both alleviate the contention for communication resources and provide the diversity required for robust, highly assured global connectivity. The Air Force needs a system approach to permit the integrated use of all available communication assets to satisfy the current and future AEF requirements for global, robust, high-bandwidth connectivity. This will permit the Air Force to take advantage of the vast number of satellites (over 8 systems with over 400 satellites) and their diversity of frequency bands being planned for deployment in the commercial sector. The Panel refers to this integrated system as the MetaNet (see Figure F-3).

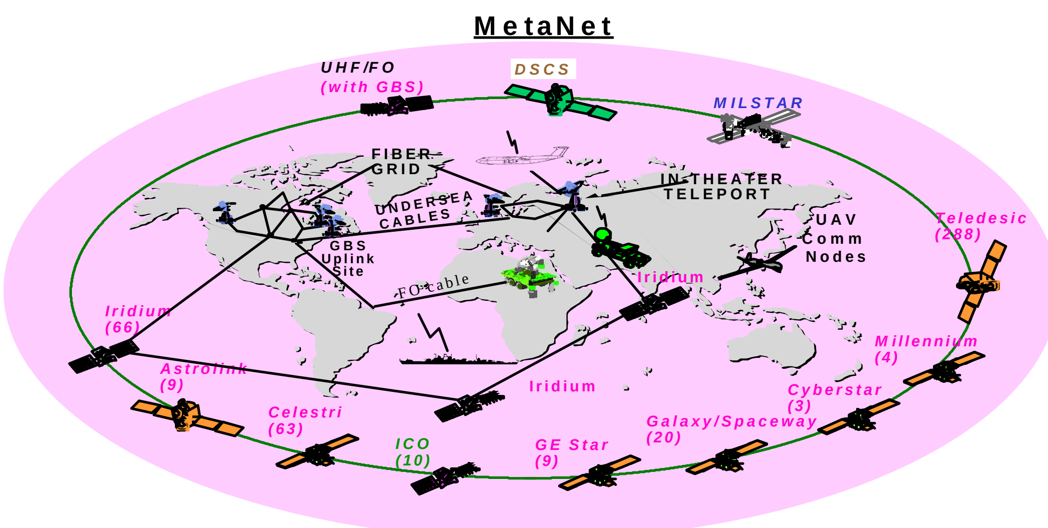


Figure F-3. *The MetaNet*

Table F-1. *Some Planned Commercial Satellite Systems*

System Name	*Company*	*Service Area*	*Satellites*	*Orbital Locations*	*User Data Rates*	*Capacity Per Satellite*	*Deploy-ment Start Year*	*Deploy-ment End Year*	*System Cost (million)*
Astrolink	Lockheed Martin	Worldwide	9	5	16-8,448 kb/s	7.7 Gb/s	2000	2003	$3,994
Galaxy/ Spaceway	Hughes Comm	Worldwide	20	15	16-6,000 kb/s	4.4Gb/s	1999	2005	$5,171
Voicespan	AT&T	Worldwide	12+4 spares	7	32-1,544 kb/s	5.9 Gb/s	2000	2002	$4,300
Cyberstar	Loral, Aerospace	N. America, Europe, Asia	3+1 spare	3	384-3,088 kb/s	4.9 Gb/s	2000	2003	$1,050
GE Star	GE Americom	Worldwide	9	5	384 kb/s (up to 40 Mb/s?)	1.8 Gb/s	2000	2005	$2,600
Millen-nium	Comm Inc. (Motorola)	Much of Western Hemisphere including all of U.S.	4	4	384 kb/s–51.84 Mb/s (OC-1)	7.5 Gb/s	1998	2001	$2,375
Teledesic	Teledesic (Boeing Prime)	Worldwide	288+36 spares	12 planes	16-2,048 kb/s and 155-1,200 Mb/s	2 Gb/s	2001	2002	$9,000
Celestri	Motorola	Worldwide	63+7 spares	7 planes	64-10,000 kb/s and 52-155 Mb/s	1.3 Gb/s	2001 pending FCC author-ization	2002 pending FCC author-ization	$12,900

We should not conclude from this that *all* future military communications requirements can be satisfied solely through the use of commercial communication systems. Unique military requirements, such as antijam, will continue to drive the development and use of military systems. Exploiting all possible communications assets, both military and commercial (see Table F-1), can alleviate the contention for communication resources and provide the diversity required for robust, highly assured global connectivity. What is needed is a system approach to permit the integrated use of all available communication assets to satisfy the current and future AEF requirements. This will permit the Air Force to take advantage of the vast number of satellites and their diversity of frequency bands being planned for deployment in the commercial sector. We refer to this integrated system as the “MetaNet.” Although the concept is related to and can build on such existing programs and technologies as Global Grid and Internet, we choose to use a different term to emphasize that the concept is not necessarily tied to existing programs and requires extensions to current technology.

Such an integrated system will provide more than just increased bandwidth and connectivity. It will also provide a significant increase in connectivity strength through the resulting redundancy and diversity. Taking advantage of the multiplicity of commercial systems in a flexible manner allows communication through any of the possible communication paths. Furthermore, the increased number of frequency bands of the commercial systems provides increased frequency diversity, thereby mitigating the effects of jamming.

The SAB's October 1996 report on *Vision of Aerospace Command and Control for the 21st Century* recommended moving toward a Global Grid vision using a wide variety of underlying communications technologies. It described a set of actions to move toward this vision, most notably exploiting three planned (but to this date, not carried out) ACTDs: SPEAKeasy, Global Hawk Communications Relay (now referred to as the Airborne Communications Node), and Information Grid. We reaffirm these recommendations, particularly in the context of an AEF, where MetaNet is critical to the success of the AEF missions.

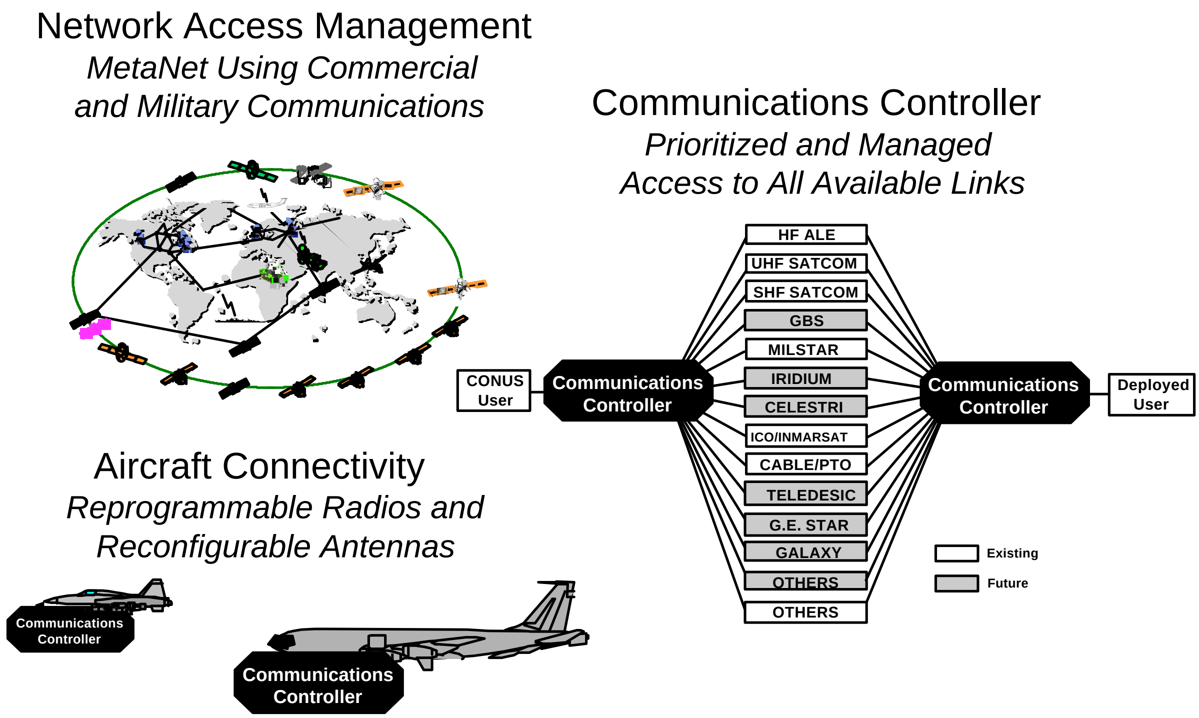


Figure F-4. *Accessing Robust AEF Global Connectivity*

Achieving the MetaNet will require a long-term vision coupled with a sound architecture and strategy for moving from current capabilities toward that vision. Three specific areas of development are recommended (see Figure F-4):

- **Network access management concepts** consistent with Global Grid and the Global Command and Control System (GCCS) that permit exploitation of all available communications assets
- A robust and agile **communications controller** deployable on ground and in aircraft that permits access to all available communications links
- **Aircraft connectivity to diverse communications**, including DoD and commercial services, requiring minimal equipment through the use of programmable radios and reconfigurable antenna suites.

2.1.1 Network Access Management Concepts

The AEF concept of operations demands an easily and rapidly deployable communications capability providing high-bandwidth connectivity anywhere, anytime, and anyplace. Accomplishing this in a cost-effective way requires a set of network management concepts that permits access to all available commercial, military, and Federal communication assets.

The MetaNet concept uses available communications as links in an overall network. Network access management technology will provide functions such as adaptability to available communications, self-healing networks, quality-of-service management, priority, preemption, and security.

The technical architecture must support integration and use of available commercial products and services. Furthermore, the Air Force must adopt a procurement strategy so that commercial and standard military systems are used to the maximum extent possible and AEF-specific systems only as required. For example, commercial off-the-shelf (COTS) communications in satellite networks can facilitate deployment into bare-base environments. The Air Force cannot afford to preposition adequate dedicated communication assets at all possible locations. It must exploit the commercial infosphere to provide needed connectivity, both on initial deployment and in sustainment.

However, the military must guard against becoming just another “dial-up” customer on commercial systems. In urgent situations, the AEF must have leased or at least reserved capability. The communications controller function mentioned earlier must provide the network access management to use such reserved capacity along with the backup military communications to provide assured connectivity. The AEF cannot accept a concept in which an F-16 might encounter a busy signal!

In addition, working with commercial vendors can help those vendors understand the requirements of a large and reliable customer. This will help them respond to these requirements in a way that directly supports the AEF need and allows the Air Force to adapt the COTS system to the need. The Defense Advanced Research Projects Agency (DARPA) is exploring concepts related to the MetaNet in their “Warfighter Internet” program. Furthermore, the DoD is pursuing related concepts through the Global Grid. The Air Force should jointly develop its needed MetaNet architecture through partnerships with DARPA and Defense Information Support Activity (DISA). This will ensure that Air Force investments in MetaNet applications will be compatible with and support joint and combined operations, while leveraging investments as much as possible. In particular, the Air Force should ensure that the Warfighter Internet program addresses the critical requirements of the Air Force AEF to use available communication assets, perform reliably in the highly dynamic Air Force environment, and support the range of required communications from data to voice to video.

2.1.2 Communications Controller

Achieving the MetaNet concept requires development of a communications controller that interfaces to and integrates the variety of communication assets. A communications controller will provide the functions needed to fully use all available communications resources, including the following:

- Interface to the communication asset
- Selection of the best communication asset and routing over the selected system
- Multiplexing of data on and off the communication assets
- Management of priorities for routing of information
- Security against access denial
- Minimal cost routing.

A communications controller allows use of all available assets (e.g., Iridium, GlobalStar, UHF SATCOM, Link 16, Global Broadcast Service [GBS], fiber optics, and cellular communications) to provide the robust connectivity needed for AEF operations, whether for aircraft en route or forward-deployed units.

A processor (see Figure F-5) provides the central functions of network management, priority and control of communications access, routing and switching, diversity management, etc. Each connected communication system has an associated interface and buffer controlled by the processor. These interfaces could be unique cards associated with each communication system, a general-purpose interface card, or an interface through a programmable radio providing flexible interface to a variety of communications links. An interface to the users and information systems provides the input and output of the information streams, whether data, imagery, voice, or video.

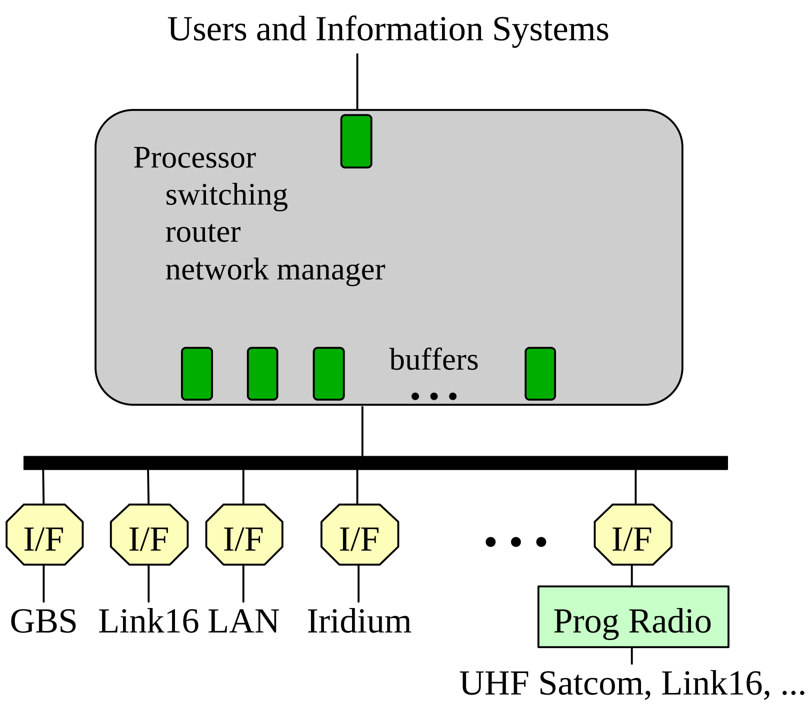


Figure F-5. *User and Information Systems*

There is a need to guard against the military's becoming just another "dial-up" customer on commercial systems. In urgent situations, the Air Force must have leased or at least reserved capability. The communications controller must provide the network access management to use such reserved capacity along with the backup military communications to provide assured connectivity.

2.1.3 Aircraft Connectivity

Critical to the AEF concept is high-bandwidth, two-way assured communications to the warfighter location, including en route aircraft. The communications controller described above will manage, prioritize, and use available communication assets. In addition, the aircraft must have onboard a rich set of communication assets, including satellite, ground, and air links, and the ability to use commercial as well as military communications.

To provide the required flexibility of communications, a "plug and play" architecture will simplify installation of communication assets consistent with the MetaNet. This architecture has three elements:

- A reconfigurable set of antenna assets will allow the required flexibility in installing radios in various frequency bands.
- Reprogrammable radios, such as SPEAKeasy, will provide flexibility in the use of radio equipment in accessing the various communications links. These reprogrammable radios can increase flexibility in ground communications as well. The Air Force should continue to invest in SPEAKeasy-type systems such as the Joint Tactical Radio and extensions to provide this capability.
- The AEF requires increased range of connectivity because of its need for flexibility in deployed locations. UAVs can provide a critical range extension function for connectivity to both ground and air. DARPA is exploring the concept of a UAV communications node, marrying SPEAKeasy-type programmable radios with advanced UAV platforms. The Air Force should continue to partner with DARPA in exploring this concept and adapting it specifically to the AEF requirement for global connectivity.

Finally, the Air Force must develop the communications access controller described above to provide for the integration of all connected communications assets.

The MetaNet concept of flexible communications requires the ability to use whatever communications assets are operable in the operations area. Since these assets will be operating in a variety of frequency bands with a variety of bandwidths, a flexible approach to antennas needs to be adopted. Efforts are already underway to develop small, easily deployed antennas, both onboard and on the ground. These efforts should be supported and directed toward such a reconfigurable and managed set of antenna assets.

Similarly, the need to provide connectivity through a variety of communications assets without requiring unique equipment for each communications link demands a flexible radio approach. The SPEAKeasy program is targeted at such capabilities in the 2-megahertz (MHz)-2-gigahertz (GHz) frequency bands. SPEAKeasy-like radios, with their ability to operate over a variety of frequencies, bands, and modulation types, would allow the needed flexibility. Such reprogrammable radios can then be used to provide increased flexibility in ground communications as well. The Air Force should continue to invest in SPEAKeasy and related technologies to provide this capability.

2.1.4 Assurance of Connectivity (see Figure F-6)

The MetaNet approach of using all available communication assets provides alternate routing across the diverse communication links and paths. Thus, failure of a single communication system does not cause failure of connectivity. The communications access controller would simply select an alternate link transparent to the user. This concept has been proven in multiple systems, including the ARPANET and Internet, and is directly applicable to the Air Force assurance requirement.

Moving in these directions will provide the robust, high-bandwidth, global connectivity required for future AEF operations. By using the high capacity, redundancy, and diversity provided by the commercial sector in an integrated manner, the Air Force can satisfy the AEF needs in a cost-effective manner.

Availability of high-bandwidth commercial connectivity provides a second option for increasing the robustness and antijam capability. Coding at the interface to the communication link can provide increased processing gain at the expense of bandwidth. For example, coding of a 1-Mbps data stream onto a 1-Gbps channel can yield an increase in processing gain of 30 decibel (dB). This coding can be done adaptively in response to the changing environment and threat. Last but not least, military highly robust antijam links can be used as an integrated part of the MetaNet and would be selected automatically by the communications access controller based on threat environment and priority of requirement.

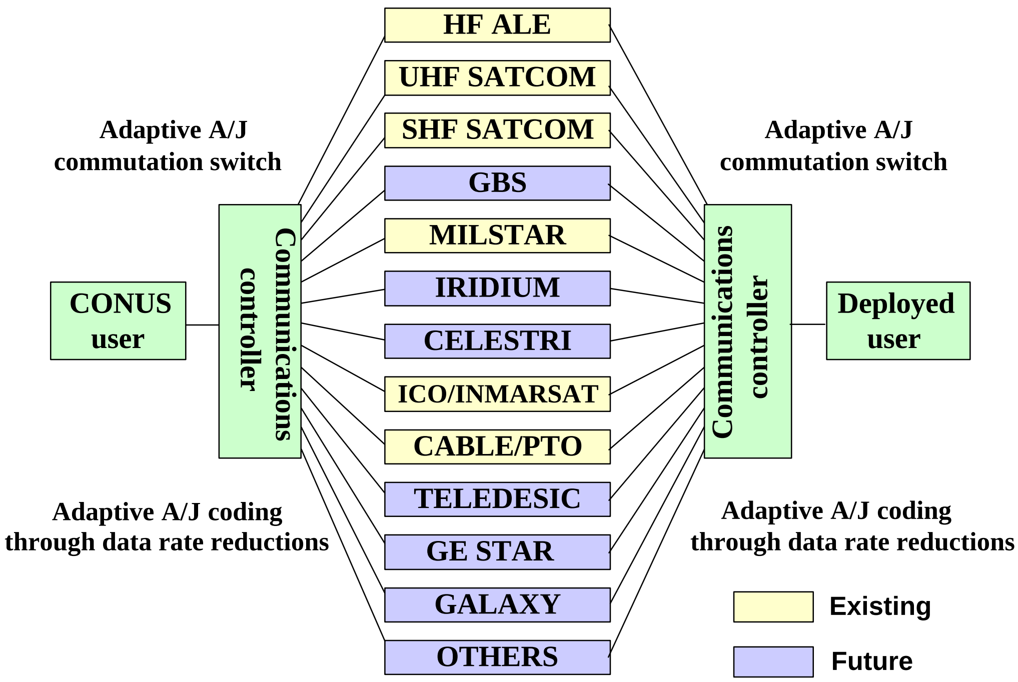


Figure F-6. *Responses to Communications Jamming*

2.2 AEF Information Management

Information and its effective use are fundamental to the success of the AEF described in this report. In the past there have been very deep and artificial distinctions between various forms of needed information; for example, most intelligence and its collection have never been directly controlled by operational forces. The pace of an AEF cannot afford such distinctions. To conduct its missions an AEF must be totally integrated in how it gathers information, how it uses it effectively in decision making, and how it disseminates it to the forces for execution. Success of such time-critical operations demands that the Committee think of just one integrated command and control (C^2) information support system.

Battlespace awareness, i.e., all relevant information pertaining to the battlespace, including both enemy and friendly forces, is the input to the C^2 process. The C^2 process, in turn, is what the commander uses to arrive at future courses of action. The C^2 process is supplemented by computer-based decision aids which in the AEF may be broadly distributed. Finally, the dissemination of orders, with its attendant explanations and conditions, goes to the executors. The result of those executions forms part of the modified battlespace and the whole process proceeds recursively.

2.2.1 The Need for Information Integration and Management

An important aspect of the overall improvement in information management (IM) required by the new AEF paradigm involves the automation and integration of the various components of planning and executing contingency operations (see Figure F-7 which builds upon the efforts and technology of the DARPA Battlefield Awareness Data Dissemination ACTD). The Air Force has made progress in replacing manual tools and procedures with work stations running on a local area network. However, the Air Force needs to better integrate the tools and processes used by operational planners, logistics planners, force protection planners, and other functional areas. Clearly, operations must lead the process by defining the mission, target list or other outcomes, weapon systems, and other basic parameters. Traditionally, however, independent groups make operational plans and then pass them to other groups to complete the next phase and implement the plans. This must give way to a more collaborative environment that ensures that plans are feasible and represent optimum use of available resources. In effect, IM requires an automated integrated product team (IPT), led by operations planners with participation by other functional areas and supported by effective tools. An IPT will shrink planning cycle times, generate a better plan, and eliminate the inefficiencies inherent in today's practices.

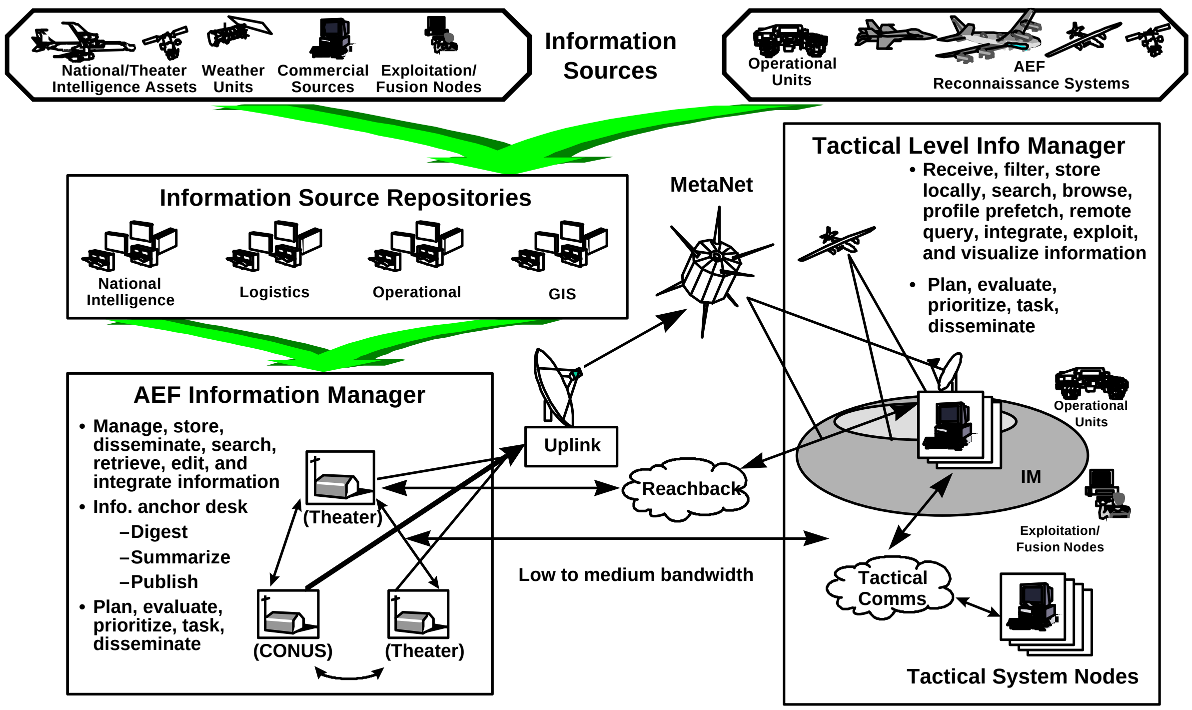


Figure F-7. *Information Management Provides the Right Knowledge to the Right User at the Right Time*

The key to success of our AEF concepts, based on austere deployment and employment of force, is the availability of information. The Air Force's present information push distribution systems will overwhelm users in almost any AEF operation without well organized combat information concepts, integrated with training and exercises. IM means significantly more than just scheduling bandwidth. The Air Force must conduct information planning simultaneously with mission planning. The operational plan should have an explicit IM annex that matches mission needs to chartered or designated collections and production. Following planning, the Air Force must focus on execution. Collection, production, and order processing all require specific attention to detail. The life cycle process needs tracking from initiation through in-transit visibility to customer receipt and satisfaction. Workflow and document management tools can aid authentication, delivery, storage, and disposal.

A federated system of infrastructure services will enable simple, timely, efficient, and secure awareness, access, and delivery of information products from producers to consumers in a dynamic, multifaceted environment.

2.2.2 Information Management

Information management is crucial for deployments with limited resources, especially those at the AEF scale. Today's military communications capacity has yet to keep pace with requirements, and with an increasingly rich infrastructural environment that can inundate an AEF. A recent Assistant Secretary of Defense (ASD)/command, control, communications, and intelligence (C^3I) command, control, communications, and computers, intelligence, surveillance, and reconnaissance(C^4ISR) Mission Assessment (CMA) concluded that DoD has only 25 percent of needed communications services in deployed rear areas and only 2 percent of needed tactical communications. Until we have the MetaNet, and even though there is currently not enough capacity, we need to live within our means (not to mention that this contributes to the smallest possible communications footprint at any AEF deployed base). This is the challenge of information management: tailoring information for the AEF.

Information management should ensure seamless delivery of needed information via the enhanced Defense Information Infrastructure (DII), using both military and commercial systems.

At present the Defense Information Systems Network (DISN) forms the backbone of the communications structure and is the only means of delivering information, regardless of classification and releasability, to joint (and coalition) warfighters worldwide. Moreover, leaving long-haul communications to DISA permits the Air Force to concentrate on fielding AEF-mission-oriented plug-and-play hardware/software in compliance with DII Common Operational Environment (COE). The last level of Figure F-8 shows the information manager communicating with the warfighter, which automates as much of the analytical process as feasible. This function integrates the required information recourse along with the technical delivery system capabilities.

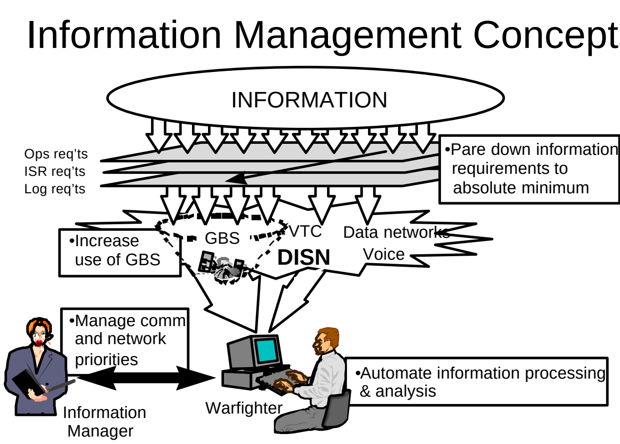


Figure F-8. *Information Management Concepts*

2.2.3 Information Management Components

Our approach to information and distribution management in the near term includes streamlining of requirements, increased use of GBS — including all currently available commercial direct broadcast service (DBS) — along with automated processing and management of communications. This can be accomplished by cutting the required amount of information to the bare minimum. Increase the use of GBS for large data files to take the load off bandwidth-constrained networks to a mode less susceptible to overload. Take advantage of automated process and analysis tools to quickly transform raw information into meaningful aids for decision making. In addition, manage communications to get the most out of available capacity. Apply priorities for information at each stage of operations to use limited resources to the best advantage.

The AEF IM concept parallels the use of other resources, keeping it to the minimum required — light, fast, with a small footprint, etc. Reduce the plethora of data by scrubbing reports such as SITREP and INTSUM to the bare essentials. Keep the information requirements relevant to the area of responsibility/area or interest (AOR/AOI). Carry relatively static information in digital form stored on various media to avoid use of communications capacity. Removable media such as CDs provide stable, high-density storage for maps, technical orders, and intelligence imagery. Where the information is more important than viewing an image, update with machine-readable graphical reporting. For imagery, to limit file transmission, update only changed portions of materials while in the field.

2.2.4 Global Broadcast Service

The GBS keeps large files off the switched network, decreases transmission time, increases overall communication system effectiveness, and enhances operations. Imagery-intensive information, full-motion video, or high-resolution single frames require considerable transmission time to meet analytical needs. A GBS also could save considerable production and distribution time for hard-copy planning documents by simultaneous receipt and reproduction at multiple distributed locations. Also, data essential for underpinning the Common Operational Picture (COP) would circumvent delays caused by passing through multiple switched networks.

2.2.5 Automated Data Processing and Analysis

Another way to increase individual productivity is to automate as much as possible of every important task. Identify and rely on information producers to populate specific databases, and establish push-pull accounts to keep both databases and customers current. Target information, battle damage assessment, and threat conditions are examples of decision-making information that requires updating from several sources. Where the process is difficult to automate, an "anchor desk" can be established for a team to correlate and fuse essential information. Automated analysis tools have proven to be effective programs to handle terrain analysis for mobile missile search, conduct mission planning, and actually perform mission rehearsal. Advanced technology demonstration (ATD)/automated target recognition (ATR)/ ATI, change detection, graphical displays and the COP are examples of ongoing efforts to automate processes and include analytical precision software tools.

2.2.6 The Information Manager

It is critical to develop an information management system. This system must distribute access and bandwidth to users across all classes of information services in accordance with AEF priorities. The system also must be able to break through bottlenecks, get to the required transfer media, and do more than allocate frequency and bandwidth — it needs to ensure that the correct information gets processed. Leveraging limited capacity for effective use requires a solid knowledge of operational requirements and technical resource capabilities. Instead of traditional methods of allocating channels or bandwidth by function and time blocks, we must do so in a dynamic manner based on the AEF commander's priorities.

We need to integrate the IM concept into the AEF and give the IM power over available communications. The IM should review information needs and pare them to the bone. Intelligent software tools need to be designed to process and analyze data, reducing the need for human intervention. The Joint Warrior Interoperability Demonstrations (JWID) have been an excellent opportunity to test these concepts and will be a natural setting for continued emphasis with the establishment of Service battlelabs. There is not a single Service with a corner on the market: we can learn from the Army's Force XXI digitized division and from the Navy's IT-21, for example.

2.2.7 Manage Priorities

The Air Force needs to exploit efforts currently being pursued in both DARPA and DISA to obtain the capabilities essential for our AEF concepts. To meet the required timeline and distributed nature of the AEF missions, the Air Force must develop dynamic management tools and systems to store, disseminate, search, retrieve, edit, visualize, exploit, and integrate information in real time. These systems must exploit and extend the capabilities of DII COE and aggressively incorporate commercial developments to ensure that the right information in the right form is at the right place at the right time.

The ability to employ comprehensive, real-time information in a time-critical AEF operation requires a system not only to gather and process information but to manage it as well. Such management is naturally software-based and an integral part of the system that supports the command decision cycle. Because the range of command support activities is large and individual components complex, an information manager, comprising a number of somewhat autonomous modules, works well. These modules will be specific to the function they represent, provide the input/output (I/O) needs of that underlying software, and act in concert to accomplish the needs of the user(s).

Figure F-9 shows a useful breakout of the functions of the command cycle. Everything but the mission and its associated information enters from a suite of sensors and other information feeds where it is consolidated into an integrated, real-time picture of the battlespace. The planning and decision-aid segments have connecting arrows because of their strong interdependence. The actual decisions, their attendant stipulations, and how and to whom they are directed form the final steps in a very recursive process.

The information manager assists the commander and staff by offering a consistent natural-language interface and abilities to parse requests among the various functions available, to retrieve information, and to display what it finds in a user-preferred way. It can invoke privilege or priority that an underlying communication system can deliver and, because it is rule-based, can permit easy changes in how it interprets such value statements. Collaboration-based subnets can be established or disestablished at will. Attributes of such a command support system have been mentioned in the 1996 SAB study on *Vision of Aerospace Command and Control for the 21st Century*.

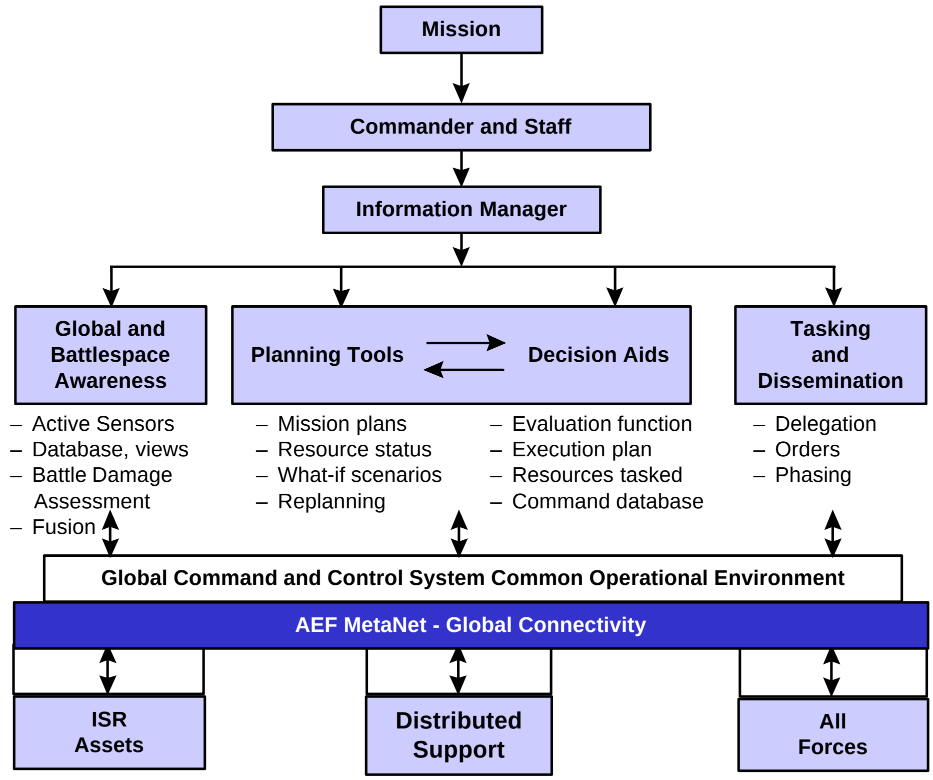


Figure F-9. *An AEF C^2 Information System*

As an applications process in the current definition of the COE, the information manager can call on any service therein. For example, it sets many of the parameters that guide the MetaNet's communications controller in selecting carrier resources.

The information manager facilitates information storage and transmission by driving bandwidth reallocation, affecting database management, driving network access management and coordination, and prioritizing the information flow. It allows new information concepts such as push-pull, control mechanisms, robustness, and fusion to really work. The information manager also enables automated information presentation and assimilation for production, display, integration, and distribution. Most importantly, it permits the integration of global capability for warfighting, information, and communications architectures, empowering the AEF to fashion its own C^2I system.

2.2.8 An Information Facilitator

To flexibly deal with the wide range of functions in a command center environment and to provide a consistent interface to the plethora of legacy and future systems involved, a system of software agents is suggested (see Figure F-10). These agents can be complex, even performing tasks that may seem autonomous to the user. But they are best thought of as a way to interpret a user-defined task in terms of the functionality available to them — that is, task-level computing.

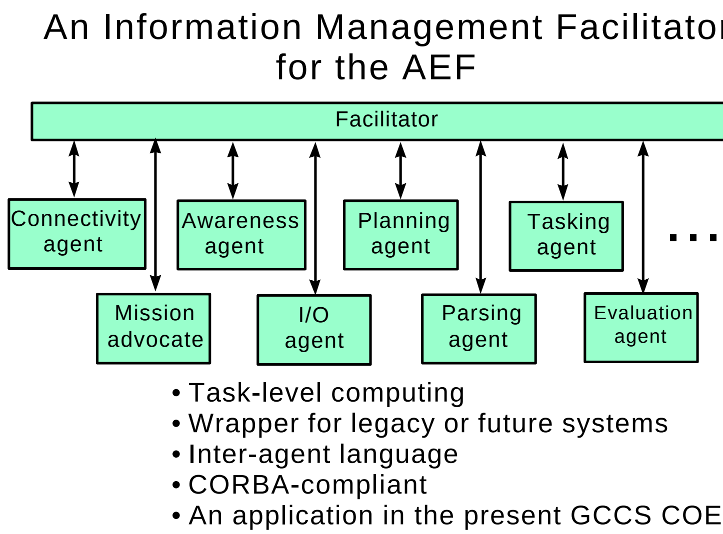


Figure F-10. *Information Management Facilitator to the AEF*

One version of software agents can be thought of as an interpreting shell around other software that provides needed functionality. Such agents can return a parsed sentence, enable speech recognition, do ballistic trajectories, maintain calendars, display electronic order of battle, or perform a host of other functions. They employ an interagent language and can be made to vie for the chance to meet a particular need expressed by the user. They can use object technology, be Common Object Request Broker Architecture (CORBA)-compliant, and be written in any language (e.g., Java).

Perhaps the best feature of such agents, though, is their modularity. They, and the functionality they represent, can be used, reused, or exchanged as new or legacy software is needed. They provide an isolation between software functions, so that strict, hard-coded interdependence among different applications does not arise. One approach, termed an open agent architecture (OAA), has been used to integrate a broad range of functionality with a consistent interface, which is nevertheless flexible in the interaction modes.

2.2.9 Information Management Services

The information manager includes a series of tools and systems that provide the capabilities depicted in Figure F-11.

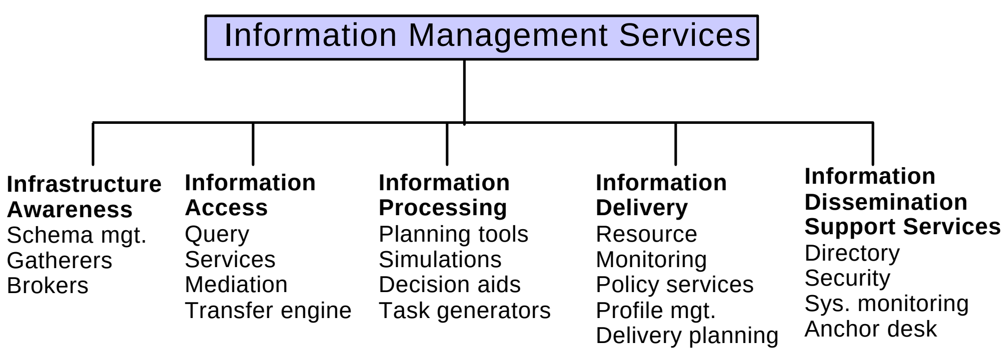


Figure F-11. *Information Management Services*

The Information Manager also facilitates

- Information storage and transmission
  - Drives bandwidth reallocation
  - Drives network access management
  - Affects database management
  - Prioritizes the information flow
- Information concepts
  - Push-pull
  - Robustness
  - Control mechanisms
  - Fusion
- Information presentation and assimilation
  - Production
  - Integration
  - Display
  - Distribution
- Integration of warfighting, information, and communications architectures
  - Empowers AEF to fashion its own C^2I system

Information management should be an integral part of both C^2 and support systems. The following infrastructure services are essential for automated system planning.

Publishing services may cover a wide range of products from relatively historical libraries to changing technical orders for equipment repair and maintenance. The publishing concepts used for directives, technical orders, and time-sensitive products such as an air tasking order (ATO) would benefit from system development.

Retrieval systems need to integrate catalog, directory, and search services. Intelligent browser agents to travel the classified and unclassified networked systems will enhance techniques to identify critical information elements and rapidly retrieve them to merge into displays for decision makers.

Subscription and delivery services relate to the push-pull for data or other information. Intelligent push can submit information and identify changes to previously transmitted information. It is important to maintain a version control mechanism for identifying changes to preclude operating with out-of-date information or requiring the customer to read all of a document to determine what has changed.

Part of a transport system should include notification to users, with a feedback system for non-delivered products or services. A forwarding capability also should exist, since changing IP addresses for network centric LANs creates problems for network administrators in tracking/assigning accounts. To create a reliable system, transport services need to assure delivery. This also can mean that when a prime node fails, other means or media should provide viable options for time-sensitive information.

Storage will vary based on numerous parameters such as frequency of updates and real-time or near real-time requirements. A total mix of media will continue to be essential, including DISA's data warehousing, writeable CDs; removable drives, disks, or tapes; and other magnetic or optical media.

Finally, performance monitoring must be automated to conduct an ongoing analysis of the entire information flow system. Metrics for quality, timeliness, and applicability to requirements should be part of the IM toolkit.

2.3 AEF Battlespace Awareness

AEF missions demand complete and timely information. Battlespace awareness capabilities must provide real-time understanding of the friendly, enemy, and geospatial situation. The short planning cycles, the need for en route planning and rehearsal, and the need for continuous battlespace surveillance with reachback to distributed resources drive AEF information requirements well beyond today's capabilities.

Thus, AEF missions are especially challenging because of their need for near real-time information with minimal advance notice. This need in turn drives the need for real-time acquisition, fusion, and dissemination of the best available Government and commercial data so that the necessary information can be assembled in time; the need to create clear, consistent images of the battlespace and battlespace situation so that distributed resources can operate without confusion; and the need to provide rapid access and clear cognitive assimilation of information at all levels so that decisions can be made quickly and accurately.

It is only through an image- and video-based battlespace awareness system that AEF missions can reach their full potential because it is the only way that information can be organized and communicated successfully. This observation has far-reaching consequences such as the need for a broadband AEF communications infrastructure.

As a result of comprehensive battlespace awareness, AEF missions will make use of new operational concepts such as self-synchronizing forces, accelerated speed of command, tactical decisions empowered at the lowest levels, ability to deceive and influence, knowledge and judgment to better manage uncertainty, and increased ability to detect and prioritize targets of high value while protecting our own forces. However, implementing these concepts will require an unprecedented emphasis on timeliness, accuracy, control, coordination, and clarity of information.

2.3.1 AEF Battlespace Awareness Challenge

Creating a common, real-time, image-based AEF battlespace awareness system presents a grand-challenge problem of integration, processing, and information management (see Figure F-12). Current technology, systems, and organizations cannot provide the needed level of performance.

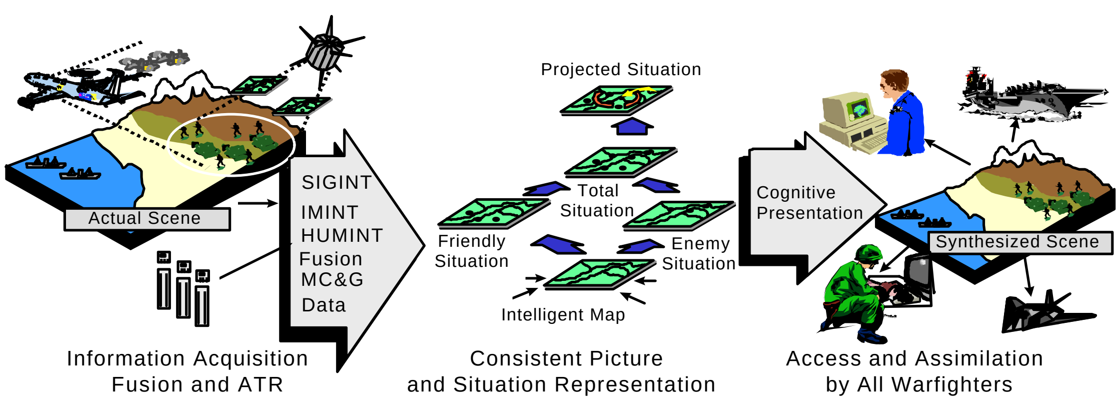


Figure F-12. *AEF Battlespace Awareness Challenge*

Creating the solution will require a serious, sustained effort. Battlespace awareness is one part of the overall AEF IM system, described in the previous section. The solution must solve the problems of real-time integration of ISR with command, control, communications, and computers (C^4) management; real-time fusion of all relevant Government, publicly available, and commercial resources; and tailorable presentation of information on different computer platforms, from immersive virtual reality systems to PCs and future Web TVs.

AEF battlespace awareness requires that national, theater, organic, and commercial surveillance and reconnaissance collections are performed as a single, integrated process. This will require real-time tasking of the appropriate collection resources and real-time automated processing for cueing, attention, and tracking with both ATR and assisted ATR. Today only a small fraction of the data collected is exploited. This problem will dramatically worsen over the next decade without powerful, real-time ATR tools. However, ATR is a difficult technical problem. Initial success will come from ATR (i.e., human-in-the-loop) systems.

In addition, the design of battlespace awareness systems must support numerous applications such as rapid, accurate targeting and battle damage assessment (BDA); dynamic, distributed, continuous collaborative planning; en route mission rehearsal and embedded training; and information warfare (IW) and spectrum dominance monitoring, planning, and execution. The wide range of AEF missions will require a suite of many other application-specific capabilities. The commercial world can provide many capabilities as long as the government adheres to the best commercial practices and standards.

2.3.2 A “System of Systems” Built on a Geospatial-Temporal Framework

AEF battlespace awareness requires the development of its own “system of systems” that includes collection, production, applications, and distribution to provide useful information in a real-time environment. The goal of AEF battlespace awareness is to ensure that we do this significantly better than our adversaries.

The AEF battlespace awareness “system of systems” requires the creative integration of collection resources; GPS and other geospatial location systems; storage and distribution systems; a family of processing tools, such as change detection and ATR; search tools, such as the Netscape Navigator; and applications, such as distributed, collaborative image exploitation. In addition, this “system of systems” must fit within the larger context of the overall AEF information management system, which includes all mission functions, such as communications control, logistics, simulation and training, planning, decision making, and tasking. Data must be represented in a form to allow real-time correlation and fusion.

A critical element in the AEF battlespace awareness system is the creation of content. This creation involves a family of processes, tools, data representations, and databases. The databases will contain layered, separable information about the geospatial history and status of the world. It will consist of data for maps, digital terrain elevation data (DTED), GPS, images, video, weather, and collateral data. The databases will need to facilitate the real-time insertion of additional data from both Government and commercial systems, along with fast search and ATR. For example, properly designed multi-resolution image representations can have a profound impact on the speed and accuracy of change detection, search, and fusion.

Collectively these capabilities create a worldwide database for global awareness. The minimum global awareness system consists of a set of “frameworks” for geospatial coordinates, time, and elevation data. This geospatial-temporal framework provides the basis for more detailed and specific content creation, such as that needed for battlespace awareness. The creation of these fundamental database structures is primarily the role of NIMA. Many Government and commercial organizations will provide specific content.

Although the global awareness system will provide the initial AEF baseline capability for battlespace awareness, in times of crises AEF missions generally will require considerable enhancement of their fidelity over a specific region (e.g., approximately 300 miles square) to be useful. In addition to Government sensor resources, commercial satellite systems will play an important role by providing additional imagery and histories, particularly of unfamiliar regions. Fortunately, in most cases there will be prior notice that a region may become an AEF mission area. AEF missions require real-time fusion of NTM and Theater sensors, UAV and hand held video, bio-detectors, ground sensors, etc. Thus, there generally will be time to create more complete battlespace awareness databases and associated mission planning, training, and analysis tools.

We refer to the need for real-time processing and display as a requirement for AEF battlespace awareness. “Real time” is defined by the application, but increasingly “real time” means within a fraction of a second. For example, UAV digital video has a latency of hundreds of milliseconds. In certain surveillance applications, this video needs to be seen in real time, fused with other image, DTED, map, and signals intelligence (SIGINT) information. Other collection resources have, or could have, low latencies that could be beneficially observed and fused with other data in real time.

Data structures and other architectural elements of the system must be designed to support the need for real-time processing and display. Other mission requirements will help drive the system in this direction. For example, video for distributed mission planning and simulation will become a normal feature of future systems and establish high-speed communications links.

In addition to content creation, the database must deal with multilevel security and related issues of data authentication and personnel identification. The latter will become more important as hierarchies are flattened by these information systems. Continuously monitoring biometric identification systems, such as iris identification, will be widely used.

2.3.3 Leveraging Developments in Commercial and Consumer Zeitgeist

As stated, the Air Force faces a considerable challenge in creating a comprehensive battlespace awareness system. Fortunately, interest and business potential is growing for most of the core technologies and systems required for such an endeavor. The Air Force must aggressively leverage and ensure compatibility with these developments to both maximize performance and minimize cost (i.e., leveraging the commercial and consumer zeitgeist).

Trends show that the commercial satellite imagery service market will soon be a multibillion-dollar-a-year business. Many developers around the world with unique features are attempting to create businesses in specific market niches. Within three years, more than 30 surveillance satellites will operate internationally. These will create content and many of the tools and capabilities needed for battlespace awareness. The Air Force should work with government and industry around the world to help influence standards that maximize interoperability.

In addition, the general area of sensing will explode over the next several decades. Data types will proliferate. Multispectral, hyperspectral small biodetector, and novel ground sensors will claim importance. Digital video on UAVs and other platforms will become a widely accepted data type and will be used in distributed collaboration, logistics, and telemedicine. Starting in 1998, high-end PCs will include a video camera. Web-based sensing of sites around the world will proliferate. Every platform, including humans, will become a potential source of sensing data. Digital high-definition television will transform the entire consumer communications infrastructure over the next decade by providing over 18 Mbps of packetized data per channel. Massive data storage systems and fully interactive information-on-demand systems will be part of the consumer landscape. Digital satellite television, already the fastest growing consumer product ever, will continue to expand and become a huge worldwide market. The prospect of 20 Mbps video offers the promise of a low-cost, high-performance infrastructure. Information navigation and search tools will become major market areas. Cost of software application tools will plummet, functionality will soar, and, as always, content will rule.

In addition to the above, the AEF battlespace awareness system and the previously discussed information system should exploit other powerful technologies, such as the Web. The Web is creating entirely new paradigms for collaboration and data search, as well as new models for broadcasting, such as data-push. The Web's bandwidth will increase to tens of megabits per second over the next decade. It will become a true image- and video-based medium with direct parallels to capabilities needed for battlespace awareness. These conceptual models and technologies must be integrated into the AEF battlespace awareness.

Air Force systems should emulate these conceptual models and integrate the best technologies into the AEF battlespace awareness system. For example, data-push can combine with mission-specific computer-screen icons (e.g., for logistics, collection tasking and coverage, UAV video, and battle orders) that when clicked open up screens with the latest, updated information — that is, a pointcast-like service for AEF missions.

AEF battlespace awareness systems will also have the ability to borrow concepts and technologies from other commercial information services. For example, Bloomberg Financial Services provides real-time financial information. Bloomberg aggressively uses state-of-the-art collection, communications, computing, and presentation technologies to provide customers with the best, most timely information. Battlespace awareness efforts can provide similar value for AEF missions.

2.3.4 AEF Battlespace Awareness Information Services Provider

The AEF battlespace awareness system is defined by the need to respond quickly and provide real-time information in a clear, compelling fashion. The new Air and Space C^2 Agency should create an organization and system concept with a focus on providing this new service.

The Information Service Provider (see Figure F-13) will be part of the creative integration of a "system of systems" that will include collection resources, GPS and other geospatial location systems, storage and distribution systems, and a family of distributed processing tools and applications, such as content creation. Global and battlespace awareness will provide access to a family of layered databases of the best information as rapidly as possible from whatever location. This requires a fundamentally different Service view within the Air Force with, like Bloomberg, a dedication to providing real-time information to support the AEF or to field a battlespace awareness AEF.

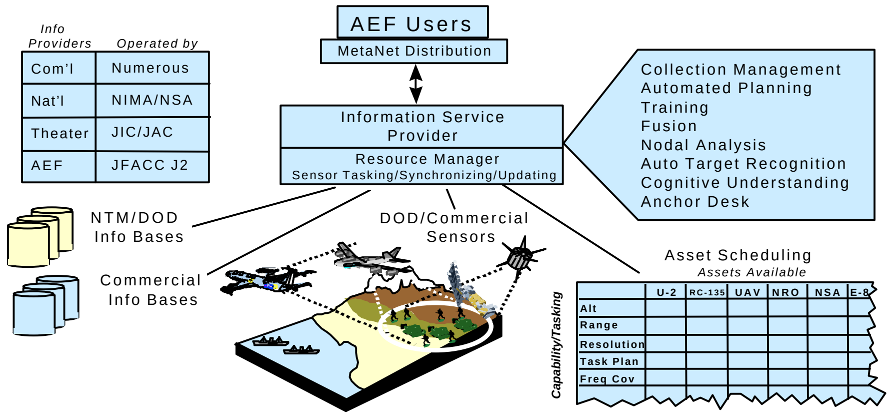


Figure F-13. *Battlespace Awareness Information Service Provides Real-Time Information Support*

Business arrangements must be set up with the best information sources around the world. The Information Service Provider would dynamically task U.S. collection resources, integrate these Government and commercial resources, and produce products useful for different AEF missions. It would cut across all U.S. intelligence and DoD organizations to produce the needed integrated, real-time results. As a consequence, the Information Service Provider would help all intelligence organizations to streamline their operations and accelerate their technological advancement.

The Information Service Provider will leverage the emerging Web paradigms for collaboration and search. This approach not only leverages technology, it leverages the conceptual paradigms and skills that will become common to all.

2.3.5 Simulation and Modeling in Support of AEF Battlespace Awareness

It is generally believed that Government ISR resources are difficult to understand and task. Radar images, for example, can have shadow regions that prevent imaging of obscured objects. The speed of AEF missions will demand that these capabilities be well understood and accurately communicated. Interactive visualization, training, and simulation tools will allow for a common understanding of what is possible. An example is the Joint Chiefs of Staff (JCS) ISR interactive visualization system under development to train users in the capabilities and use of ISR resources.

Also, since the concept of operations (CONOPS) for AEF missions cannot be completely specified, the generation of simulations based on battlespace awareness capabilities will become an important service in support not only of AEF missions, but also joint and coalition operations as well. Simulation and modeling technology will provide tools to assist C^2 planners, commanders, and warfighters in their C^2 planning, decision, and execution processes. Smart interactive tools can aid in providing faster-than-real-time assessment of alternate courses of action (COAs) for particular theaters and situations. These assessments will leverage communications and Web developments to allow distributed staff and joint planning. As new situational data become available, the simulation databases can be automatically updated and the assessments quickly reevaluated. Beyond the traditional assessment of battle outcomes, embedded smart algorithms can help assess broader economic and political influences and issues. Realistic visualization of the promising COAs can aid in both selection of the COA and its execution.

Simulation and modeling tools will need to be developed for use at various levels of fidelity and sophistication, from very-high-definition Pentagon systems to laptops used by deployed forces.
(It is interesting to note that children now can play interactive games that teach about Jane’s ships.)

2.3.6 Battlespace Awareness as an AEF Mission Itself

The AEF battlespace awareness system can support AEF missions or act as a stand-alone mission (see Figure F-14). The ability to rapidly deploy AEF battlespace awareness resources could provide real-time ISR, IW, public exposure, or deception. It could provide a worldwide Government “CNN” capability. The Air Force could find such abilities increasingly advantageous to prove to adversaries our understanding of their capabilities or to manage world perceptions. Accurate, believable information disseminated worldwide about a crisis or conflict situation may aid in the decision making process and gain public support and international cooperation, in addition to supporting deploying forces.

Although reconnaissance and surveillance satellites will continue as major sources of battlespace awareness for an AEF, often for political reasons the U.S. will need to provide a more obvious indication that activities in a region of the world are being observed. Existing deployments in such cases include a single type of aircraft or several operating independently. In the future, battlespace awareness AEFs need to operate collectively and require a deployable C^2 element when deployed independent of combat forces.

Battlespace awareness is an essential element of the Information Superiority core competency. The consolidation of all ISR assets into a single organization, whose commander is assigned the responsibility to integrate their capabilities into a single battlespace awareness system, would assist in building this AEF capability and the eventual integration of sensors operations and information.

Joint Surveillance, Target, and Attack Radar System (JointSTARS) ground surveillance should become the foundation of future battlespace awareness AEFs in which aircraft are deployed and integrate UAV capability into a coherent view of activity. Airborne battlespace awareness AEFs will require rapid deployability to lead, or simultaneously deploy with combat forces.

- AEF requires global capability for Battlefield Awareness
- Rapidly accessible real-time information from ISR assets may be only AEF mission required
- JFACC must be able to dynamically direct and integrate C^2I

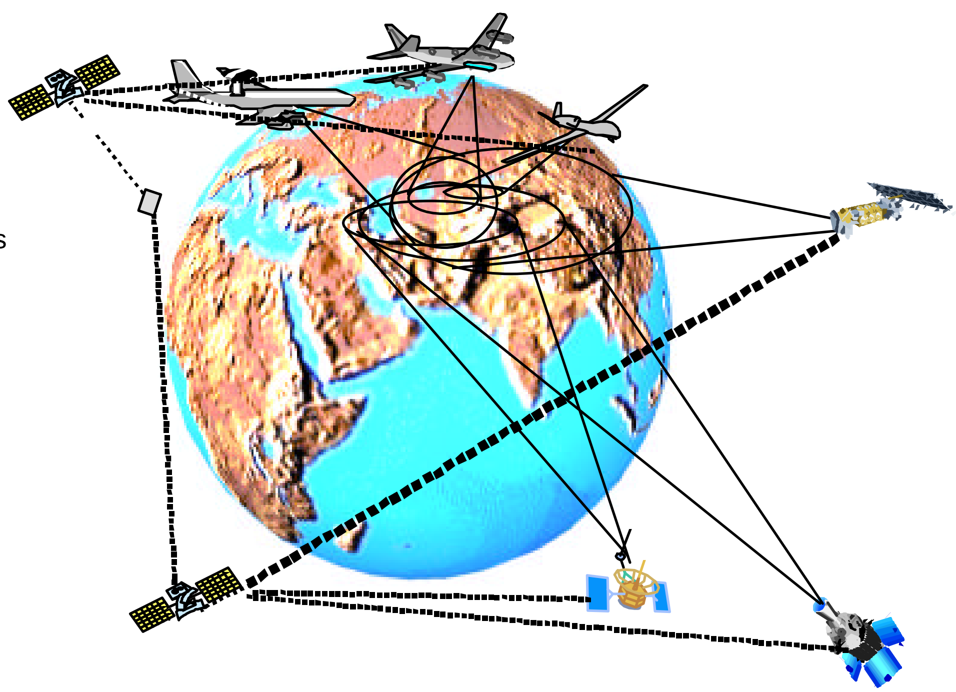


Figure F-14. *Battlespace Awareness As an AEF Mission Itself*

2.4 Geospatial Position, Navigation, and Timing

A common, geospatial and temporal reference system will lay the foundation for all future military operations. Moreover, AEF commanders will prefer weapons using GPS and inertial navigation system (INS). GPS navigation and landing systems will permit remote Air Traffic Control (ATC).

To achieve the needed operational efficiencies and battlefield awareness, the AEF requires a common geospatial and temporal reference system. Therefore, the Air Force must field position, navigation, and timing systems beyond the current GPS with improved geospatial accuracy, antijam, and survivability to enable precision weapons delivery, remote ATC operations, and geospatially based information fusion.

2.4.1 A Geospatial-Temporal Framework

Meeting AEF operations timelines demands a common framework for creating and integrating battlespace awareness products. Battlespace awareness requires a large family of databases that contain layered, separable information about the status of the world. A framework currently being developed to be fielded by National Imagery and Mapping Agency (NIMA) includes maps, terrain, imagery, video, weather forecasts, and other information. These data have varying resolution, completeness, timeliness, and accuracy. This step toward a global geospatial and temporal database will allow integration, fusion, and correlation of other formatted data in real time. Global capability will provide initial AEF baselines in times of crisis when regions will need to have their fidelity dramatically improved. Commercial data will play an important role in providing baselines and time histories. AEF missions will require real-time fusion of national and theater sensors, UAVs, hand-held video, and other information sources. Other AEF distributed content creation and distribution requirements include multilevel security, emphasis on data integrity, security, authentication, and personal identification (including continuous biometrics).

A precision position, navigation, and time-referenced battlespace will enable precise target location. In turn, these location data will permit dynamic retargeting, dramatic improvement of kill probability, and a significantly reduced logistics tail. Simultaneously, this location data will maximize the effect of weapons capabilities. For the first time, the Air Force will have pinpoint control of resources, and comprehensive, cooperative engagement. Furthermore, this common geospatial and temporal reference will allow dispersed C^2 of forces, new levels of fusion, a common grid for all sensors, and realistic trend analysis.

The Air Force needs to craft a long-term PNT service rather than just a system. Given that the United States, and indeed the world, is not now receiving or expecting to receive all of its PNT capabilities from the GPS, it should explore the possible evolution of a global PNT service prior to locking into a future plan for the GPS system. This means defining what PNT services the users (military and civil) require and how best to provide those services rather than merely focusing on what any given system, or any evolution of a system, can provide as user services.

GPS development and evolution always have been impacted by a number of factors and constraints. First, there has never been a single mission user that needed a GPS system in the sense that our strategic nuclear forces needed a system to provide warning of nuclear attack. This dictated that the decision to develop and deploy GPS be made at the Office of the Secretary of Defense (OSD) with the need driven from the top down.

Second, technology limitations at the time, combined with a requirement that the capability not be dependent on foreign basing, dictated a space-based solution.

Third, when the decision was made to assign development responsibility for the entire system to a program office at the Air Force Space and Missile Systems Center, fielding of a self-contained stovepiped system was inevitable at the time.

Finally, when responsibility for collecting and advocating user needs was assigned to Space Command — where they needed to work through established and rigid DoD processes (mission need statement, Joint Operational Requirements Document, program management directive, etc.) — the ability to focus on the full range of "user operational" needs was limited. The process does not easily respond to non-DoD needs, and the real users of PNT services had to work through a Space System Operator to develop needs that may or may not be best satisfied by a space system. The result has been the continued implementation of a stovepiped system defined, developed, and operated by the Air Force space community — which has done a fine job in spite of all these constraints.

The current GPS III efforts to define the system's future evolution, coupled with the recent establishment of the Interagency Executive Board chartered to manage GPS and all of its U.S. augmentations, may provide an opportunity to step back and take an operations needs–driven look at PNT Service requirements in general. However, any such effort should include not only GPS and related augmentations as solutions to PNT needs, but also should consider other capabilities that could provide these services, including inertial systems, other time-transfer systems, and other viable techniques for satisfying users' position, navigation, and timing needs. We need to get out of the stovepipe view and optimize our investments across the entire PNT mission area.

Any attempt to address the spectrum of global PNT service needs to look at whether the service should or can be provided by a single system, or whether it should or must be provided by a combination of systems. One of the advantages of a space-based system is that it can provide a global service with uniform capability and may do so at less cost than a distributed ground- or air-based system. However, not all PNT users require the same level of service at all times. For example, an aircraft in flight requires different levels of accuracy and integrity (assured accuracy) in each of its flight regimes (en route, approach, air-to-air and air-to-ground military operations, and landing). In the same way, land navigation requirements are the most stressing in situations where targeting or collision avoidance is the issue, and then relative positioning may be the real requirement rather than absolute global positioning. This has led the FAA and the Coast Guard to develop wide-area and local-area augmentation systems with different (enhanced) capabilities. An extension of this concept would be to deploy a global system to provide a basic level of service, accuracy, and integrity, and then to deploy a series of augmentation systems to provide enhanced levels of service in those areas that require improvements. This type of architecture could then be expanded to include application-unique enhancements such as inertial, dead-reckoning, laser ranging, and other. Another extension would be to provide a global service at an approved civil or international capability level, with a military or national security level of service being added by a separate global or local overlay. Which of these or other approaches would be most appropriate is not clear, but this is an issue to consider.

2.4.2 GPS/Inertial Weapons As the Weapons of Choice

Advances in GPS technology and demonstrated enhancements to the GPS infrastructure have proved the ability to supply the GPS signal-in-space to an accuracy of better than 1 meter. This capability enables the concept of precision weapon delivery to a total circular error probable (CEP) of fewer than 3 meters using an augmented GPS guidance system. Such weapons are inherently low cost and all-weather — both significant advantages over other precision weapon concepts.

To maximize the effectiveness of GPS-guided weapons, two issues take priority: (1) assuring the precision of the munitions delivery and (2) assuring the availability of the GPS signal (even in the presence of enemy countermeasures). Ongoing GPS development activities address both of these issues.

Differential GPS (DGPS) methods have already been employed to demonstrate the improved positioning performance possible with GPS. Sub-meter accuracies are possible when the GPS system errors are corrected. However, because a communication link to the munitions is needed to receive the DGPS corrections, this approach has not met with full user acceptance. In the far term, the Air Force must adopt an autonomous approach to achieve full operational effectiveness for wide-scale precision weapons delivery. However, in the mid-term the Air Force should investigate the use of a UAV for the relay of DGPS correction signals.

The EDGE and WAGE programs both have demonstrated the ability to communicate GPS corrections through the navigation data broadcast by the satellites. This interim capability allows for precision of less than 3 meters CEP to be provided into a modified GPS receiver. The infrastructure needed to support wide-area differential GPS operation consists of a dispersed network of ground reference stations. The GPS satellite data collected from these reference stations is processed to compute the in-theater GPS satellite corrections, which then are relayed to the GPS master control segment for insertion into the navigation message. The differential corrections then become part of the GPS navigation data that needs to be downloaded to the munition before it is deployed.

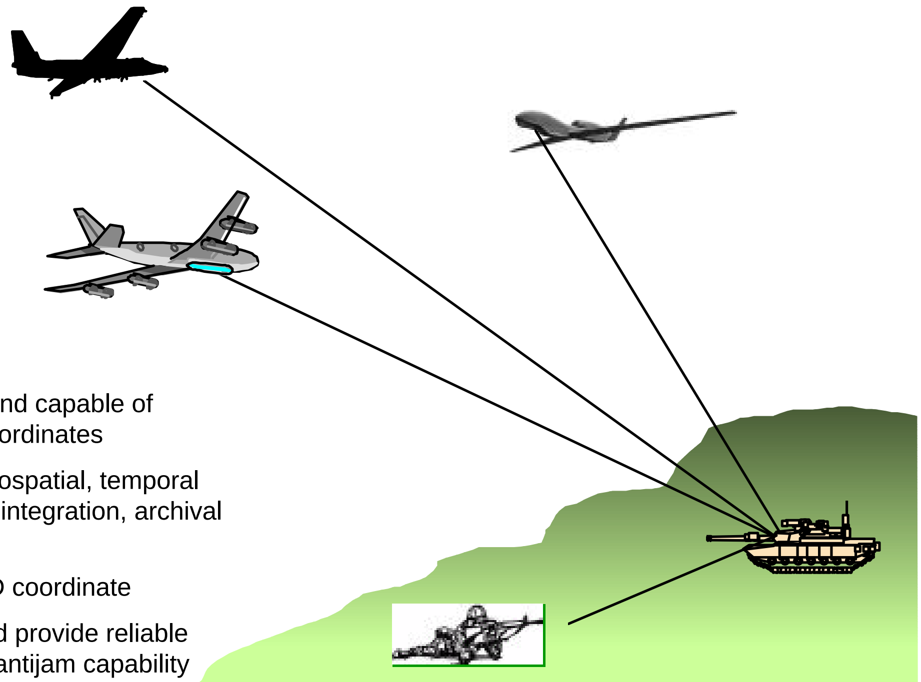
The Accuracy Improvement Initiative (AII) proposed for GPS (but as yet unfunded) will enable 1-meter signal-in-space performance to be achieved directly from the satellite broadcast. This will involve an expanded network of ground monitoring stations (which also increases the redundancy of the ground segment), improved satellite ephemeris estimation, and frequent satellite uploads to correct for clock drift.

Any of the previous methods described (DGPS, WAGE/EDGE or the GPS AII) will support weapons delivery with less than 3 meters CEP. The choice of GPS augmentation for precision weapon delivery becomes a question of maximizing operational effectiveness.

The ability to continue precision munition delivery in the presence of enemy countermeasures is discussed in Section 1.2.6.4 (page 34).

The DARPA Micro-Electro Mechanical System (MEMS) program has achieved significant advances in inertial instrumentation resulting in a miniaturized, low-cost INS. For air-to-ground munitions with a short time of flight, high-precision accuracy can be achieved with a relatively low quality INS. For short times of flight, the dominant error source for an inertial navigation system becomes the level to which it can be initialized from the aircraft (e.g., position, velocity, or heading). Even without continuous GPS corrections, with correct initialization onboard the weapon's delivery platform, the weapon's INS can sustain an accuracy of 10 to 20 meters for short times of flight (less than 60 seconds). However, with the improved MEMS upgrades, accuracies of 2 to 3 meters have been achieved.

The integration of GPS and INS technology provides a robust, high-accuracy guidance capability for munitions delivery. The performance of existing GPS/INS weapon systems, such as the Joint Direct Attack Munition (JDAM), have already proved the effectiveness of precision weapons as a force multiplier. With the GPS performance and antijam enhancements in development, further accuracy and robustness in "smart" weapons can enable fewer than 3 meter CEP weapons delivery.



- Sensors must be digital and capable of deriving precise target coordinates
- Sensor products need geospatial, temporal referencing for electronic integration, archival and retrieval actions
- Every pixel must be a 3-D coordinate
- GPS improvements would provide reliable one meter accuracy and antijam capability

Figure F-15. *Precision Delivery Requires Precise Target Location*

To capitalize on the ability to find, fix, track, and target any object on the globe, the AEF must geospatially derive precise range, elevation, and azimuth to the desired point (see Figure F-15). Once this information is determined and transmitted to the appropriate weapon system, GPS/INS-enabled weapons will achieve the desired results.

2.5 C^{2}I System Assurance

Commanders worry about catastrophic failure of combat systems on which they must depend. The Global Grid concept inherently provides increased reliability through diversity and redundancy. A wide variety of dynamically controlled military and commercial links significantly assures the communications connectivity. Information and communications controller features of the MetaNet must provide for controlled degradation of performance as bandwidth is reduced or communications links are eliminated.

2.5.1 Information Warfare

The increased dependence on modern information technology offers the opposition an opportunity to an Achilles' heel if the Air Force is not careful to block the many access paths. At the same time, aggressive use of these techniques will minimize the loss of life on both sides. The myriad uses of specialized software and hardware complicates the opposition's ability to access the Air Force system, but the Air Force move to a more compliant architecture will make the attack easier and increase the risk for greater damage. Therefore, the Air Force must design all future systems to be tamper-free.

End-to-end encryption as promised by the use of Fortessa-like encryption cards in all laptops and terminals will greatly reduce the access to our circuits. Gateway monitoring for illicit attempts provides necessary detection and isolation of the attempted activity. An enhanced quick reaction IW response team can provide the means to recover from an attack.

Physical security to protect all hardware and disks, even unclassified, will reduce the likelihood of access that will allow the aggressor to monitor, control, or deny our use of systems. Access verification is the first line of defense of an information system. The retina pattern and fingerprint comparisons provide an easy approach to assuring the user proper identification. Passwords still have a place in layered defense. Multilevel security access limits also add protection. The total security package must have an in-depth architecture that can be continuously monitored and upgraded.

2.5.2 Connectivity Assurance

The $40 billion commercial SATCOM revolution will be in operation in 4 years. The Air Force must start preparation now to take advantage of the plethora of commercial satellite systems with exceptional bandwidths of up to 2.048 gigabits. This new technology will allow an architecture that provides an assured reachback capability through multiple robust circuits, augmenting the military system. This diverse capability dramatically reduces the current concerns of jamming, interference, IW, and terrorism. Instead of having communications anchored to the military frequency band, commercial SATCOM will allow communications to be distributed throughout the mass of commercial and civil traffic.

The concept of a distributed staff depends on continuous communications that must have the redundancy to assure connectivity under stressed conditions. If care is not taken, communications could be the Achilles' heel of an AEF deployment. The detection of the AEF's radiofrequency (RF) signature will provide the opposition information on its build-up and expected arrival time. The steadily increasing dependence on communications, computers, and GPS provides opportunities, even for Third World countries, to disrupt the AEF deployment.

The basic system architecture proposed for an AEF was conceived to meet the stressing situation of wideband communications en route. The selected architecture has an overabundance of available communication paths and bandwidth that enables the user to automatically select the optimum channel available. This results in a redundancy that assures the desired connectivity during equipment malfunctions, co-channel interference, and jamming. A narrow-band survival link provides the service channel for switching circuits and reconfiguring the hardware and antennas to the next-best communications link. If this backbone line is lost a priority link sequence will engage. To ascertain the availability of diverse circuits, continuous loop probes aid the selection of a valid current access. Bit rate monitoring on each circuit will dynamically allow the redistribution of data if the circuit fails for any reason. The use of numerous independent communications systems that are spread out physically and spectrally provide the confidence that communications will be possible. Today's end-to-end encryption systems can ensure information integrity.

The Air Force can adapt the very wide-band commercial system to provide either antijam or reduced antenna size for inflight use. When the 1.2-Gbps data rate available is reduced to a 1.2-Mbps rate, a 2-inch dish can replace the usual 5-foot dish. On the ground, a full-sized dish can be used. The reduced bandwidth mode will then provide a 30-dB margin where the jamming threat is greatest. The current JBS wideband broadcast requires a 2-foot dish for its 30 megabits (Mb) of data. If the rate were reduced to an acceptable 1 megabit while continuing to spread the data at a 30-Mb rate, a 15-dB system processing gain would be realized. This would allow a 4.5-inch dish that could use a sextant dome to provide a collection aperture for airborne broadcast reception. The tracking required could be limited to azimuth only, since the smaller antenna has only an 18-degree beamwidth and the elevation angle could be manually set as long as the aircraft holds roll to less than 9 degrees. Data throughput rate should be matched to the available signal-to-noise rate or jammer activity. To maintain reliable communications even under extreme jamming, the data rate could be reduced to 1.2 kilobits, providing protection in a 60-dB jammer-to-signal ratio, for a resultant of one million to one. This certainly provides assurance that messages would get through.

The current antennas needed to provide diversified SATCOM access do not match the AEF's need for inflight operation and simple, lightweight ground deployment. A single antenna does not allow broad-spectrum coverage (UHF to millimeter wave). An azimuth and elevation tracking electronically steered antenna will provide access to nonsynchronous SATCOM and enable inflight operations.

The return path requires more attention, because if the local radiated signals are detected they will provide a tip-off of the upcoming operations.

Using the GBS concept in a forward broadcast mode and INMARSAT, Teledesic, or other commercial linkback systems for the return link would provide some cover that would not be found in the normal military frequency bands. Their elevated antenna look angles could be augmented with null patterns on the horizon. High-frequency automatic link establishment (HFALE) also could be used to provide a low-data-rate response and request channel. The HFALE could be covered with a high-powered ground-based mask to hide the high frequency (HF) response signals.

The current use of narrow UHF military band is the key search spectrum when looking for U.S. military build-ups. In addition, the reliability problem with UHF SATCOM is not fully appreciated. Problems experienced in the Bosnian theater are believed to be the result of co-channel interference and low look angles. The elevation angle to EASTPAC 72 is 18 degrees, and to ATL 23 West is 27 degrees. Most UHF airborne SATCOM antennas point up at 90 degrees with broad nulls forming on the horizon. The needed circular wave polarization also is a problem at these low look angles. The development of a quality airborne antenna with auto null steering or at least a sharp null on the horizon is urgently needed for airborne UHF SATCOM.

2.5.3 Jamming Concerns

Jamming has a renewed importance for AEF operations as it becomes more dependent on C^2 systems. If the AEF is to use the needed reachback architecture, it must ensure dependence on these systems.

To prevent jamming, an AEF system must avoid identification as a hostile communication circuit or emission. The use of commercial systems for AEF applications will spread its data through diverse routine traffic, making the access very complex for the attacker. Antijam protection on existing systems can be provided by adapting the data throughput, allowing normal power to dwell longer on each bit of information where necessary. This would improve the signal-to-jamming ratio, effectively reducing the jammers' range. Using the AN/TSC-85 as an example, the current 4.6-Mb data rate that carries 96 channels of 16-kilobit (kb) voice could be adapted to reduce the effects of jamming by 30 dB (1/1000) if the modulation rate were slowed to only one voice channel using the entire bandwidth and power. If the jammer-to-signal ratio were less than 30 dB, then additional channels could be added dynamically to match the needed signal-to-jammer processing ratio.

2.5.4 GPS Jamming Concerns

The AEF will lose the tremendous gains of using GPS to control smart weapons if the opposition is allowed to jam the system. Only dramatic upgrades will avoid this threat. The enemy can easily use off-the-shelf troposcatter hardware to jam GPS operations. By shifting digital troposcatter systems like the U.S. AMTD4 down 8 percent in frequency to the GPS range, a user can produce 10 kilowatt (kW) with data rates up to 8.5 Mbps. A small 200-watt drum-sized package could be assembled from modified ham gear at a cost of $3,000, will allow a large distributed field deployment.

The Air Force can combine a variety of demonstrated techniques for a robust battlefield capability, including adaptive nulling antenna arrays, integration and fielding of the numerous receiver upgrades available to provide matched dynamic tracking and increased dynamic range, and airborne UAV-carrying pseudo-satellites (pseudolites which provide high-power and close-in GPS navigational data), which will overpower jammers. Developing and using out-of-band pseudolites with GPS down converters for weapons, developing cheap radiation homing weapons for GPS and military communications frequencies, and developing a joint jamming evaluation group will also counter the effects of jamming. The appropriate combination of these to obtain 30 dB of processing gain will decrease the effectiveness of a 60-mile jammer to 1¼ miles and allow an inertial system to provide the desired weapons accuracy.

Figure F-16 depicts in graphical form the relationship between the jammer size and the GPS receiver antijam capability that determines the target protected area. The current military receivers have a jammer tolerance of 54 dB above the received signal levels from the satellites. Using advanced receiver improvements and nulling antennas in the future, the AEF can raise the tolerance level to a combined level of 98 dB. This 44-dB increase in protection will reduce the protected target area against a 1-kW jammer from a 190-km diameter circle to a 1.2-km diameter circle. The AEF can even raise the jamming margin up to 120 dB, reducing the protected circle to a 184-meter diameter. At the 120-dB level, the enemy must use psuedolites and homing weapons to offset this capability. A HARM missile tuned to the antijammer frequency can negate this jamming effort. (see the area colored red [shaded area above 120 dB] in Figure F-16.)

Figure F-16 highlights current and future capabilities. As the Air Force improves its system, the opposition can increase its effective radiated power up to approximately 100 megawatts before it becomes too costly for the jammer to continue. Thus, antijam weapons provide an effective capability.

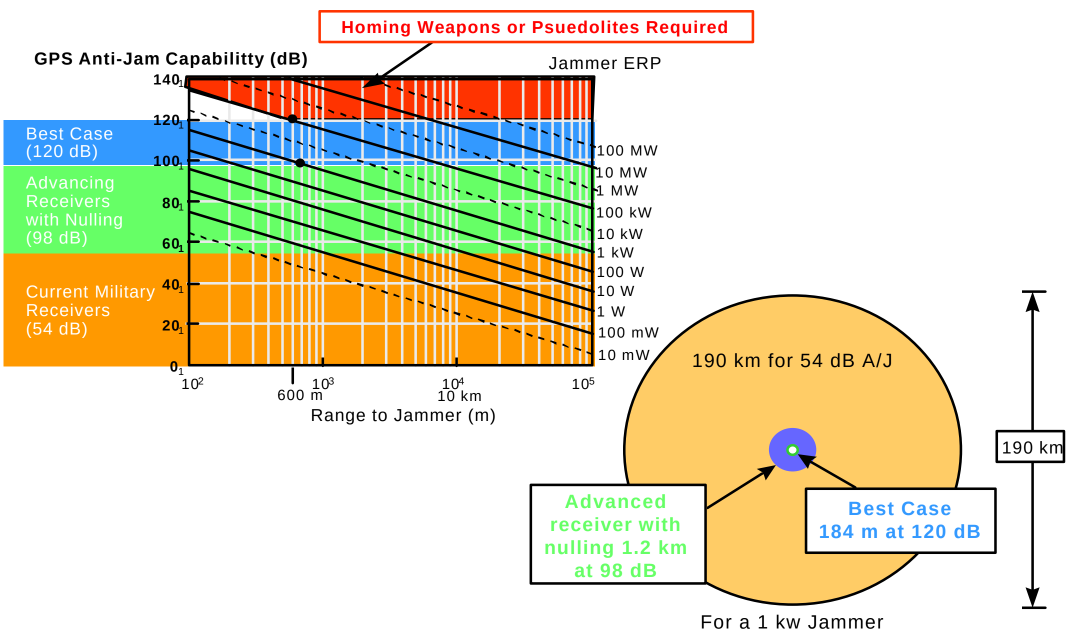


Figure F-16. *Potential Exists to Alleviate GPS Jamming*

The number of jammers that might be deployed in the target area is an unknown, but the antenna nulling system must be capable of forming multiple nulls. Figure F-17 depicts the range of protection achieved.

A significant upgrade to the troposcatter jammer conversion could be realized by using an L-band radar antenna and pedestal. The aperture would be equivalent to a 30-foot dish with the gain over 40 dB. That results in a beamwidth of 0.45 degrees for 0.25 dB and 1.5 degrees for 3 dB beamwidth. The narrow beam developed from the large antenna will require an accurate radar vector to assure illumination of the target area. Colocation with a search radar that would provide the pointing azimuth would be the simplest solution, but they could be separated significantly. A remote mountaintop location would give the jammer better low-altitude access.

Using this approach, an area with a diameter of 120 kilometers could be protected, even from a receiver capable of defeating a 120:1 dB jammer-to-GPS ratio. This demonstrates the need for radiation homing weapons that can operate against GPS and communication bands, for use against enemy jammers.

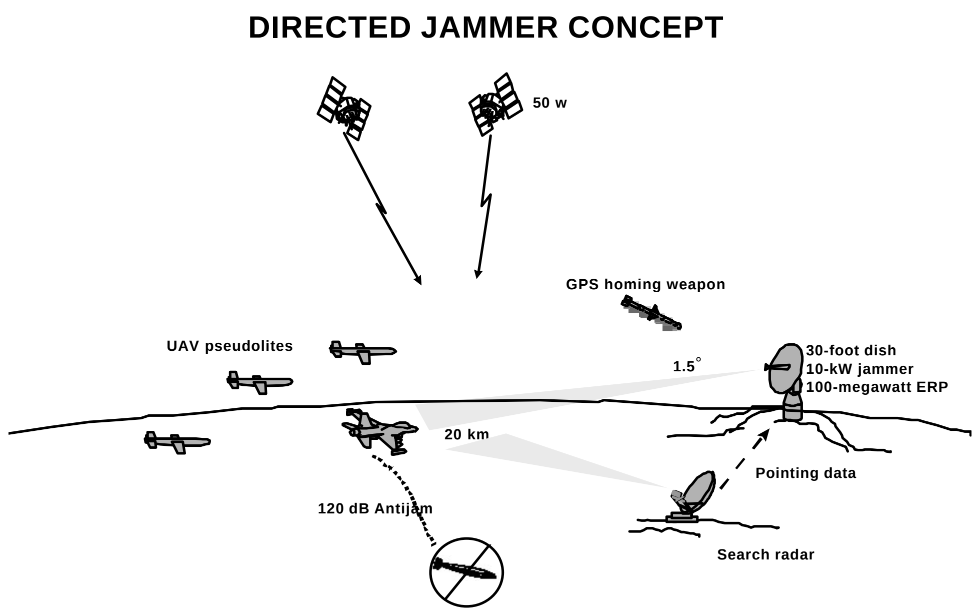


Figure F-17. *Directed Jammer Concept*

2.6 Recommendations

A variety of techniques have been demonstrated and should be combined to provide a robust battlefield capability. They are

- Use adaptive nulling antenna arrays.
- Integrate and put into use the numerous receiver upgrades available to provide matched dynamic tracking and increased dynamic range.
- Use airborne UAV pseudolites to overpower jammers.
- Develop and use out-of-band pseudolites with GPS down-converters for weapons.
- Develop a cheap radiation homing weapon targeted to GPS and military communications frequencies.
- Develop a joint jamming evaluation group.

Using the appropriate combination of these efforts to obtain 30 dB of antijam capabilities will decrease the effectiveness of a 60-mile jammer to 1.25 miles, allowing a GPS inertial system to provide the desired weapons accuracy.

3.0 New Operational Concepts Enabled by New Command and Control Capability

The above C^2 enablers naturally lead to new operational concepts and even new AEF missions. The following sections give some examples of these new concepts, which are aggregated into two groups: those dealing with the ability to distribute resources according to the situation unconstrained by line-of-sight connectivity and those enabled by an ability to have real-time knowledge and to dynamically plan and execute accordingly.

3.1 Distributed Operations

Distributed operations with continuous and complete connectivity may now give the Air Force a capability it could never afford. As a consequence, the Air Force has the flexibly to locate available resources where and when the situation dictates. The information technology world simply sees this concept as distributed digital systems that have the virtue of fidelity, independent of intervening distance.

3.2 Real-Time Planning and Execution En Route

The pace of an AEF demands that aircraft be aloft before all planning and target selection is done. The JFACC en route needs to have the capability to plan the operation en route through reachback and onboard systems.

3.3 Distributed JFACC

Figure F-18 illustrates a distributed but fully connected JFACC. To be general, Figure F-18 shows JFACC components deployed, airborne, and the continental United States (CONUS)- or theater-based. Normally, only the JFACC with the direct staff would be forward deployed, and the main support group, with all of its resources and connectivity, would remain back in CONUS or theater. It is, of course, the complete connectivity that permits this virtual assemblage of people and continuous, fail-safe operation.

In the short term, the Air Force should configure the existing Air Operations Groups (AOGs), such as the 32nd AOG at Ramstein AB, Germany, to exercise the distributed JFACC operation to aid in the definition and development of the proper information tools to support the distributed JFACC vision.

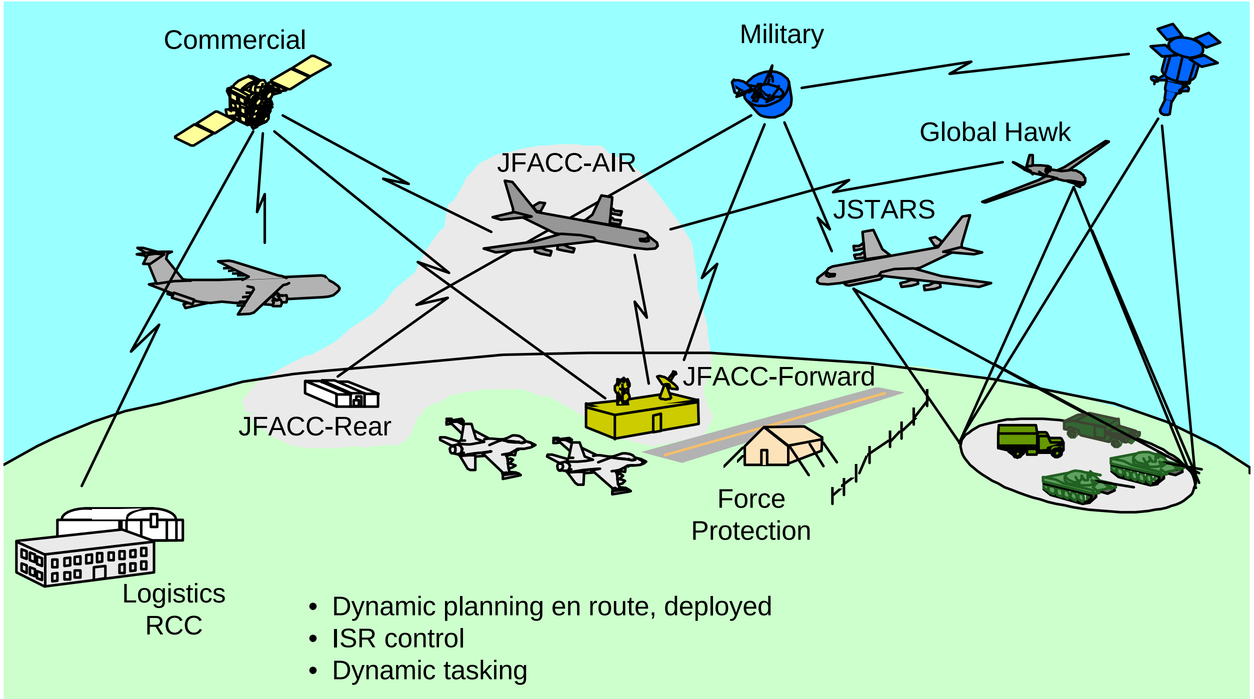


Figure F-18. *A Distributed JFACC Reduces the Planning Staff Forward by More Than an Order of Magnitude*

3.4 Dynamic AEF Operation

The pace of an AEF demands that aircraft be launched before all planning and target selection is done. That fact and the need to respond dynamically as the AEF mission unfolds require an inflight planning system. This capability may come from onboard equipment or reachback or, for sake of assurance, both.

Although real-time dynamics are involved in the concept of en route planning mentioned above, the new operational concepts for all-weather close air support and dynamic air interdiction are also enabled.

3.5 All-Weather Close Air Support (CAS)

Night and weather currently limit the operational capability of the Air Force in the close air support mission. For example, the winter months in Bosnia permit close air support only 13 percent of the time. Precise target location in a three-dimensional GPS reference system, GPS inertial guided weapons, and aircraft equipped for weapons delivery of GPS weapons provide the key to creating an all-weather CAS capability.

Precise GPS target coordinates can be derived by airborne sensor systems if they are properly modified. Actions are underway to modify U-2, JSTARS, and Predator platforms to provide geospatial and temporal referencing that will determine GPS target coordinates. In addition, a handheld device incorporating a GPS receiver linked to a MEMS inertial chip, an encrypted precision code capability (P/Y code), and a laser range finder will generate a three-dimensional, geospatially correlated location of a selected target. By moving this device rapidly before aiming it at the target, it provides a differential GPS accuracy of 2 to 3 milliradians.

Precision target location allows targeting with GPS-guided weapons. The Joint Stand-Off Weapon (JSOW) and JDAM will enter the inventory soon. A MEMS inertial chip integrated with the GPS will permit delivery accuracy of less than three meters. Small Smart Bomb or similar programs will improve accuracy and increase weapons effectiveness.

This operational capability enables all-weather day and night close air support and has other operational implications. Target destruction can be accomplished from higher altitudes in level flight rather from low level attacks. All types of aircraft with GPS capability can be used for close air support, expanding the force that can be applied to that mission.

3.6 Dynamic Air Interdiction

JSTARS and other ground surveillance systems enable a new operational concept called Dynamic Air Interdiction. Presently, interdiction campaigns are planned and executed through the ATO process. Target lists generally include bridges, key intersections, and roads traversing limiting terrain. The ability to see enemy vehicle movements with Moving Target Indicator (MTI) permits analysis of the enemy's attack plan and in some cases, enemy intention. It will also show enemy positions relative to friendly forces. The ground and air commanders or their representatives, using the same information, decide on the pattern of interdiction to halt or shape the flow of enemy forces dynamically. Strike aircraft are assigned targets in real time and interdict them using day or night all-weather GPS delivery described in the paragraph above. Interdicting targets, only when a specific objective requires increased pace of combat, provides further advantage to the force that can dynamically respond. It also reduces collateral damage.

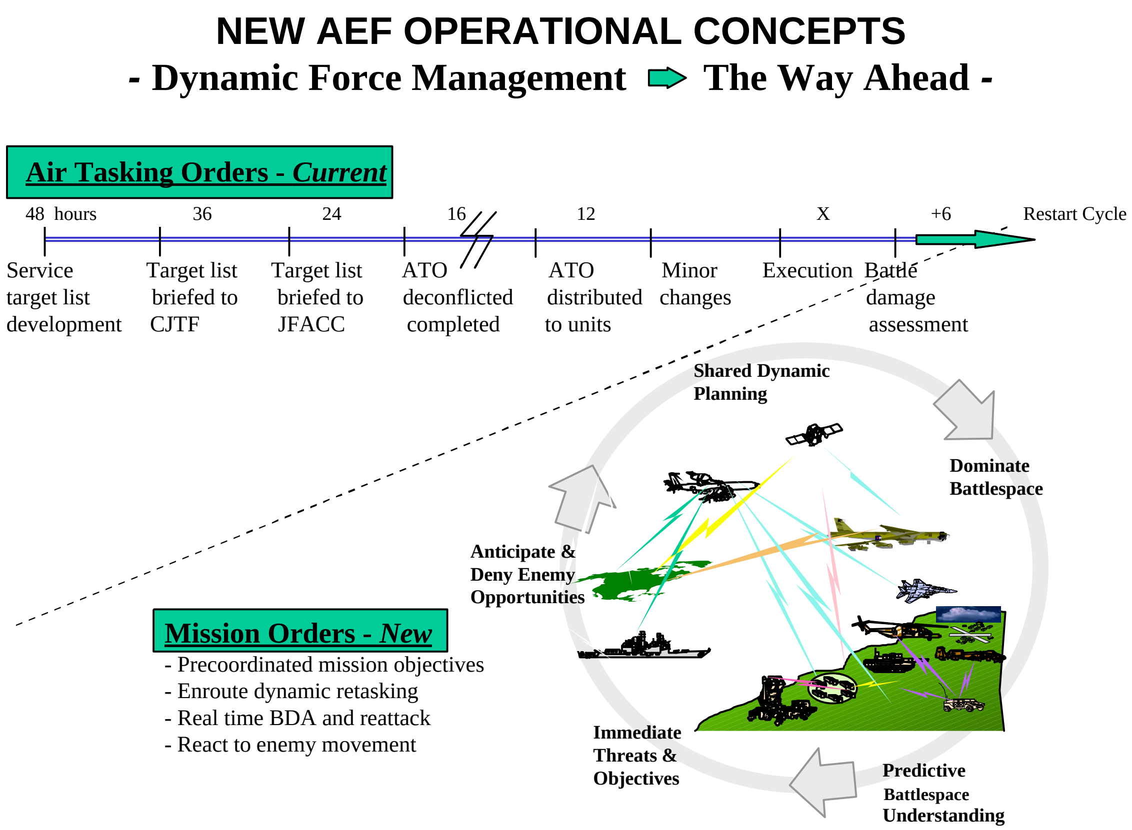


Figure F-19. *New AEF Operational Concepts*

To capitalize on this dynamism, the relatively static ATO should be replaced with Mission Orders (see Figure F-19). These Mission Orders are based on outcomes desired by the Joint Forces Commander (JFC) instead of listing specific targets for each scheduled mission. Operations conducted under Mission Orders and geospatial tools will enable the JFC to retask airborne assets to attack the most viable targets depending on the evolution of the battle environment. The commander also can redirect target priorities to shape the battlefield, bombing strategic choke points ahead of an advancing enemy, for example, or utilizing direct data links to weapon platforms.

3.7 Modern Battlespace Management

A precise knowledge of the battlespace is an ideal that is increasingly more achievable. When the AEF commander employs this knowledge with real-time planning and execution systems, enormous advantages accrue. An AEF can continuously surprise the enemy by predominantly operating inside the enemy's decision or reaction time. Also, a single platform or sortie can carry many more precise weapons. The carrying of a large number of individually targetable weapons also means that inflight targeting will become common practice. Above all, the AEF has the ability to orchestrate a confluence of precise power in time and space that will appear decisive to the enemy (see Figure F-20).

Beyond the advantage of "out-knowing" the enemy in combat, however, the AEF commander can use that information to preempt the need to engage the enemy with force at all. While the nation occasionally has employed selective release of special, sensor-derived knowledge, such as during the Cuban blockade, the Panel believes that more beneficial opportunities to do so exist. Selective public release of specific imagery or other intelligence may act both as a deterrent and as a way to limit the U.S. involvement in hostile action. For example, in cases in which specific adversary activity may prove inimical even to those around him, letting local authorities witness the activity through a form of public release, such as CNN, may help the U.S. hand off some of its peacekeeping role to those most affected. In other cases, the United States may benefit by deploying the same kinds of intelligence gathering assets that support its forces to a locality where they can provide information to an ally.

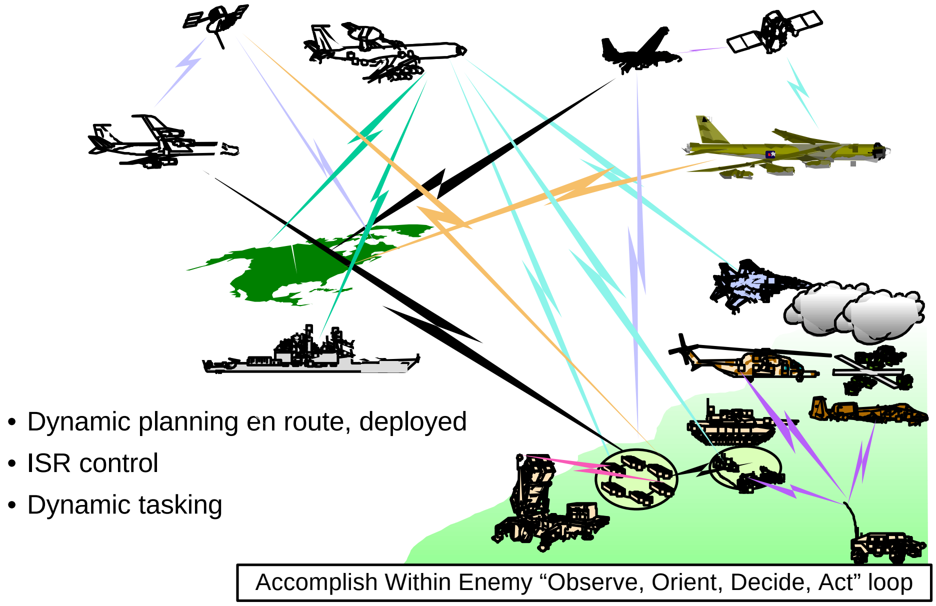


Figure F-20. *New Operational Concepts Are Enabled by the Dynamic Nature of the AEF*

3.8 Remote, Distributed Air Traffic Control Operations

3.8.1 GPS Navigation and Landing Systems With Remote Air Traffic Control Functions

The International Civil Aviation Organization has endorsed a new communications, navigation, and surveillance/air traffic management (CNS/ATM) concept that will capitalize on military and commercial technological advancements to improve air traffic management. As the Air Force upgrades its equipment to comply with the intent of the National Airspace Management program and as it capitalizes on worldwide communications and global positioning connectivity, it can conduct approach control and landing activities for the forward-based AEF units from CONUS locations. In this distributed mode of ATM, pilot-to-controller voice and data connectivity will supply the precision information needed to separate and sequence aircraft, without requiring the controller or equipment to be physically deployed to the AEF airfield.

The “communications” part of CNS/ATM relies on the use of data link communications to replace voice communications, and on the expanded use of aeronautical satellite communications to provide both data and voice services. It also introduces the concept of a “required communication performance” (RCP) rather than carriage of specific radio equipment. The “navigation” part of CNS/ATM involves the use of a global navigation satellite system (GNSS) and introduces the concept of “required navigation performance” (RNP). The “surveillance” part of CNS/ATM introduces the concept of automatic dependent surveillance (ADS), in which aircraft periodically report their identity, position, and intent. The ADS reports can be either addressed (sent to oceanic ATC centers) or broadcast (sent to all within line of sight); these two concepts are sometimes known as ADS-A and ADS-B, respectively. Use of ADS-A (usually called simply ADS) requires the availability of a beyond-line-of-sight data link. The CNS/ATM concept allows for the ultimate definition of “required surveillance performance” (RSP) and — eventually — for combining RCP, RNP, and RSP into a definition of required total system performance (RTSP).

Many of the required communication, navigation, and surveillance performance concepts included in CNS/ATM could be accommodated through the use of existing military systems. This offers the potential for enabling the Global Air Navigation System (GANS) through the enhancement of existing military capabilities and infrastructure, rather than solely through aircraft avionics upgrades. Not only may this provide a cost benefit to the Air Force, due to the scale of the GANS aircraft equipage, but the assured navigation, communication, and situational awareness enhancements required to be compliant with CNS/ATM performance standards also would be of significant military utility. (For more detailed explanation of the technical utility of GPS within the required navigation performance, see SAB *Global Air Navigation Study* report).

The Joint Requirements Oversight Council (JROC) has validated the need for a deployable, reliable, survivable, maintainable, jam-resistant, and interoperable precision approach capability. Future systems are being evaluated by the Air Force, Navy, and Army through the Joint Precision Approach and Landing Systems Program (JPALS). The FAA intends to incorporate GNSS-based navigation into the National Airspace System (NAS) through implementation of the wide-area augmentation system (WAAS), an integrity monitoring and differential GPS system. The WAAS, as planned, will allow GPS to meet performance requirements for all phases of flight up to CAT I landings. The FAA expects to issue a notice of public policy on turning off ground navaids when the WAAS achieves initial operating capability, planned for 1998. Full operating capability is planned for 2001. The FAA expects WAAS to be approved for primary-means CAT I landings in 1998 and as sole means for CAT I landings in 2001. Additional augmentation will be needed to achieve CAT II and III precision approach capability using GPS. The FAA is now defining the requirements for the local-area augmentation system (LAAS); it expects that the MOPS and a specification will be published around mid-1998.

Assuming that all ground navaids and landing systems will be turned off, all NAS airspace users will need to transition to GPS navigation and landing capabilities, including WAAS and eventually LAAS. The NAS architecture calls for all the FAA's ground navaids (Omega, LORAN-C, VOR, NDB, DME, and CAT I ILS) to be decommissioned by 2008 and for CAT II/III ILS to be decommissioned by 2010.

There is an opportunity to leverage the installed base of aircraft communication systems (such as HF or INMARSAT SATCOM) to support command and control functions, and also to enable installation of the future global grid communication infrastructure to be used to support CNS/ATM functions. Although INMARSAT is the only beyond-line-of-sight communications system currently approved for use as an ATC data link or for direct pilot-to-controller voice communication, the FAA and airline groups already are investigating the use of planned low-earth-orbit (LEO) or medium-earth-orbit (MEO) systems for ATC. Moreover, there are ongoing discussions of the need for direct pilot-controller communications via satellite for oceanic navigation to assure safety of flight under the proposed reduced separation standards.

Investment in this ATC network infrastructure will have global impact (and payback) for Air Force operational effectiveness and global access. The Iridium LEO system provider (Motorola) has stated its intention to provide aeronautical service suitable for use in ATC communications. Aeronautical communication data networks are currently operated in the U.S. by ARINC (for the ACARS system) and in most of the rest of the world by SITA (the Societe Internationale de Telecommunications Aeronautiques) via the Aircom system. These systems support the Future Air Navigation System (FANS) data distribution to ATC centers, both aeronautical operational control and airline administrative control. The International Civil Aviation Organization's planned future infrastructure is the Aeronautical Telecommunications Network (ATN). Expansion of this planned network architecture to support voice and data connectivity into the ATC infrastructure will enable pilot-to-controller communications through a communications network and would avoid the necessity for upgrading aircraft avionics to be compliant with all regional communication systems. An ATC-compliant communication network, operated and maintained by the Air Force, also will enable distribution of current ATC support functions between different regional (fixed) and mobile facilities. This construct will lead to the opportunity to implement ATC in a distributed "reachback" function in support of the AEF mission. This would in turn obviate the need for substantial airlift, which currently is required to relocate surveillance and precision landing radars, as these assets can be left in their fixed environment.

The adoption of this distributed ATC management concept will obviate the need to generate airlift to move heavy TPN-19 precision and surveillance approach radar systems (requires a C-5), older and logistically demanding MPN-14K mobile radar systems, TRN-26 TACAN systems, and associated support equipment (requiring 1 to 2 C-141s and 30 personnel). Operational timelines will improve as no one will need to calibrate and certify these ATC systems. Using the CNS/ATM concept for ATM operations could greatly enhance controller certification and exercise scenarios.

3.8.2 Remote, Distributed Air Traffic Control Operations

GPS and communication reachback capability remotely provide ATC services to any AEF location. Aircraft modified to receive these data and equipped with a ground proximity warning device can land at any AEF location without the need for ATC equipment at that location. This concept greatly reduces AEF footprint while increasing the timeliness of achieving desired outcomes (see Figure F-21).

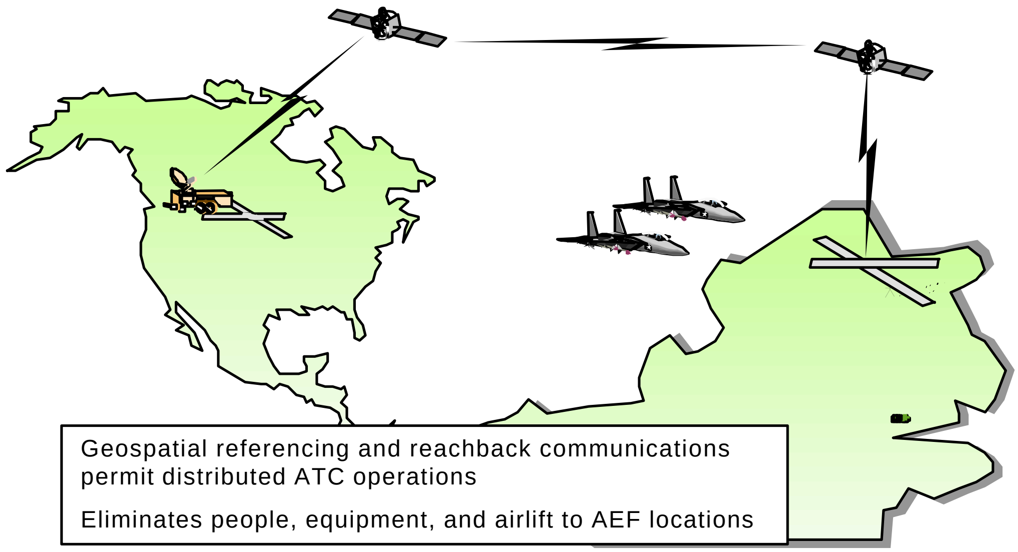


Figure F-21. *Distributed Air Traffic Control Operations Are Now Feasible Using GPS and Assured Connectivity*

4.0 C²I Transition Plan

4.1 Change as the Baseline

The end state described for the Panel's key enablers of global connectivity, battlespace awareness, information management, geospatial PNT, and system assurance should be seen as change — a constantly evolving set of capabilities on our road map to attain C^2I capabilities vital to the AEF concepts proposal. Section 3.3.2 of Volume 1 provides an expanded view of important research, development, and acquisition (RD&A) activities vital to this transition plan. In addition, Section 4.2 provides valuable ACTDs and experiments that will facilitate more rapid implementation of the C^2I roadmap.

Implementation of the full C^2I concept described here throughout the Air Force will require time. This implementation will have to occur eventually, regardless of AEF operations, in order to maintain the capability of the Air Force in the modern world. Initially AEF implementation might be limited to certain types of aircraft (i.e. one bomber type, one fighter type, one cargo aircraft type, etc.) and certain quantities of aircraft (e.g., one squadron of F-16 HARM Targeting System). New aircraft such as the Joint Strike Fighter (JSF) and F-22 should have the needed capability incorporated initially.

4.2 Fully Embracing the Commercial World of Information Technology

Given the tremendous advances the commercial world already has made in information systems, and the major impending growth of commercial worldwide space-based communications systems and commercial and foreign space-based imaging systems, the keys to successful migration are

- Enhancements and exploitation of the DII to satisfy Air Force and AEF needs
- Establishment of an AEF C^2I system architecture that fully incorporates commercial capabilities and AEF requirements
- Development of new military value-added capabilities that integrate naturally with those obtained from the commercially based architecture

Fundamental to this approach, the Air Force must realign the Air Force laboratory efforts and Air Force Materiel Command (AFMC) acquisition centers to exploit commercial capabilities for all program baselines and to focus on unique military value-added functionality to a commercial base.

Converting this AEF architectural philosophy into a C^2I migration will lead to global connectivity. This near-term capability could consist of leased very small aperture terminals (VSATs), a Joint Broadcast System (JBS), Challenge Athena, DBS, and existing military satellite communications tied together through an Internet router connecting AEF ground elements, large airborne platforms, and joint and coalition elements to provide a rapidly available grid and communications controller consistent with the long-term MetaNet architecture. An immediate major expansion in use of commercial DBS will dramatically enhance the viability of proposed AEF concepts in the near term. In the near and long term, as Iridium, Celestri, Teledesic, GlobalStar, GBS, and other assets are fielded, they will be tied into the grid, and a joint DARPA/Air Force-fielded communication and network controller based on commercial capabilities will evolve from the Internet router. Similarly, incorporating existing Web tools into a battlespace awareness anchor desk will enable near-term fusion of military, intelligence, and commercial information.

Current 24-hour responsiveness for deployable communications brings a mixture of 1970s vintage hardware and software to meet rapidly growing bandwidth needs. Initial packages include UHF, super high frequency (SHF), satellite terminals, air-to-ground radios, telephone switches, message terminals, hand-held radios, tactical secure data communications, and copper wire, requiring almost two C-141 aircraft. The future AEFs should continue with increased requirements for bandwidth to transmit imagery, allow collaborative planning, and accomplish real-time access to distributed data through the reachback concept of operations. This migration will lead to fewer people and fewer than one C-141, as shown in Figure F-22.

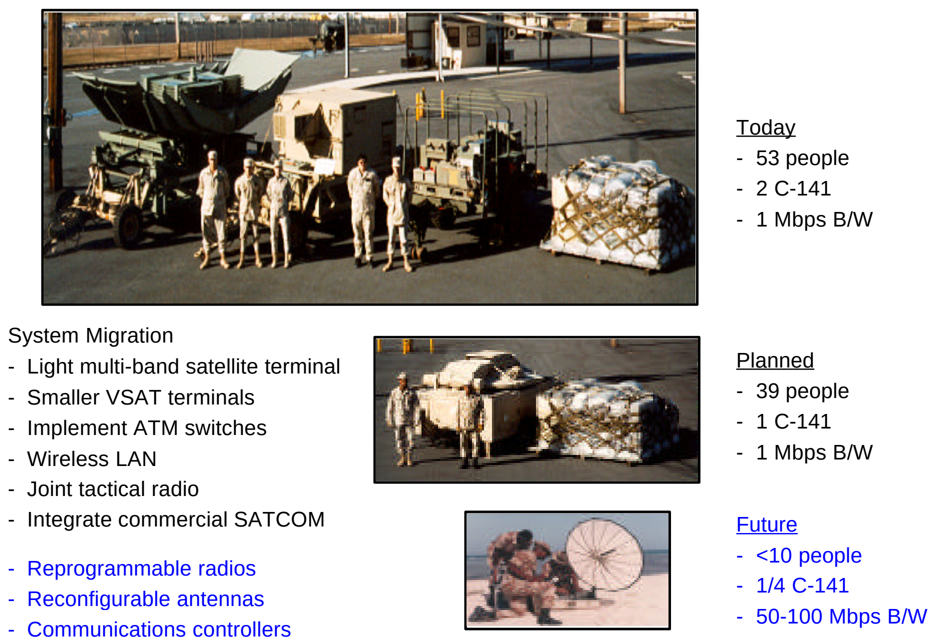


Figure F-22. *AEF Deployable Communications Will Require Less Airlift and Provide More Capacity*

The application of commercial tools based on the Bloomberg and information manager models previously discussed will enable fielded battlespace awareness and information management systems in the mid term. The first AEF mission could be battlespace awareness with the goal to task and deploy collection resources and use reachback capability to bring the information back to the JFACC, integrating these resources in a common, cognitive, friendly form. Today's commercial tools can fundamentally accomplish this.

DARPA programs such as JFACC After Next, Battlefield Awareness Data Dissemination (BADD), and Battlefield Command and Control Architecture (BC^2A), together with commercial systems, provide a road to successful C^2I for AEFs.

5.0 Required Experiments and Demonstrations

Air Force Requirements for Battlefield Awareness and Dissemination ACTDs. The Air Force must take an aggressive approach and drive AEF requirements into several ongoing ACTDs and deployments, including Advanced Joint Planning, High Altitude Endurance (HAE) UAVs, BADD, JFACC After Next, BC^2A, and Bosnia drawdown redeployment.

MetaNet ACTD. The Air Force should sponsor an ACTD to validate the use of an information and communications controller, integrated commercial and military communications, and the associated management concepts necessary to achieve robust connectivity and enable implementation of the reachback concept for support operations.

En Route Planning and Execution. The Air Force should conduct a family of interrelated communications connectivity experiments that demonstrate use of commercial and other available antennas, programmable radio, satellite, and distribution systems along with the information and a communications controller to achieve the required connectivity, reliability, and bandwidth both en route and at the forward deployment location. The experiments should validate the concepts that en route connectivity supports en route planning and execution, and verify that software reprogrammable radios are required.

Battlespace Awareness Expeditionary Force Experiment (EFX) 98. As part of EFX 98, the Air Force should prototype and validate a battlespace awareness and control system utilizing representative commercial, international, DoD, intelligence community, and targeted AEF sensors, directing the collection to the maximum extent possible in support of forward operations. The exercise should validate battlespace awareness development and control system concepts, demonstrate AEF's required global capability for battlespace awareness, and evaluate battlespace awareness as an AEF mission.

Distributed JFACC. The Air Force should develop a Memorandum of Understanding (MOU) with DARPA to jointly develop, implement, and experiment with software agents to manage information in support of distributed JFACC concepts. The Air Force should validate distributed JFACC concepts through reachback at EFX 98 and JWID 98, demonstrating distributed staffing and the potential for significant reductions in the number of JFACC personnel forward deployed to the area of operations through the reachback concept and en route and forward distributed planning.

Precision Navigation, Position, and Timing. The Air Force should validate the use of precision navigation, position, and timing as the foundation of the future battlespace infosphere by conducting an ACTD to integrate representative sensors, weapon systems, and databases using a geospatial system based on precise navigation and timing information. The Air Force should measure the effect of accurate location and timing information on multisensor data fusion. The system should be tested in a jamming environment as well as a benign environment. The impact of the geospatial and temporal database on the ability to perform multisensor fusion should be evaluated.

Remote ATC. The Air Force should conduct an experiment during EFX 98 to demonstrate the feasibility of substituting GPS-based navigation for precision approach radars to enable a reachback ATC concept.

6.0 Recommendations

Government-Commercial MetaNet: To support the AEF concepts, the Air Force must, in conjunction with DISA, develop a Mission Need Statement for the "MetaNet" that documents the requirements for global connectivity to achieve robust reachback and en route distributed operations. The Air Force must initiate development of communications controllers, reprogrammable radios, reconfigurable airborne antenna suites, and network access management tools to integrate military and rapidly emerging commercial services.

- Assign responsibility for development and management of an overall architecture that consists of use of the global grid along with all available communication assets in support of AEF missions.
- Develop an acquisition process that allows the Air Force to partner with commercial businesses to assure access to a broad variety of commercial communication services.
- Pre-negotiate landing right agreements and commercial contracts at all potential areas of interest.
- Develop wideband omni distribution systems for inflight communications.
- Develop wideband covert communications back to the fleet for use by special operations ground teams.
- Develop a process to obtain required bandwidth on demand from commercial and military providers.

Information Service Provider for Battlespace Awareness: To establish an AEF global capability for battlespace awareness, the Air Force must develop and field an "Information Service Provider" that captures all government and commercial sources to provide real-time content collection, creation, fusion, distribution, and control. This system must enable unprecedented timeliness, accuracy, control, coordination, and clarity of information assimilation at the JFACC in support of Air Force, joint, and combined operations.

- Develop and prototype a battlespace awareness/planning system and facility that allows AEF missions to be created in less than 2 hours.
- Develop cognitive presentation systems that allow for distributed, continuous, real-time AEF planning and execution, including systems for the cockpit.
- Develop a policy on the release of real-time intelligence.
- Create an MOU with DARPA on an Air Force system that integrates intelligence products and provides consistent on-line tailored views.

Battlespace Awareness as an AEF Mission: The Air Force must develop CONOPs and train units to use the assets of battlespace awareness as a stand-alone AEF mission.

Dynamic Information Management: The Air Force must develop dynamic management tools and systems to store, disseminate, search, retrieve, edit, visualize, exploit, and integrate information in real-time. These systems must exploit and extend the capabilities of the DII COE and aggressively leverage commercial developments to ensure that the right information in the right form is at the right place at the right time.

- Field the AEF global awareness capability and the MetaNet management and control capability as a JFACC service to land, naval, and air components of expeditionary forces.
- Integrate network management and information management, and develop a network information and communications controller.
- Supplant the ATO with continuous mission orders.
- Develop and prototype AEF simulators that allow for en route planning and training.
- Study and experiment with the benefits and consequences of delegation in information-intensive operations.

Geospatial Position, Navigation, and Timing: To achieve the operational efficiencies and battlefield awareness required by the AEF, a common geospatial-temporal reference system is needed. Therefore, the Air Force, in conjunction with NIMA, must field position, navigation, and timing services beyond the current GPS, with improved geospatial accuracy, antijam capability, and survivability to enable precision weapons delivery, remote air traffic control operations, and geospatially based information fusion.

- Accelerate integration of GPS into all platforms, including sensors.
- Demonstrate remote ATC procedures utilizing the GPS system.

System Assurance: To provide the robustness required by AEF information systems, the Air Force, in conjunction with DISA, must fund and collaborate with commercial providers to assure adequate protection for its growing dependency on information systems, including end-to-end encryption, data authentication, use of diversity for robustness, and continuous user identification.

- Conduct ACTDs to verify the integrated use of commercial and military communications and information in an electronically hostile environment, including both IW and jamming.
- Conduct a GPS robustness improvement program to include pseudolites, etc.
- Develop a process that will demonstrate the efficacy of GPS weapons delivery in a stressed communications environment.
- Establish a special project in AFMC and the Air Force Test and Evaluation Center (AFOTEC) to focus on system assurance. Include a stressed C^2I environment in all Flag exercises.

7.0 Summary

This section on C^2I shows that to plan, coordinate, and manage distributed resources prior to and during a very time-critical AEF operation requires the integrated use of commercial and military systems to achieve the following capabilities:

- Continuously available global communications with joint and coalition forces through **global connectivity**
- Real-time and precise knowledge of the location and status of both friendly and enemy forces from **battlespace awareness**
- Dynamic, real-time planning based on battlespace awareness to control all combat, sensor, and support resources through **information management**
- Ability to conduct remote operations and derive high platform and weapon efficiency based on precision, **geospatial positioning, navigation, and timing**

All of the above are to be done with very high **systems assurance**.

These C^2I enablers will provide capabilities allowing the AEF to become a far more effective fighting force through the use of new C^2 concepts, including dynamic force execution, a Global Awareness AEF, and reachback support. These new capabilities will facilitate cycle-time dominance, permitting us to always operate inside the enemy's "observe, orient, decide, act" (OODA) loop through proactive preparation of battlespace. Moreover, these new concepts will facilitate phase dominance, allowing us to control the rhythms of the battlefield (both offense and defense), thus creating windows of opportunity for exploitation. Information is a weapon; we must learn to use it effectively if we are to field the AEF concepts proposed in this study.

Annex to Appendix F

Acronyms and Abbreviations

ACTD	Advanced Concept Technology Demonstration
ADS	Automatic Dependent Surveillance
AEF	Aerospace Expeditionary Force
AFMC	Air Force Materiel Command
AFOTEC	Air Force Test and Evaluation Center
AII	Accuracy Improvement Initiative
AOG	Air Operations Group
AOI	Area of Interest
AOR	Area of Responsibility
ASD	Assistant Secretary of Defense
ATC	Air Traffic Control
ATD	Advanced Technology Demonstration
ATM	Air Traffic Management
ATN	Aeronautical Telecommunications Network
ATO	Air Tasking Order
ATR	Automated Target Recognition
BADD	Battlefield Awareness Data Dissemination
BC^2A	Battlefield Command and Control Architecture
BDA	Battle Damage Assessment
C^2	Command and Control
C^2I	Command, Control, and Information
C^3I	Command, Control, Communications, and Information
C^4	Command, Control, Communications, and Computers
C^4I	Command, Control, Communications, Computers, and Intelligence
C^4ISR	Command, Control, Communications, and Computers, Intelligence, Surveillance, and Reconnaissance
CAP	Crises Action Plan
CAS	Close Air Support
CEP	Circular Error Probable
CMA	Command, Control, Communications, and Computers, Intelligence, Surveillance, and Reconnaissance Mission Assessment
CNS	Communications, Navigation, and Surveillance
COA	Course of Action
COE	Common Operational Environment
CONOPS	Concept of Operations
CONUS	Continental United States
COP	Common Operational Picture
CORBA	Common Object Request Broker Architecture
COTS	Commercial Off-the-Shelf
DARPA	Defense Advanced Research Projects Agency
dB	Decibel

DBS	Direct Broadcast Service
DGPS	Differential Global Positioning System
DII	Defense Information Infrastructure
DISA	Defense Information Support Activity
DISN	Defense Information Systems Network
DTED	Digital Terrain Elevation Data
EFX	Expeditionary Force Experiment
FANS	Future Air Navigation System
GANS	Global Air Navigation System
Gbps	Gigabits per Second
GBS	Global Broadcast Service
GCCS	Global Command and Control System
GHz	Gigahertz
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HAE	High Altitude Endurance
HF	High-Frequency
HFALE	High-Frequency Automatic Link Establishment
IM	Information Management
INS	Inertial Navigation System
I/O	Input/Output
IPT	Integrated Product Team
ISR	Intelligence, Surveillance, and Reconnaissance
IW	Information Warfare
JBS	Joint Broadcast System
JCS	Joint Chiefs of Staff
JDAM	Joint Direct Attack Munition
JFACC	Joint Force Air Component Commander
JFC	Joint Forces Commander
JointSTARS	Joint Surveillance, Target, and Attack Radar System
JPALS	Joint Precision Approach and Landing Systems
JROC	Joint Requirements Oversight Council
JSF	Joint Strike Fighter
JSOW	Joint Stand-Off Weapon
JWID	Joint Warrior Interoperability Demonstrations
kb	Kilobit
kW	KiloWatt
LAAS	Local-Area Augmentation System
LEO	Low-Earth-Orbit
Mb	Megabits
Mbps	Megabits per Second
MEMS	Micro-Electro Mechanical System
MEO	Medium-Earth-Orbit
MHz	Megahertz
MOU	Memorandum of Understanding
MTI	Moving Target Indicator
NAS	National Airspace System
NIMA	National Imagery and Mapping Agency
OAA	Open Agent Architecture

OODA	Observe, Orient, Decide, Act
OSD	Office of the Secretary of Defense
PNT	Position, Navigation, And Timing
R&D	Research and Development
RCP	Required Communication Performance
RD&A	Research, Development, and Acquisition
RF	Radiofrequency
RNP	Required Navigation Performance
RSP	Required Surveillance Performance
RTSP	Required Total System Performance
SATCOM	Satellite Communications
SHF	Super High Frequency
SIGINT	Signals Intelligence
UAV	Unmanned Aerial Vehicles
UHF	Ultra High Frequency
VSAT	Very Small Aperture Terminals
WAAS	Wide-Area Augmentation System

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Appendix G

Technology Thrusts

1.0 Long-Term Vision of Aerospace Expeditionary Force (AEF)

Volume 1 of this report addresses operations, training, and equipment that, if implemented, would make major improvements in the effectiveness of Aerospace Expeditionary Forces in the near- and midterm time frames (through 2012). In the future, however, it may be possible to provide an even faster response with an even smaller footprint forward. There exist concepts and emerging technologies that, if developed and employed, could make paradigm-changing improvements to AEF operations mainly in the longer term, that is beyond about 2012. These concepts and technologies, and a vision of their potential effect on AEF operations, are described in this appendix.

1.1 Technology Thrusts Panel Membership

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1.2 Limitations of the Near- and Midterm AEF

The term "limitation" is not intended to be pejorative here, since notable improvements will result from implementation of the recommendations of Volume 1. However, as the Air Force evolves from the "air and space" force of today to the adopted vision of a "space and air" force in the future, the migration of more Air Force missions to space through the application of new technologies may reduce or eliminate dependence on ferrying fighters to the fray, establishing an "air bridge" of tankers, creating a forward operating location, stocking Regional Contingency Centers (RCCs), and placing our people in harm's way. It is in this spirit that the "limitations" of the significantly improved AEF described in Volume 1 are cited in the following paragraphs.

The near- and midterm AEF response would be lowered from 72 hours to about 24 hours by implementing the recommendations in Volume 1 of this report. Even though this is a major improvement, it still may be too long to act as a deterrent and prevent enemy movements in certain situations. Furthermore, the attainment of even this 24-hour response time is dependent on establishing an air bridge to refuel transport and fighter aircraft, and facilitated by prepositioning of equipment and supplies at a number of RCCs on foreign soil worldwide. The number and placement of these RCCs are set by the unrefueled range of the theater transport aircraft needed to establish and support the forward operating location for the AEF action. This 24-hour capability also is crucially dependent on implementation of total global awareness capability over the tactical area. Though this may be difficult in the midterm, it is clearly achievable and even more necessary in the longer-term future.

Another limitation is that, while it is desirable to deploy unmanned assets such as Unmanned Aerial Vehicles (UAVs) to the crisis area as the first AEF presence to limit exposure of crews, the cruise speeds of even the fastest UAVs such as the Global Hawk are only 350 knots, and thus they cannot show up until well after crewed vehicles make their appearance. Even if they were carried by transport aircraft, they would not appear before 24 hours. A means to deliver UAVs to the tactical area in much shorter times would be highly beneficial.

The entire AEF concept of operations (CONOPS) is centered on the use of inhabited platforms to carry out functions for force application, as well as reconnaissance, defense suppression, and battle area surveillance. While it is intended to make increasing use of UAVs for some observation and communications functions, the overwhelming midterm view is that of a manned operation, greatly dependent on visual observations and guidance by the human eye. All of this exposes a large number of crews to harm. It would thus be desirable to greatly decrease manned presence.

The above limitations could be substantially reduced by greatly increasing the AEF's use of and dependence in four areas: (1) use of space for total battlefield awareness, (2) use of unmanned combat air vehicles (UCAVs), (3) use of global-range large transport aircraft, and (4) use of space for force projection. The next section describes a vision of an advanced AEF employing a number of concepts and technologies that could be available in the longer term, which, if implemented, would go a long way toward achieving this goal. The last section describes the technologies and concepts that need development and demonstration in order to enable the vision. In employing these techniques, the Air Force would make a giant leap toward becoming a "Space and Air Force," as envisioned by its leaders.

1.3 A New Vision of AEF Operations in the Longer Term

The AEF would make its first presence known from space within 1 hour of the execution order by delivery of many independently targeted small bomb systems, delivered to the target area by spaceplanes from continental United States (CONUS bases or, to a lesser extent, by deorbiting space-based assets. The bulk would be used in suppression of enemy air defenses and targeted against command and control (C^2) nodes, radar sites, surface-to-air missile sites, etc. Some would be deep penetrators that could destroy very deeply buried C^2 bunkers.

These spaceplanes also could deliver large numbers of mini-UAVs to the tactical area as well as to the forward operating location, to loiter for much longer times. These mini-UAVs would gather information on the chemical, biological, and nuclear status, the status of the runway, and other aspects of the forward operating location or bare base selected for AEF operations. These mini-UAVs also would act as imaging and communications platforms, scouting out the theater engagement area for the later arrival of the manned aircraft and the commencement of operations.

The reentry vehicles deployed from spaceplanes or spacecraft also would deploy and seed the tactical area with tens of thousands of tiny and inexpensive sensors, responsive to a wide variety of sensory inputs, including sound and vibration. These sensors would be read out by spacecraft, or by local units via UAVs, and the information assimilated for best force projection and protection.

New large, global-range transport aircraft would be employed to transport much of the needed logistics and materiel to the forward operating location directly from CONUS, minimizing the dependence on the RCCs. These transports would achieve maximum effectiveness if they used a modular design so that the cargo-carrying portion were detachable, allowing many to be loaded and off-loaded off-line. This also would minimize the size and cost of the “air bridge” that would have to be established, as it would mostly have to refuel only fighter aircraft en route, avoiding the refueling of the transports that represents a large portion of the fuel requirements in the AEF operation.

Large imaging systems in geostationary orbit would obtain detailed information on the tactical area, dwelling for hours to days on the same area to detect changes as they occur. Electronic intelligence (ELINT) and imagery intelligence (IMINT) data would be fused in space, and change or other relevant information on targets, rather than massive amounts of raw data, would be sent to friendly forces in Global Positioning System (GPS) coordinates. These coordinates then could be used by aircraft to hit the targets using small bomb systems. If particularly heavily defended, the targets could be hit by small bomb systems delivered by spaceplanes or air-based stand-off platforms. Space-based systems performing functions similar to those of Joint Surveillance, Target, and Attack Radar System (JointSTARS) and Airborne Warning and Control System (AWACS), though with radar techniques optimized for use with large and/or distributed space systems, and operating in conjunction with the UAVs, would be used to sweep the tactical area to assess the situation early. These systems also would direct offensive counter-air and close air support (CAS) operations throughout the AEF operations.

Airborne lasers (ABL) would be used for destroying tactical guided missiles incoming against the forward operating location or against critical tactical elements in the engagement zone. Space-based lasers could also be used to destroy enemy aircraft and contribute to air superiority long before any inhabited AEF platform arrived at the tactical area. These space-based lasers also would be used to maintain space control by neutralizing hostile satellites.

UCAVs would be used in conjunction with inhabited fighters to maximize the air combat capability while minimizing the exposure of inhabited platforms and their crews to enemy fire. The UCAVs would initially be used to suppress enemy air defenses, and later, as experience developed, to augment conventional platforms in defensive counter-air and air-interdiction missions.

These UCAVs, as well as many of the UAVs operated around the forward operating location (FOL) or at the tactical area, would be increasingly commanded and controlled from CONUS as the situation allowed, by use of UAV communications nodes as well as by communications satellites. Highly interconnected secure communications with very wide bandwidth would be established throughout the forces in the tactical area. Robust reachback to CONUS and command echelons would be attained by using many communications satellites and the UAVs themselves to relay laser and high power microwave (HPM) or millimeter-wave communications. Not only could many of the support elements of the Joint Force Air Component Commander (JFACC) be moved to CONUS and connected via communications links to the commander and his staff, but also increasingly the planners and UAV controllers would be able to remain CONUS-based, thus further decreasing the logistics footprint of the AEF and reducing the number of personnel in harm's way.

Logistics movement and inventory control could be greatly aided by attaching a reusable, self-contained "tag" containing a chip to each item, box, or crate, to track its location. The chip would contain an inexpensive GPS set and a low-rate digital transponder. Spacecraft would periodically interrogate all the earth's area and address each "tag" in sequence. Each tag would respond with its identification and position, in a short, low-power digital burst. Calculations indicate that 6 billion separate items could be continuously tracked from space in this manner. Accurate and instantaneous knowledge of each item's position in near real-time would greatly aid efficient and economical logistics movement and automatic inventory control.

Once the Air Force fighters, bombers, command elements, and their support logistics started to arrive at the tactical area, and manned platform engagements began to occur, HPM and radiofrequency (RF) beams projected from space would aid defense suppression, CAS, and other battle support functions. These would include active denial techniques for non-lethal enemy force control, electronic countermeasures (ECM), information warfare (IW), and jamming of communications, command, and control elements (C^3) and centers. Escort jamming from space could augment aircraft self-protection against air defenses, creating a safe zone around aircraft flights.

Foliage penetration and subsurface mine detection also would be used from space to detect force concentrations, movement patterns, and minelaying operations as they occur, as well as to characterize previously mined runways, fields, etc.

After desirable targets were detected, they could be hit using GPS-guided Small Bomb Systems (SBS), which could be deployed from aircraft or from space. Alternatively, these targets could be hit by homing bombs using laser designators located in space, to minimize the exposure to hostile fire of airborne target designators using manned platforms. In this latter case, a ground laser would be bounced off a space mirror for target designation. This would be particularly useful for engaging relocatable or mobile targets, with the target being identified via imaging optics associated with the mirror spacecraft, and the laser beam placed on the target via the space mirror. The mirror and its required pointing accuracy have already been demonstrated by the Ballistic Missile Defense Organization (BMDO).

The general picture that emerges is that the initial AEF presence of weapons, sensors, and UAVs at the tactical area and the forward operating location are provided via space from CONUS beginning not later than 1 hour after start. The AEF presence then continues for the next 10 to 20 hours, maintained in part by the mini-UAVs, which loiter until the main AEF aircraft arrive. At that time the combat and logistics aircraft, along with their support personnel and equipment, arrive and take over the bulk of the operations. Space then provides a supporting capability for battlefield awareness, total communications connectivity, reachback for minimizing the logistics footprint, force projection, and force protection.

It is conceivable that the very rapid presence from space, combined with the logistics support provided directly from CONUS by the large global transport aircraft, may reduce the scope of the RCCs. Certainly the diplomatic and political approval process would be helped if the initial strikes were not carried out from foreign soil.

Space will thus provide an indispensable “tip of the spear” that cannot be provided any other way in the longer-term AEF operations.

2.0 Advanced Technologies to Enable This AEF Vision

The principal concepts and emerging technologies that need development and demonstration to enable the previous vision fall into five categories (1) ultra-rapid delivery of assets to the FOL and combat areas from CONUS or space; (2) force projection from space; (3) use of unmanned platforms for many functions contemplated for crewed vehicles; (4) greatly increased capability for global tactical battlefield awareness; and (5) large global-range transport aircraft.

2.1 Ultra-Rapid Delivery of Assets

2.1.1 Spaceplane

The spaceplane is a system concept that combines the attributes of aircraft and spacecraft. It is envisioned as an unmanned CONUS-based launch vehicle that places a payload carrier in orbit. The carrier can deorbit a payload over a target, lower its altitude to change orbit plane and re-orbit to perform multiple-pass delivery or reconnaissance, and be reusable many times. The spaceplane would have turnaround times measured in hours. It could deliver weapons, mini-UAVs, or other items to either the FOL or to the combat area directly from CONUS within 1 hour of the execution order. It also could perform a number of other missions, described in the next section.

Early versions could consist of a payload carrier with 1,000- to 3,000-pound capability on top of a conventional expendable booster or converted intercontinental ballistic missile (ICBM), which could be available as the residual operational capability from a demonstration program within 5 years and for about $1 billion. Ultimately, vehicles could be self-contained, single-stage-to-orbit (SSTO) designs with 30,000- to 40,000-pound payload capability, which could be available in 10 to 20 years with investments on the order of $10 billion.

New technologies are not needed for the early versions. The ultimate version could benefit from airbreathing propulsion combined with a rocket engine, in which the airbreather is operated up to about Mach 6 and then rocket power used for the rest of the trajectory to orbit. Though it is essentially immaterial whether the vehicle takes off vertically or horizontally, its trajectory must be basically vertical to avoid the low-acceleration, long-duration, high-altitude hypersonic cruise phase that technically challenged the National Aerospace Plane (NASP). Similarly, hypersonic cruise aircraft to perform the same mission would be inefficient, difficult and expensive to develop, and slow compared to orbital-insertion spaceplanes and thus should be avoided.

The Air Force should participate in the NASA-sponsored technology and demonstration programs of Hyper-X and Rocket-Based Combined Cycle, rather than develop its own competing technologies. Structural and thermal-protection material advancements are needed and could be pursued jointly. Cooperation between the Air Force and NASA programs, and between the airbreathing and rocket communities within both agencies (which traditionally have been separate), is highly recommended.

Though some of the spaceplane advantages (such as speed of delivery) are self-evident, the overall utility of spaceplanes in AEF operations must be demonstrated. One way would be to perform Battlelab experiments designed for that purpose. The AEF and Space Battlelabs could cooperate in such experiments. These in turn could lead to an Advanced Concept Technology Demonstration (ACTD), which could result in an early initial residual operational capability.

2.2 Rapid and Lethal Force Projection From Space

2.2.1 Spaceplanes

The description in the previous section applies. The spaceplanes could deliver a large number of SBSs from a dispenser, which would be a simple protective aeroshell fitted with a retro rocket to initiate reentry. An early spaceplane, which could be operational in the 2005 time frame, could carry up to about 3,000 pounds, i.e., about 10 such bombs. An ultimate spaceplane could carry 100 or more such SBSs, each independently targeted and GPS-precision-guided.

In addition, spaceplanes could deliver a number of GPS-guided, deep-penetrating, long-rod payloads that could destroy very deeply buried and hardened C^2 bunkers. All these weapons could arrive with no warning and within 1 hour of the order. The technologies required are identical to those described above.

2.2.2 Space-Based Weapons

Non-nuclear weapons identical to those described above could be “prepositioned in space” and used in the same manner as a spaceplane. Firepower could thus be brought to bear on the combat area without even the type of warning given by a rocket spaceplane launch in CONUS. An alternative use for psychological effect would be to announce in advance destruction of a given ground target at a precise time. The technologies required are the same as for the basic spaceplane, plus those for long-term dormant ability to survive in space.

2.2.3 High Power Microwave Weapons

All electromagnetic functions that can be performed from aircraft, including ECM, jamming, defense suppression by HPM pulses, and injection of IW signals, can, in principle, also be performed from space. The advantages would be long dwell times over the target area, particularly if geostationary satellites are used, and avoidance of placing aircrews in harm’s way. The disadvantages would be that to place the same power density on the targets as is attained from aircraft requires higher power and/or larger antennas by a factor of 10 to 100 or more.

In space, however, large antennas are readily implemented. Concepts exist for very large reflecting thin membranes measuring hundreds of meters or more across, as well as smaller subarrays of thin-film phased-array elements. These technologies, as well as the technologies for generating large amounts of prime power, need development and demonstration.

HPM would be used for force protection and suppression of enemy air defenses (SEAD). Their effect is to disable electronics by disruption or burnout through “back door” entry of very high, peak-power pulses. The effects are not dependent on whether the electronics are defensive or offensive, or employed in radars, C^2, or other functions. It also is possible in space to implement antenna patterns that have a hole in the middle, so that entire AEF aircraft flights could be protected by an enveloping “escort” HPM beam from space while the aircraft are not harmed.

If these technologies are matured, demonstrated, and implemented in operational systems, a hugely powerful capability for electronic and information warfare from space will exist. These developments can be leveraged from existing programs under way in the Air Force Research Laboratory (AFRL).

2.2.4 Jamming, ECM, and IW

From space, large power densities can be delivered to air and ground targets for jamming, ECM, and IW. The difference is that high peak powers and low average powers suffice for HPM equipment negation, but jamming and some other forms of ECM need high average powers. In this case, lightweight high-average-power sources and prime power in space must be developed.

The technology programs under way at the AFRL are not aimed at sufficiently high power levels for some of these applications. However, it is likely that in the far term the civilian community concerned with delivery of large amounts of ecologically clean and inexhaustible energy to earth power grids from space will demonstrate commercial space-based, multi-megawatt power sources, including power delivery by microwave beams. Should that happen, the DoD could leverage such developments and avoid most of the required research and development, simply procuring additional production models. These then would be used for powering jammers and ECM from space, as well as providing space-based radar and other military applications.

2.2.5 Active Denial

Active denial is a technique for using electromagnetic beams to control enemy troop formations. These technologies could be employed from space as well as from air vehicles by employing large, lightweight antennas in space to project the same power densities on the targets. The technologies are similar to those for HPM weapons, described above.

2.2.6 Space Mirrors and Sensors for Designating Targets

Force projection against relocatable or mobile targets requires laser designation for a homing version of the SBS, as GPS guidance will not be feasible in many cases. Laser target designation from air vehicles is current practice, but it exposes aircrews to harm and may not be practical in heavily defended or denied areas. For those cases it is possible to designate targets from space by pointing a laser, located either in space or on the ground, to the target. In either case, an imaging sensor in the spacecraft would be used to find the target, using either a human operator on the ground or an automatic target-recognition algorithm.

The preferred configuration is with the laser on the ground and the mirror in space. The laser beam would reflect off the space mirror and onto the target. The BMDO has demonstrated the requisite stabilization and pointing technologies. This system would require demonstration in conjunction with an imaging sensor on the space mirror, and against surface targets in a typical cluttered ground environment.

2.2.7 Space-Based Laser

A space-based laser system with sufficient power aperture to destroy ballistic missiles may soon be developed by BMDO. If the chosen laser frequency permits penetration of the atmosphere, such a laser system, with changes principally to its targeting system, also could be used against air and surface targets. The modifications or additions are similar to those that would be needed for the space target designator. The laser could provide a powerful means to rapidly destroy such targets, with a great psychological as well as lethal effect. The laser could be space-refueled after the AEF engagement to allow its subsequent strategic use, or it could be shared between the two missions. The technology is the same. These technologies are being pursued by BMDO and the AFRL.

2.3 Use and Control of Unmanned Platforms

2.3.1 Unmanned Combat Air Vehicle

Unmanned combat air vehicles would range from weapon-carrying UAVs, similar to the Global Hawk, all the way to high-performance fighters or fighter-bombers outfitted with communications and sensor suites to enable them to undertake one or several missions in an automated mode. Their availability would reduce exposure of crews to harm, with command and control by trained operators in CONUS.

These unmanned aircraft could be used for all AEF missions, including air interdiction, CAS, SEAD, and offensive and defensive counter air.

The technologies required are considerably more advanced than simply automating the flight control system. Automatic target search, recognition, and tracking systems must be developed, and their capabilities must be demonstrated in simulated and real exercises. Initially, the vehicles could be controlled by ground controller "pilots," as are UAVs, but eventually the goal would be to allow for their autonomous operation in certain classes of engagements.

2.3.2 Multiple-Platforms-Control Satellite

The simultaneous command and control of a large number of UAVs and unmanned combat air vehicles in and around a forward operating location, and throughout the combat area, is an ambitious undertaking. It would benefit from having a geostationary communications relay satellite dedicated to that function. This satellite would be outfitted with multiple steered antennas, or with a phased array capable of multiple simultaneous beams, to establish each link with adequate bandwidth, security, and jamming resistance.

Such a spacecraft could be built with near- and midterm technologies from the civilian and military SATCOM programs if the will and budget were there; however, the command and control of a very large number of unmanned vehicles simultaneously through a single spacecraft needs to be demonstrated.

2.4 Global Tactical Battlefield Awareness

2.4.1 Very Large, Lightweight Optical Systems in Geostationary Orbit

A lightweight optical imaging system in geostationary orbit is required to image the combat area continuously with resolution under 1 meter. Conceptually, such a system is feasible, but the technology of the requisite 25- to 50-meter lightweight optics is extremely demanding. Such an optical system could consist of either a thin membrane with active correction of surface errors, or a sparse aperture with solid mirrors and image combination. These technologies probably can be matured within 10 years, but they then need to be demonstrated; consequently, the resultant capability is unlikely to be available until the far term.

If developed and fielded, this system would be revolutionary, able to image the combat area continuously and to detect changes, many mobile or relocatable targets, etc., without the enemy's being able to hide by knowing overhead pass times, as is done today.

2.4.2 Large, Lightweight, High-Power RF/Radar Sensors in Space

The functions of ELINT, etc., can be performed readily from space, including geostationary orbit, where large antennas are relatively easy to implement because of the benign force environment. In addition, it is possible to implement functions similar to those now performed by AWACS and JointSTARS with space-based radars, though that is much more difficult. Given the availability of solar-array power systems in the 10- to 30-kW range, a JointSTARS-like function could be implemented from space. An AWACS-like capability also is possible, but would require power levels and arrays at least an order of magnitude greater.

Given the developments possible in the civilian community in power-beaming from space to earth, these power sources could become available in the far term. If that occurs, space-based radar functions could readily be implemented from space. None of these space-based systems would be a scaling of the airborne systems, but rather would be systems optimized for space use, including use of distributed spacecraft cooperating to achieve the function. Existing technology programs at AFRL and other places could be a basis for the required technology developments.

2.4.3 High-Power Phased Arrays of Semiconductor Laser Diodes

It is possible to have active lidar sensing from space, analogous to radar, as well as high-power coherent sources of laser energy for aircraft protection countermeasures and defense suppression from space, in the same way they are provided from airborne platforms. The ability rests on forming large arrays of high-power semiconductor laser diodes; however, in space these arrays will have to be larger to be effective, so that tight beams can be projected.

The technology of laser diode coherent arrays is being pursued by the AFRL, but this research needs to be extended to much larger coherent arrays.

2.4.4 Mini- and Micro-UAVs

UAVs that weigh a few pounds could be deployed by the hundreds from aircraft or from a spaceplane. These would operate in the combat area, performing numerous functions, including readout of sensors, imaging, communications, and jamming. These UAVs would be controlled from CONUS or the local command, but would be inexpensive and expendable, yet capable. The technology for such mini- or micro-UAVs needs development or acceleration, including sensor suites and satellite communications sets that weigh only a few ounces.

These technologies should leverage commercial developments in personal communications and a number of commercial imaging system developments, which could form the basis for incorporation into the mini/micro-UAV programs.

2.5 Large Global-Range Transport Aircraft

Development of a large global-range transport aircraft with an unrefueled range of 8,000 to 9,000 miles would enable a large reduction in the air bridge necessary for AEF operations. The air bridge still would have to be established to refuel fighters and smaller transports, which would not have such a global range, but the large transports would be refueled on the ground or in the air at most once. Since the large transports require a disproportionate amount of fuel, this should enable a sizable reduction in the air bridge and its logistics.

3.0 AEF Concepts and Technologies

Over a period of 5 months, the SAB AEF Technology Panel collected and archived a concept and technology database of one-page "templates," each describing an advanced concept or technology relevant to future AEF operations. Sources of advanced concepts and technologies included the AFRL and other government organizations, as well as industry responses to a *Commerce Business Daily* Request for Information. All templates, including more in-depth support materials (e.g., slide show presentations), were integrated into a World Wide Web database enabling all AEF Committee members to remotely evaluate and rank technologies as they were identified. This process, depicted in Figure G-1, ultimately led to a prioritized list of AEF concepts and technologies from which high-priority items could be shared among Panels, evaluated for relevance and funding adequacy, and incorporated into the individual sections of the final report, Volume 1.

Out of nearly 200 concepts and technologies documented, the 63 listed in this appendix were determined to offer the greatest leverage to AEFs for the Air Force. Table G-1 lists these 63 concepts and technologies by category, and cites the likely time period in which fielding could begin. The accounts of the concepts and technologies that appear in this appendix describe the programs as presented to the Technology Panel, and in many cases were authored by the organization sponsoring or executing the planned or current program. The degree, if any, to which each of the concepts and technologies presented in this appendix needs to be altered in order to offer the greatest benefit to an AEF is addressed in Volume 1.

Although the Panel does not claim to have identified every existing or conceivable concept or technology offering high leverage for an AEF, the comprehensiveness of the search can be defended somewhat by the variety of sponsoring or executing organizations that offered the 63 descriptions cataloged in this appendix:

- 39 from the AFRL
- 7 from the Defense Advanced Research Projects Agency (DARPA)
- 5 from the Army
- 4 from Air Force System Centers
- 4 from NASA
- 2 from the FAA
- 2 from industry independent research and development (IR&D)

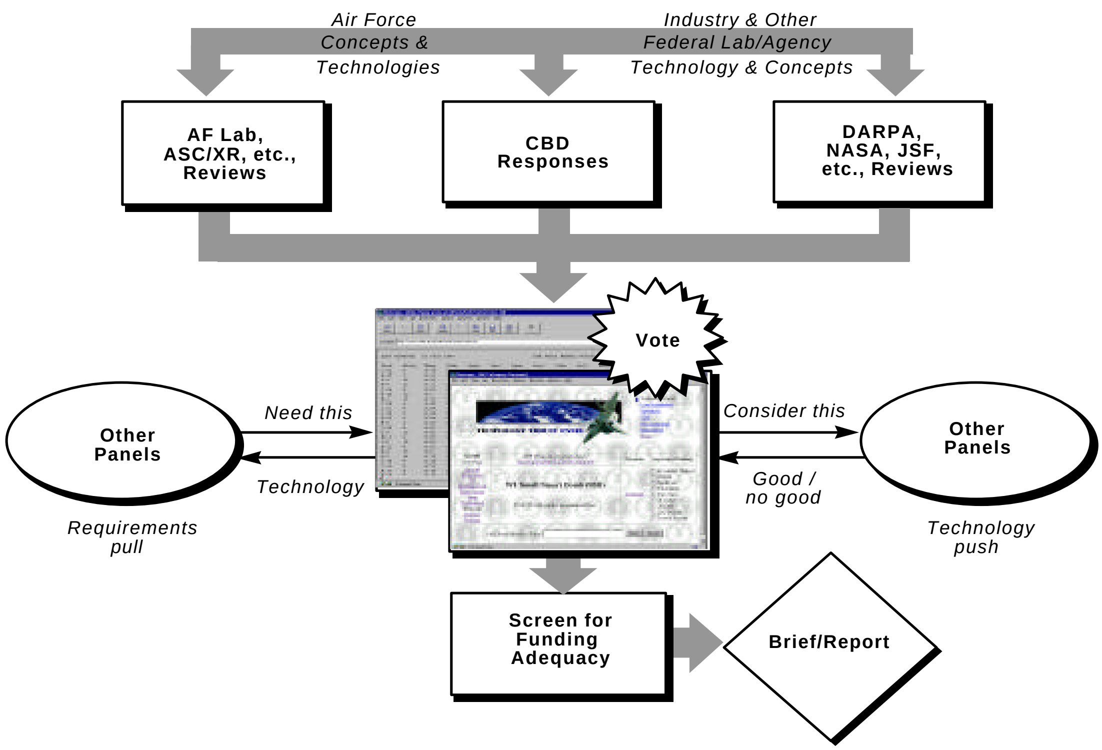

Figure G-1. *Concept and Technology Processing Scheme*

Table G-1. *Concept and Technology Time Frames*

(Item No.) ⇒ Concept or Technology Time Frames	*Near Term 0-5 yrs*	*Midterm 5-15 yrs*	*Far Term >15 yrs*
Aircraft Protection			
(1) Advanced Threat Infrared Countermeasures (ATIRCM)	*		
(2) High Power Microwave (HPM) Aircraft Self-Protection (ASP)		*	
Training			
(3) Distributed Mission Training (DMT)	*		
(4) Intelligent Computer-Assisted Instruction (ICAI)	*		
Environment			
(5) Arrive Alive	*		
(6) Physical Trace Detection	*		
(2) Active Denial Technology		*	
(7) Joint Chemical and Biological Agent Water Monitor (JCBAWM)		*	
(8) Aircrew Laser Eye Protection (ALEP)		*	
(9) Biothreat Detection and Destruction (Chemical Alert on a Chip)		*	
(10) Joint Chemical Agent Detector		*	
(11) Panoramic Night Vision Goggles (PNVG)		*	
(12) Remote Vital Signs Monitor		*	
(13) Seek Smoke		*	
(14) Airborne Stand-Off Minefield Detection System		*	
(15) Optical Trace Detection		*	
Command and Control			
(16) Strike II Architecture	*		
(17) JointSTARS Enhancements	*		
(18) Image Product Library (IPL)	*		
(19) Battle Damage Assessment (BDA) Sensor	*		
(20) Joint Forces Air Component Commander Battle Management Program		*	
(21) UAV Integrated C^2 Operations		*	
(22) DARPA Battlefield Awareness Programs		*	
(23) Distributed Air Operations Center (DAOC)		*	
(24) Aircraft Extremely High Frequency (EHF) SATCOM Antenna		*	
(25) SPEAKeasy Programmable Modular Communications System		*	
(26) Conventional High-Altitude Endurance UAV (Global Hawk)		*	
(27) Integrated Real-Time (Data) In/Out of Cockpit (RTIC/RTOC)		*	
(28) Smart Push		*	
(29) Multiple-Source Correlation System (MSCS)		*	
(30) Airborne Communications Node (ACN)		*	
(31) In-Theater Airlift Scheduler (ITAS)		*	
(32) Expanded Situation Awareness Insertion (ESAI)		*	
(33) Information for the Warrior (IFTW) (Reachback)		*	
(2) HPM C^2 Warfare		*	
(62) Surveillance Targeting And Reconnaissance satelLITE (STARLITE)		*	

Table G-1. *Concept and Technology Time Frames (continued)*

(Item No.) Concept or Technology Time Frames ⇒	*Near Term 0-5 yrs*	*Midterm 5-15 yrs*	*Far Term >15 yrs*
Systems			
(34) JSF and JSF Technology Maturation Program		*	
(35) Airborne Laser (ABL)		*	
(36) Common Air Transport (CAT)		*	
(37) Unmanned Combat Air Vehicle for SEAD			*
(38) Lasers and Space Optical Systems (Global Touch)			*
(39) Military Spaceplane (Miniature Spaceplane Technology)			*
Weapons			
(40) Small Smart Bomb (SSB)		*	
(41) Low-Cost Autonomous Attack System (LOCAAS)		*	
(2) HPM SEAD		*	
(42) Low-Cost Dispenser (LODIS)		*	
(43) Common Aero Vehicle (CAV)			*
Lean Sustainment			
(44) Logistician's Contingency Assessment Tools (LOGCAT)		*	
(45) Modular Aircraft Support System (MASS)		*	
(46) Affordable Guided Airdrop System (AGAS)		*	
(47) Pathfinder Autonomous Landing System		*	
(48) Deployable Pavement Repair System (DPRS)		*	
(49) Lightweight Material/Rapid Base Stabilization		*	
(50) Aircraft Battlefield Damage Assessment and Repair (ABDAR)		*	
(51) Advanced Man-Portable Airfield Pavement Evaluation System		*	
(52) More Electric Aircraft (MEA) Technologies		*	
(63) Pilots' Landing System (Fog Eye)		*	
Enabling Technology			
(53) Inertial Pseudo-Star Reference Unit (IPSRU)		*	
(54) Integrated Modular Avionics (IMA)		*	
(55) Photonic Beamforming for Communications and Guidance		*	
(56) High-Power Semiconductor Laser Technology (HPSLT) Program		*	
(57) Dynamic Database			*
(58) UCAV Flight Control			*
(59) Rocket-Based Combined Cycle (RBCC) Engine Propulsion			*
(60) Reusable Launch Vehicle (RLV)			*
(61) Hyper-X			*

NOTE: Pages G-14 – G-85 present a more detailed description of each of the items listed in Table G-1. Since the time this appendix was compiled, the four Air Force laboratories (Armstrong Laboratory [AL], Phillips Laboratory [PL], Rome Laboratory [RL], and Wright Laboratory [WL]) have been reorganized into one laboratory, the Air Force Research Laboratory (AFRL). References made to AL, PL, RL, and WL should now be directed to AFRL. Also note that the data presented in this appendix are current as of July 1997. Finally, some items have no entries listed due to a lack of information available at the time this report was compiled.

TITLE: (1) Advanced Threat Infrared Countermeasures (ATIRCM)

DESCRIPTION: ATIRCM is a joint aircraft protection program led by the Army's Night Vision Laboratory (NVL). Initial production of ATIRCM begins in FY 00, with preplanned product improvement (P^3I) for diode laser IRCM (DIRCM) in FY 02. The Office of the Secretary of Defense (OSD)/DDRE proposed a joint U.S./UK IRCM testing program to evaluate the PL's mid-infrared (IR) Optically Pumped Semiconductor Laser (OPSL) technology. Initial testing was successful against all seekers, protecting platforms with signatures up to 156 watts per steradian.

BENEFIT: ATIRCM will provide aircraft protection from many IR-guided surface-to-air and air-to-air missiles. Semiconductor laser technology is highly reliable in field tests with zero downtime.

PROGRAM PLAN: OSD/DDRE has requested to plus up (by $11 million in 3 years) mid-IR semiconductor laser technologies for IRCM. The plan will focus on accelerating technical base activities relevant to ATIRCM with spin-offs to DIRCM. PL technical efforts address high-brightness and high-temperature operations of semiconductor lasers. Use of 4-micrometer (μm) tapered lasers has met with very encouraging results. Band 4 semiconductor laser prototypes have been delivered to the Army, Navy, and Air Force. A flyable demonstration is planned for FY 00.

RISK:

SPONSORING ORGANIZATION: OSD/DDRE.

EXECUTING ORGANIZATIONS: Dr. Joe O'Connell, Army/NVL, (908) 427-4870, joconnel@nvl.army.mil. Dr. Clifford H. Muller, PL/LID, (505) 846-4026, muller@plk.af.mil.

TITLE: (2) High Power Microwave (HPM)

DESCRIPTION: This program develops and transitions HPM weapons technology into the operational inventory and protects U.S. systems against potential RF threats. HPM represents a major potential advance in electronic combat technology by extending conventional RF power output several orders of magnitude. This enables the damage and disruption of a much broader range of targets and simplifies the threat-specific nature of electronic combat systems. HPM therefore not only can attack multiple enemy communications and radar systems, but also is a potential generic countermeasure to a wide range of unfriendly guided weapons. The HPM program plans demonstrations in coordination with Air Force operational users in the following areas:

- HPM Aircraft Self-Protection (ASP) provides an airborne countermeasure against IR, RF, electro-optical (EO), focal plane array (FPA), or advanced dual-mode guided missiles in a non-system-specific manner. It employs an HPM source to disrupt a missile's seeker/tracker/guidance systems with minimal prior information of threat susceptibilities and/or characteristics, and can provide self-protection to both fighters and large aircraft.
- HPM SEAD provides lethal suppression of enemy air defenses through permanent damage to the electronic components of integrated air defense systems (IADS). It employs an air-delivered, ultra-high power microwave source to burn out components of communications, computers, and fire-control radars associated with IADS.
- HPM Command and Control Warfare (CCW) provides damage and disruption of enemy C2 electronic systems in a surgical manner at times and locations of our choosing. It employs both high-peak power burnout and long-duration rep-rated disruption weapons depending on mission scenarios and requirements.
- The RF Active Denial Technology (ADT) description is classified.

BENEFIT: The programs described above are directed toward the following Air Force needs, which have been validated and incorporated in the Air Combat Command Mission Area Plans and Air Force Materiel Command (AFMC) Mission Area Development Plans:

- Generic guided missile countermeasures
- Damage/isolation of enemy IADS
- Weapons effectiveness against area targets
- Multiple kills per pass
- Minimization/negation of collateral damage
- Suppression of enemy C2 systems

PROGRAM PLAN: ASP is currently limited to ground (pole) tests against IR missiles. It has unfunded requirements for RF and FPA, guided missiles and airborne demonstrations. SEAD is on track for single-shot warhead development/demonstration. It has unfunded requirements for rep-rated system development and integration into UAV platforms. CCW and ADT are on-track.

RISK: Program risks are assessed as follows:

- ASP — medium
- SEAD — high
- CCW — medium
- ADT — low

SPONSORING ORGANIZATION: AFMC through program elements (PEs) 62602 and 63605.

EXECUTING ORGANIZATION: AFRL (PL) at Kirtland AFB, NM.

TITLE: (3) Distributed Mission Training (DMT)

DESCRIPTION: Using real-time man-in-the-loop simulation technology, DMT will create the affordable, deployable, full mission training tools necessary to fulfill Chief of Staff of the Air Force (CSAF) push for more effective and efficient training. This technology will enable unconstrained combat mission training and mission rehearsal as part of the Joint Synthetic Battlespace. DMT will provide a local area network of high-fidelity weapon system trainers, mission planning systems, brief/debrief tools, and validated training methods and strategies for achieving and maintaining a high level of skill proficiency and combat readiness. In addition, DMT will provide the technology and training methods necessary to use these training devices and methods as part of a wide area network that integrates additional DMT nodes to create an environment that includes all essential mission elements.

BENEFIT: The AEFs require high-fidelity, deployable training systems capable of mission training and mission rehearsal to achieve the highest possible level of operational effectiveness. DMT provides the technology and methods for such systems. It will allow the AEF (1) routine practice of high-end mission tasks in a realistic mission environment that includes command, control, communications, computers, and intelligence (C^4I) and joint-Service components, (2) capability to assess alternative mission plans under “what if?” conditions, and (3) a full mission training system that “goes to war” with the force. The resulting benefits to the AEF will include (1) better training for individual and team skills, (2) capability to train for theater-specific requirements prior to deployment, (3) opportunity to develop and test alternative mission plans prior to deployment, and (4) maintenance of skills while deployed. This will increase operational effectiveness as measured by mission accomplishment, higher kill ratios, less attrition, and less fratricide across a wide variety of missions. Implementation of this technology also will save the AEF millions of dollars annually in acquisition and life-cycle costs by reducing the training demands on the aircraft themselves.

PROGRAM PLAN: The current program plan calls for the design, development, implementation, and evaluation of a DMT testbed at Luke AFB in FY 99. Once this testbed is in place, training effectiveness research will be conducted to determine the optimal mix of in-aircraft and simulator-based training. Funding shortfalls have reduced the scope of the threat system and the training support system (instructor operator, mission planning, and debrief systems).

	FY 97	FY 98	FY 99	FY 00	FY 01	TOTAL
REQUIRED (thousands)	$4,121	$4,004	$2,430	$2,430	$2,430	$15,415
FUNDED (thousands)	$2,005	$3,781	$2,287	$2,300	$2,302	$12,675

RISK: The overall risk of this program is medium. The highest technical risk involves developing visual displays that combine wide field of view (FOV) and high resolution. The DMT project is developing a high-risk laser-based projection system to meet this need. Other risk areas include high-fidelity threat and electronic subsystem components (high to medium risk), multilevel security management (high to medium risk), high-bandwidth, low-cost communication networks (medium risk) and communication protocols capable of supporting high-fidelity, real-time networked flight simulation (medium to low risk). Whenever possible, technical risk is being reduced through the use of commercial, off-the-shelf (COTS) components and open architectures that will allow alternative technical solutions and planned upgrades.

SPONSORING ORGANIZATION: AFMC/ST, Maj Gen Richard Paul, DSN 787-3344.

EXECUTING ORGANIZATION: Col Lynn Carroll, Aircrew Training Research Division, Armstrong Laboratory (AL/HRA), (602) 988-6561, DSN 474-6561 ext. 101.

TITLE: (4) Intelligent Computer-Assisted Instruction (ICAI)

DESCRIPTION: Demonstrated in AL Fundamental Skills Tutorial (FST) project and advanced through development of simulation-based authoring tools:

- RIDES: Authoring application suite that supports creation of object-oriented simulation linked to instructional design support templates and delivery incorporating student-centered tutorial support.
- VIVIDS: Addition of 3-D rendering in an advanced RIDES environment
- JavaRIDES: Advanced RIDES variation coded in Java for device-independent Internet delivery

BENEFIT: ICAI provides highly interactive, computer-delivered education and training, tailoring instruction to individual student strengths and weaknesses. It provides coaching by artificial intelligent instructional agents, capitalizes on cognitively engineered instructional methods, reliably boosts student outcome performance by 34 percent (if time-to-learn is held constant), and reduces time-to-learn by 55 percent (if student outcome performance is held constant). ICAI is the most affordable alternative for achieving large gains in student learning. Authoring tools and the simulation-based approach permit diminishing average production rates to about 40 hours per hour of high-end tutorial instruction within the first 10 hours of instruction. ICAI lowers training costs and increases training flexibility by reducing the need for expensive operational systems or training aides.

PROGRAM PLAN: VIVIDS is in advanced development, based on the very mature RIDESBASE. The parallel development of JavaRIDES will begin as soon as funding becomes available (since the contract vehicle and technical base are already in place). VIVIDS prototype-based applications are being field-tested. VIVIDS will require an 18-month advanced development and evaluation effort, which currently is 75 percent funded. JavaRIDES will require a 12-month effort pending incremental funding for the majority of that effort.

RISK: The risk is extremely low; all critical performance components have been proven.

SPONSORING ORGANIZATION: The Office of the Under Secretary of Defense (OUSD), with applications within Air Education and Training Command (AETC), Air Intelligence Agency (AIA), Navy Fleet Training Center, and dozens of public schools nationwide through FST.

EXECUTING ORGANIZATION: AL, Advanced Training Technology Branch, within the Cognition and Performance Division of the Human Resources Directorate. The URL for more information: www.brooks.af.mil/AL/HR/ICAI/icai.htm, e-mail: fleming@alhrt.brooks.af.mil.

TITLE: (5) Arrive Alive

DESCRIPTION: Prior to landing any aircraft at the AEF FOC, small unattended sensors are air-dropped around the airfield to detect the presence of chemical and biological agents. The sensors transmit their measurements back to the aircraft that dropped them to confirm that the airfield is free of contaminants before any aircraft land to commence preparations for air operations.

BENEFIT: Surveying a previously unoccupied forward operating base before the first aircraft lands avoids the risk of exposing AEF personnel and equipment to chemical or biological agents.

PROGRAM PLAN: No capability or development program currently exists. We recommend demonstration combined with (14) Airborne Stand-Off Minefield Detection System (ASTAMIDS).

RISK: This concept could be implemented by integrating currently available equipment, but a demonstration program is required.

SPONSORING ORGANIZATION: None currently. AFRL is recommended.

EXECUTING ORGANIZATION: None currently.

TITLE: (6) Physical Trace Detection

DESCRIPTION: A portable analysis is made of a physical wipe of the vehicle or driver to detect bomb residues.

BENEFIT: Physical trace detection allows detection of bombs within vehicles.

PROGRAM PLAN: This method can be used now as a quick fix.

RISK: Portable TV-size commercial systems are available now.

SPONSORING ORGANIZATION: Department of Energy/Department of Defense (DoE/DoD) Technical Support Working Group.

EXECUTING ORGANIZATION: FAA, Dr. Lyle Malotky.

TITLE: (7) Joint Chemical and Biological Agent Water Monitor (JCBAWM)

DESCRIPTION: The Air Force (AL/CFD) initiated a program with the Army to develop a portable, field-deployable modular water monitor. The biological modular components are being developed by AL/CFD. The monitor will consist of a Portable Sampling and Processing System (PSPS) to recover biological agents from the water and process agents to ensure sensitive and accurate detection (submitted for patent). A miniature, portable DNA-based detector will identify recovered biological agents. The Army's Edgewood Research, Development, and Engineering Center (ERDEC) will develop the chemical agent water monitor part of this detector system.

BENEFIT: To establish a bare-base operation, the Air Force base must have a landing strip and potable water. The Air Force needs to develop technology for reliable, field-deployable detection of biological and chemical agents in water supplies. This will provide rapid response to overt/covert terrorist actions or airfield/battlefield fallout; effective surveillance of military water supplies on base or in the field; and benefits to the drinking water industry and public health. The exact requirements are being detailed in the Joint Operational Requirement Document, JCBAWM.

PROGRAM PLAN: The sample collection, processing, and DNA accessibility will be completed by FY 98. In FY 99 the DNA application and PSPS breadboard will be completed. During FY 00 and FY 01 the prototyping and evaluation of the PSPS will be completed. From FY 98 to FY 01 the evaluation and adaptation of DNA-based detectors will be worked and completed. The following 6.2 funds have been requested through the chemical/biological DoD program, primarily the Joint-Service Materiel Group (JSMG) and Joint Science and Technology Panel (JSTP) for Chemical/Biological Defense: FY 98 to FY 01 $940,000 per year.

RISK: The risk is medium to low because some of the work has been reduced to practice and the patent.

SPONSORING ORGANIZATION: Office of Deputy Assistant to the Secretary of Defense (Nuclear, Biological, Chemical Defense Program), Col Ellen Pawlikowski, 3050 Defense Pentagon, Room 3C125, Washington DC, 20301.

EXECUTING ORGANIZATION: Dr. Robert J. Reyes/Dr. Jon Calomiris, AL/CFD, AMSCB-AL, E5101 Hoadley Rd., Aberdeen Proving Ground, MD 21010-5423.

TITLE: (8) Aircrew Laser Eye Protection (ALEP)

DESCRIPTION: ALEP development programs are divided into two major categories based on the hazards and threats: out-of-band (invisible) and in-band (visible). Out-of-band ALEP protects against U.S. laser systems — e.g., Low-Altitude Targeting and Navigation for Night (LANTIRN), night vision goggles (NVG) laser illuminator, and antipersonnel threats. In-band ALEP protects against antipersonnel laser weapons or outdoor laser light show technologies that could be exploited for military purposes. ALEP technologies protect through absorption (organic dyes, glass), reflective (dielectric stacks, rugates, holograms), or switching mechanisms. ALEP is a joint WL and AL program. WL/ML is developing materials while AL/OEO conducts science and technology (S&T) studies to define personnel protection requirements and susceptibility to lasers. In 6.3 AL demonstrates that ALEP prototypes will integrate into advanced cockpits without jeopardizing safety-of-flight and combat effectiveness. Risks are reduced for multiple product designs using single or multiple technologies. Current efforts focus on self-protection technologies for the F-15E and F-117, and protection for “green” threat wavelengths for all Air Force aircraft.

BENEFIT: For self-protection requirements, ALEP enables use of laser systems that enhance operational capabilities without risking eye injury. These systems include LANTIRN, LANTIRN air-to-air, NVG illuminator for A-10s, and enhanced target designator for AC-130U. These systems are increasing in power such that eye injuries will occur within the operational envelopes for certain tactics. For threat protection, ALEP enhances mission ability to survive antipersonnel laser threats. The threats could degrade mission performance by impairing combat vision and interfering with target identification, landing at night, use of NVGs, etc. Many of the first generation of laser weapons are invisible, and, as such, present no situational warning to aircrews.

PROGRAM PLAN: For AL, the program plan consists of 6.2 and 6.3 efforts. The technical areas include injury thresholds for off-axis laser exposures, development of a lighting compatibility model, demonstration of head-up display (HUD) and avionics compatibility of in-band ALEP, development of engineering tests to measure reflective protection, development of a wraparound frame for NVG use, protection validation, and establishment of specifications for haze, ballistics, and scratches that will reduce life-cycle costs.

- Total current 6.2 and 6.3 funding for ALEP is about $400,000 per year. About $100,000 is available for 6.3 contracts and $300,000 for 6.2 contracts. In FY 96, 6.3 funding for contracts was $300,000. Scheduled transition is FY 05.
- A special program was started by Secretary de Leon in the fourth quarter of FY 96. He released $1.5 million of 6.3 funds in FY 96 to conduct an accelerated demonstration of advanced self-protection technologies for the F-15E and F-117. Funding ended in December 1997. Congress authorized a $2.5 million plus-up to continue risk reduction of the program. However, the funds were identified for reprogramming by the Assistant Secretary of the Air Force, Acquisition (SAF/AQ) in April 1997 due to higher funding priorities.

RISK: Risk is high for in-band threat protection, and medium to high for advanced self-protection.

SPONSORING ORGANIZATION: SAF/AQR, Col Blackhurst, DSN 32-9200 ext. 52#.

EXECUTING ORGANIZATIONS: AL/OEO and WL/MLPJ, e-mail: robert.cartledge@platinum.brooks.af.mil.

TITLE: (9) Biothreat Detection and Destruction (Chemical Alert on a Chip)

DESCRIPTION: The objective is to develop a chip to which an array of artificial sensors with interactive properties is attached. Detection is achieved when a viral, biotoxin, or bacterial component binds to the array. This signature will identify biological agents and will allow the sensors to learn of new agents by varying signatures that later can be corroborated by other methods and added to the lookup table in a local or remote processor of the signal output of the central processing unit. Following rapid identification, the biological agents are destroyed with directed-energy sources tuned to characteristics of the agents that minimize collateral damage and human injury.

BENEFIT: The AEF can benefit greatly from the rapid detection, identification, and destruction of biological agents and contaminants in the immediate operational environment and in remote sites that contain biological agents. The unique signatures act as a natural encoding mechanism that must be deciphered by an appropriate computer code (even at a remote site). The remote encoding of unique signatures of unknown agents for later identification can be used to offset technological surprises.
The concept of using RF radiation to destroy biological weapons (BW), thus freeing personnel from working in BW protective gear, has great value. Additional advantages accrue with the capability to decontaminate delicate aircraft components.

PROGRAM PLAN: $50,000 was available in FY 97 to demonstrate discrete pattern formation on the biochips and decontamination concepts. Over the next 5 years, $1.85 million will be required to make the technology available for transition to integration in field detectors, and $2.7 million over three years for the development of proof-of-concept decontamination demonstrations.

RISK: The risk is medium if the technology is available by the predicted date at the level of performance necessary to achieve the stated benefit. The use of RF radiation for decontamination countermeasures is cutting-edge technology, and must be considered high risk.

SPONSORING ORGANIZATIONS: Dr. Robert J. Reyes, Joint Services Material Board, Aberdeen Proving Ground, MD, (410) 671-3995. Dr. Nancy Chesser, Directed Energies Inc., 4001 N. Fairfax Drive, Suite 775, Arlington, VA 22203, (703) 243-3383.

EXECUTING ORGANIZATION: Dr. Jonathan L. Kiel, AL/OERT, 8303 Hawks Rd., Brooks AFB, TX 78235-5234, (210) 536-3583, DSN 240-3583.

TITLE: (10) Joint Chemical Agent Detector

DESCRIPTION: A program that addresses joint-Service requirements for an advanced chemical agent detection system with significantly enhanced levels of sensitivity.

BENEFIT: Detects the presence of toxic agents inside cargo aircraft, both on the ground and during flight. Provides one-minute quick detection to check for gross contamination while loading. Provides long-term, low-dose monitoring of aircraft interiors. Detects gross contamination on personnel and equipment.

PROGRAM PLAN: The Air Force is the lead service. The draft Joint Operational Requirements Document is in coordination.

RISK:

SPONSORING ORGANIZATION:

EXECUTING ORGANIZATION:

TITLE: (11) Panoramic Night Vision Goggles (PNVG)

DESCRIPTION: PNVG is a revolutionary change to traditional image intensifier–based night vision devices. The initial focus of the PNVG project centered around developing an "enhanced capability" NVG. A primary candidate parameter for enhancement was the NVG FOV with such other parameters as resolution, weight, center of gravity, and integrated display symbology overlay as secondary objective enhancements.

A conceptual working model was developed and fabricated that displays a 100-degree horizontal by 40-degree vertical intensified FOV. This increased the intensified image seen by the warfighter 160 percent compared to the current 40-degree circular field of view systems. The larger FOV was achieved by using four off-the-shelf image intensifier tubes to produce four ocular channels. Two channels produce a full 30-degree by 40-degree binocular FOV; the other two produce monocular left and right eye channels of about 35 degrees by 40 degrees. The PNVG's folded optical system resulted in a much better center of gravity than the AN/AVS-6 and AN/AVS-9 NVG configuration. Even with the added image intensifier tubes and associated optics, the overall weight of the device was comparable to currently fielded NVGs.

BENEFIT: The large, panoramic FOV and better center of gravity should reduce fatigue during long missions and improve operational performance and safety. Applications such as low-level turn point identification, terrain avoidance, objective area acquisition, tanker/receiver operations, and force protection will be greatly enhanced. Additionally, this unique approach potentially permits the PNVG in fighter/bomber platforms to be retained upon ejection for use in evasion, escape, and rescue.

PROGRAM PLAN: The PNVG program is an Air Force Advanced Technology Demonstration within the Helmet-Mounted Sensory Technologies 6.3 program office. It is being executed as part of a Phase II Small Business Innovative Research (SBIR) Program and 10 advanced development working models will be available for operational utility evaluations beginning in April 1998. No additional funding is required within the current program scope.

	FY 96	FY 97	FY 98	FY 99
SBIR	$375,000	$375,000		
6.3		$1,695,000	$1,941,044	$187,870

RISK: The risk for PNVG is medium.

SPONSORING ORGANIZATION: Jeffrey L. Craig, AL/CFHV, 2255 H St., Rm. 300, Wright-Patterson AFB, OH 45433-7022, (937) 255-7592, DSN 785-7592.

EXECUTING ORGANIZATION: Danny Filipovich, Night Vision Corporation, 7301 N. Lincoln Ave., Suite 180, Lincolnwood, IL 60646.

TITLE: (12) Remote Vital Signs Monitor

DESCRIPTION: We are developing a device that measures vital signs in the human. Much of the proof-of-concept work already has been done. Work on a remote vital signs monitor began over 10 years ago in AL (then the Air Force School of Aerospace Medicine) to provide a capability to remotely triage casualties. Engineering models were built for the Air Force and the Navy and demonstrated. A short-range (approximately 10 m) version was built for the Air Force, and a longer-range (approximately 100 m) version was built for the Navy. The devices were put on the shelf until recently, when the technology was resurrected to support NLT applications. The device uses low-power RF to measure small movements of the chest wall, even in fully clothed individuals. The peaks and nulls of the reflected waveform indicate heart rate and respiration. The heart rate and respiration, in turn, indicate level of physiological stress or help determine optimum, safe application of an NLT. This puts the operator in a position to determine accurately how much nonlethal force to apply and when to cease application of that force, further reducing risk to the target.

BENEFIT: When fully developed, a fieldable device could be used to clandestinely detect human targets. It also could be used in a chemical or biological warfare environment to determine vital signs through a chemical ensemble, i.e., without removal of the protective suit. Other uses have been envisioned.

PROGRAM PLAN: This device is being built at the Georgia Institute of Technology. The vital signs monitor will use an operating frequency of 35 GHz and a coherent frequency modulation approach (FW-CW). Quadrature channels will be used to ensure that the reflected signal always is sufficient to permit reliable processing. A microprocessor-based module will allow the extraction of cardiac and respiratory rates. The device will permit measurement of cardiac and respiratory rates in a clothed individual located at a range of approximately 7 to 10 m. The candidate device will be available by about 1 November 1997 under the current funding of $55,000. The development of a fieldable, 100-meter range, man-portable system would require $300,000 in additional funding and could be available in 2 years.

RISK: The technology risks are minimal. One of the challenges is to make the device insensitive to motions of the target, e.g., small movements of the chest wall could be masked by large movements of the target.

SPONSORING ORGANIZATION: James H. Merritt, AL/OER, 8308 Hawks Rd., Brooks AFB, TX 78235, DSN 240-4703.

EXECUTING ORGANIZATION: James Toler, Georgia Institute of Technology, 240 14th St., Atlanta, GA 30332, (404) 894-3964.

TITLE: (13) Seek Smoke

DESCRIPTION: Seek Smoke is a laser “fence” for detection of drifting clouds of hazardous chemical and biological agents.

BENEFIT: Seek Smoke provides continuous monitoring of the perimeter of the AEF forward operating location for the presence of chemical and biological agents. It gives adequate warning to personnel to don protective gear and take other precautions.

PROGRAM PLAN:

RISK:

SPONSORING ORGANIZATION: Maj Greg Vansuch, PL (LIDA), (505) 846-5786.

EXECUTING ORGANIZATION:

TITLE: (14) Airborne Stand-Off Minefield Detection System

DESCRIPTION: Second-generation forward-looking infrared (FLIR) in helicopters uses automatic target recognition to interpret thermal anomalies and detect mines from an altitude of 1,000 feet at 70 to 80 mph. This 100-pound package provides both passive and active detection. A 35-pound lightweight sensor package also is in development.

BENEFIT: The low-speed pass of the first aircraft to arrive at a previously unattended AEF forward operating location surveys the runway for mines.

PROGRAM PLAN: The system will begin fielding in 2000. The lightweight package could be fielded by 2006. We recommend demonstration in conjunction with (5) Arrive Alive stand-off chemical and biological detection.

RISK:

SPONSORING ORGANIZATION: Dave Heberling, Army NVL, Fort Belvoir, VA.

EXECUTING ORGANIZATION:

TITLE: (15) Optical Trace Detection

DESCRIPTION: Optical trace detection provides stand-off laser detection of bomb residues or vapors.

BENEFIT: This system screens vehicles entering an AEF forward operating location for bombs.

PROGRAM PLAN: Optical trace detection is currently in research.

RISK:

SPONSORING ORGANIZATION: DoE/DoD Technical Support Working Group.

EXECUTING ORGANIZATION: FAA, Dr. Lyle Malotky.

TITLE: (16) Strike II Architecture

DESCRIPTION: Strike II architecture provides high-bandwidth SATCOM capability for large aircraft and lower-bandwidth Link 16 in all large and fighter aircraft, permitting cross-linking among all airframes.

BENEFIT: Strike II architecture extends digital data communications capability to all aircraft in the AEF. It enables en route planning and expanded situation awareness, contributing to improved responsiveness and lethality of the AEF.

PROGRAM PLAN:

RISK:

SPONSORING ORGANIZATION: Dan Turner, AFRL (WL/AAZT), Wright-Patterson AFB, OH, (937) 255-4794, DSN 785-4794.

EXECUTING ORGANIZATION:

TITLE: (17) JointSTARS Enhancements

DESCRIPTION: The Off-Board Augmented Theater Surveillance (OBATS) program provides off-board cueing and correlation information, which enables the ISR triad (JointSTARS, Rivet Joint, and AWACS) and other advanced platforms to focus their resources on hostile target areas. OBATS provides resource allocation to the off-board ISR platforms, enabling them to optimize their common operating picture through resource management onboard each platform. JointSTARS has been the initial focus for the first OBATS node, providing the enabling technology to implement and demonstrate several highly visible enhancements, including:

- Enhanced synthetic aperture radar (ESAR)/automatic target recognition (ATR). ESAR provides a factor-of-six improvement over the baseline JointSTARS synthetic aperture radar (SAR) system capability. Based on STARLOS algorithms, the ATR provides a high probability of correct identification (greater than 90 percent) while maintaining a low false-alarm rate (.0001 sq km) in densely cluttered environments. The ATR can identify Tactical Erector Launchers (TELs) in the clear with up to 30 percent obscuration of the target.
- Moving target indicator (MTI)/high-range resolution (HRR)/ATR. This technology provides ground vehicle target length measurement while in MTI mode, a factor-of-three improvement over the baseline JointSTARS SAR system capability. A 1-degree range-profiling ATR algorithm is in development for target identification.
- Inverse SAR (ISAR)/ATR. ISAR develops images according to the motion of the target with respect to the sensor. It selects appropriate moving targets by tracking algorithms used to predict traffic flow over curved segments of the road network. Based on ISAR images, two-dimensional ATR algorithms are in development for target identification.
- Moving target exploitation (MTE). MTE is developing a toolbox of algorithms to help the JointSTARS operators interpret the large number of targets (up to 10,000) being detected by the sensor. This toolbox includes trackers, domain analysis, area delimitation, movement analysis, and convoy detection.

BENEFIT: JointSTARS consists of a Boeing 707 with a 24-foot phased-array antenna. The JointSTARS platform surveys ground force movement and provides spotlight SAR images of fixed targets on the ground. This platform can be deployed quickly to react to the AEF requirements in support of advanced deployment of DoD assets. The JointSTARS technology enhancements developed and demonstrated by the Rome Laboratory (RL) provide for an immediate warfighting capability significantly greater than that seen in Operation Desert Storm and Operation Joint Endeavor. These technologies provide for the accurate, reliable, and timely detection and identification of critical mobile and fixed targets.

PROGRAM PLAN: The JointSTARS enhancements program has evolved over the past several years. Many of the technologies have been flight tested on board the test system number 3 (T-3) platform located at Northrop-Grumman Melbourne. Close coordination among the product center (Electronic Systems Center [ESC]/JS), requirements (ACC/DRR), and acquisition (SAF/AQ) has been ongoing. ESC/JS, in cooperation with RL, has identified the required processing upgrades to allow for the transition of these technologies to the production aircraft. SAF/AQ and ACC/DRR have provided the necessary support and funding to enable the signal processing upgrades for insertion of these technologies. RL is implementing these technologies onboard T-3 for flight demonstration and technology transition.

RISK: The technology risk transitions from low to high according to the level of maturity within the algorithm development. These are rated as follows:

Technology	Tech. Demo.	Risk	Funding to Date	Funding Required
ESAR/ATR	Sep 97	Low	$7 million	$2 million
MTI/HRR/ATR	Dec 97	Medium	$1 million +ATR	$3.5 million
ISAR/ATR	Sep 98	Low	$2 million +ATR	$5 million
MTE	Sep 99	Medium	$5 million	$10 million
OBATS	Sep 00	Medium-High	$7 million	$12 million

SPONSORING ORGANIZATION: Jon S. Jones, AFRL/Rome, 26 Electronic Pkwy., Rome, NY 13441-4514, (315) 330-1665, fax (315) 330-3703, e-mail jonesj@rl.af.mil.

EXECUTING ORGANIZATIONS: Dr. Arnold Bramson, Northrop-Grumman, (407) 726-7717. Dr. Larry Hostetler, Sandia National Laboratories, (505) 844-4885. Joe Alt, Pacific Sierra Research, (703) 516-6303.

TITLE: (18) Image Product Library (IPL)

DESCRIPTION: IPL is a server-based archive for imagery products, video products, and documents. Network access to the IPL can be local (through LANs) and remote (through SIPRNET or JWICS networks). Users access an IPL using a browser interface such as Netscape, Mosaic, or Internet Explorer. The browser interface provides structured query, geographic, and keyword database searches. IPL servers support server-to-server communications for auto-replication and remote queries.

BENEFIT: IPL will provide AEFs with access to image and imagery-derived products. An IPL server could be prepopulated with imagery products and deployed with an AEF. Alternatively, the AEF team could immediately access IPL servers, which are located at 60 sites worldwide, via satellite and/or JWICS and SIPRNET networks. To access IPL imagery products requires a personal computer with Mosaic or Netscape, helper applications to view products, and network connectivity.

PROGRAM PLAN: IPL 1.0 is fully funded and was fielded during the summer of 1997. IPL 2.0 development contract was awarded in the third quarter of FY 97.

RISK: Low-Image Product Archive (IPA) is currently fielded at more than 60 sites. The IPL 1.0, which is the IPA successor, was deployed in the summer of 1997.

SPONSORING ORGANIZATION: Maj Al Womble, National Imagery and Mapping Agency, 14675 Lee Rd., Chantilly, VA 20151-1715, (703) 808-0541.

EXECUTING ORGANIZATION: Joe Stooks, IRD-1 Rome Laboratory, 32 Hangar Rd., Rome NY, 13441-4114, (315) 330-4042.

TITLE: (19) Battle Damage Assessment (BDA) Sensor

DESCRIPTION: Hughes Aircraft Company has developed a concept and prototype hardware for a real-time BDA sensor. This low-cost and expendable (use-only-once) sensor system consists of a small gliding flight vehicle. It carries an onboard microprocessor, independent GPS navigation capability, various sensors including a television or infrared imager, and a communication link to satellites or to distant airborne platforms. The BDA sensor is small enough to ride along with an attacking munition, such as a precision strike weapon. Shortly before weapon impact, the BDA sensor detaches from the weapon and begins an autonomous gliding flight. Following weapon detonation, it can circle the target location several times while transmitting live imagery. Alternatively, the BDA sensor may be deployed directly from a strike aircraft. Post-strike imagery and chemical, acoustic, and electromagnetic signatures of the target are sent directly to a departing aircraft or to a satellite or other communication input node within the first few minutes of the actual strike. In 3 to 4 minutes of typical low-altitude orbit time, the sensor can transmit approximately 100 images from all target aspect directions. We are currently flying prototype BDA sensors, which are 20 inches long, weigh under 8 pounds, fly at 100 knots, navigate autonomously, carry imaging sensors, and communicate directly with synchronous-altitude satellites. These robust flying vehicles can be produced for a few thousand dollars each. They contain no fuel or engine and require no recovery system. They are highly covert and can be used to employ sensors with precision in denied areas. Glide ratios of up to 20:1 are feasible. When the sensors are released from 40,000 feet, the glide range can reach 150 miles.

BENEFIT: BDA can be provided immediately following a strike package or as needed from other support aircraft. This capability will reduce the number of forward-deployed strike aircraft required to sustain air operations by reducing restrike missions on targets already destroyed. Immediate BDA strike from a package can be used for dynamic reassignment of surviving ground targets. The improved situational awareness will permit a higher tempo of strike operations.

PROGRAM PLAN: To date, the air-dropped BDA gliding sensor has been developed solely on Hughes discretionary IR&D funds. A ground-launched, rocket-boosted gliding sensor is being developed for Army field artillery applications in a cost-shared program between Hughes and the Army. Development of an operational BDA sensor for Air Force applications would benefit from additional investment in the following areas: (1) aircraft integration and Seek Eagle certification, (2) integration with specific precision-guided weapon systems, (3) integration with existing or planned C^4I and dynamic mission planning systems, and (4) possible development of high-altitude (60,000-foot mean sea level [MSL]) flight capability for the BDA sensor. An advanced technology demonstration of the BDA sensor from strike aircraft could cost on the order of $4 million in less than 2 years.

RISK: The risk is medium to low. The BDA sensor makes maximum use of commercially available electronic components. Prototype flight hardware and image transmission to satellites has been demonstrated under our IR&D program.

SPONSORING ORGANIZATION: U.S. Army Commander, ARDEC, AMSTA-AR-FSP-A, attn: Greg Bischer, Picatinny Arsenal, NJ 07806, (201) 724-7197.

EXECUTING ORGANIZATION: Dr. James G. Small, Hughes Missile Systems Co., Tucson, AZ 85734-1337, (520) 794-7664.

TITLE: (20) Joint Forces Air Component Commander Battle Management Program

DESCRIPTION: The JFACC Battle Management Program will substantially change the way we plan and control air operations in the joint arena. Current methodology is based on a fixed-time window of operations (24 hours) for which we plan air missions as part of an ATO. The generation of the ATO is accomplished by a set of "stovepipe" applications, with very little interoperability between them, little flexibility to respond to dynamically changing events, and limited capability to support "small-footprint" forward deployments. The JFACC Battle Management Program will develop the capability to plan and control air operations based on a continuous planning, execution, assessment, and replanning model. It will be able to respond to situation changes and support fully dispersed operations. The strategy for accomplishing this task is as follows:

- **Develop a new process.** An objectives-oriented planning, execution and assessment process provides enhanced responsiveness, efficiency, effectiveness, and flexibility.
- **Enable the process with advanced technologies and systems.** A common plan representation provides the foundation for strategy-to-task, cross-domain (Ops-Intel-Support) integration in a continuous, dynamic, event-driven operational tempo.
- **Empower the JFACC with next-generation capabilities.** Transition advanced information technologies and systems to integrate and synchronize forces in time, space, and purpose.

BENEFIT: The DARPA JFACC Battle Management Program will revolutionize C^2 of joint and coalition air forces through the incremental development, integration, and transition of advanced technologies focused on enhancing the decision-making capabilities of the next-generation JFACC. The resulting system of tools, applications, and services will enable revolutionary new and improved concepts of operations for the planning, execution, and assessment of future joint air operations support needs.

PROGRAM PLAN:

Phase 1–The JumpStart Effort

The JumpStart phase (March 1996 to January 1997) was intended to provide an early proof and demonstration of the JFACC Battle Management Program concept and a focused example of the underlying operational and technical vision. The goals of the JumpStart phase were to

- **Prototype** an objectives-oriented C^2 process to provide significant improvements in both the efficiency and effectiveness of air battle management.
- **Develop** an underlying common plan representation to support cross-domain and continuous integration of planning activities in a dynamic environment.
- **Demonstrate** advanced information technologies, such as object-oriented information structures, collaboration agents, and advanced visualization tools designed to integrate and synchronize the actions of military forces in time, space, and purpose.

Phases 2-5

The Phase 2 development efforts began in early March 1997 with three major areas of activity:

- Technology base investigations were begun in five areas: (a) active databases, (b) plan quality evaluation, (c) mixed initiative planning, (d) continuous planning, and (e) knowledge management.
- Applications and Services development efforts address: (a) plan generation, including prototype planners in force support and ISR, (b) workflow management, (c) campaign assessment, and (d) visualization.
- An overall technical integration, evaluation and demonstration effort ties together all of the technology efforts in a series of prototype demonstrations.

The program is a multiphased effort designed to bring the benefits of advanced technologies to bear on the operational problems that confront a JFACC. Each phase will see the emergence of new technologies offering new and improved solutions to these problems. Over the life of the program, the best of these will be evaluated, matured, and finally selected for transition into the Service's operational systems.

RISK: The risk associated with the effort is moderate to high since we are breaking new ground not only on the C^2 process, but also in numerous technology areas. To mitigate this risk, an evolutionary development strategy is being used, with numerous integration and demonstration efforts, coupled with a high degree of user involvement.

SPONSORING ORGANIZATION: Col Robert Plabanek, DARPA/ISO, (703) 696-2375, e-mail: plabanek@darpa.mil.

EXECUTING ORGANIZATION: Richard A. Metzger, RL/C3A, (315) 330-4175, e-mail: metzger@cs.rl.af.mil.

TITLE: (21) UAV Integrated C^2 Operations

DESCRIPTION: Enabling technology and demonstrations of UAV concepts have matured significantly. The ongoing ACTD of Global Hawk and Dark Star, and the field testing/deployment of Predator, attest to the growing maturity of UAV technology. However, in order to exploit the capabilities of UAVs, it is critical that their operations be integrated into the warfighters' C^2 battlefield environment. This integration includes the development of operational concepts, technologies, and demonstrations that enable robust, global operations. The UAV needs to fit into an operational scenario and architectures as a taskable asset that meets Global Engagement (GE) objectives as outlined by CSAF. These GE objectives will be met by integrating UAVs into the Air Force command, control, communications, and computers, intelligence, surveillance, and reconnaissance (C^4ISR) infrastructure as outlined in Global Awareness, Global Information Exchange, and Dynamic Planning/Execution C^4ISR vision.

BENEFIT: In meeting Global Awareness objectives, the UAVs must operate and interrelate with other sensor assets such as airborne TRIAD sensors (AWACS, Rivet Joint, and JointSTARS) and space-based sensors. The grouping of assets must be integrated into a powerful information source that exploits the capabilities of each asset, retasks appropriately, and fuses the dispersed surveillance information with intelligence data into high-confidence situational awareness and targeting information directly useful to the warfighters, planners, and commanders. Specifically, it integrates UAVs into the battlefield as a valuable asset in executing ISR, communications relay, SEAD, or a weapon system.

PROGRAM PLAN: The plan for this activity is still in the initial phases. This initiative is a major part of the Air Force S&T emphasis area plan on UAVs. The premise of this area plan is to leverage available UAV platforms and capabilities to *demonstrate* potential to fulfill battle commander needs as critical technologies are being developed. The critical technology areas are (1) distributed mission planning, (2) survivable distributed communication/networks and control, (3) multisource data exploitation, collection management, and fusion, and (3) enhanced sensors, e.g., bistatics. Funding has been provided to develop enabling technologies.

RISK: The risk for this is medium for the development and implementation of operational deployment capabilities. As the technologies are implemented to extend current UAV payloads to handle additional functions (e.g., bistatics, communications relay, or distributed retaskable control), the risk becomes medium to high.

SPONSORING ORGANIZATIONS: Aeronautical Systems Center (ASC) UAV System Program Office (SPO), Air Combat Command (ACC), DARPA, and DARO.

EXECUTING ORGANIZATION: The program is still in the planning stages, so RL is the executing organization.

TITLE: (22) DARPA Battlefield Awareness Programs

DESCRIPTION: DARPA is pursuing programs to develop new battlefield sensors, and to provide for their management, and for the exploitation, correlation, and fusion of the data they collect. Sensor approaches include high-resolution SAR in the near term, foliage penetration radar in the midterm, and coherent change detection in the far term. Sensor exploitation approaches include template-based ATR in the near term, model-based ATR in the midterm, and hyperspectral ATR in the far term. Correlation and fusion approaches include birth-to-death tracking of time-critical targets in the near term, birth-to-death tracking of everything on the battlefield in the midterm, and prediction of enemy course of action in the far term. Sensor management approaches include preplanned single-sensor management in the near term, centralized dynamic sensor management in the midterm, and distributed multisensor tasking in the far term.

BENEFIT: The objective of these DARPA programs is to support the Chairman's Joint Vision 2010 with consistent battlespace understanding. Most of the included programs are directly relevant to an AEF (e.g., BADD and the War Fighter Internet [WFI]). WFI is intended to provide a World Wide Web–like mobile, wireless, multimedia, joint tactical Internet to support warfighters.

PROGRAM PLAN:

RISK:

SPONSORING ORGANIZATION: Troy A. Crites, Deputy Director Information Systems Office, DARPA, (703) 696-7447.

EXECUTING ORGANIZATIONS: Various.

TITLE: (23) Distributed Air Operations Center (DAOC)

DESCRIPTION: The DAOC extends the deployable Joint Task Force (JTF) concept to the force planning level of Air Battle Planning and Operations. Both existing and planned Contingency Theater Automated Planning System (CTAPS) software modules have been adapted for true distributed operation using modern, object-oriented, distributed computing systems. Without changing the functionality of the user interface, the software tools of the Air Operations Center (AOC) can collaborate across wide area networks in different geographical areas, allowing a JTF Commander and the JFACC to provide full AOC capabilities without deploying an entire AOC staff.

BENEFIT: User and developer benefits:

- Extended capability to deployed elements
  - Forward and reachback capability
- Greater reliability through distribution and replication
- Mission-specific configurable
  - Scaleable architecture
- Common Object Request Broker Architecture–based, COTS-compliant architecture
  - Reduced reliance on vendor-specific features
- Benefits of object-oriented design
  - High-quality software development
  - Reusable software components
  - Management of changes
  - Ability to deal with complexity
  - Software design support in the application domain

PROGRAM PLAN: The program is in the final stages as initially laid out. A no-cost extension until the end of FY 97 was established to support the integration of multilevel security (MLS) technology for support of coalition operations. This enhancement was demonstrated at the Joint Warrior Interoperability Demonstrations (JWID) 97. No further funding of this particular program has been planned. However, lessons learned and technology transfer into the current Force Level Execution (FLEX), JFACC, and Theater Battle Management Core Systems (TBMCS) programs are planned.

RISK: The risk for DAOC is medium.

SPONSORING ORGANIZATION: Carl Defranco, RL/C3AB, 525 Brooks Rd., Rome, NY 13441, (315) 330-3096, and fax (315) 330-2807.

EXECUTING ORGANIZATION: Tamara Petroff, LOGICON, Inc., 222 W. 6th St., P.O. Box 471, San Pedro, CA 90733-0471, (310) 831-0611 ext. 2329.

TITLE: (24) Aircraft Extremely High Frequency (EHF) SATCOM Antenna

DESCRIPTION: Communication antennas are needed to meet the data rate, mission, and performance requirements of aircraft deployed in the AEF.

BENEFIT: Communication with the deploying aircraft is critically important to the AEF mission. High data rate communication from data sources in CONUS is required to update the mission commander during deployment to a conflict scenario at intercontinental ranges. In-theater communications are essential between command, surveillance, and tactical aircraft, and between ground and air units using airborne UAV communications nodes. This will not happen without advanced antennas to meet the data rate, mission, and performance requirements of each of the aircraft in the AEF.

PROGRAM PLAN: RL is developing EHF antennas for SATCOM with the MILSTAR and GBS. Eight years ago, EHF phased arrays were not technically possible. Since then RL has invested about $10 million. Prototype receive phased arrays at 12 GHz and 20 GHz are now being flown on demonstration aircraft. Hybrid, electromechanically scanned antennas also are being developed. These will be lower cost and will permit larger apertures for higher data rate requirements on large aircraft. Funding to continue development of EHF airborne antennas is inadequate to nonexistent. If there are going to be production receive and transmit EHF antennas by 2000, $5 million to $8 million is required. Other antenna technologies that must be developed include wide-band and multiband antennas to reduce the proliferation of antennas on aircraft and beamforming/nulling antennas for UAV links to mobile and hand-held cellular phones. In the future there will be commercial EHF SATCOM systems; the DoD must take advantage of these. However, the DoD operates in hostile environments and must develop unique SATCOM capabilities.

RISK: The risk of developing EHF antennas for airborne SATCOM by 2000 is considered medium.

SPONSORING ORGANIZATION: John Turtle, RL/ERAA, (617) 377-2051, DSN 478-2051. Bill Cook, RL/C3BA, (315) 330-7439, DSN 587-7439.

EXECUTING ORGANIZATIONS: Raytheon, Hughes, Datron, Texas Instruments, and Boeing.

TITLE: (25) SPEAKeasy Programmable Modular Communications System

DESCRIPTION: SPEAKeasy is developing a Multiband Multimode Radio (MBMMR) that will be capable of operating from 2 MHz to 2 GHz, employing waveforms selected from memory, downloaded from floppy disk, or reprogrammed over the air. Key to the program is the publication of specifications for the radio Open Systems Architecture (OSA). A joint Government/industry forum is providing feedback and insight into the design.

BENEFIT: An OSA, software-programmable radio would have many benefits. The OSA aspect would ensure that many components will be off-the-shelf and, as the system becomes more accepted, several sources for individual components should emerge. This will result in a lower overall cost for the system for initial acquisition, as well as for repair and product enhancement. Software programmability will allow the system to become interoperable with whatever radio it has software to emulate. This becomes advantageous when it is not practical or cost-effective to bring as many radios to a deployment as would be needed to communicate on every desired waveform or system. An additional benefit is the ability to easily upgrade the system by adding new waveform software when the communications standards change or evolve.

PROGRAM PLAN: The program is a joint R&D program with funding and participation on the part of the Air Force (RL), the Army (Communications and Electronics Command), and DARPA. DARPA's participation ceased at the end of FY 97. The program has experienced cost growth and is awaiting an Air Force/Army decision to find additional funding to complete the 4-channel, fully programmable, narrow-band and wide-band capable units by FY 99.

RISK: The technology to accomplish the SPEAKeasy stated goals appears to be available in the time frame needed, and is therefore medium to low risk. The wide-band front end for transmit and receive is the item with higher technical risk. The funding to fully develop the technology is not available, making the risk high for completing the program on time (FY 99).

SPONSORING ORGANIZATION: Wayne Bonser, RL/C3BB 525, Brooks Rd., Griffiss Business and Technology Park, Rome, NY 13441-4505, (315) 330-3829.

EXECUTING ORGANIZATION: Joseph Debes, Motorola Space and Systems Technology Group, Diversified Technologies Division, 8201 E. McDowell Rd., P.O. Box 1417, Scottsdale, AZ 85252 , (602) 441-6737.

TITLE: (26) Conventional High-Altitude Endurance (HAE) UAV (Global Hawk)

DESCRIPTION: The Global Hawk is being developed as an ACTD program to identify and demonstrate a platform, sensors, a datalink, and a ground station system that satisfies warfighters' extended reconnaissance needs within reasonable cost guidelines. It is a vanguard program to purchase maximum military capability at fixed per-unit cost (i.e., $10 million unit flyaway cost per vehicle in FY 94 dollars). The Global Hawk air vehicle will be capable of sustained high-altitude surveillance and reconnaissance. With an endurance of over 42 hours at altitudes in excess of 60,000 feet, it can loiter for 24 hours over a target area 3,000 nautical miles (nmi) from the launch area. The UAV will be capable of carrying EO, IR, and SAR with ground moving target indicator (GMTI) payloads simultaneously. It also will be capable of both wide-band satellite and line-of-sight (LOS) communications.

BENEFIT: A range of reconnaissance shortfalls and lessons learned were identified during Operation Desert Storm. Some of these shortfalls were

- Lack of broad area coverage
- Inadequate BDA
- Limited imagery dissemination to users
- Limited information retrieval and distribution of intelligence data
- Lack of over-the-horizon communications for reconnaissance elements
- Insufficient information to support warfighter situational awareness
- Insufficient high-resolution IMINT and signals intelligence (SIGINT) to support precision strikes
- Reconnaissance coverage that is not synchronized with the warfighter

The Global Hawk HAE UAV directly addresses many of these shortfalls. Benefits include

- Long operational range, in excess of 3,000 nmi from the launch area
- Extended endurance and improved sensors to provide continuous dwell and broad area coverage
- The use of satellites for over-the-horizon C^2 and sensor links
- Near real-time imagery dissemination directly to operations and intelligence users
- Dynamic retasking to enable coverage of time-critical targets
- Ready interface with existing C^4I architecture
- Improved situational awareness support to warfighters
- High-resolution sensors with a stare capability to support precision strikes
- Geolocation accuracy to support targeting for precision-guided munitions
- Improved collection access and accuracy for BDA
- Reconnaissance that is synchronized with warfighter combat plans and execution

PROGRAM PLAN: The HAE UAV ACTD is managed by DARPA. The Aeronautical Systems Center Reconnaissance Systems Program Office (ASC/RA) is an integral part of the ACTD team. DARPA will transition program management responsibility to ASC/RA and the Air Force in 1998. The first Global Hawk rolled out in February 1997. Low speed, medium speed and high speed taxi tests began in late 1997. Flight tests will begin in February 1998 and continue through the end of 1999. At the conclusion of flight demonstrations, a decision will be made whether to incorporate the Global Hawk into the force structure immediately, modify the system via a formal acquisition, or terminate the effort. Projected HAE UAV ACTD costs to fabricate five Global Hawk UAVs, three DarkStar UAVs, two mission control elements, and launch and recovery elements, integrate surveillance/reconnaissance payloads, and complete the demonstration program is $1.2 billion.

The unit-flyaway cost requirement for operational Global Hawk UAVs is $10 million in FY 94 dollars.

RISK: Risk is moderate to low.

SPONSORING ORGANIZATION: Maj Gen Kenneth Israel, DARO, Washington, DC, (703) 697-8763.

EXECUTING ORGANIZATION: Chuck Heber, DARPA/TTPO, Washington, DC, (703) 524-5199.

TITLE: (27) Integrated Real-Time (Data) in Cockpit (RTIC)/Real-Time (Data) out of Cockpit (RTOC) for Combat Aircraft (IRRCA)

DESCRIPTION: The IRRCA program will demonstrate the ability of strike aircraft to perform real-time mission changes based on off-board and onboard data. These mission changes include the ability to locate and destroy time-critical targets from off-board information such as target imagery, target coordinates, textual data, weather data, and route information. IRRCA also will demonstrate increased situation awareness through the use of an onboard mission manager, developed by the ESAI program, coupled with an onboard auto router to provide maximum mission flexibility. When the onboard mission manager determines that a threat must be avoided, it will task the auto router to provide a new route to the aircrew, which they can either accept or reject. Coupling these multiple technologies provides enhanced capabilities for the aircrew to respond to target changes, threat updates, and new mission routes.

BENEFIT: The benefit of this technology for the AEF mission is that an RTIC-equipped squadron of aircraft could be taken to remote locations throughout the world to perform various missions, provided they have a data link and a ground dissemination station. Providing this information to the cockpit requires a data link (e.g., Link 16 or SATCOM) to give the aircraft the capability to receive the off-board data. In addition, any off-board imagery and textual information must be packaged by a work station such that the aircraft can understand and use the data once received. This ground dissemination station consists of three work stations that could either remain in CONUS and pass the information via SATCOM, or be placed into a mobile van and deployed with the AEF.

PROGRAM PLAN: This technology will be developed and demonstrated through a series of building-block steps between now and FY 99. A ground demonstration was performed in January 1998 to show the basic feasibility of using an onboard mission manager together with an auto router to provide enhanced mission flexibility and effectiveness. In FY 98, we will perform a test of this equipment in an aircraft hot mock-up and then perform a simple flight checkout. In FY 99, we will perform a full-scale demonstration of this system on a designated range with real-world emitters, reconnaissance sources, and real targets. This demonstration will show the end-to-end capability to respond to multiple mission changes through the exploitation of RTIC information along with an onboard mission manager and auto router. This capability will be ready in early FY 00.

	FY 97	FY 98	FY 99	FY 00
Funding (thousands)	$1,115	$393	$2,058	$711

As this funding profile shows, we need an additional $10 million in FY 98 and FY 00 to be able to perform all of the technical work necessary to demonstrate this end-to-end capability.

RISK: The technical and schedule risks for performing this effort are medium.

SPONSORING ORGANIZATION: Dan Turner, WL/AAZT, Communications, (937) 255-4794, DSN 785-4794.

EXECUTING ORGANIZATION: Jim McFadyen, Lockheed Martin, (914) 964-2833.

TITLE: (28) Smart Push

DESCRIPTION: The Smart Push information dissemination technology will be incorporated in the Image Product Library architecture to allow the user to build standing information requirement profiles. When new information becomes available that meets a user's profile, the system notifies the user regarding the new information.

BENEFIT: AEFs could establish profiles for all new imagery and information for their area of regard. By establishing these profiles, they would not have to query multiple systems for new data. The Smart Push technology would automatically notify the user that new information is available and provide a link to pull the new information.

PROGRAM PLAN: In FY 97 $1.25 million was invested in Smart Push technology. Another $1 million will be allocated in FY 99.

RISK: The risk for this technology is medium.

SPONSORING ORGANIZATION: Capt Matt Kell, 497 IG/INDXP, Bolling AFB, (202) 767-0272.

EXECUTING ORGANIZATION: John Salerno, IRD-1, RL, 32 Hangar Rd., Rome, NY 13441-4114, (315) 330-3667.

TITLE: (29) Multiple Source Correlation System (MSCS)

DESCRIPTION: The MSCS provides an automatically correlated real-time air and ground situation display using information from multiple intelligence and C^2 sources. The system also has the ability to disseminate the correlated information to tactical consumers via existing intelligence and C^2 communications networks. The MSCS currently is fielded worldwide in support of Air Force operations.

BENEFIT: The benefit of the MSCS to an AEF is the enhanced situation awareness that can be provided to deploying and deployed forces.

PROGRAM PLAN: The MSCS is a component of a larger RL SIGINT correlation and fusion program, with approximately $100,000 per year of 6.2 funding, $500,000 per year of 6.3A funding, and $1.5 million per year of 6.3B funding. Efforts are ongoing in the areas of algorithm development, prototype system development, and enhancements to fielded systems. Advanced Technology Demonstrations (ATDs) exist to evaluate the systems developed prior to formal transition. In addition, smaller, less formal demonstrations and evaluations, such as the recent Recognized Air Picture on the Tactical Information Broadcast Service (RAP on TIBS) demonstration for the senior Air Force leadership, are conducted to address specific requirements.

RISK: The risk is low: this technology should be available in the time frame and at the level of performance necessary to achieve the stated benefit.

SPONSORING ORGANIZATION: Daniel R. Kupiak, RL/IRAP, (315) 330-3206, DSN 587-3206.

EXECUTING ORGANIZATION: James Horton, Lockheed Martin Tactical Aircraft Systems, Fort Worth, TX, (817) 763-2841.

TITLE: (30) Airborne Communications Node (ACN)

DESCRIPTION: This 900- to 1,500-pound communications payload in Global Hawk (Tier II+) UAV provides a surrogate communications satellite. It covers a 300- to 400-mile-radius communications footprint on the ground (200-mile footprint at T1), and employs a programmable radio. ACN will provide broadcast to forces on the move to augment GBS, provide a theater paging system, permit the use of small, inexpensive handsets for secure voice and data, and provide a communications gateway among dissimilar radios.

BENEFIT: ACN augments commercial and military satellite communications for AEF. It also relays differential GPS corrections to GPS-guided weapons.

PROGRAM PLAN: A flight demonstration is scheduled for 2001.

RISK:

SPONSORING ORGANIZATION: Col Roy T. Edwards, U.S. Army, DARPA, (703) 696-2352.

EXECUTING ORGANIZATION:

TITLE: (31) In-Theater Airlift Scheduler (ITAS)

DESCRIPTION: ITAS supports scheduling of in-theater airlift. Given resources and requirements, ITAS generates flyable schedules in a format ready for insertion into the daily ATO.

BENEFIT: ITAS provides quicker, more efficient response to crisis requirements involving in-theater air transportation for AEFs.

PROGRAM PLAN: An ITAS prototype is being used in the Pacific Air Forces (PACAF). Air Mobility Command (AMC) and DARPA are funding the development of an operational strategic airlift and air refueling scheduler.

RISK: The risk for ITAS is low.

SPONSORING ORGANIZATION: John F. Lemmer, RL/C3CA, 525 Brooks Ave., Rome, NY 13441-4505, (315) 330-3655, DSN 587-3655.

EXECUTING ORGANIZATION: Dr. Mark Burstein, BBN Technologies, 10 Moulton St., Cambridge, MA 02138, (617) 873-3861.

TITLE: (32) Expanded Situation Awareness Insertion (ESAI)

DESCRIPTION: There has been a recent JTF Command-level demand for timely dissemination of both theater-level and global ISR information to provide the level of situation awareness desperately required by the warfighter. ACC's Mission Need Statement 315-92 (Real-Time Information in the Cockpit), AGM-88 High-Speed Antiradiation Missile (HARM) Statement of Operational Need (SON) 312-90 (Cueing for Lethal/Manned Destructive SEAD), and Tactical Air Forces (TAF) System Operational Requirements Document (SORD) 312-87 (Mission Planning Systems), confirm the need for expanded situation awareness, improved threat location and identification, and enhanced ground-based and en route mission planning. In addition, the Air Force Scientific Advisory Board 1991 Summer Study "Off-Board Sensors to Support Air Combat Operations" recommended equipping aircraft for improved data communications and receipt of SATCOM broadcast, and recommended demonstrations of technology for airborne cueing, correlation, and display.

BENEFIT: ESAI developments provide the following:

- RTIC insertion into combat aircraft for timely and accurate real-time update of mobile targets and threats for self-defense, combat identification, and targeting
- Optimal correlation of off-board all-source information with onboard sensor information
- Low-cost angle of arrival and precision emitter location techniques
- Use of new unique parameters for friend/foe separation and electronic BDA
- Improved precision weapon delivery against fixed/mobile targets
- Enhanced management of onboard sensors and countermeasure resources
- En route updates to mission planning for route replanning/threat avoidance
- Optimized response strategy for self-defense for combat aircraft

Demonstrations will clearly highlight not only the technical developments and improved capabilities but will demonstrate transition opportunities for fielded and developmental radar warning receiver (RWR), IR warning, ELINT, and countermeasure systems. Advanced supercomputing developed or used in this program could be used to fulfill a core computer upgrade providing more computing power, faster processing, and weight reduction for other airborne and ground applications.

PROGRAM PLAN: This program builds on WL/Avionics Directorate (AA) efforts such as Advanced Defensive Avionics Response Strategy (ADARS), Electronic Warfare Preprocessing Elements (EWPE), Random Agile Deinterleaver (RAD) sort and identification, Quiet Knight (QK) I and II, and Air Force Space Command TENCAP efforts such as FASTBALL, TALON SWORD, and TALON LANCE. Over the past five years, these programs have been providing risk reduction developments of sensor fusion, sensor management and response software technologies, supercomputing, emitter identification techniques, and RTIC technologies. The ESAI program will further develop and integrate these critical processing and software technologies into flyable hardware and onto frontline military aircraft (e.g., B-1B, F-16, and C-130) within the size, weight, and power constraints of the existing avionics systems, with minimum Group A changes to the aircraft. This program will deliver to WL the prototype hardware and software modules developed on the program. The delivery includes ESAI hardware and software specification drawings, test reports, and user manuals. A final report will document the effort. The program will result in the baseline for integrating the necessary processing/software technologies into flyable avionics hardware to provide an expanded situation awareness capability for tactical, strategic, airlift, and special operations missions and aircrews.

RISK:

SPONSORING ORGANIZATION: Charles M. Plant, Jr., WL/AAZW, DSN 785-6649.

EXECUTING ORGANIZATION: John Geise, ASC/ENAD, DSN 785-2625 ext. 3007.

TITLE: (33) Information for the Warrior (IFTW) (Reachback)

DESCRIPTION: The IFTW program is incrementally developing and demonstrating advanced technologies for real-time communications to deployed AMC ground elements and aircraft worldwide. The focus is to provide the capability to reach back to the Tanker Airlift Control Center (TACC) and to provide in-transit visibility (ITV) on the status of the aircraft, crew, passengers and/or supplies/cargo being transported. The IFTW program will demonstrate assured seamless connectivity to deployed units/aircraft using available military and commercial communications (including wireline, wireless, and satellite networks) and interconnectivity and interoperability with joint-Service and allied communications systems.

BENEFIT: This program directly supports documented requirements by AMC for affordability and reduced costs per flight hour for global air mobility as a foundation of the United States national security strategy. AMC has estimated that 30 percent greater efficiency and responsiveness can be attained with an improved C^2 capability.

PROGRAM PLAN: IFTW is a continuing program to develop, integrate, and demonstrate prototype hardware and software necessary to support major operations involving AMC assets from CONUS, deploying to anywhere in the world and supporting military and civilian organizations in accomplishing their missions. ATDs are integral to the program and will be performed every 2 years, formalized with the signing by RL, AMC, and ESC of Technology Transition Plans. The initial ATD, with close interaction with AMC and using one of their operational aircraft, occurred in November 1997.

RISK: This program shares the risk with any of the supporting technologies targeted for AMC. However, on balance, it affords the opportunity for our Air Force customer to obtain the best technology in support of operations at the earliest possible time.

SPONSORING ORGANIZATION: Col Stephen Bunn, AMC/DOU, Scott AFB.

EXECUTING ORGANIZATION: Dr. John Evanowsky, RL/C3B, 525 Brooks Rd., Rome, NY 13441, (315) 330-7667.

TITLE: (34) JSF and JSF Technology Maturation Program

DESCRIPTION: *Air Force:* Multirole aircraft (primarily air-to-ground) will replace the F-16 and A-10 and complement the F-22. *Navy:* First-day-of-war, survivable strike fighter aircraft will complement the F/A-18E/F. *Marines:* A STOVL aircraft will replace the AV-8B and the F/A-18. *Royal Navy*: A supersonic replacement will be developed for the Sea Harrier.

BENEFIT: Common components, modularity, and a production line across Services reduces production and sustainment cost while decreasing logistical footprint during AEF deployment. Advanced avionics, C^4I integration, and autonomous diagnostics/logistics improve supportabilty, survivability, and training. Integrated subsystems, such as electro hydrostatic actuators, significantly reduce complexity and increase durability.

PROGRAM PLAN: The Joint Operational Requirements Documents (JORD) in 2000, first flight of prototypes in 2000, milestone II downselect to a single engineering and manufacturing development (EMD) contractor in 2001, and first operational aircraft in 2008.

RISK:

SPONSORING ORGANIZATION: Col Phil Faye, JSF Program Office.

EXECUTING ORGANIZATION:

TITLE: (35) Airborne Laser (ABL)

DESCRIPTION: The ABL weapon system will be a high-energy laser and beam-control system integrated on a wide-body aircraft capable of operating at high altitudes for extended periods of time. The primary mission of the ABL is to defeat theater ballistic missiles (TBMs) in their boost phase of flight. The ABL target list includes approximately 30 missiles with ranges between 150 km and 3,000 km and represents the known and postulated TBM threat into the 21st century. A predominant target of the ABL system over its lifetime is expected to be similar to SCUD variants that exist today. The ABL will provide a surgical, high-payoff, boost-phase destruction of multiple TBMs launched from random, dispersed sites at long ranges while staying within friendly airspace. As the forward line of troops (FLOT) moves, so will the ABL.

BENEFIT: The ABL weapon system provides protection for allied troops from TBMs as they are deployed in the field. When ABL is deployed with the earliest aircraft to the theater, this robust protection is vital to the ground campaign.

PROGRAM PLAN: The ABL entered the Program Development Risk Reduction (PDRR) phase in November 1996. The ABL PDRR system is scaleable and traceable to the ABL EMD system. In addition to demonstrating all key technologies for the EMD system, the ABL PDRR system will provide a residual operational capability (ROC) to ACC in 2002. Following the ABL PDRR phase (2003), the program is expected to enter EMD and production. The EMD ABL represents a mature system having increased laser power, improved sensors, and communication and navigational aids from the PDRR system. Results of testing performed on the ABL PDRR system will further refine requirements placed on the EMD system. The initial operational capability (IOC) for this system (three aircraft) will be in the FY 06 time frame with an expected full operational capability (FOC) date (seven aircraft) occurring in FY 08. The EMD and the PDRR aircraft will be retrofitted to full production configuration as two of the seven delivered production systems by 2008. The ABL PDRR program and first year of EMD is fully funded in the FY 98 budget estimate submission (BES).

FY 98 BES (millions) for the ABL

	97	98	99	00	01	02	03	Total
PDRR	$37	$157	$297	$323	$157	$183	$158	$1,312
EMD	-	-	-	-	-	-	$287	$287
Total	$37	$157	$297	$323	$157	$183	$445	$1,599

RISK: The risk for ABL is medium to low.

SPONSORING ORGANIZATION: Col Mike Booen, System Program Director, SMC/TM, Kirtland AFB, NM 87117, (505) 846-5740, DSN 246-5740.

EXECUTING ORGANIZATION: Paul Shennum, Program Manager, Boeing Military Aircraft, (206) 662-0808.

TITLE: (36) Common Air Transport (CAT)

DESCRIPTION: The CAT is a subsonic in-theater transport aircraft (C-130 class). This aircraft will carry two side-by-side semitrailer-sized cargo pods. These detachable pods will be preconfigured ground modules — such as a C^2, a hospital, a chemical and biological warfare (CBW) decontamination unit, or a fuel tank farm — that can be moved to an operating location quickly. Pod segments will be interconnected with expanded inflatable sides to form large hangars for special aircraft, such as the F-117. The pods also can carry standard roll-on/roll-off cargo modules internally. The CAT can be converted to perform special missions such as AWACS, JointSTARS, or aerial refueling.

BENEFITS:

- Preloaded payload provides quick response.
- Payload module minimizes ground time and ramp space.
- Ground modules are preconfigured as operating facilities minimize setup time.
    - Commercial interest may provide improved Civil Reserve Air Fleet (CRAF) and shared development costs.

PROGRAM PLAN: Contracted concept studies will be conducted to define beneficial AEF configurations. Contrasting the podded approach with conventional internal carriage will identify advantages and disadvantages.

RISK: The risk is medium to low. No new technologies are required. However, the CAT offers an opportunity to integrate many of the recent technology advances designed to minimize both production and logistical support costs, especially for the CAT modules.

SPONSORING ORGANIZATION: J. Michael Snead, AFRL/XPR, (937) 257-9572. Barth Shenk, AFRL/FIM, (937) 255-6156.

EXECUTING ORGANIZATION: To be determined.

TITLE: (37) Unmanned Combat Air Vehicle for SEAD

DESCRIPTION: Although the SEAD UCAV program is in the formulation phase, the general concept is for a 15,000-pound class UAV capable of receiving cues from off-board electronic surveillance systems, acquiring the target based on the cues, executing an attack, and conducting BDA. Such a capability opens the path for interdiction and supporting sorties.

BENEFIT: The SEAD UCAV can

- Open corridors for interdiction attack by conventional attack aircraft
- Provide loiter readiness for pop-up emitting targets
- Offer reduced cost alternatives to limited manned SEAD assets

PROGRAM PLAN: DARPA and the Air Force are jointly developing a SEAD UCAV ATO program. At this point, a Memorandum of Agreement (MOA) is being formulated to establish the funding and management strategies. The program will be conducted in two phases. In the first phase, agreements will be awarded to multiple performers to conduct studies comparing operational vehicle cost to capability design trade to establish performance characteristics of a SEAD. In Phase II, the winning contractor will build one or two demonstrator UCAVs and conduct ground and flight test demonstrations under an ATD program.

RISK: The risk is medium. Specific risk areas include human-system integration (medium to high), system reliability (medium), target acquisition (medium), and system integration (medium).

SPONSORING ORGANIZATION: Dr. Larry Birckelbaw, DARPA/TTO, (703) 696-2362. Maj Mike Leahy, AFRL, (703) 696-2362.

EXECUTING ORGANIZATION: To be determined.

TITLE: (38) Lasers and Space Optical Systems (Global Touch)

DESCRIPTION: Lasers and optical systems in orbit can deter hostilities by rapidly displaying the ability and intent to use deadly force against specific targets, regardless of their location. If deterrence fails, such systems can be used swiftly and accurately to apply deadly force from airborne systems by designating targets, illuminating battlefields, assessing damage, transmitting huge quantities of battlefield data, and controlling large constellations of satellites or UAVs over the battlefield.

BENEFIT: These systems benefit the conduct of AEF missions in the far term.

PROGRAM PLAN: There are no known plans to implement these concepts.

RISK: The technical risk of the applications varies, based on current laser power limitations at required wavelengths.

SPONSORING ORGANIZATION: There are no known sponsoring organizations for these concepts; we recommend that AFRL sponsor this program.

EXECUTING ORGANIZATION: There are no known executing organizations for these concepts.

TITLE: (39) Military Spaceplane (Miniature Spaceplane Technology)

DESCRIPTION: Military Spaceplane Technology Program

BENEFIT: The Military Spaceplane concept of operations being pursued by the Air Force Space Command includes a weapons delivery platform called a Common Aero Vehicle (CAV). The ASC at Eglin AFB has a design concept for a highly maneuverable CAV that reenters the atmosphere either from orbit, or more likely from a sub-orbital “pop-up” trajectory flown by an unmanned Military Spaceplane. The CAV is designed to carry next-generation smart munitions being developed by ASC, and thus can employ most of the same conventional munitions planned for use on the F-22, JSF, B-1, and B-2. Moreover, the pop-up deployment mechanism eliminates the requirement for a Single Stage to Orbit (SSTO) spaceplane while still enabling extremely heavy weapon throwweights. For example, one small SSTO military spaceplane with only a 6,000-pound orbital payload can throw 40,000 pounds of weapons on 12 to 16 CAVs each with multiple submunitions. Hence, on one mission this Military Spaceplane concept could kill 30 to 50 independent targets.

PROGRAM PLAN: There is no budgeted Air Force funding for Military Spaceplane. However, there has been $105 million in congressional adds in the past 4 years. Air Force Space Command–Air Force Materiel Command (AFSPC-AFMC) also just concluded a joint study of the Military Spaceplane concept and have agreed to pursue development of the technologies in the FY 00 POM. Assuming FY 00 money is in the approved POM, the development roadmap includes the following steps:

- Develop and demonstrate the technology on the ground. We’re currently starting that effort with a contract called Integrated Technology Testbed using congressional add dollars.
- Early in the next decade, build and flight-test a suborbital Mark I demonstrator that flies in the Mach 15 to 18 range. Flight tests are notionally scheduled to start in 2004. The demonstrator will have a residual operational capability to pop-up small satellite or weapons payloads. It also can deploy to orbit an unmanned Miniature Spaceplane with a fully recoverable 1,200-pound payload. A full-scale version of this vehicle was tested in the fall of 1997 to validate the autonomous approach and landing capability. This test vehicle is not of flight weight and does not use any rockets; these enhancements will come later if money is made available.
- Toward the middle of the next decade, the AFSPC roadmap calls for initiating a program to build, fly, and produce a full-scale orbital Military Spaceplane.

RISK: The risk inherent in building the Mark I vehicle is medium to low, depending on what technologies are selected for incorporation in the vehicle. The risk in the orbital vehicle is medium to high, with SSTO systems being in the high range.

SPONSORING ORGANIZATION: Lt Col Jess Sponable, PL/VT-X, (505) 846-5929. Capt John Anttonnen, (505) 846-8927 ext. 144. Maj Andy Dubrot, AFSPC POC, (719) 554-2567. Greg Jenkins, ASC Eglin AFB, FL (904) 882-2746.

EXECUTING ORGANIZATION:

TITLE: (40) Small Smart Bomb (SSB)

DESCRIPTION: The SSB initiative is an air-to-surface concept designed to provide the warfighter with an increased kills-per-pass and multiple kills-per-sortie capability against ground targets — hard and soft, fixed and relocatable. With each bomb independently targeted and autonomously guided, the number of targets killed by a single fighter or bomber sortie can be tripled or even quadrupled. Besides the capability to increase sortie effectiveness and the number of kills per pass, the smaller volume and weight of 250-pound munitions versus the more typical 2,000-pound munition means three to four times as many bombs can be transported as with our current airlift capability. This allows a much more rapid deployment of warfighting capability to the region of conflict and allows aircraft designers to reduce the size of aircraft weapons bays, in turn reducing the size and cost of future delivery platforms. The bomb's accuracy and lower explosive yield will focus the bomb's lethality on the target while reducing the potential for collateral damage on friendly forces and noncombatants. A time-phased approach will continue to integrate emerging technology into an SSB munition to increase its capability. Recently the Miniaturized Munition Technology Demonstration (MMTD) program, conducted in support of the SSB concept, demonstrated the operational utility and baselined the technology for a 250-pound air-to-surface munition. The program objectives include the following exit criteria: 6-inch diameter, 72-inch length, 250-pound tactical all-up munition, ability to penetrate 6 feet of reinforced concrete and survive at impact angles of 70 degrees and 2 degrees angle of attack (AOA), utilization of the Hard Target Smart Fuse, approximately 50 pounds of high explosive, and sufficient guidance accuracy to maintain a 3-meter CEP against a surveyed target. A follow-on demonstration program will integrate advances in antijam GPS, autonomous terminal seeker technology, improved miniaturized smart fusing, and extended-range technology with the proven Miniaturized Munition Technology (MMT) inertial navigation system (INS)/GPS and warhead technology from the MMTD program. Additional efforts are being considered to enhance explosives, increase case fragmentation, and demonstrate multiple carriage technology necessary to provide high-loadout capability to delivery platforms.

BENEFITS: The SSB increases sortie effectiveness, provides multiple kills-per-pass, reduces logistic tail and footprint, reduces collateral damage, and leverages stealth capability of delivery platforms.

PROGRAM PLAN: Two distinct programs exist. Following the successful WL MMTD program, the Small Bomb System Program Office formed, and FY 99 funds have been included in the POM for an 18-month PDRR followed by a 24-month EMD and low-rate initial production (LRIP) beginning in the third quarter FY 02. This program will be based on the INS/GPS-guided munition demonstrated in the MMTD program and concentrate on aircraft integration issues. The laboratory follow-on program — MMT Precision Guided Flight Test — will integrate the development technologies of WL/MN with the weapon test expertise of Air Force Development and Test Center (AFDTC). This combined Eglin team will run the entire development program from weapon design to air drops of live weapons against targets in a 48-month period (FY 99 to FY 03). The program will integrate a low-cost terminal seeker with an antijam GPS/INS guidance system. Extended range using folding lift surfaces integrated with residual assets from the previous MMTD program will be conducted. Extensive hardware-in-the-loop and captive carry testing will be accomplished to verify successful integration of these technologies. Final drop tests will confirm that the guidance and autopilot design can tightly control the impact conditions to meet warhead survivability and penetration goals.

RISK: The risk for the SSB program is moderate.

SPONSORING ORGANIZATION: Greg Jenkins, Armament Product Support Group (ASC/WM), Eglin AFB, FL.

EXECUTING ORGANIZATION:

TITLE: (41) Low-Cost Autonomous Attack System (LOCAAS)

DESCRIPTION: The objective of the LOCAAS program is to provide a single, affordable, autonomous miniature munition capable of engaging the entire spectrum of ground mobile targets. The LOCAAS munition has a Laser Radar (LADAR) seeker with three-dimensional imaging and ATR algorithms. The LADAR/ATR provides the ability to search for and find critical targets over large areas and to discriminate between types of targets or between targets and nontargets. According to the type of target identified by the LADAR/ATR, the LOCAAS can select on-the-fly three different modes of operation for the warhead, which are optimized for varying stand-off distances and degrees of target hardening. The warhead has two armor penetration modes plus a fragmentation mode for soft targets. Stand-off range and flexible mission planning options are provided by a combination of a miniature turbojet engine and INS/GPS mid-course guidance. The vehicle is capable of 30 minutes of flight time, which can be traded off between additional stand-off range (up to 100 nmi) and longer search times. The small size of LOCAAS allows for submunition packaging in existing dispensers, such as the SUU-64 Tactical Munitions Dispenser (4 LOCAAS/TMD), Army rockets such as the Army Tactical Missile System, cruise missiles such as Tomahawk, and future captive dispensers, which will allow internal carriage on next-generation aircraft. Affordability is a primary objective of the LOCAAS program, with a design-to-unit production cost goal of $30,000/munition in quantities of 12,000 units in FY 04.

BENEFITS: The anticipated benefits are:

- Ability to destroy time-critical targets
- Greatly expanded search/relaxed target location error requirements
- Increased ordnance loadouts/multiple kills per pass
- Target discrimination/minimal collateral damage

PROGRAM: A team consisting of lab (WL/MN), System Program Office (SPO) (ASC/LKG), and user (ACC/DRP) has put together a proposed ACTD program for consideration by the OSD for a FY 98 start. The program leverages a $50 million technology investment by both Air Force and Army since FY 90. The objectives of the ACTD are to integrate mature component technologies and demonstrate an all-up tactical munition system, to assess the military utility of the LOCAAS system in the mission areas of lethal SEAD and Theater Missile Defense (Attack Ops), and to refine the concept of operations. The program will use an initial competitive phase to demonstrate and evaluate the LADAR/ATR subsystem, further mitigating risk associated with this critical technology. Following downselect to a single contractor team, the subsystems will be integrated with a tactical LOCAAS munition, the munition will be integrated with the SUU-64 dispenser, and the dispenser will be integrated with an F-16 or B-52 for system test. Mission planning, engagement simulation software, and a hardware-in-the-loop simulation will be developed as evaluation and risk-mitigation tools. A leave-behind operational capability of 16 TMD/64 LOCAAS will be provided to the user at the end of the ACTD program. While the Air Force has taken the lead for the LOCAAS ACTD program, the Army has been asked to sign on as a joint sponsor, and the BMDO has agreed to cosponsor this ACTD.

RISK: The risk for LOCAAS is moderate.

SPONSORING ORGANIZATION:

EXECUTING ORGANIZATION: Maj Tim Parmer, ACC/DRPW, Langley AFB, DSN 574-7068. Maj Dave Jacques, WL/MNAV, Eglin AFB, DSN 872-8876 ext. 3369.

TITLE: (42) Low-Cost Dispenser (LODIS)

DESCRIPTION: The main objectives of the LODIS program are to conduct trades studies, develop concepts, and demonstrate a low-cost captive dispenser system that is compatible with all Air Force fighters and bombers. The intent of the LODIS program is to develop a common dispenser system that can support LOCAAS and SSB miniature munition systems and other future smart weapon systems. LODIS provides cost-effective means of carrying and releasing large numbers of precision-guided munitions from the B-1, JSF, F-22, F-117, and B-2, and for external carriage on the F-15 and F-16.

BENEFITS: The benefits of LODIS are:

- Increased loadout by 200 percent over other inventory systems
- Common carriage system for multiple munitions
- Technologies that support external carriage
- Integral shipping container
- No foreign object damage (FOD)
- Modularity
- Design that is compatible with all MIL-STD-1760 compliant aircraft
- LODIS exit criteria: successful flight testing of a dispenser with LOCAAS submunition from a test-expedient aircraft

PROGRAM PLAN: Advanced Dispenser Studies (ADS) will conduct a systems requirements analysis. The LODIS program is scheduled to be awarded in the fourth quarter of FY 98 and will use the data from these studies to select a concept to carry through detailed design and fabrication. The prototype hardware will be subject to ground and wind-tunnel testing. After ground tests are complete, the prototype hardware will be loaded internally on an F-117 or externally on an F-15 or F-16 for free flight testing of both LOCAAS and SSB munition simulators.

RISK: The primary risk area is safe munition ejection and dispenser separation, which has been assessed to be moderate.

SPONSORING ACTIVITY: Jerry Provenza, WL, Armament Directorate, (904) 882-8876, ext. 3383.

EXECUTING ORGANIZATION: Jerry Provenza, WL, Armament Directorate, (904) 882-8876, ext. 3383.

TITLE: (43) Common Aero Vehicle (CAV)

DESCRIPTION: The objective of the CAV program is to develop, test, and produce a single common vehicle capable of performing a wide variety of force application missions from and through space. The basic mission requirement for the CAV is to deliver a payload of approximately 1,000 pounds to anywhere on earth from a military spaceplane release point over the central CONUS. The CAV platform design will have sufficient flexibility to allow delivery of payloads from and through space by ballistic missiles and military spaceplanes. Multimission capability will be derived from the ability of this platform to deploy a variety of weapons and other payloads. This ability enables the CAV to engage fixed and mobile targets. To expedite development, the CAV program will concentrate on using previously defined glide vehicle designs (such as HPMaRV, AMaRV, and HAVE NOT) and deploying current or planned payloads (e.g., LOCAAS, SSB, penetrators, and sensors).

BENEFITS: Benefits of the CAV concept include the following:

- Rapid global engagement
- First-strike capability
- Reduction of forward basing requirements

PROGRAM PLAN: An initial 6-month CAV research program will be executed by WL to determine technical and affordability issues associated with the development of a hypersonic glide, reentry aero vehicle capable of combat missions. Four tasks will be accomplished under the initial study. First, a determination of the detailed technical requirements for this class of vehicle based on the overall mission needs and delivery platform requirements will be completed. This will include a trade study to determine the most technically feasible and cost-effective approaches for delivering unitary penetrators. The second task will involve definition of CAV concepts capable of meeting the technical requirements and an assessment of the maturity and risk levels of the required technologies. The third and fourth tasks will determine technical issues and overall CAV program cost, the generation technology, and the CAV development roadmap.

Following the initial study, the CAV program will enter a planned development phase during which detailed designs will be completed and fabricated. Several flight tests will be conducted to demonstrate CAV capability. Successful completion of the flight tests will then lead into a planned production phase beginning in approximately 2005.

RISK: The risk for the CAV program is low to moderate.

SPONSORING ORGANIZATION: Maj Kris Johanesson, AFSPC, (719) 554-6162.

EXECUTING ORGANIZATION: Lt Col Terry Tosh, ASC/WM, (904) 882-9601.

TITLE: (44) Logistician's Contingency Assessment Tool (LOGCAT)

DESCRIPTION: LOGCAT's goal is to apply advanced technologies to improve the quality and timeliness of wing logistics planning and replanning for short-notice contingencies. LOGCAT directly supports the Air Force's core competencies of rapid global mobility, information superiority, and agile combat support and plays a key role in moving the Air Force towards full spectrum dominance. LOGCAT will demonstrate new technologies and processes to improve the deployment/employment planning process, reduce deployment footprint, reduce deployment/employment response times, and use deployment resources more efficiently and effectively. There are currently five components within the LOGCAT program.

Logistics Analysis to Improve Deployability (LOG-AID): This requirements analysis studies the wing-level deployment process firsthand and streamlines it at the base level.

BENEFIT: Combat capability starts at the unit level, and LOG-AID focuses on getting those forces to the fight as quickly as possible. In addition, a recent modification to this effort will expand the research up to the Joint Forces Commander and across all facets of combat support.

PROGRAM PLAN: LOG-AID is programmed until June 1998. A follow-on field test will start in FY 98.

FUNDING:

Total	FY 95	FY 96	FY 97	FY 98
$1,899,723	$5,000	$533,273	$851,499	$509,951

RISK: The risk for LOG-AID is medium to low.

Survey Tool for Employment Planning (STEP): STEP provides an automated and integrated tool to collect reception site information using multimedia collection tools, then allows for worldwide access of the data for contingency support analysis.

BENEFIT: Critical to the development of a lean deployment package. STEP provides accurate and accessible information on a beddown site which is being considered for AEF deployment..

PROGRAM PLAN: STEP was programmed until 15 October 1997 and slated for transition to HQ USAF/ILXX. STEP underwent a field test in Europe in May 1997.

FUNDING:

Total	FY 95	FY 96	FY 97
$974,934	$87,020	$476,980	$410,934

RISK: The risk for STEP is low.

Beddown Capability Assessment Tool (BCAT): BCAT utilizes STEP and other contingency planning data to determine the site-specific shortages and overages based on sortie profile and the site's capability.

BENEFIT: This capability will allow deploying forces to analyze their supportability and sortie generation capabilities and deficiencies in time to resolve them in a contingency environment.

PROGRAM PLAN: BCAT was programmed with Unit Type Code-Development and Tailoring (UTC-DT) through SIDAC until 23 May 1997. BCAT is slated for follow-on work under the LOG-AID contract until transition to HQ USAF/ILXX in fall 1998.

FUNDING:

Total	FY 95	FY 96	FY 97
$691,934	$79,000	$320,695	$292,239

RISK: The risk for BCAT is medium to low.

UTC-DT: UTC-DT provides a rule-based and collaborative means of creating and refining the personnel and equipment in a given deployment package (UTC) such that only mission-essential resources are deployed, in the most efficient manner possible.

BENEFIT: UTC-DT reduces the deployment support package to the truly required items and allows for the rapid development of forces packages to meet situation-specific requirements.

PROGRAM PLAN: The plan under SIDAC terminated on 23 May 1997, with required — but unfunded — efforts still remaining before UTC-DT will be ready for transition.

FUNDING:

Total	FY 96
$301,416	$301,416

RISK: The risk for UTC-DT is medium.

Unit Type Code-Optimization (UTC-O): UTC-O is a knowledge-based tool that provides the best possible means of loading a given set of equipment onto standard pallets, maximizing the weight and space available.

BENEFIT: UTC-O provides optimized airlift utilization and possible training aid for pallet build-up.

PROGRAM PLAN: Only the initial exploratory work has been accomplished.

RISK: The risk for UTC-O is medium.

SPONSORING ORGANIZATION: Capt Scott Harbula, Capt Joe Martin, and Capt Rusti Pool, AL, Logistics Research Division, 2698 G St., Bldg. 190, Wright-Patterson AFB, OH 45433, (937) 255-2606, DSN 785-2606.

EXECUTING ORGANIZATION: BCAT, UTC-DT, LOG-AID: Synergy Corp., 3100 Presidential Way, Suite 300, Fairborn, OH 45324, (937) 429-8660.

STEP: Analytic Sciences Corp., 2555 University Blvd., Fairborn, OH 45324, (937) 426-1040.

Initial UTC-O work: CSC, 4 Skyline Pl., 5113 Leesburg Pike, Suite 700, Falls Church, VA 22041, (703) 824-7100.

TITLE: (45) Modular Aircraft Support System (MASS)

DESCRIPTION: The objective of the MASS program is to research and develop technologies and methodologies to reduce the life-cycle costs (LCCs) and deployment footprint of aerospace ground equipment (AGE) used for aircraft maintenance within the constraints of operational requirements. The data analyzed to date show AGE to be a high driver of deployment footprint. Powered AGE also has relatively poor reliability and maintainability statistics that adversely affect the LCCs of the equipment. A majority of this equipment was originally developed decades ago and appears to be a prime candidate for technological upgrade. The technologies and packaging concepts resulting from MASS will support reduced footprint through multifunctional units that are common to multiple weapon systems. The multifunction units also will apply modularity to improve maintenance and allow cart reconfiguration to support multiple weapon system use.

BENEFIT: The anticipated benefits of MASS are a reduction in the deployment footprint and LCCs of AGE. The goal is to reduce by 50 percent the deployment footprint for common AGE and all associated deployable items (e.g., spare parts, fuel, tools, and technical orders). LCCs are not well defined for current AGE, so defining a goal at this time is not possible. However, this project will be required to define a concept that is affordable from both an acquisition and LCC perspective. Additionally, technologies supporting ecological improvements will be reviewed and included as appropriate. The result will allow operational units with multiple aircraft (both current and future) to deploy and operate with a smaller footprint while saving operations and maintenance funds.

PROGRAM PLAN: The MASS program will approach the problem by researching technologies and methodologies used in more modern equipment, aircraft, and laboratory programs to determine the best methods to provide utilities to Air Force aircraft during maintenance. These data help determine the feasibility of numerous MASS design concepts. Once a concept is defined and deemed acceptable to the Integrated Product Team (IPT), it will be designed sufficiently to manufacture one proof-of-concept unit. This unit will be demonstrated and tested at operational bases, and feedback will be collected.

	FY 96	FY 97	FY 98	FY 99	FY 00	FY 01	Total
PE63106F (thousands)	$5	$1,573	$1,573	$1,784	$1,837	$626	$7,398

Funding is acceptable to create one proof-of-concept unit. The Air Force will need to purchase additional units to allow full application for a squadron or wing separately. Costs will be defined during the program. Concept demonstration will take place in FY 00.

RISK: The risk of MASS is medium to low.

SPONSORING ORGANIZATION: Matthew Tracy, AL/HRGA, 2698 G St., Wright-Patterson AFB, OH 45433-7604, (937) 255-8360, DSN 785-8360, e-mail: mtracy@alhrg.wpafb.af.mil.

EXECUTING ORGANIZATION: Paul McTaggart, Arthur D. Little, Acorn Park, Cambridge, MA 02140-2390, (617) 498-5847, e-mail: mctaggart.p@adlittle.com.

TITLE: (46) Affordable Guided Airdrop System (AGAS)

DESCRIPTION: AGAS is a system designed to guide and control standard cargo parachutes. It is based on the observation that, if winds are essentially known or can be measured in near real-time, then cargo can be dropped from high altitude and land with precision, needing only limited parachute control authority and without the need for high glide performance. AGAS makes use of inventory parachutes and airdrop equipment with GPS-based guidance, navigation, and control, and a novel type of pneumatic actuator. The proprietary actuator mechanism can shorten or extend some of the parachute lines to reconfigure and thereby steer the parachute. One of the initial goals of the system is to be capable of dropping single- and mass-container delivery systems from an altitude of 25,000 feet with a drop accuracy of 100-meter CEP.

BENEFIT: Accurate airdrop supports the AEF-desired attributes of dispersed operating style, light footprint, and "consumables provided daily." AGAS particularly benefits point-of-use delivery for humanitarian missions.

PROGRAM PLAN: AGAS is an IR&D project of the Boeing Company.

RISK:

SPONSORING ORGANIZATION: Robert Olshan, Senior Principal Specialist Market Development, Advanced Weapon Systems, the Boeing Company, St. Louis, MO, (314) 234-4916.

EXECUTING ORGANIZATION:

TITLE: (47) Pathfinder Autonomous Landing System

DESCRIPTION: Pathfinder integrates GPS, Digital Terrain Elevation Data (DTED), and onboard sensors to provide an austere field landing capability down to 50-foot decision height.

BENEFIT: This system will alleviate the need for ground-based landing aids, thus reducing additional sorties to bring in traditional landing systems equipment, and will reduce the need for additional personnel to operate the equipment. It will reduce the mission postponements and mission aborts that are due to adverse weather conditions at the landing site.

PROGRAM PLAN: On 31 March 1997, WL completed a flight test of the necessary onboard sensors that will enable the Pathfinder capability. A program plan has been generated to integrate the sensors with GPS and DTED and conduct operational tests. The program was costed out at $11 million, of which no funds have been identified.

RISK: The Pathfinder effort involves minimal risk. The sensors were the final technology to be developed. The only remaining step is integration and testing of the technology pieces.

SPONSORING ORGANIZATION: Bill Young, WL/FIGS, 2210 Eighth St., Suite 11,Wright-Patterson AFB, OH 45433-7521, (937) 255-4026.

EXECUTING ORGANIZATION: To be determined.

TITLE: (48) Deployable Pavement Repair System (DPRS) for expedient repair of airfields

DESCRIPTION: New equipment, methods, and materials are needed to rapidly repair airfield pavements at AEF deployment locations. The DPRS is a prototype mobile mixer capable of 1 cubic yard per minute; it soon will be fielded to RED HORSE and Prime BEEF units throughout the Air Force. This effort will leverage off the existing prototype to meet AEF-specific needs related to damaged airfields.

BENEFIT: A damaged or FOD-generating airfield can be an AEF showstopper. Pavements may be initially deteriorated from aging or neglect, or damaged during the course of the mission by military aircraft that stress the pavement beyond its capacity. Deployable repair equipment and materials will allow pre-operational upgrades to prepare a marginal airfield, and mid-operational local repairs to extend the life of the airfield to meet mission requirements.

PROGRAM PLAN: Working with the Air Base Systems System Program Office (ASC/VXO), WL already has developed new high-performance material systems for use with the DPRS that will apply to AEF scenarios. Additional required tasks include:

- Adapt the DPRS system and develop high-performance repair materials to produce thin overlays on marginal or deteriorated flexible pavements. Demonstrate for AEF scenario.
- Increase the capacity/throughput of the DPRS to accommodate larger repair jobs.
- Maximize the use of locally available, in-theater materials to rapidly repair and recover airfields. Specifically reduce the use of support resources for transport of aggregates, quickly identify and locate locally available repair material resources, and recycle useable materials from damaged or demolished existing pavements and structures. Demonstrate increased capacity and use of local materials.

Funding (thousands)	FY 97	FY 98	FY 99	FY 00
Currently planned				
Additional required		$350	$200	$450
Tasks		1	2	3

RISK: For the first task — thin flexible overlay — risk is low to medium. For tasks 2 and 3, involving larger jobs and local materials, risk is low.

SPONSORING ORGANIZATION: Jonathan R. Porter, WL/FIVC, Air Base Technology Branch, 139 Barnes Dr., Suite 2, Tyndall AFB, FL 32403-5232, (904) 283-3073, DSN 523-3073, fax: (904) 283-4932), DSN 523-4932.

EXECUTING ORGANIZATION: Jonathan R. Porter, WL/FIVC, Air Base Technology Branch, 139 Barnes Dr., Suite 2, Tyndall AFB, FL 32403-5232, (904) 283-3073, DSN 523-3073, fax: (904) 283-4932), DSN 523-4932.

TITLE: (49) Lightweight Material/Rapid Base Stabilization for Aircraft Parking Apron Expansion

DESCRIPTION: The plan is to demonstrate methods for rapidly expanding parking apron space at AEF airfields. Two key issues are (1) rapidly stabilizing the foundation (underlying soils) for the expanded parking area, and (2) surfacing the area for additional strength or to provide an FOD cover.

The main goal for rapid soil stabilization is to achieve a minimum 6 California Bearing Ratio (CBR) for any type of soil, using only air-transportable mixing and placing equipment. The weight and volume of imported stabilizing materials must be minimized, and construction and curing time to produce ramp space should be days (not months). Transportable lightweight matting will support parking and taxiing operations of fighter and transport aircraft, on a minimum 6-CBR surface. The mats must pack efficiently and reduce transport weight by 50 percent (from baseline weight of AM-2), cost no more than existing (AM-2) matting, and allow rapid, safe placement with minimum labor.

BENEFIT: For many AEF scenarios, ramp space at deployment locations will not be adequate for parking the required numbers and types of mission aircraft. This effort will provide a way to quickly correct this problem, minimizing the potential impact of inadequate parking space on AEF success.

PROGRAM PLAN: Working with the Army (WES), WL has demonstrated a technique for using polypropylene fibers and a resin material to stabilize sand. Under simulated C-130 traffic, dramatic improvements were accomplished (with no stabilization, a 12-inch rut in one pass; with fibers and resin, a 1.4-inch rut in 1,000 passes). Required stabilization technology tasks are:

- Collect new results and existing stabilization methods in a convenient handbook format for transition to the AEF support engineers.
- Extend the fiber/resin binder stabilization technique to aircraft other than the C-130 and to different types of surfaces.
- Identify and test new stabilization techniques for fine-grained soils.

The Air Force has recently indicated joint interest in developing a new mat system with the Marine Corps. Lightweight mat development tasks are as follows:

- Model and test potential mat panels.
- Develop a panel joining system and define performance metrics.
- Establish an effort with industry to produce the required matting.

Funding (thousands)	FY 97	FY 98	FY 99	FY 00
Currently planned				
Additional required		$300	$400	$450
Tasks		1-3	3-4	5-6

RISK: For the first two stabilization tasks, risk is low. Risk for task 3, fine-grained stabilization technique, risk is medium to high. Lightweight mat development risk is low to medium.

SPONSORING ORGANIZATION: Jonathan R. Porter, WL/FIVC, Air Base Technology Branch, 139 Barnes Dr., Suite 2, Tyndall AFB, FL 32403-5232, (904) 283-3073, DSN 523-3073, fax: (904) 283-4932, DSN 523-4932.

EXECUTING ORGANIZATION: Jonathan R. Porter, WL/FIVC, Air Base Technology Branch, 139 Barnes Dr., Suite 2, Tyndall AFB, FL 32403-5232, (904) 283-3073, DSN 523-3073, fax: (904) 283-4932, DSN 523-4932.

TITLE: (50) Aircraft BDA and Repair (ABDAR)

DESCRIPTION: The main purpose of the ABDAR program is to provide aircraft maintainers with quick and easy access to information needed to rapidly assess and repair battle-damaged aircraft. Because of the loss of experienced technicians and reductions in personnel, technicians need an automated method of accessing the large amount of technical data required to assess a battle-damaged aircraft and to aid them in determining the most efficient route in repairing the aircraft and returning it to the battle. This will be accomplished by presenting electronic technical data and enhanced diagnostic capabilities on Portable Maintenance Aids (PMAs) at the point of maintenance. Through the PMA, the assessor will have access to a multitude of maintenance information including technical orders, supply information, mission scheduling, and personnel availability. Through the diagnostics provided in the assessment logic, the ABDAR program will assist technicians in the assessment process regardless of their level of experience. It also will be capable of automatically collecting and documenting data.

BENEFIT: One of the largest benefits to the AEF is the reduction of the logistics footprint. The technician will be required to bring along a PMA the size of a laptop computer, rather than the numerous stacks of technical orders and related documentation forms currently necessary to perform aircraft BDA and repair. The ABDAR system also will decrease the amount of time required to assess and repair aircraft that have been battle damaged, a crucial factor to the AEF. Since a small number of aircraft will be in-theater, each one will represent a larger percentage of the warfighting capability and will be required to fly the most sorties possible. They will need to be returned to operational commanders as expeditiously as possible when they become damaged. The ABDAR system will allow this by decreasing assessment and repair times. It also will give less experienced technicians the ability to perform more efficiently and effectively by guiding them through the assessment process and providing them with information that they might not have thought to look at. It also will enhance experienced personnel's abilities by automating the documentation process and providing them with information at their fingertips that they would normally have to retrieve from multiple sources.

PROGRAM PLAN:

- Phase I, Requirements Analysis: September 1996 (complete)
- Phase II, System Design: June 1997
- Phase III, System Development: October 1998
- Phase IV, System Test and Evaluation: September 1999

Funding (thousands)	FY 96	FY 97	FY 98	FY 99
	$1,000	$1,900	$1,600	$1,100

RISK: The risk for ABDAR is medium to low.

SPONSORING ORGANIZATION: Capt Michael Clark, AL/HRGO, 2698 G. St., Bldg. 190, Wright-Patterson AFB, OH 45433-7604, (937) 255-2606, DSN 785-2606.

EXECUTING ORGANIZATION: Ron Dierker, NCI, Information Systems, Inc., 3150 Presidential Dr., Bldg. 4, Fairborn, OH 45324, (937) 427-0252.

TITLE: (51) Advanced Man-Portable Airfield Pavement Evaluation System

DESCRIPTION: Lightweight, deployable pavement evaluation equipment for use by Combat Control Teams (CCTs) and other forward-deployed civil engineering teams. The equipment will be used to rapidly determine the load-carrying capability of airfields at potential or selected AEF deployment locations.

BENEFIT: This new technology will provide the commander and staff with rapid, continuous, and accurate data on candidate AEF airfields. Quick access to and analysis of this data will maximize the AEF commander's options for selecting a deployment location and will allow fast, agile relocation of an air base.

PROGRAM PLAN: Wright Laboratory is developing a man-portable ground penetrating radar (GPR) system to provide continuous pavement evaluation data, maximize the area of coverage on the airfield between intrusive test locations, detect layering in both thin and thick pavement systems, and capture and automate the expertise needed to interpret the evaluation data. Currently in Phase II, this effort has produced a prototype GPR equipment set with a new multifrequency single-unit antenna, providing the ability to evaluate a range of pavement depth. A complete prototype man-portable GPR system will be available in January 1998.

Additional effort is required for AEF application to:

- Integrate the device with a GPS system and existing pavement evaluation software (FY 98).
- Add remote data uplinks and mesh in with AEF-specific planning and monitoring software (FY 99).
- Develop a device to reliably and continuously measure in situ concrete strength (FY 00).

Funding (thousands)	FY 97	FY 98	FY 99	FY 00
Currently planned	$150			
Additional required		$250	$250	$250
Tasks		1	2	3

RISK: For the first and second phases, a GPS-integrated system and AEF-specific software, risk is low. Risk for accomplishing the third phase, continuous evaluation of strength by the end of FY 00, is medium.

SPONSORING ORGANIZATION: Jonathan R. Porter, WL/FIVC, Air Base Technology Branch, 139 Barnes Dr., Suite 2, Tyndall AFB, FL 32403-5232, (904) 283-3073, DSN 523-3073,
fax: (904) 283-4932, DSN 523-4932.

EXECUTING ORGANIZATION: Jonathan R. Porter, WL/FIVC, Air Base Technology Branch, 139 Barnes Dr., Suite 2, Tyndall AFB, FL 32403-5232, (904) 283-3073, DSN 523-3073,
fax: (904) 283-4932, DSN 523-4932.

TITLE: (52) More Electric Aircraft (MEA) Technologies for Self-Protection and Air Strike Missions (Includes Integral Starter/Generator)

DESCRIPTION: In order to use the highly reliable, efficient MEA "electrified" loads, larger amounts of electric power are required on aircraft than ever before. Onboard electrical power requirements have increased nearly linearly since the 1940s. Now, with the advent of revolutionary concepts like the MEA and future hypersonic vehicles, the rate of increase of electrical power requirements is expected to be significantly greater. In the nearer term, the Integral Starter/Generator (IS/G)–Integrated Power Unit (IPU) combination will provide a total of up to 500 kW in flight. Even with conservatively high power requirements for electric fuel pumps, avionics, environmental control systems, and flight control, the maximum peak electrical power required for an MEA is only approximately 200 kW. That means that MEA can provide several hundred kilowatts of excess electrical power to enable directed-energy weapons (DEW) such as self-protection lasers, typically through a "soft kill" (i.e., deception or jamming of a threat sensor) or possibly even a "hard kill" (i.e., physical damage). This is being coordinated with the PL laser developers and is applicable to both manned and unmanned aircraft.

In the farther term, the cryogenic generator technology will provide 1 to 4 MW of onboard electrical power in very compact packages. This is definitely enough power to enable hard-kill DEWs (e.g., laser damage to a threat missile or a SEAD application in which a microwave weapon takes out a threat radar site). These are envisioned as primarily UCAV-type missions. This work also is being coordinated with the PL microwave weapons developers.

MEA technologies are critical to meeting the operability and supportability (O&S) requirements projected for UCAV in that these aircraft will need long-term storage (up to 10 years) since they need not even be flown for training purposes. Such long-term storage is not practical with (often leaky) hydraulic subsystems, for example. Also, long-term maintenance-free operation (up to 500 hours) is desired, and becomes much more feasible with the reliability and maintainability (R&M) benefits that the MEA concept offers.

BENEFIT: For the self-protection and air strike missiles, MEA allows the combat mission to be performed with DEW rather than conventional weapons, which require ordnance to be transported/carried to the AEF base. Also, MEA technologies are critical for the UCAV concept to become a reality, since the long-term storage and maintenance-free operation goals can be met only with MEA technologies.

PROGRAM PLAN: To meet these new large onboard electrical power requirements, technologies we are working on include:

- An IS/G internal to the jet turbine engine capable of generating up to 375 kW of electrical power inflight. The innovative aspect of this system is that the starter/generator is for the first time actually internal, on the main spool, eliminating the need for the power take-off shaft and its associated accessory drive gearbox and leaving only electrical wiring coming off the engine. This technology is expected to be demonstrated along with the MEA Generation II technologies in the FY 02 to FY 05 time frame.
- An IPU that provides 200 kW of preflight auxiliary power, but also can provide this power inflight. This unit eliminates the need for both the existing auxiliary power unit (APU) and emergency power unit (EPU). It is expected to be demonstrated with the MEA Generation II technologies.
- Compact, very-high-power turbo-generators, such as the cryogenic superconducting generator, which are capable of producing several MW of power. These are farther-term technologies, which can be categorized as MEA Generation III, and are expected to be demonstrated in the FY 07 to FY 10 time frame.

Funding (thousands)	FY 97	FY 98	FY 99	FY 00	FY 01	FY 02	FY 03
6.3 IPU	$458	$1,430	$1,998	$1,500			
6.2 IPU	$100						
6.2 IS/G	$1,560	$1,300	$1,000	$1,000			
Other 6.2	$2,109	$2,313	$2,345	$2,440	$3,430	$3,430	$3,430
Air Force 6.1	$50	$50	$50	$50	$50	$50	$50
J/IST	$5,000	$15,000	$15,000	$12,000	$3,000		
JSF (proposed)		$5,000	$15,000	$20,000	$10,000	$4,500	
Total	$9,277	$25,093	$35,393	$36,990	$16,480	$7,980	$3,480

RISK: Overall risk today is high to medium. With the successful 6.3 demonstration of the IS/G and IPU, risk drops to medium. With the successful JSF/Integrated Subsystems Technology (J/IST) flight demonstration in FY 99, risk drops to medium to low. With the successful flight demonstration of the proposed JSF follow-on to J/IST, risk drops to low.

SPONSORING ORGANIZATION: Maj Michael Marciniak, WLI/POO, (937) 255-6226.

EXECUTING ORGANIZATION: IS/G: Dr. Eike Richter, General Electric, Evendale, OH, (513) 243-6350. IPU: Dr. Ed Beauchamp, Allied Signal, Phoenix, AZ, (602) 512-1096. Glen Smith, Sundstrand, Rockford, IL, (815) 394-2870. Cryogenic generators: Cal Gold, American Superconductor, Westborough, MA, (508) 836-4200.

TITLE: (53) Inertial Pseudo-Star Reference Unit (IPSRU)

DESCRIPTION: The IPSRU is a high-precision line-of-sight stabilization and three-axis attitude reference unit.

BENEFIT: The IPSRU enables highly accurate line-of-sight stabilization and attitude reference for the Space-Based Laser (SBL) program, enabling acquisition, tracking, and pointing of boost-phase missiles by the SBL system, facilitating their destruction.

PROGRAM PLAN: The IPSRU development is complete. The IPSRU was delivered to the Air Force in 1994 and currently is integrated into the High-Altitude Balloon Experiment (HABE), a risk-reduction acquisition, tracking, pointing, and laser fire-control demonstration experiment for the BMDO on the SBL program. Since IPSRU has been completed and delivered, there is no money planned for IPSRU development this fiscal year or in the out years. The IPSRU will be used in the Space-Based Laser readiness demonstrator program.

RISK: This program has no risk. The IPSRU exists, is in use, and meets the required performance specifications.

SPONSORING ORGANIZATION: Lt Col Mark Nelson, BMDO/TOD, (703) 604-3807, DSN 644-3807.

EXECUTING ORGANIZATION: Capt Norm Hetzel, PL/SXPH, (505) 846-1263, DSN 246-1263.

TITLE: (54) Integrated Modular Avionics (IMA)

DESCRIPTION: In today's tactical platforms, individual avionics systems typically are developed for each new requirement, resulting in a proliferation of discrete or black box systems, called federated systems. IMA systems can consolidate up to 20 federated avionics systems into a single integrated system. IMA systems are composed of a minimum number of dynamically reconfigurable, modular building blocks, which (1) can be used to tailor the system capability for a particular mission or aircraft, (2) greatly increase mission availability, (3) reduce single point failures, and 4) greatly reduce maintenance and consequently LCC. For example, in an IMA system, if greater signal processing is required, an additional signal processing card is added to the system; if an additional receive channel is required, a receiver module is added to the system. IMA systems can time share resources or have additional module types as "hot backups" in case of module failures. This reduces single point failures, increases mission availability, and prevents mission aborts that are due to avionics failures. Reduced LCCs are achieved primarily because modules, instead of line-replaceable units (LRUs), are replaced. The depot surcharge for a spare (typically around 10 percent) is based on acquisition cost, which is far less for modules than LRUs ($10,000 for a module compared to $100,000 for an LRU).

IMA for the AEF concept is proposed as the only affordable way to upgrade existing platforms with multiple functional requirements. Several studies over the past several years, along with a recent cost-benefit analysis (CBA) on IMA, have indicated that, because of budget constraints, performing single-function upgrades (one function at a time) is best accomplished using a federated approach. Single-function, federated upgrades to currently fielded aircraft may not be the most cost-effective approach. However, multifunction, integrated systems have a larger infrastructure and hence a greater up-front cost than single-function, federated systems. With the budget constraints the Air Force faces today, our primary customer, ACC, usually can afford only single-function upgrades to their tactical and bomber fleets.

BENEFIT: IMA would allow functional requirements to be added to AEF aircraft. Some possible communications, navigation, and identification (CNI) requirements for an AEF tactical platform are (1) Joint Tactical Information Distribution System (JTIDS), (2) over-the-horizon communications, such as SATCOM, MILSTAR, and GBS, (3) reception of Intel links (TRAP, TRIXS, TDDS), and (4) reachback capability.

PROGRAM PLAN: The main challenge to any IMA system to be considered for AEFs is affordability. Several IMA systems are in development or near production. Systems in development include SPEAKeasy and the Joint Combat Information Terminal (JCIT). Systems nearing production include the F-22 avionics suite. The IMA program for AEF would address affordability of current technology and IMA systems. Digital and signal processing capability would leverage commercial technology and would require little or no development cost. The main focus area would be in the military-unique, analog RF front-end electronics. This focus area would leverage several ongoing and planned Air Force programs addressing RF electronics technology.

	FY 98	FY 99	FY 00	FY 01	Total
Current funding (millions)	$3	$4	$3	$2	$12
Additional funding (millions)	$5	$6	$5	$4	$20

At current funding levels, an affordable AEF CNI IMA system would not be available until after FY 05. The F-22 program is investigating cost reduction of its avionics suite (a possible candidate) utilizing acquisition reform, which looks promising. Other IMA programs have applications different from AEF-specific requirements and may require modifications to meet AEF objectives.

RISK: Risks of developing an IMA system for AEF are low. The technology base for an IMA CNI suite for AEF exists but is fragmented across the Air Force and other Services. Funding for an IMA CNI suite for AEF should address affordability. We suggest that only AEF-designated tactical platforms be upgraded with the required functionality and not the whole fleet. This would keep total dollar amounts of AEF platform modifications to an affordable level. The CBA on IMA performed by the Air Force indicates that squadron-level modifications have a much better chance of obtaining the required funding and approval rather than fleetwide modifications (e.g., to all F-16s).

SPONSORING ORGANIZATION: Mark Minges, WL/AAM, 2241 Avionics Circle, Suite 31, Wright-Patterson AFB, OH 45433-7333, (937) 255-1608, ext. 3401, e-mail: mingesme@aa.wpafb.af.mil. This proposed effort probably would have RL as a cosponsor.

EXECUTING ORGANIZATION:

TITLE: (55) Photonic Beamforming for Communications and Guidance

DESCRIPTION: Photonically fed phased arrays provide greatly increased (10 to 50 percent fractional) bandwidth capability over traditional electronically steered arrays. Conventional electronic phase shifters are replaced by photonic true time delay (TTD) modules, which steer a wide-band signal over vast angular coverage with minimum beamsquint (spatial broadening of the main lobe). Additionally, the photonic TTD beamformer can place highly accurate nulls to suppress both intentional and unintentional broadband interferers (jammers). Compact, lightweight, low-power, photonic architectures can form multiple beams from a single array, and low-loss fiber-optic cable can remote the control circuitry away from the array.

BENEFIT: Using SATCOM, AEFs operating beyond line-of-sight communications would be independent of terrestrial repeaters. Photonically controlled phased arrays will provide wide bandwidth signal capability, will be less vulnerable to intercept, and will have more resistance to jamming. The transmit signals can be steered to the intended recipients and on receive nulled at specific locations to mitigate the jamming effects of other signals. GPS signals are used for accurate aircraft positioning and precision-guided munitions. Photonics provides beamforming and remoting via lightweight fiber optics, reducing the space and weight required in the aircraft or munitions.

PROGRAM PLAN: The program plan is as follows:

- Super high frequency (SHF): Phase 2 contract effort with Hughes to produce a prototype unit demonstrating the control and operation of an SHF-phased array. Funding of $2 million is programmed, engineering development model (EDM) available April 1999. The EDM is a scalable unit. Construction of a full-up array is contingent on additional funding for an ATD.
- EHF: Phase 1 dual contract effort with TRW ($282,000) and Boeing ($434,000) to study and design a photonically controlled EHF-phased array. Scheduled completion is September 1998. A Phase 2 program and any further efforts are contingent on additional funding for an ATD.
- GPS: In-house effort supported by a cooperative agreement with the University of Florida and a broad agency announcement with Ensco Inc. to study, develop, and fabricate a TTD beamformer with jammer nulling for GPS applications. The current funding profile has $750,000 programmed over 3 years, with completion scheduled for January 2000; an infusion of FY 98 funds ($400,000) would move the program forward to a January 1999 completion. This effort is coordinated with Dr. Randy Zachery of WL/MNAG.

RISK: The risk is low for SHF; medium to low for EHF; and medium for GPS.

SPONSORING ORGANIZATION: RL/OCPC, 25 Electronics Pkwy., Rome, NY 13441-4515; SHF: James R. Hunter, ext. 7045; EHF: James E. Nichter, ext. 7423; GPS: Paul M. Payson, ext. 7911.

EXECUTING ORGANIZATIONS: SHF: Fred Rupp, Hughes Aircraft Co., Bldg. R01, MS B533, 2000 E. Imperial Hwy., El Segundo, CA 90009-2426, (310) 334-8876. EHF: Dr. John Brock, TRW Electronics Systems Division, Space & Electronics Group, 1 Space Park, Redondo Beach, CA 90278, (310) 812-0087. Dr. Suwat Thaniyavarn, Boeing Defense & Space Group, P.O. Box 3999 MS 3W-51, Seattle, WA 98124-2499, (206) 657-9110. GPS: Paul M. Payson, RL/OCPC, 25 Electronics Pkwy., Rome, NY 13441-4515, (315) 330-7911.

TITLE: (56) High-Power Semiconductor Laser Technology (HPSLT) Program

DESCRIPTION: Semiconductor lasers have many attractive features for military applications: robustness, efficiency, small size, and suitability for mass production. The HPSLT program has increased the power of semiconductor lasers many orders of magnitude in the past 13 years, and continues to improve the power and beam quality of semiconductor lasers for a wide variety of civilian and military applications.

BENEFIT: The HPSLT can help the AEF with near-term, midterm, and far-term applications of technology. Near-term applications include nonlethal weapons for air base protection, hazardous agent detection and warning, battlefield medicine, and covert communications and airfield marking. A midterm application is aircraft self-protection against IR missiles through laser deceptive jamming (IR countermeasures). Far-term applications include laser communications and multiapplication (e.g., surveillance, communications, protection, and weapons) electronically steerable conformal laser arrays (e.g., Fotofighter).

PROGRAM PLAN: The near-term applications already have been built in prototype or semi-production status. The midterm IRCM program and far-term Fotofighter program are fully supported for FY 98 to FY 00 by OSD through a Defense Technology Objective.

RISK: The risk for the near-term products is zero; they already have been built. The midterm IRCM program has low risk for protecting aircraft with small signature (e.g., helicopters and C-130) and medium risk for protecting large-signature aircraft (e.g., C-17). The far-term Fotofighter is of high to medium risk.

SPONSORING ORGANIZATION: Maj Gregory J. Vansuch, PL/LIDA, 3550 Aberdeen Ave. SE, Kirtland AFB, NM 87117-5776, (505) 846-5786, fax: (505) 846-4313, e-mail: vansuchg@plk.af.mil.

EXECUTING ORGANIZATION: Maj Gregory J. Vansuch, PL/LIDA, 3550 Aberdeen Ave. SE, Kirtland AFB, NM 87117-5776, (505) 846-5786, fax: (505) 846-4313, e-mail: vansuchg@plk.af.mil.

TITLE: (57) Dynamic Database

DESCRIPTION: This technology is an intelligence, imagery, cartographic, and meteorological database with automated fusion and interpretation. It stores new data and extracts meaningful change from that storage to push to appropriate users.

BENEFIT: The benefit of dynamic database is improved situational awareness and mission prosecution.

PROGRAM PLAN: The first dynamic database will be built in 3 to 4 years, costing $30 million to $40 million per year. It basically is a 15- to 20-year program.

RISK: The risk for this program is high.

SPONSORING ORGANIZATION: Maj Tom Burns, Air Force Information Systems Office, DARPA, (703) 696-7441.

EXECUTING ORGANIZATION:

TITLE: (58) UCAV Flight Control

DESCRIPTION: This is the flight control system technology for (37) UCAV for SEAD.

BENEFIT: UCAV flight control technology enables UCAV.

PROGRAM PLAN:

RISK:

SPONSORING ORGANIZATION: Dave Bowser, AFRL, Wright-Patterson AFB, OH.

EXECUTING ORGANIZATION:

TITLE: (59) Rocket-Based Combined Cycle (RBCC) Engine Propulsion

DESCRIPTION: RBCC is a propulsion concept with four operating modes: (1) air-augmented rocket operating at 0 to 3 Mach, (2) ramjet operating at 3 to 6 Mach, (3) scramjet operating at 6 to 10 Mach, and (4) rocket operating at 10 to 25 Mach.

BENEFIT: Potential propulsion for a military spaceplane.

PROGRAM PLAN: Funding will be interrupted in FY 99 and picked up again in FY 00.

RISK:

SPONSORING ORGANIZATION: Jim Turner, Marshall Space Flight Center, Huntsville, AL.

EXECUTING ORGANIZATION:

TITLE: (60) Reusable Launch Vehicle (RLV) Technology Development Program

DESCRIPTION: The objective of the RLV program is to reduce the cost of access to space by enabling the use of completely reusable and operable launch vehicles. The RLV technology development program is an integrated ground and flight demonstrating program with the goal of reducing the technical risks for a subsequent full-scale RLV development program. The program ranges from laboratory technology research and development to large experimental flight demonstrators intended to mature the technologies in a use environment.

BENEFIT: The reduction of the cost of access to space is required to enable the U.S. commercial launch providers to more readily compete in the world market and to reduce the Government's cost for launch services in the face of shrinking Federal budgets. Reusable launch vehicles will reduce the costs of access to space. Extensive reuse of the launch system hardware coupled with highly operable systems will minimize recurring operations costs. The program is targeted to a Single Stage to Orbit configuration, which offers the largest reduction in operations costs if the technologies can be matured.

PROGRAM PLAN: The program consists of the DC-XA flight demonstration project (which has been completed), the X-34 booster technology flight demonstration program (which is ongoing), and the X-33 advanced technology flight demonstration program (also ongoing). A long-term high-payoff technology development program also is integrated into the RLV family of programs. The program is aimed at technologies leading to lightweight, high-mass fraction vehicles, high-performance propulsion systems, and highly operable systems.

X-33 Phase II initiated	FY 96, fourth quarter
X-34 program initiated	FY 96, fourth quarter
DC-XA project complete	FY 96, fourth quarter
First X-34 flight	FY 99, first quarter
First C-33 flight	FY 99, third quarter
X-33 flight test program complete	FY 00, second quarter

Funding (thousands):	FY 97	FY 98	FY 99	FY 00
	$288	$354	$353	$97

RISK: The risk for the RLV program is moderate to high.

SPONSORING ORGANIZATION: Gary Payton, NASA Code R; Frederick Bachtel, NASA MSFC Code RA01.

EXECUTING ORGANIZATION: J. Wayne Littles, NASA MSFC.

TITLE: (61) Hyper-X

DESCRIPTION: Hyper-X demonstrates airbreathing hypersonic propulsion with an airframe-integrated, dual-mode scramjet. It uses a Pegasus boost off a B-52.

BENEFIT: Hyper-X provides potential propulsion for a military spaceplane or a Mach 10 strike-reconnaissance aircraft.

PROGRAM PLAN:

RISK:

SPONSORING ORGANIZATION: Vince Rausch, NASA Langley Research Center, VA.

EXECUTING ORGANIZATION:

TITLE: (62) Surveillance Targeting And Reconnaissance satelLITE (STARLITE)

DESCRIPTION: STARLITE will consist of 24 to 48 satellites with X-band SAR/MTI radar at a cost of less than $100 million per satellite.

BENEFIT: STARLITE is intended to be the low end of a complementary high/low mix with national systems that will provide timely, precise targeting data directly to the warfighter in response to the warfighter's direct tasking.

PROGRAM PLAN: The request for proposal for concept demonstration will be issued September 1998 for a December 1998 contract start. Launch of demonstration satellites is scheduled for September 2001.

RISK:

SPONSORING ORGANIZATION: Dr. David Whelan, Director, Tactical Technology Office, DARPA, (703) 696-2307.

EXECUTING ORGANIZATION:

TITLE: (63) Pilots' Landing System (Fog Eye)

DESCRIPTION: Fog Eye is an electro-optical sensor that operates in the ultraviolet portion of the electromagnetic spectrum. It operates in a region where there is no natural background to compete with an array of signals. In addition, the signals experience minimum attenuation and scattering while propagating through the atmosphere. These favorable characteristics allow for augmenting airport navigation lights such that they emit signals that can be detected by small but highly sensitive receivers installed on aircraft. These receivers have the ability to record the location of an array of these navigation lights and project these locations onto a HUD in the cockpit of an aircraft. These lights are directly superimposed over the actual locations of the lights that the pilot views through the HUD on a clear day. The Fog Eye signals penetrate fog. The pilot, therefore, can sense the location of the signals on the HUD despite the presence of fog, and use these locations to effect a smooth and safe landing under low visibility.

BENEFIT: The AMC has expressed a requirement for a near-term low-visibility landing capability for transport aircraft in advance of the Joint Precision Approach and Landing System procurement. It has listed seven desirable features for such a capability. These features dovetail with the characteristics of an electro-optical system, Fog Eye, that recently demonstrated an ability to see through fog. This system can be used with any Cat I (2,400-foot visibility) landing system. A Pilots' Landing System configured for this requirement consists of a Fog Eye Receiver, a HUD, a GPS receiver, and a Contingency Airfield Lighting System (CALS) that is modified with Fog Eye light adjuncts. The HUD and the receivers are located in the aircraft. The augmented CALS is deployed at an airfield. The approach and runway lights can be operational within 6 hours. In addition, this capability can complement other Cat I landing systems, such as the Mobile Microwave Landing System (MMLS) or the Instrument Landing System, to allow operations under Cat IIIa (700-foot visibility) landing conditions.

PROGRAM PLAN:

	Funding Required	Time
1. Provision of two aviation-qualified receivers	$300,000	2 months
2. Provision of two CALS augmentation kits	$200,000	1 month
3. Installation and ground test	$300,000	1 month
4. Flight test	$800,000	3 months
5. Data reduction	$50,000	1 month
6. Preproduction/EDM	$500,000	9 months
7. Production (nonrecurring)	$3,000,000	12 months

RISK: The risk for Fog Eye is low.

SPONSORING ORGANIZATION: NASA/Dryden Flight Research Center, Code A, P.O. Box 273, Edwards, CA 93523-0272.

EXECUTING ORGANIZATION: Norris Electro Optical Systems, 9001 Manordale La., Ellicott City, MD 21042.

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Annex to Appendix G

Acronyms and Abbreviations

AA	Avionics Directorate
ABDAR	Aircraft Battlefield Damage Assessment and Repair
ABL	Airborne Laser
ACC	Air Combat Command
ACN	Airborne Communications Node
ACTD	Advanced Concept Technology Demonstration
ADARS	Advanced Defensive Avionics Response Strategy
ADS	Advanced Dispenser Studies
ADT	Active Denial Technology
AEF	Aerospace Expeditionary Force
AETC	Air Education and Training Command
AFDTC	Air Force Development and Test Center
AFMC	Air Force Materiel Command
AFRL	Air Force Research Laboratory
AFSPC	Air Force Space Command
AGAS	Affordable Guided Airdrop System
AGE	Aerospace Ground Equipment
AIA	Air Intelligence Agency
AL	Armstrong Laboratory
ALEP	Aircrew Laser Eye Protection
AOA	Angle of Attack
AOC	Air Operations Center
APU	Auxiliary Power Unit
ASC	Aeronautical Systems Center
ASC/RA	Aeronautical Systems Center, Reconnaissance Systems Program Office
ASP	Aircraft Self-Protection
ASTAMIDS	Airborne Stand-Off Minefield Detection System
ATD	Advanced Technology Demonstration
ATIRCM	Advanced Threat Infrared Countermeasures
ATO	Air Tasking Order
ATR	Automatic Target Recognition
AWACS	Airborne Warning and Control System
BADD	Battlespace Awareness and Data Dissemination
BCAT	Beddown Capability Assessment Tool
BDA	Battle Damage Assessment
BES	Budget Estimate Submission
BMDO	Ballistic Missile Defense Organization
BW	Biological Weapons
C^2	Command and Control
C^3	Command, Control, and Communications
C^4I	Command, Control, Communications, Computers, and Intelligence

C^4ISR	Command, Control, Communications, and Computers, Intelligence, Surveillance, and Reconnaissance
CALS	Contingency Airfield Lighting System
CAS	Close Air Support
CAT	Common Air Transport
CAV	Common Aero Vehicle
CBA	Cost-Benefit Analysis
CBR	California Bearing Ratio
CBW	Chemical and Biological Warfare
CCT	Combat Control Team
CCW	Command Control Warfare
CECOM	Communications and Electronics Command
CEP	Circular Error Probable
CNI	Communications, Navigation, and Identification
CONOPS	Concept of Operations
CONUS	Continental United States
CORBA	Common Object Request Broker Architecture
COTS	Commercial Off-the-Shelf
CRAF	Civil Reserve Air Fleet
CSAF	Chief of Staff of the Air Force
CTAPS	Contingency Theater Automated Planning System
DAOC	Distributed Air Operations Center
DARPA	Defense Advanced Research Projects Agency
DE	Directed Energy
DEW	Directed-Energy Weapon
DIRCM	Diode Laser Infrared Countermeasures
DMT	Distributed Mission Training
DoE	Department of Energy
DPRS	Deployable Pavement Repair System
DTED	Digital Terrain Elevation Data
ECM	Electronic Countermeasures
EDM	Engineering Development Model
EHF	Extremely High Frequency
ELINT	Electronic Intelligence
EMD	Engineering and Manufacturing Development
EO	Electro-Optical
EPU	Emergency Power Unit
ERDEC	Edgewood Research, Development, and Engineering Center
ESAI	Expanded Situation Awareness Insertion
ESAR	Enhanced Synthetic Aperture Radar
ESC	Electronic Systems Center
EWPE	Electronic Warfare Processing Elements
FAA	Federal Aviation Administration
FLEX	Force-Level Execution
FLIR	Forward-Looking Infrared
FLOT	Forward Line of Troops
FOC	Full Operational Capability
FOD	Foreign Object Damage
FOL	Forward Operating Location

FOV	Field of View
FPA	Focal Plane Array
FST	Fundamental Skills Tutorial
GBS	Ground-Based Systems
GE	Global Engagement
GMTI	Ground Moving-Target Indicator
GPR	Ground Penetrating Radar
GPS	Global Positioning System
HABE	High-Altitude Balloon Experiment
HAE	High Altitude Endurance
HARM	High-Speed Anti-Radiation Missile
HPM	High Power Microwave
HPSLT	High-Power Semiconductor Laser Technology
HRR	High-Range Resolution
HUD	Head-Up Display
IADS	Integrated Air Defense System
ICAI	Intelligent Computer-Assisted Instruction
ICBM	Intercontinental Ballistic Missile
IFTW	Information for the Warrior
IMA	Integrated Modular Avionics
IMINT	Imagery Intelligence
INS	Inertial Navigation System
IOC	Initial Operational Capability
IPA	Image Product Archive
IPL	Image Product Library
IPSRU	Inertial Pseudo-Star Reference Unit
IPT	Integrated Product Team
IPU	Integrated Power Unit
IR	Infrared
IR&D	Independent Research and Development
IRCM	Infrared Countermeasures
IRRCA	Integrated Real-Time Data in Cockpit/ Real-Time Data out of Cockpit for Combat Aircraft
IS/G	Integral Starter/Generator
ISAR	Inverse Synthetic Aperture Radar
ISR	Intelligence, Surveillance, and Reconnaissance
ITAS	In-Theater Airlift Scheduler
ITV	In-Transit Visibility
IW	Information Warfare
JCBAWM	Joint Chemical and Biological Agent Water Monitor
JCIT	Joint Combat Information Terminal
JFACC	Joint Forces Air Component Commander
J/IST	JSF Integrated Subsystems Technology
JointSTARS	Joint Surveillance, Target, and Attack Radar System
JORD	Joint Operational Requirements Document
JSF	Joint Strike Fighter
JSMG	Joint-Service Materiel Group
JSTP	Joint Science and Technology Panel
JTF	Joint Task Force

JTIDS	Joint Tactical Information Distribution System
JWID	Joint Warrior Interoperability Demonstrations
LADAR	Laser Radar
LANTIRN	Low-Altitude Navigation and Targeting for Night
LCC	Life-Cycle Cost
LOCAAS	Low-Cost Autonomous Attack System
LODIS	Low-Cost Dispenser
LOG-AID	Logistics Analysis to Improve Deployability
LOGCAT	Logistician's Contingency Assessment Tools
LOS	Line of Sight
LRIP	Low-Rate Initial Production
LRU	Line-Replaceable Unit
MASS	Modular Aircraft Support System
MBMMR	Multiband Multimode Radio
MEA	More Electric Aircraft
MLS	Multilevel Security
MMLS	Mobile Microwave Landing System
MMT	Miniaturized Munition Technology
MMTD	Miniaturized Munition Technology Demonstration
MOA	Memorandum of Agreement
MSCS	Multiple-Source Correlation System
MSL	Mean Sea Level
MTE	Moving Target Exploitation
MTI	Moving Target Indicator
NASA	National Aeronautics and Space Administration
NASP	National Aerospace Plane
nmi	Nautical Miles
NVG	Night Vision Goggles
NVL	Night Vision Laboratory
O&S	Operability And Supportability
OBATS	Off-Board Augmented Theater Surveillance
OPSL	Optically Pumped Semiconductor Laser
OSA	Open Systems Architecture
OSD	Office of the Secretary of Defense
OUSD	Office of the Under Secretary of Defense
P^3I	Preplanned Product Improvement
PACAF	Pacific Air Forces
PDRR	Program Development Risk Reduction
PE	Program Element
PL	Phillips Laboratory
PMA	Portable Maintenance Aids
PNVG	Panoramic Night Vision Goggles
POM	Program Objectives Memorandum
Prime BEEF	Prime Base Engineering Emergency Force
PSPS	Portable Sampling and Processing System
QK	Quiet Knight
R&D	Research And Development
R&M	Reliability And Maintainability
RAD	Random Agile Deinterleaver

RAP on TIBS	Recognized Air Picture on the Tactical Information Broadcast Service
RBCC	Rocket-Based Combined Cycle
RCC	Regional Contingency Center
RF	Radiofrequency
RL	Rome Laboratory
RLV	Reusable Launch Vehicle
ROC	Residual Operational Capability
RTIC	Real-Time Data in the Cockpit
RTOC	Real-Time Data out of the Cockpit
RWR	Radar Warning Receiver
S&T	Science and Technology
SAF/AQ	Assistant Secretary of the Air Force, Acquisition
SAR	Synthetic Aperture Radar
SATCOM	Satellite Communications
SBIR	Small Business Innovative Research (Program)
SBL	Space-Based Laser
SBS	Small Bomb Systems
SEAD	Suppression of Enemy Air Defenses
SHF	Super High Frequency
SIGINT	Signals Intelligence
SON	Statement of Operational Need
SORD	System Operational Requirements Document
SPO	System Program Office
SSB	Small, Smart Bomb
SSTO	Single Stage to Orbit
STARLITE	Surveillance Targeting and Reconnaissance Satellite
STEP	Survey Tool for Employment Planning
STOVL	Short Takeoff/Vertical Landing
TACC	Tanker Airlift Control Center
TAF	Tactical Air Forces
TBM	Theater Ballistic Missile
TBMCS	Theater Battle Management Core Systems
TEL	Tactical Erector Launcher
TMD	Tactical Munitions Dispenser
TTD	True Time Delay
UAV	Unmanned Aerial Vehicle
UCAV	Unmanned Combat Air Vehicle
UK	United Kingdom
UTC-DT	Unit Type Code-Development and Tailoring
UTC-O	Unit Type Code-Optimization
WFI	War Fighter Internet
WL	Wright Laboratory

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Appendix H

Lean Sustainment

1.0 Introduction

The Lean Sustainment Panel was charged with examining the logistics aspects of preparing, deploying, sustaining, and redeploying an Aerospace Expeditionary Force (AEF), with particular attention to reachback and other concepts under consideration by HQ USAF/ILX. The highlights of our data collection, analysis of alternatives, and recommendations for improvement are succinctly stated in Volume 1 of this study report. Here, we present substantiating detail, material of interest mostly to the logistics community, and a number of specific findings and recommendations.

This Panel was given primary responsibility for analyzing AEF timelines, identifying their limiting factors, and suggesting ways to shorten them. Our work substantiates the overall finding of the study that significant improvements in response time, lift requirements, global deployability, and use of austere forward bases are possible with modest — sometimes zero — resource investments. Most if not all of the AEF scenarios we examined could be executed within 24 hours from execution order to delivery of effect, whether that means bombs, bread, or broken eardrums. However, for this to be realized, there must be fundamental changes in almost every aspect of preparing for, planning, and executing deployed airpower operations.

In preparing this report, the Panel visited a wide variety of organizations in the continental United States (CONUS) and Europe, reflecting the fact that many functional areas, from fighter squadrons to depots to civil engineers, play vital roles. Much of this interaction was with planners, maintenance supervisors, program managers, and others at the working level who deal with real problems every day. Table H-1 lists the organizations that provided information, ranging from maintenance statistics to program briefings to lessons learned in recent operations. To ensure that the maximum relevant information was gathered in the limited time frame of the study, the Panel coordinated with the AEF Logistics Concept of Operations Working Group led by HQ USAF/ILX, and with other Air Force–sponsored studies under way at RAND Corporation, Synergy, Inc., and elsewhere. However, our findings and recommendations are the result of independent analysis, Panel discussions, and the expert judgment of the members, based on the evidence available.

Table H-1. *Summary of Organizations Visited*

Field Units	
52nd Fighter Wing (Spangdahlem AFB) 16th Special Operations Wing (Hurlburt AFB) 2nd Marine Air Wing (Cherry Point Air Station) 2nd Bomb Wing (Barksdale AFB)	31st Fighter Wing (Aviano AB) 347th Fighter Wing (Moody AFB) 366th Composite Wing (Mountain Home AFB)
Headquarters	
HQ USAFE, including the LG Staff (Ramstein AB) HQ AFMC/XP (Wright-Patterson AFB) HQ RAF Strike Command and Permanent Joint HQ HQ 5 Allied Tactical Air Force (Vicenza)	HQ USAF/IL (Pentagon) HQ SOCOM (Hurlburt AFB) HQ AMC & Tanker Airlift Control Center (Scott AFB)
Logistics Organizations	
Central Region Storage Depot (Sonem, Lux.) F-15 SPO (Wright-Patterson AFB)	Warner Robins ALC (Robins AFB) F-16 SPO (Wright-Patterson AFB)
R&D and Acquisition Organizations	
F-22 SPO (Wright-Patterson AFB) Multiple Air Force Research Laboratory Organizations at Wright-Patterson AFB and Tyndall AFB RAND Corp. (Santa Monica, CA)	ASC/WM (Eglin AFB) Synergy, Inc. (Washington, DC, and Dayton, OH) DARPA (Arlington, VA)

In the sections that follow, we examine a number of matters affecting transportation, supply, forward base operations, maintenance, and other logistics areas. We believe that reforms must take a process view, defining what must be done and how it can be done better; only then can improved tools, procedures, and training be effectively implemented. This theme of process improvement recurs throughout our report. A related overall thought is that processes and organizations that historically have operated as largely independent stovepipes must now be integrated in a collaborative structure to plan and execute missions. In many cases, the means to accomplish this are in hand or in an advanced state of development, needing only leadership emphasis and some resources to make them available quickly.

Our analysis has been based on the framework established by the Operations Context and Training Panel. The example AEF missions, described in Appendix E, especially the postulated force packages and the time, logistics, and infrastructure elements of the scenarios, have framed our efforts to quantify AEF sustainment.

A word on abbreviations is in order, especially since the world of logistics rejoices in an exceptionally rich and confusing collection of acronyms and other jargon. We have tried to spell them out often enough to avoid serious annoyance, and a very detailed list, including summary descriptions of most terms, is given in an annex to this report.

1.1 Lean Sustainment Panel Membership

Dr. John M. Borky, Chair
Vice President and Chief Scientist
BDM International, Inc.

Mr. Robert J. Patton, Deputy Chair
Private Consultant

Dr. Duane A. Adams
Vice Provost for Research
Carnegie Mellon University

Dr. James D. Lang
Director of Technology
Boeing Company

Prof. Digby D. Macdonald
Director, Center for Advanced Materials
Pennsylvania State University

Mr. Andrew W. Bennett
Program Manager, Advanced Design
Lockheed Martin Aeronautical Systems

Mr. Robert F. Ewart
Director, Concepts and Analyses, Advanced C-17
Boeing Company

Mr. Hyman L. Shulman
Consultant
RAND Corporation
Advisor: Mr. Edward S. Boyle, Armstrong Laboratory (AL)/HRG

Advisor: Lt Col Anthony Dronkers, AF/ILXX

Executive Officer: Capt Maria L. Garcia, Air Force Logistics Management Agency (AFLMA)/LGX
Technical Writer: Capt Kabrena E. Goeringer, U.S. Air Force Academy

2.0 Deployment Processes and Timelines

2.1 Dimensions of the Problem

Some initial background will be helpful in navigating the discussion. The Panel found that the space defined by functions, organizational levels, and time as sketched in Figure H-1, also known as "the cube,"[19] is one way to keep any given detail or issue in context.

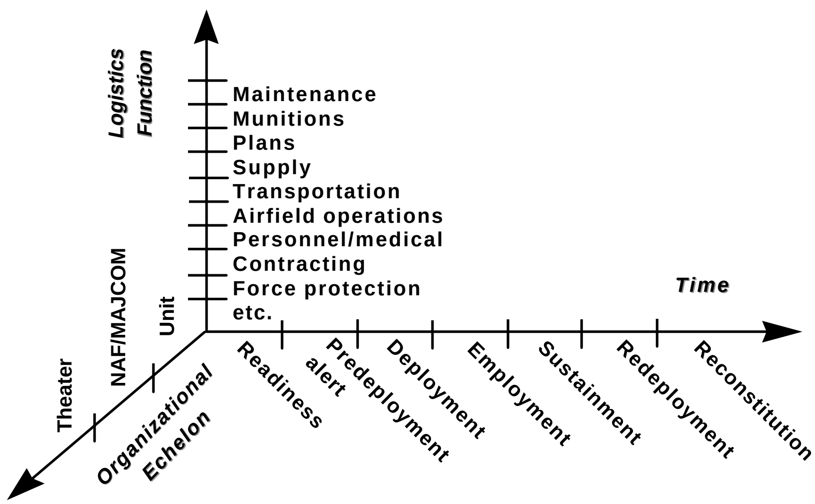

Figure H-1. *Context for Considering Deployed Logistics*

The vertical axis shows traditional logistics functions such as supply and maintenance, as well as force protection and others that place demands on logistics resources. The time axis is divided into the phases of an operation. Readiness means normal peacetime training and preparation, while predeployment denotes the status of a unit designated as vulnerable to AEF tasking; this could include some form of alert. The employment phase (roughly the first week) and the sustainment phase (which follows) are distinct in that the former is assumed to involve very austere operations, while an operation that continues past this point will require higher levels of sustainment at the forward base. (It is important to remember that the deployed force must some day come home and undergo reconstitution to return to fully combat-ready status.) The third axis is organizational; it recognizes that different activities may occur and different tools may be used at the strategic and tactical levels and at various command echelons, even when dealing with the same logistics process and mission phase.

We use the categories and terminology of Figure H-1 to describe deployed logistics and to identify tools and databases that enable the support of an AEF. This framework helps deal with the diversity of taskings and force compositions to be considered. Regardless of whether a given AEF is tasked to halt an armored

[19] Developed by the AEF Logistics command and control (C^2) concept of operations (CONOPS) Working Group chaired by HQ USAF/ILXX.

thrust, support a threatened ally, or deliver disaster relief, many common planning and execution processes are involved, and the phasing of the operation is much the same as the time axis of the figure. As an example, the process of supplying a deployed force at an austere forward base requires actions at all echelons and must operate in a consistent fashion from initial preparations in the readiness phase through replenishment of stocks during reconstitution. A big-picture view helps ensure that all aspects of this or other processes are properly accounted for.

2.2 Current Capabilities

Deploying tailored airpower packages to unpredictable places on very short notice is obviously a complex undertaking. The Air Force has limited recent experience in this area because deployments have been to familiar, developed bases that were stocked with prepositioned materiel and on timelines of several days rather than 24 hours. Three recent operations in areas relevant to the mission scenarios of this study illustrate current demonstrated Air Force capability:

- In Operation Desert Strike, the 2nd Bomb Wing reconfigured nine B-52Hs to carry conventional air-launched cruise missiles (CALCMs) in approximately 22 hours. Four aircraft deployed to Anderson AFB in 16 hours, left after crew rest for an 18-hour flight to the area of responsibility (AOR), and delivered the strike approximately 65 hours after the "go" order. This could have been closer to a 40-hour response had the force been able to take the shorter eastbound route and flown straight to the launch point. It was possible at all only because of two years of prior work in developing the wing's "Light/Lethal" concept and in bringing Anderson AFB back up to readiness to support B-52 operations.
- In the recent Southwest Asia (SWA) deployment generally labeled AEF IV, the fighter force deployed from East Coast bases and delivered the first sortie about 70 hours after the warning order. This was preceded by several months of planning and preparation and by 10 days of transport missions and base preparations prior to the warning order to receive the arriving fighters. AEF IV is the fastest recent fighter deployment we know of, although the Cope Thunder exercise in July 1997 was based on a no-notice 72-hour deployment.
- In Operation Provide Relief, the humanitarian operation in Somalia, the first C-130 relief delivery sortie occurred 7 days after the President's order, and the full force of 13 C-130s was in place and flying missions approximately 1 month later. More recent medical/ humanitarian operations by the 3rd Air Force in sub-Saharan Africa have shown the ability to deploy and set up to deliver medical treatment in 24 to 36 hours and to operate with a minimal forward base footprint by relying on extensive reachback.

Figure H-2 is a top-level summary of the many thousands of identifiable steps in the deployment of a fighter package from a CONUS base to a forward location. Compiled from multiple sources, [20, 21, 22, 23] it shows the major categories of activity by the National Command Authorities (NCA), higher HQ, and the mobility force and deploying units. It assumes that the regional commander–in–chief (CINC) and staff perform ongoing deliberate planning, deployment site data collection, etc., producing some sort of planning basis on which to erect the operational plan for a contingency. This illustration assumes that neither the fighters nor the mobility force is in an alert posture. Crisis Action Planning (CAP) in theater is assumed to

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[20] IDEFO Model of the Base-Level Deployment Process, Synergy Inc., 1997.

[21] "Deployment Requirements Flow Process: A Case for Change," Joint Transportation Corporate Information Management Center (JTCC), 22 April 96.

[22] Draft Logistics Command and Control Concept of Operations, HQ USAF/ILXX, 1997.

[23] HQ USAF/IL briefings.

start in response to a determination by the NCA, shown as a "Preparatory Decision," that the world situation makes use of airpower likely. Very important, the diplomatic clearance process, which generally is a serious limitation on response time, also is triggered by this decision. If the NCA issues a Warning Order, the initial stages of deployment preparation, especially positioning of tankers and transports to support the air bridge, can begin, and the supporting command (Air Combat Command [ACC], U.S. Air Forces in Europe [USAFE], or Pacific Air Forces [PACAF]) starts its own CAP to decide how the supported CINC's operations plan will be supported. Each tasked fighter unit activates its own deployment process, up to but not including actual launch of combat forces. Under the law, actual launch can happen only in response to a valid Execution Order. As soon as possible after this is issued, the fighters and their support take off, fly to the forward base, set up the operation, turn the aircraft, and start generating sorties. Factors such as crew rest and mission planning must be accounted for in the timeline.

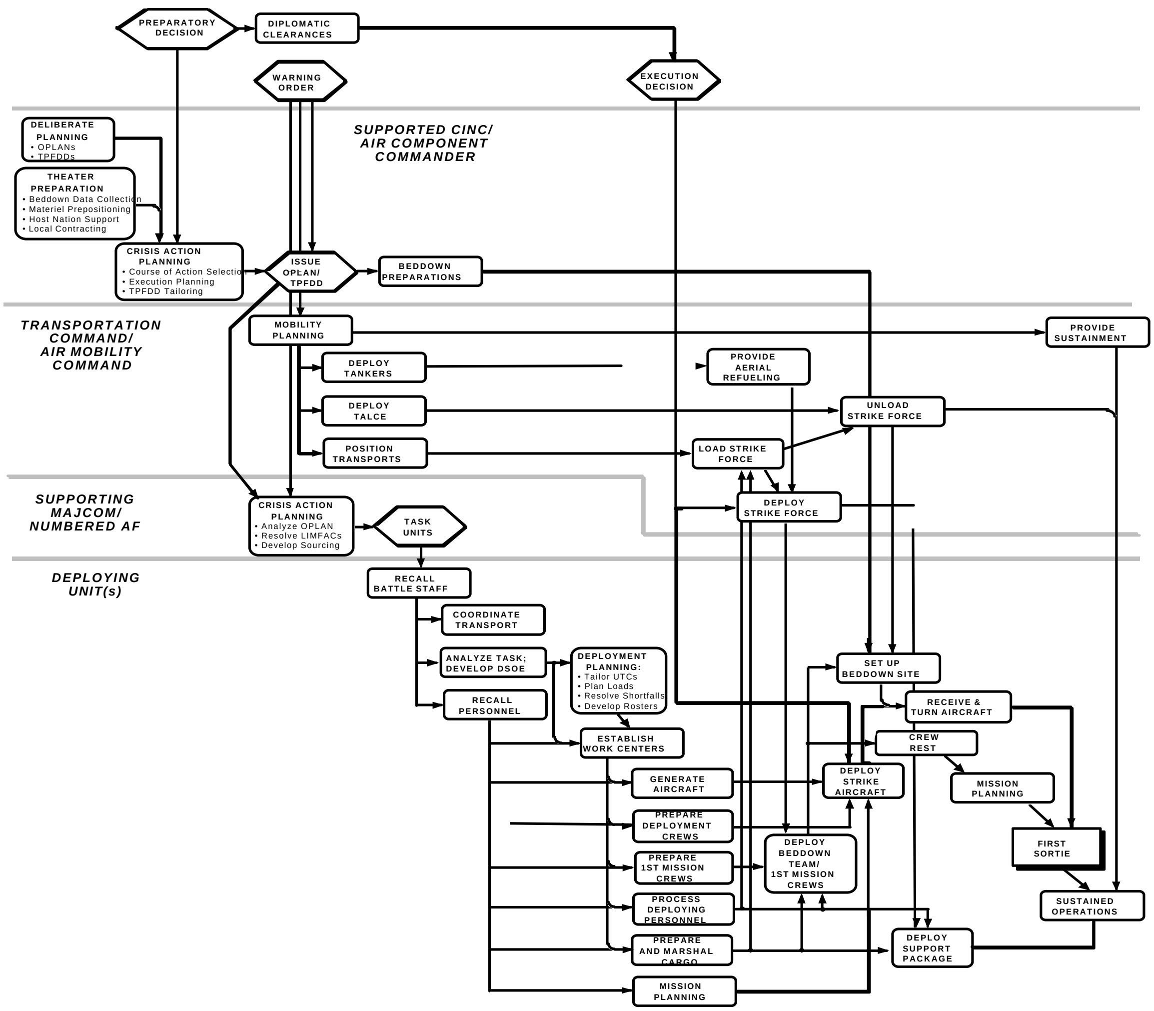

Figure H-2. *A Fighter Deployment Flow Illustrates the Complexity of the Process*

Although not shown in the figure, another essential element is the production of targeting and threat data, sortie timing, and other inputs to fighter mission planning, without which effective combat operations are impossible. It is entirely possible that positioning sensors, collecting and processing data, and planning the initial operation may be the pacing factor in time to effect. In other very real situations, the condition of the beddown site in terms of pavements, local fuel sources, presence or absence of prepositioned materiel, and many other factors have a large impact on the time to prepare to support a flight line as well as the amount of cargo and number of personnel to be deployed, and thus on the required airlift. These, in turn, largely determine how fast operations can be established. End-to-end representations of such deployment sequences have been the principal basis for the Panel's timeline analysis.

2.3 Categories of Deployments

In assessing their timelines, it is helpful to map the mission scenarios of this study onto a group of deploying force categories. Thus Combat Operations, Show of Force, and other missions employing mostly fighters and bombers are very similar logistically, the chief difference being the required supply transportation for various sortie rates and munitions consumption. Humanitarian Operations are impossible to treat as a single analysis case because of the range of requirements involved, but these operations rely on transport aircraft and frequently medical, civil engineering, transportation, security police, and other ground operations units. Intelligence, Surveillance, and reconnaissance (ISR) packages are in a category by themselves. These three categories are examined in the timeline analysis that follows. The Counterproliferation mission generally will involve a single strike, launched from and returning to CONUS, USAFE, and PACAF bases and involving no forward sites. The timeline here is however long it takes to generate the force and fly to the target, and this case is not considered further.

In keeping with the overall study ground rules, our primary metric is elapsed time from Warning Order to Delivery of Effect. Within each of the force types, we can postulate various levels of readiness and alert posture, and compute the effect on the metric. Since the worst case is deployment to an undeveloped and unfamiliar beddown site, this is assumed in the Combat and Humanitarian cases; ISR platforms such as the Airborne Warning and Control System (AWACS) and the Joint Surveillance, Target, and Attack Radar System (JointSTARS) provide global coverage out of a network of established bases, and the timeline analysis accounts for the time to reach first orbit over the AOR from the nearest suitable site. This set of conditions gives us a basis for evaluating the fundamental study goal of describing an AEF concept that can deliver desired results in 24 hours or less from an order to execute.

2.4 Doing It Faster

Under current law and regulations, the launching of an AEF can be governed by as many as four successive operational orders. A Planning Order establishes a requirement, usually long term, to begin planning for a given contingency or geopolitical situation. A Warning Order notifies specific units that they have been identified for an operation and should start preparing. An Alert Order starts the deployment process and authorizes the dispatch of strategic lift forces. Finally, an Execute Order is required for launch of combat forces. The response time of interest is from Alert Order to delivery of first military effect. Figure H-3 illustrates the challenge of moving from the current response time of 70 hours or greater for CONUS tactical wings toward the goal of 24-hour global application of power. In the analysis, we examine a range of actions that can move the Air Force to a much more responsive posture without demanding excessive use of resources.

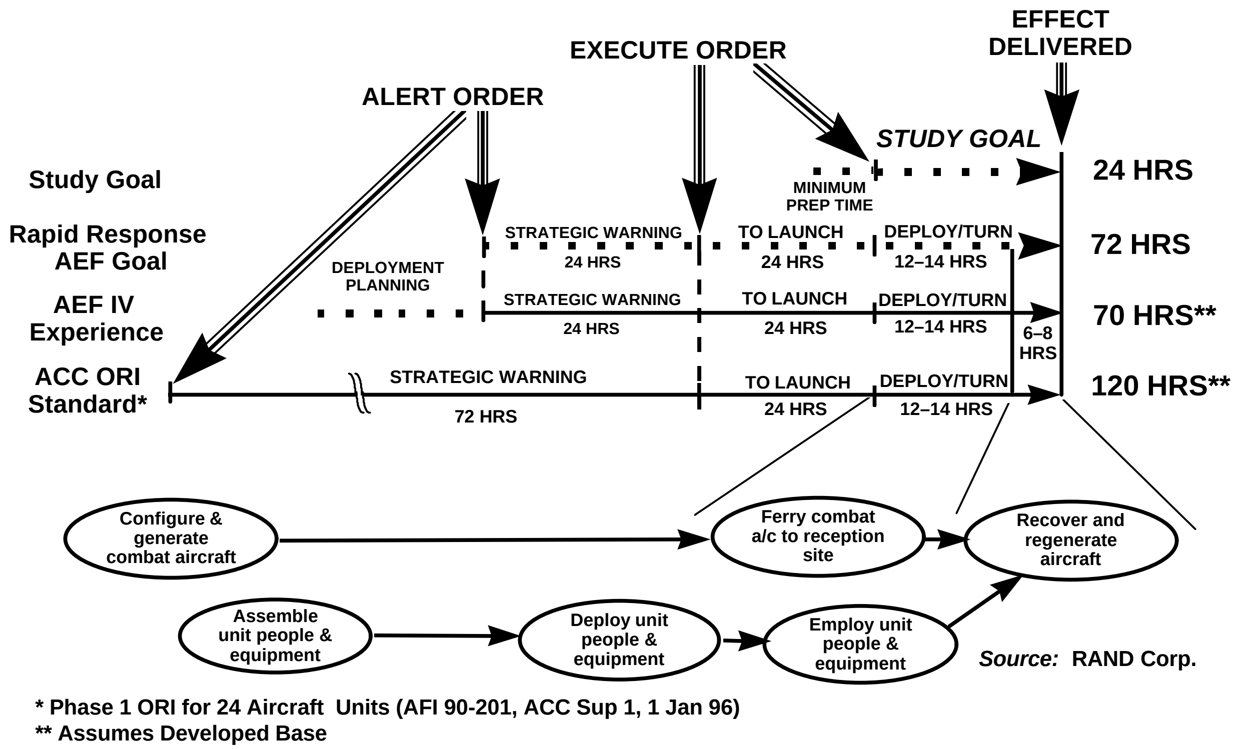

Figure H-3. *Timelines for Current Capability and More Responsive Goals*

2.4.1 Analysis Approach

For the combat, humanitarian, and ISR cases, we assumed one or more typical force packages, constructed a simple model of the sequence of steps in the deployment, accounting for activities that happen in parallel and those that must occur in sequence, and computed the time metric under several conditions. The model cannot be considered validated until actual field experiments are performed to check its predictions. However, it incorporates data from recent operations and has been checked for reasonableness by knowledgeable people. In the case of the most elaborate analysis, that for Combat Operations, a Microsoft Project file was constructed, closely matching Figure H-2, and incorporating the appropriate relationships among activities. The Gantt chart view of this file is given in Figure H-4. The program then makes it easy to vary durations and relationships to quickly assess the impact of various conditions. Less detailed analysis was done for the other cases because of the spread of possibilities for humanitarian and, conversely, the rather deterministic nature of ISR deployments.

Figure H-4. *Gantt Chart*

2.4.2 Combat Operations

Two typical force packages were evaluated: a Central Command (CENTCOM) model grouping of 30 fighters or 6 bombers. The analysis is insensitive to the size of the deployed package if the assumption remains valid that no single base deploys such a large fraction of its resources that the efficiency of the process is impaired.

For the fighters, four cases were examined:

(1) The current deployment process, as demonstrated in AEF IV, was optimized to reduce each step to a reasonable minimum while retaining the basic nature of the operation. Neither the fighters nor the mobility forces are on alert, and the fighters land in the AOR, are turned, and fly the first sortie with crews brought over with the initial beddown team. The analysis assumes

- Theater CINC planning is *prior* to Strategic Warning, and CAP by the supported CINC is not counted in the deployment timeline. This appears to require an initial NCA "Preparatory Decision," which is assumed to occur 12 hours prior to the Warning Decision, but could be much earlier.
- Diplomatic clearances are obtained not later than the Execute Order (24 hours after Strategic Warning).
- Planning and processing times are significantly shorter than current times
  - Tanker air bridge is in place 24 hours after cold start.
  - First transports arrive at Aerial Port of Embarkation (APOE) 18 hours after cold start.
  - MAJCOM/NAF actions add no more than 2 hours to the timeline.
  - Passenger and cargo processing, aircraft preparation, etc., happen very quickly.
- There are no delays due to
  - Actions to resolve shortfalls or other limiting factors at the deploying unit(s).
  - Timing and sequence of the transport stream (effectively, assume the transports achieve perfect departure reliability).
  - Setup at the beddown site (material-handling equipment is available, pavements are adequate, etc.).
  - Availability of fuel, water, munitions, etc., at the beddown site.
- Planning is fully integrated, automated, and effective based on the use of CAP tools such as those described in this report.
  - Existing deliberate plans and Time-Phased Force and Deployment Data (TPFDD) documents require only minor tailoring.
  - Planners at all levels have perfect knowledge of the beddown site, operational tasking, etc.
  - Transportation coordination is routine and fast.
- The overall deployment process is highly disciplined and understood; there is none of the mismatch between arriving transports and ready cargo and passengers often referred to as "TPFDD turbulence."
- Flight time from home base to the beddown site is 14 hours for both fighters and transports.
- Initial operations are conducted under the Minimum Bare Base concept described elsewhere in this report, so that the initial lift requirement is held to 25 to 35 C-141 equivalents, spaced over 36 to 48 hours.

The result of this "Enhanced Baseline" is shown as an MS Project Gantt chart in Figure H-4. It predicts a total time of 24 hours from Warning Order to launch of the fighter package and 26 hours longer to the first sortie in the AOR. This is approximately the timeline called for in the Rapid Response AEF Air Force Instruction now in draft.[24] Although no Air Force fighter unit could do this today, especially deploying to a bare base, it is achievable with the right planning tools, adequate provisioning of units designated for deployment, and improved procedures and training. The limiting factors are associated with aircraft movement, specifically erection of the tanker air bridge and movement of fighters and transports, rather than with the packing up and aircraft generation activities at the deploying unit.

(2) The first excursion from the Enhanced Baseline involves prepositioning of mobility assets with tankers on 4-hour standby at staging bases and transports managed so that a predefined lift stream begins arriving at the deployment base also in 4 hours. Another key measure is to forward-locate the assets and personnel who will erect the Tanker Airlift Control Element (TALCE) or other aerial port at the beddown site, so that the port is in operation within 12 hours. Now the critical path involves packing up and moving the force and setting up at the operational site. The 50 hours of the baseline comes down to 40 hours at the cost of some constraints on the routine utilization of the mobility fleet.

(3) A major improvement in response time appears to demand some kind of alert by the deploying fighter units. The next analysis excursion assumes crews and support teams on a 4-hour recall for a 6-hour time to takeoff. Mission planning and crew rest for the first strike crews take place on their transports during the flight to the AOR. The beddown team leaves in 4 hours to arrive ahead of the fighters and quick-turn them for the first sortie. This reduces the metric to 26 hours.

(4) A final speedup is to deliver the first strike upon arrival in theater, without landing at the beddown site. Although stressful after a long ferry flight, such missions are feasible in the opinion of experienced fighter pilots. This eliminates the turn time at the forward base and brings the metric down to 20 hours. This is the feasible minimum for forces stationed in the rear and in an alert status that allows reasonable family interaction, recreation, and other elements important to quality of life.

The Panel believes that bombers have an important role to play in achieving the goals of a rapid response AEF. Our analysis assumes that the mission profile involves deployment of a six-ship bomber force from a CONUS base directly to the target, delivery of the strike by at least four aircraft, and recovery to a regional Main Operating Base as discussed elsewhere in this report. Then the two cases of interest revolve around whether an alert force is maintained. Without alert, it easily could require 18 to 24 hours to generate the aircraft, reconfigure them for conventional weapons, do mission planning, and launch. Allowing the same 14 hours to reach the target as for the fighter cases, this leads to metrics of 32 to 38 hours. With an alert force ready to depart in 6 hours, the same 20-hour metric as for the fastest fighter case applies. After the first strike, it would be expected that at least four of the six deployed bombers would fly on any given day in continuing operations, and that these aircraft would deliver one sortie per day, depending on the range to the target and other factors. Thus, the supported theater could count on at least four bomber strikes per 24 hours, spaced as appropriate to the operational situation.

The results of the fighter and bomber analysis are summarized in Table H-2. The Panel sees considerable merit in combining fighters and bombers in combat AEF scenarios. Typically, the critical first strike would be delivered by an alert bomber force, with fighters arriving in theater and beginning to generate high sortie rates shortly thereafter. In some threat situations, bombers will require escort, which must either be provided from in-place theater forces or be deployed with the bombers. In Desert Strike, the Navy provided an F-14 escort very effectively from a carrier in the AOR.

[24] Draft Air Force Instruction (AFI) 110-XXX, "Rapid Reaction Air Expeditionary Forces."

One further important point concerning timelines involves the possibility that an AEF may prove to be only the opening of a larger operation, up to and including Major Theater Warfare. Nothing that is done to enhance the AEF option can hinder the ability of a CINC to bring forward such a larger force, often referred to as "flowing the TPFDD." The point is that the tanker air bridge needed for a fast first strike would support such a follow-on and, in any case, would be there to assure timely sustainment lift to an AEF during its deployment. Thus, as long as its transport requirements are not excessive, an AEF actually *improves* the CINC's ability to deal with a growing contingency.

Table H-2. *Summary of Combat Operations Timeline Analysis*

AEF Option	Characteristics	Time to First Delivery
Fighters		
Baseline	AEF IV	70 hours
Enhanced Baseline	Minimum feasible time is required to position tankers and transports. No delays are caused in deploying force. Beddown site has adequate pavements, fuel, water, etc. High-quality Contingency Action Planning tools are in use.	50 hours
Prepositioned Lift	Tankers are on 4-hour standby at en route bases. Transports are designated to arrive at departure base in 4 hours. Forward-positioned aerial port is in operation after 12 hours. Minimum mobility planning time is required.	40 hours
Alert Strike Force	Both deployment and first-strike crews are on 4-hour recall to take off in 6 hours. Mission planning and crew rest during flight to operational theater. Support cargo and personnel leave in 4 hours.	26 hours
Employ/Deploy Mission Profile	Strike force takes off in 6 hours direct to target area.	20 hours
Bombers		
Without Alert	Current practice.	32-38 hours
With 4-Hour Alert	Crews and support personnel are on 4-hour recall.	20 hours
Intelligence, Surveillance, and Reconnaissance Aircraft		
Without Alert	Current practice.	48-96 hours
With 4-Hour Alert	Crews and support personnel are on 4-hour recall.	20 hours

2.4.3 Humanitarian Operations

Two AEF packages have been examined: a mobile trauma team comprising three C-130 loads or two C-141 loads of passengers and cargo, and an aerial port and transport stream to lift in relief supplies.

Extensive theater lift will be required in any distributed scenario, and both C-130 and rotary-wing transports may be needed, especially in the absence of good pavements throughout the area. Cirafici has analyzed the Provide Relief operation in detail[25] and provides a set of cautionary tales about the difficulties of executing these missions in remote areas.

[25] Lt Col John L Cirafici, USAF, *Airhead Operations: Where AMC Delivers*, Air University Press, Maxwell AFB, 1995.

The timeline will vary widely, depending on the circumstances. Factors include:

- If the Aerial Port of Debarkation (APOD) requires upgrading of air traffic control (ATC), pavements, water supply, etc., a substantial initial lift package with the required equipment and supplies plus time to do the work will be needed at the start of the operation. Delivery of large amounts of relief supplies demands a large, high-quality ramp, which may have to be built from scratch or extended. This could involve one or more days to deploy and one to several more days at the APOD. If pavements adequate to operate and unload strategic transports are not available, the initial operation might have to be supported from a staging base with C-130s or helicopters (the CV-22 could be invaluable in this situation), by road, or in some other fashion.

- If a field hospital or other major equipment must be removed from storage, packed, deployed, and erected, several days will be required for it to be fully operational at the deployed site. This could occur in parallel with other efforts once a runway able to handle strategic transports is ready.

- The trauma team can deploy and set up in 24 to 48 hours, depending on distance and the amount of cargo required by the medical situation. Extensive sustainment lift is likely to be required for bottled water, casualty evacuation, and other support.

- Humanitarian forces, by definition, tend to drop into the middle of unsettled conditions; it may be necessary to secure the area and set up force protection before the delivery of relief can commence. In addition, until transports are equipped with effective self-protection systems against the rapidly proliferating threat of portable surface-to-air missiles, there often will be constraints on their ability to operate in threat environments; at the least, frequent disruptions to the orderly flow of supplies, as seen in Bosnia, can be expected.

In summary, a humanitarian AEF could respond in as little as 24 hours or as long as several days, depending mostly on conditions at the APOD and, if applicable, other delivery sites. The current practice of rapidly deploying a survey team to assess the situation and gather the information needed for better planning of the operation will continue. Better data on airfields around the world would minimize this requirement. Some limited humanitarian relief can be generated in as little as four hours, as was demonstrated recently in response to a plane crash in Ecuador. The speed and effectiveness of relief delivery also can be optimized by close coordination with the International Red Cross and other agencies. However, in general the Panel did not find many opportunities to train, organize, and equip Air Force units for significantly faster humanitarian response than is being achieved today.

2.4.4 Intelligence, Surveillance, and Reconnaissance Operations

Today, and for some time to come, the primary sources of information for an AEF will come from manned aircraft, including AWACS, JointSTARS, RIVET JOINT, and U-2 platforms. The other Services also operate ISR assets that may be of great value, such as the electro-optical imaging sensors on modified P-3 aircraft being used in Bosnia to deliver a unique intelligence product. In addition, it may be possible to task overhead systems (many of which require clear viewing weather), to use human agents, and to rely on previously surveyed locations of fixed targets such as bridges. As high-endurance Unmanned Aerial Vehicles (UAVs) enter the inventory, they will create new options for placing collectors over an area, including short-notice deployment from CONUS or theater bases. In general, however, the Air Force today must expect to rapidly deploy or redeploy its own systems either as the entire force of a Global Awareness AEF or as the indispensable first phase of other AEF missions. It may be necessary to assess conditions at a forward base before allowing a deploying force to land. Even humanitarian missions, faced with uncertainties about threats to health and safety in the AOR, may have to be preceded by high-quality information gathering.

Current deployment plans for manned ISR platforms call for repositioning aircraft and establishing orbits at a new location in 48 to 96 hours. These plans can provide global coverage from an existing base network and require 9 to 12 C-141 equivalents of airlift to deploy the three-aircraft package needed to support 24-hour coverage. This is too slow to meet the AEF timelines considered in this report. The data available to the Panel did not allow as in-depth an analysis of ISR deployments as of the other AEF categories. A thorough review of the current limiting factors, followed by action to make ISR assets more responsive, is of great importance to the overall AEF concept. Assuming ISR assets were maintained on alert, the same 20-hour response as for bombers should be achievable, as suggested in Table H-2.

An interim strategy, already practiced to some extent, is to preposition aircraft based on the world situation at any given time. Additional steps to consider include aircraft modifications to allow longer flight times (e.g., to divert aircraft already flying in one theater directly to another with refueling) and to reduce the required external support environment, and thus the required airlift to deploy. UAVs are strong candidates for forward positioning, especially since alert airframes do not need to be flown to maintain crew proficiency, which will rely primarily on simulators. Regional Contingency Centers (RCCs) would be logical UAV storage locations.

Perhaps the most attractive near- to midterm option, although the concept has a long history of failure, would be some kind of podded or internal sensor package that could be deployed rapidly on tactical aircraft. Such systems have been thought of as limited area reconnaissance collectors rather than wide-area sensors, but recent developments in synthetic aperture radar, electronic intelligence, and other sensors suggest that no breakthroughs are needed to develop small sensor packages with high resolution, broad area coverage, and all-weather capability. In the longer term, increased spaceborne ISR capability, with its rapid response to collection needs, can complement airborne platforms, which allow focused and synoptic coverage once they are in place.

The present ISR deployment capability of the Air Force must be considered a limitation on the response time in many AEF scenarios. The high operations tempo (OPTEMPO) they must support, even without unpredicted contingencies, is a further concern. Careful planning of the geographical dispersion of these limited fleets is clearly of great importance. It may be necessary to move platforms early in anticipation of a developing hot spot so that they can establish orbits and collect data far enough in advance of the first sortie by the deploying combat or humanitarian force. A further area of concern is the lack of capability to remotely assess biological and chemical contamination. As these threats proliferate, the ISR mission can be expected to grow to sensing these agents both prior to landing an AEF force and for force protection during the operation.

2.4.5 Summary of Limiting Factors

A number of things come up repeatedly in our analysis as underlying timeline drivers. Steps to reduce these would yield overall improvement in AEF responsiveness. They include:

- **Diplomatic Clearances.** While largely beyond Air Force control, this problem has been a consistent and baneful limitation on virtually every operation of the past several decades.
- **Mobility Positioning.** Erecting the tanker air bridge and, in some cases, retasking transports to pick up deploying forces is currently a major limitation. Deploying and activating an aerial port from CONUS has roughly a 24-hour lead time.

- **Aircraft Movement.** Flight time from CONUS to typical target areas is on the order of 12 to 18 hours.
- **Fuel and Munitions.** At non-prepositioned bases, establishing a fuel supply and building up ready munitions stocks can take from hours to days.
- **Generating the Force.** Under normal readiness conditions, 12 to 24 hours may be consumed in generating aircraft, preparing personnel, and packing and marshaling cargo.
- **Beddown Site(s).** Airfields with adequate runways, parking areas, and water supplies are essential; availability of quarters, utilities, and other support factors reduces the required lift and shortens the timeline.
- **Force Protection.** Considerations of local area threat level, availability of host nation security, and requirements for deployment of force protection assets and personnel can significantly influence both the lift required and the timeline, especially if such things as negotiation with the host nation must be completed prior to deploying.

In summary, the Panel's analysis suggests that major reductions in current response times are feasible through improved planning tools and procedures, organizational changes, selective use of varying levels of alert, and some investments in spares and support equipment.

3.0 Tools for Employment-Driven Crisis Action Planning

3.1 Enhanced Processes for Crisis Action Planning and Execution

In implementing the AEF concept, no process improvement is more urgent than reform of planning and execution monitoring as they are practiced today. As our posture changes from the Cold War to a multipolar world, the Air Force must be able to respond quickly to taskings across the spectrum of airpower applications and at any spot on the globe. The underlying mindset associated with planning and executing these AEF missions also must change. A number of recent and ongoing studies by various organizations have examined the use of AEFs to provide lean, rapid responses across these myriad scenarios. Today, the Services base their operations on deliberate plans that have taken months to develop and even more time to practice. Moreover, the current planning environment maintains the relatively isolated "stovepipes" among the various functions involved in deploying, employing, and sustaining a force. When a contingency occurs, such plans seldom can be executed as written, as the recent AEF IV experience in the Persian Gulf vividly illustrated. Instead, tasked units tailor the operations plan to meet the mission. Figure H-5[26] summarizes the "as is" CAP situation. The figure shows the primary participants and taskings, with specific documents identified. The supported CINC sends a TPFDD document to the supporting major commands. They analyze the requirement and task wings to provide the necessary manpower and equipment via a Deployment Manning Document (DMD) and Logistics Detail (LOG-DET) data. The supported CINC and Air Component Commander issue operational tasking through the air tasking order (ATO). The "as is" process is seriously deficient in integrating logistics and operational functions. For example, there is no adequate means of gathering and incorporating data on the beddown sites to which the force is to deploy.

[26] Lt Col Anthony Dronkers, USAF, "Logistics for the Warrior: 'Integrated With Command and Control,' " unpublished manuscript.

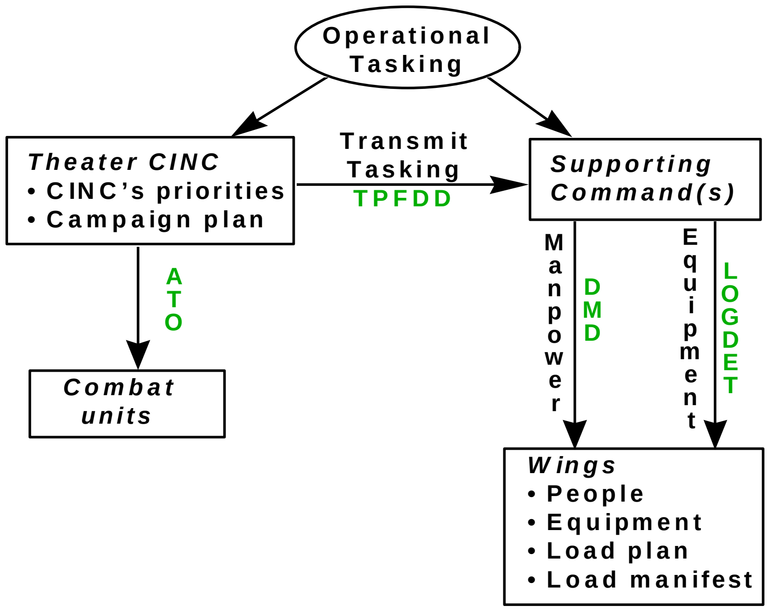

Figure H-5. *Current Deployment Tasking Process*

The nature of an AEF operation requires the thoroughness of deliberate planning to be combined with the speed of CAP. As part of this, many logistics processes need to be automated and integrated through tools that make planning faster, the information used more accurate, and the execution more efficient. At the same time, converting to a CAP environment is indispensable to the AEF concept. The CAP environment must be based on the concept of employment-driven planning and on a collaborative process in which the various functional specialties work together to ensure that a plan is feasible and optimized.

The necessary process improvements are based on these fundamental principles:

- Logistics requirements, including deployment lift and all the other functions portrayed in Figure H-5, must be derived from specific operational outputs, which may range from combat sorties generated to tons per day of relief supplies to be delivered, depending on the mission.
- Traditional logistics planning, based on "pushing" materiel to the engaged forces on the basis of peacetime supply planning, must give way to "operational pull" based on fast, time-definite transportation to deliver what the forces actually need when they need it.
- Logistics planning must be based on accurate, current, and comprehensive data about the site(s) where the AEF will be bedded down.
- Planning and execution monitoring must be supported by information systems that automatically integrate operational and logistics data, support good decisions, and allow CAP to be accomplished in hours rather than days, tailoring existing plans when possible and developing new ones when necessary.
- CAP must occur in an "integrated product team" (IPT) mode, which assures the necessary cross-functional interactions to produce plans that are feasible and optimized in terms of all required activities.

Figure H-6 shows the evolution of the "as is" situation into the "should be" process, in which tools and databases support all the necessary interactions and automate the development of plans and other implementing information. The various abbreviations are defined in the annex to this appendix and in Section 1.2.2 below. For each transaction, the figure identifies the tool to be used in red and the document involved in green. The Joint Operation Planning and Execution System (JOPES) is listed in quotes to reflect the urgent need to upgrade or replace the existing deliberate planning tool set with one that can deal with the time urgency of CAP.

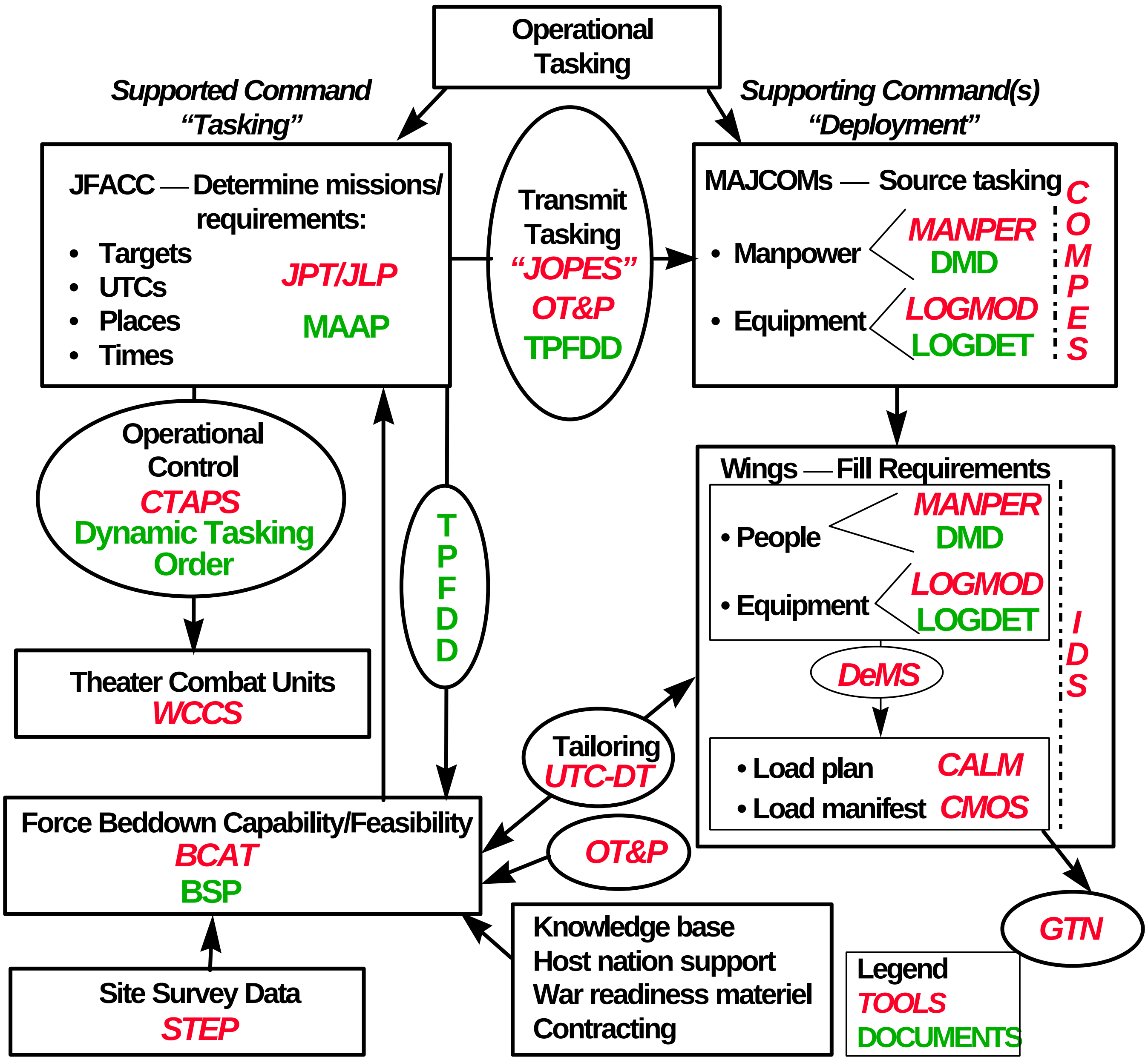

Figure H-6. *The Goal CAP Environment Supports the Required Interactions and Facilitates Rapid Employment-Driven Planning*

Figure H-7 looks at the same planning processes from a sequential flow viewpoint and highlights the stages where new tools such as the JFACC Planning Tool (JPT), the JPT Logistics Planner (JLP), and the Logistician's Contingency Assessment Tool (LOGCAT) support plan development. This environment is characterized by:

- **Responsiveness.** In an environment characterized by short-term crisis and rapid change, the ability to react quickly is paramount.
- **Flexibility.** The AEF must operate within the joint and coalition forces command structure and yet meet Air Force requirements and situations across an extremely diverse operational spectrum.
- **Scalability and Tailoring.** The AEF plan must be adapted to the size of the engagement, the differing force sizes, and the duration of operations.
- **Interoperability.** The AEF supports a CINC, and its information and equipment must be interoperable with other elements of joint and combined forces.
- **Simplicity.** Tools must be friendly to the community of users.

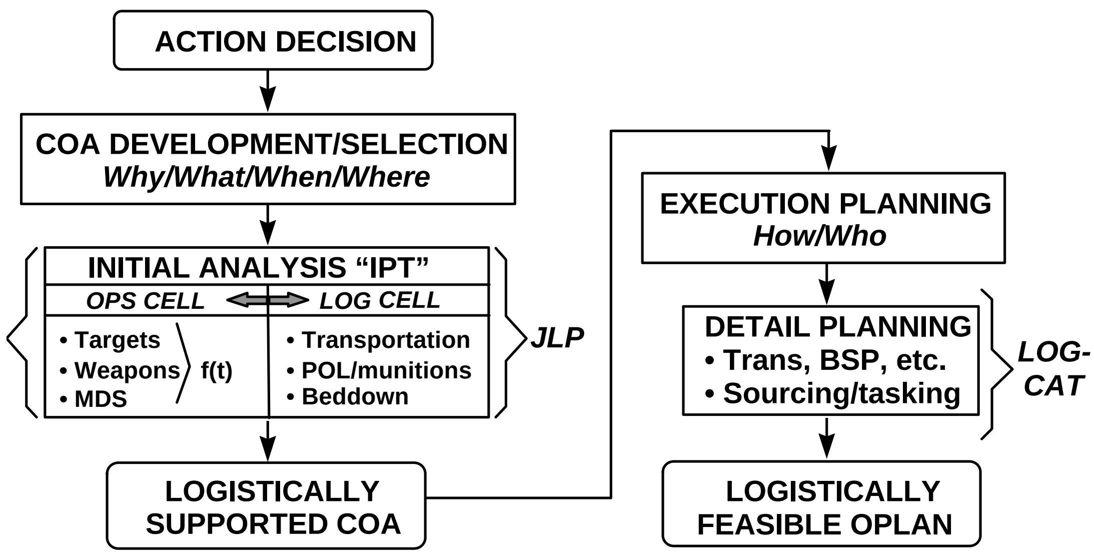

Figure H-7. *A Collaborative Process Is Essential to Achievement of Feasible Plans*

This new vision of CAP is consistent with the concept of the Distributed Joint Force Air Component Commander (JFACC) described in Volume 1 and the Command and Control Appendix. Replacing manual, *ad hoc* procedures with modern information systems is essential to the kind of "virtual staff" interaction we envision as a key element of reducing the forward-deployed AEF footprint.

3.2 Crisis Action Planning Tools

The array of information systems in use or in development for CAP can be bewildering. Technologies and tools are being developed for use at all levels of command that will speed the planning and execution process. The Panel tried to capture the relevant tools as part of the assessment of these critical AEF processes. Table H-3, using the time and organizational dimensions of Figure H-1, lists the many applications that exist or are in development. The most important of these are briefly described in the following paragraphs. This list is not all-inclusive and is intended to identify those items that have potential or are already in use. The tools listed in the table provide a starting point for attaining the required automated planning and execution process.

Table H-3. *Current and Developmental Crisis Action Planning and Execution Tools*

COMMAND LEVEL	READINESS	CRISIS ACTION PLANNING	DEPLOY-MENT	EMPLOY-MENT	SUSTAIN-MENT	REDEPLO Y-MENT	RECONST I-TUTION
CINC/AF	SORTS ALP JL-ACTD WRM Viz GTN TC-AIMS II JTAV/ITV	ALP JL-ACTD JOPES EKB WRM Viz GTN TC-AIMS II JTAV/ITV	JOPES JL-ACTD WRM Viz GTN TC-AIMS II JTAV/ITV	JOPES JL-ACTD WRM Viz GTN TC-AIMS II JTAV/ITV	JL-ACTD ALP WRM Viz GTN TC-AIMS II JTAV/ITV	JL-ACTD WRM Viz GTN TC-AIMS II JTAV/ITV	JL-ACTD ALP WRM Viz GTN TC-AIMS II JTAV/ITV
MAJCOM/ NAF	JOPES SORTS COMPES STEP BCAT WRM Viz GTN TCAIMS II JTAV/ITV	JOPES COMPES STEP BCAT JLP/JPT WRM Viz GTN TCAIMS II JTAV/ITV	JLP/JPT COMPES BCAT UTC-DT JFACC JOPES WRM Viz GTN TCAIMS II JTAV/ITV	BCAT JLP/JPT JOPES JFACC WRM Viz GTN TCAIMS II JTAV/ITV	JLP/JPT BCAT JFACC WRM Viz GTN TCAIMS II JTAV/ITV	JLP/JPT COMPES BCAT UTC-DT JFACC JOPES WRM Viz GTN TCAIMS II JTAV/ITV	WRM Viz GTN TCAIMS II JTAV/ITV
WING/SQ	SORTS COMPES STEP BCAT WRM Viz GTN	BCAT STEP WRM Viz GTN	IDS UTC-DT UTC-O BCAT STEP WRM Viz GTN	BCAT WRM Viz GTN	BCAT WRM Viz GTN	IDS UTC-DT UTC-O BCAT STEP WRM Viz GTN	WRM Viz GTN WRM Viz GTN

- **JFACC Planning Tool (JPT).** JPT provides an environment to analyze potential hot spots around the world, develop air schemes of maneuver, and archive developed plans for future use. It is a tool used by the JFACC planner to develop the air campaigns necessary to execute the CINC's operational objectives and strategies. JPT allows the air campaign planner to develop air operation plans, rapidly assess a plan's potential to achieve the desired objectives, and visualize/track execution. It reviews operational objectives and builds a campaign strategy to meet the objectives. The tool allows for the planner to identify specific target sets that must be hit in order to meet the campaign strategies. It also identifies the necessary force structure and mission tempo that will be required to destroy the target set.
- **Joint Logistics Planner (JLP).** JLP currently consists of three modules relating to munitions (complete rounds), transportation, and supply/maintenance. Additional modules covering fuel and resupply need to be developed. The JLP is a high-level tool for rapid logistics planning that will support the campaign outlined by the JPT. It looks at the number of combat aircraft required to meet the goals of a specific scenario, then allocates these packages to beddown locations based on runway length, the maximum load-bearing capacity of the runway, ramp space, and fuel capacity. It allows the operator to explicitly allocate packages to bases and calculates a feasible beddown solution for the remaining packages. The JLP also contains components that review the supply, maintenance, and transportation feasibility of the air campaign plan.

The JPT and JLP modules work together as follows: (1) The Aircraft Beddown Allocation Module (ABAM) evaluates the initial Master Air Attack Plan (MAAP) and determines whether the proposed force structure beddown is feasible. ABAM takes a high-level look at the airfield infrastructure to determine whether there is sufficient ramp space, runway length, and an adequate load-bearing capacity. (2) The JLP-Munitions (JLP-M) module evaluates a time-phased munitions requirement and determines whether a sufficient munitions inventory exists to support the MAAP for that particular theater. Insufficient munitions will result in the generation of a munitions (supply class V) movement requirement that is input to the JLP-Transportation (JLP-T) module. (3) JLP-Maintenance/Supply (JLP-S) evaluates sortie generation capacity at a base. A shortfall in supply results in a class IX (repair parts) transportation requirement. (4) JLP-T evaluates the closure of forces and sustainment requirements generated by the JLP-M and JLP-S modules. (5) The results of the JLP analysis are the identification of unsupportable sorties, the reason (no munitions, late unit closure, etc.), the targets not attacked, and the strategic airlift apportionment required for the modeled force structure.

- **Joint Force Air Component Commander (JFACC).** The JFACC After Next program will improve command and control of joint and coalition air forces through the development, integration, evaluation, demonstration, and transition of technology and systems to enable new concepts of operation for air operations planning and execution.
- **Joint Logistics Advanced Concept Technology Demonstration (JL-ACTD).** The objective of JL-ACTD is to provide operational users such as CINCs and Joint Task Force Commanders with the capability to plan and execute more responsive and efficient logistics support. Through the use of information technology, significant improvements in mission capability can be obtained. These improvements include enhanced logistics situational awareness, better predictive models, and better communications among decisionmakers.
- **Joint Decision Support Tools (JDST).** Phase II of the JL-ACTD calls for the development of JDST. The Joint Office for Logistics Technology (JOLT) has drafted seven areas where JDST are needed. These areas include: Course of Action Generation, Visualization of Materiel Management and Distribution Capability, Consumption (Materiel) Planning and Analysis, Force Capabilities Assessment, Force Flow Analysis, Reconstitution, and Other Requirements. The Other Requirements category includes issues such as medical logistics, worldwide status of prepositioned assets, and military operations other than war.
- **Advanced Logistics Program (ALP).** The goal of DARPA's ALP is to develop a set of tools to provide the right material in the right place at the right time while supporting lean logistics concepts. The program will develop a shared technology base of information manipulation and planning tools to support planning, execution, monitoring, and focused replanning throughout the logistics pipeline. It will operate in an interoperable environment for the operators and logisticians, linking CINC Operations and the Logistics Staff, Defense Logistics Agency (DLA), and TRANSCOM. In a nutshell, ALP will demonstrate the feasibility of an automated logistics system, end-to-end. Completion of the program is projected for FY 02, with technology milestones being accomplished consistently over the next 4 years. As technologies are developed to proof-of-concept phase, they will be transferred to the JOLT office for further development.
- **Transportation Coordinator's Automated Information for Movement System (TC-AIMS II).** TC-AIMS II standardizes and automates planning and scheduling tasks for the movement of cargo and people from origin to port of embarkation (POE) and from port of debarkation (POD) to destination. It prepares transportation and communicates

transportation information to managers, customers, and other end users. TC-AIMS II shares information on cargo/passenger and unit movement. This is a U.S. Transportation Command (USTRANSCOM)-sponsored family of systems providing automation support for base/post-level transportation organizations. Implementation originally slated for May 1997 was not attained. Currently, each Service has a unique version of this system. The Army version is TC-ACCIS, the Navy version is TC-AIMS, the Air Force version is CMOS, and the Marine Corps version is MAGTAF II.

- **Global Transportation Network (GTN).** GTN is an automated transportation information system that provides command and control and in-transit visibility. The system allows access to and transfer of information across geographically dispersed databases. It supports transportation users and providers, DoD, and commercial movers by collecting and integrating transportation data. The resulting data is provided to the National Command Authorities, USTRANSCOM's commander-in-chief and component commands, and DoD customers to support transportation planning and decisionmaking during both peacetime and wartime. GTN supports the entire spectrum of transportation functions, including the development and evaluation of plans; in-transit visibility of personnel, equipment, and supplies; tracking and status of transportation assets; and day-to-day traffic management. It supports all phases of military operations including mobilization, deployment, execution, and sustainment.
- **In-Transit Visibility (ITV).** ITV is a major capability to be provided by the GTN. As a minimum operational performance requirement, GTN must provide oversight of defense transportation by monitoring movement of items (forces/cargo/passengers) and movement of military and commercial airlift, sealift, and surface assets. This includes retrograde shipments from theater, Nonunit Replacement Personnel, and evacuation of noncombatants. GTN will collect, integrate, and distribute transportation information to CINCs, Services, and other DoD customers for timely visibility of transportation information requirements. The system will allow visibility of a requirement when it is initiated and provide continuing visibility as it moves through the transportation pipeline. The status of itineraries, schedules, and manifests of transportation assets and resources also will be included. In general, ITV requirements can be characterized as customer-controlled views of integrated transportation data. GTN will focus the customer's view of transportation by providing requirements, scheduling, and actual movements for passengers, patients, forces, cargo, and air refueling.
- **Joint Total Asset Visibility (JTAV).** JTAV is the capability to provide timely and accurate information on the location, movement, status, and identity of units, personnel, equipment, and supplies. It also includes the capability to act upon that information to improve the overall performance of DoD's logistics and personnel practices. JTAV has the potential to contribute substantially to greater efficiency by providing materiel managers with the visibility to offset wholesale procurements with excess retail assets; by increasing user confidence in logistics and personnel systems, thereby reducing duplicate requisitions; and by reducing logistics response time as a result of exposing bottlenecks in supply and transportation systems. Asset visibility encompasses both logistics and personnel assets. JTAV addresses the following assets: (1) In-storage — materiel being stored at retail and wholesale inventory at organic or commercial sites, and at disposal activities;

(2) In-process — materiel being acquired from vendors, but not yet shipped, or being repaired at intermediate- and depot-level organic or commercial maintenance facilities; (3) In-transit — personnel and materiel assets being shipped or moved from origin (such as units, vendors, storage activities, or maintenance facilities) to destination (such as units, storage activities, or maintenance facilities); (4) In-theater — materiel stored, procured, maintained, and shipped, and personnel moving, within the geographical boundaries of a theater.

JTAV is not a separate automated information system (AIS). Rather, it is a capability that a family of logistics systems can provide. JTAV information requirements are not limited to the visibility of materiel and personnel. Visibility of other logistics assets, such as facilities and infrastructure, as well as logistics workloads that affect those assets, also is needed. The key features of the JTAV architecture are the databases of asset information, timely updates to the information, the ability to assess and update that information, and the ability to act on the information.

- **Joint Operation Planning and Execution System (JOPES).** JOPES is the integrated command and control system currently used to plan and execute joint military operations. This system is a combination of joint policies, procedures, personnel, training, and a reporting structure supported by automated data processing on the Global Command and Control System. These capabilities support translation of NCA policy decisions into planning and execution of joint military operations. JOPES and its predecessor systems have been used for the past two decades for developing operation plans and TPFDD lists during peacetime and in crisis situations. Recently, JOPES has become integral in the execution of real-world operations for management of the deployment of forces, accompanying cargo and supplies, sustainment resources, and personnel into and out of a theater of operations. JOPES automatic data processing (ADP) systems must interface with selected Service applications, providing data essential for joint planning and execution. JOPES supports the Office of the Joint Chiefs of Staff (OJCS), the worldwide commanders of unified and specified commands, and the Services by maintaining support information for contingency operations planning, review, and implementation. JOPES was conceived and implemented as a deliberate planning tool at theater level. It requires extensive supplementation with newer technologies and information systems to allow CAP on today’s timelines and at various levels of conflict.

- **Contingency Operations/Mobility Planning and Execution System (COMPES).** COMPES is an Air Force standard automated data processing system at both the MAJCOM and base levels. The COMPES-MAJCOM Level (COMPES-M) is directly supported by JOPES. The capability is required for MAJCOMs to task units down to the Air Force Specialty Code (AFSC), individual social security number (SSN), and item national stock number (NSN) level of detail in support of CINC-tasked UTCs supporting specific operational plans and orders (OPLANs/OPORDs) and contingency operations. The functions of COMPES-M that support operations, logistics, manpower, and personnel planning must be modernized to achieve these capabilities. COMPES identifies those units and resources to be moved. Currently, COMPES data files are transmitted to deployment and employment locations, the supported CINC’s air component, and AFPC via the Automated Digital Network (AUTODIN).

- **Status of Resources and Training System (SORTS).** SORTS is a computer software system that provides current information to NCA, Joint Chiefs of Staff (JCS), and specified commands with location and resource information for crisis actions. The information concerns the status, location, posture, readiness, and activities of military forces worldwide. SORTS allows Services to monitor unit resources and training in peacetime. A unit typically is reported as being from C1 (fully combat ready) to C4 (not combat ready).

- **Integrated Deployment System (IDS).** IDS is the result of integration and migration of five existing systems for deployment planning and execution support that streamline wing-level deployments. IDS provides the automated interfaces to processes that were manual in the past. The five systems and their purposes are as follows:
  - **Logistics Module (LOGMOD).** LOGMOD provides the equipment and cargo data for a UTC.
  - **Manpower/Personnel Module (MANPER).** MANPER provides the manpower detail for a UTC.
  - **Deployment Management System (DeMS).** DeMS provides an automated capability to identify and select personnel and equipment resources to meet the tasking requirements.
  - **Cargo Movement Operations System (CMOS).** CMOS automates cargo and passenger manifesting and supports in-transit visibility of cargo and passenger movement.
  - **Computer-Aided Load Manifesting System (CALM).** CALM is used to build Load Plans and to pass chalk (individual transport load) data back to CMOS.

Ideally, the Logistics Plans office will provide cargo and equipment data from LOGMOD, and the personnel office will provide personnel data from MANPER to DeMS users. When a wing is notified of a tasking, the log plans and personnel offices pass the unit line numbers (ULNs) to the DeMS user to assign personnel and tailor cargo requirements. Then the personnel data is passed back to MANPER, where the personnel readiness unit (PRU) processes travel orders and passes them on to CMOS for passenger manifesting. The unit deployment monitor passes the cargo data to CMOS, where the combined, accurate data is passed to CALM for load planning and then to GTN to report the movement and provide in-transit visibility.

- **Logistician's Contingency Assessment Tools (LOGCAT).** LOGCAT is a suite of new technologies to improve wing- and squadron-level deployment/employment planning processes, reduce deployment footprint, reduce deployment/employment response times, and use deployment resources more efficiently and effectively. LOGCAT combines the thoroughness of deliberate planning with the speed of crisis action planning. The current initiatives under the LOGCAT umbrella are as follows:
  - **Survey Tool for Employment Planning (STEP).** STEP uses advanced integration of computer hardware and software to automate the collection, storage, and retrieval of deployment site survey and/or Base Support Plan (BSP) Part I information. The tool can be run on a laptop, allows importing of digital video images of important base features, and can uplink data through a satellite communications terminal.
  - **Beddown Capability Assessment Tool (BCAT).** BCAT uses advanced database design to compare employment site force beddown capabilities imported from STEP against deploying forces' beddown requirements and produce an assessment of the plan, including a list of resource shortfalls and limiting factors. BCAT also provides a network dialog function through which lead and supporting units can coordinate deployment planning.

- **Unit Type Code Development and Tailoring (UTC-DT).** UTC-DT uses advanced software to automatically develop and tailor UTCs based on individual deployment scenarios.
- **Unit Type Code Optimization (UTC-O).** UTC-O uses software to automatically optimize the packing of UTC equipment onto 463L cargo pallets.
- **Logistics Analysis to Improve Deployability (LOG-AID).** LOG-AID is a requirements analysis study of the wing-level deployment process that recommends improved processes and technologies to provide significant improvements to the wing-level deployment machine. The LOG-AID contract was recently modified to expand the research up to the joint forces commander and across all facets of combat support.

3.3 Future Directions in Crisis Action Planning

3.3.1 Limitations of the Current Planning Process

The planning processes and tools described in the preceding sections have been developed to support a major theater warfare scenario, and they have the following characteristics:

- Designed to optimize the deployment of resources for a major theater war (MTW)
- Based on the assumption of adequate time for deliberate planning and to prepare beddown sites
- Based on the assumption of a long sustainment period where there is primarily a “push” of materiel to the engaged forces

When applied to an AEF, the existing planning environment

- Does not support the timelines of an AEF
- Produces a larger deployed footprint than necessary because of limited ability to tailor the force package to the specific situation and mission
- Produces logistics plans and operational plans that are not tightly integrated, particularly because of the constrained timeline
- Does not easily accommodate changes in the mission or deployment; for example, the tools do not support dynamic replanning

3.3.2 Planning Needs of an AEF

The planning needs of an AEF caused by a 24-hour deployment timeline are so stressful that the entire planning process needs to be redeveloped. The emphasis needs to be on developing processes and tools that permit planners to be effective with only a 4-hour planning cycle. Figure H-8 is a high-level view of the situation that captures some dimensions of AEF planning, which are discussed in more detail below.

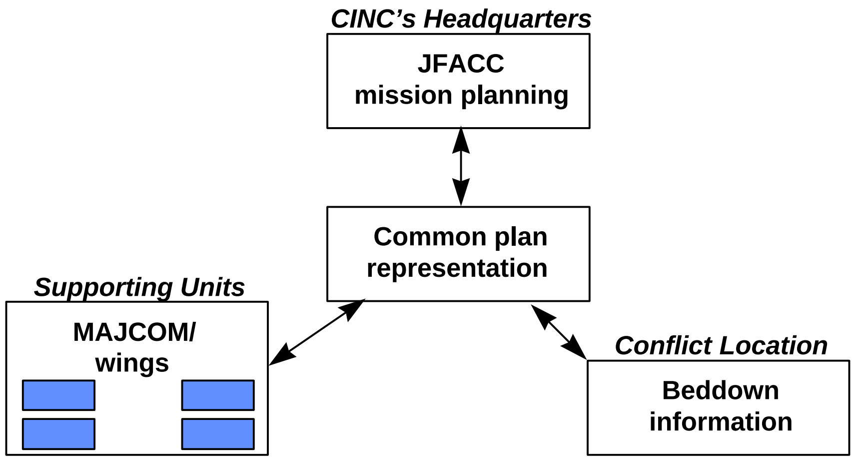

Figure H-8. *The Desired Integrated Planning and Execution Process Must Assure a Common Understanding Among All Participants*

- **Integrated Planning Environment.** The AEF planning methodology and supporting tools must integrate operations planning and logistics planning into a single plan that encompasses operations, deployment, and any necessary site preparation at the beddown location. Time does not permit sequential planning cycles. The figure depicts a common plan representation that is shared by all planners.
- **Responsiveness.** The short planning time (as little as 4 hours) will require the automation of many steps that today typically are manual. This includes having key databases on line and tools to verify plan feasibility.
- **Distributed Planning.** By the very nature of an AEF, planning will be distributed geographically. This includes, at a minimum, the CINC, the supporting commands, transportation resources, and the deploying location. In addition, both the JFACC and logistics units will need a reachback capability. Finally, the ability to continue to plan/replan and rehearse while en route requires a distributed planning capability that has a common, shared view of the plan as it evolves.
- **Employment-Driven Planning.** The large logistics footprint that results from many of today's deployments, including AEFs, is at least partly caused by failure to adequately plan for the mission that is being supported. The principles of employment-driven planning, described above, are central to this process improvement.
- **Seamless Planning.** The concept of seamless planning requires that tools be able to support planning in multiple kinds of operations. This study focuses on planning for an AEF, but the plan also must be concerned about transition to sustained operations, including the possibility of an MTW. Planning activities also must accommodate joint and coalition forces, and the tools used for deployment planning also must handle any dynamic replanning.
- **Plan Analysis.** A plan deals with a complex set of interdependent events. Simulation tools can be used to evaluate the feasibility and robustness of a plan by simulating the execution of the plan. These tools also can be used to rehearse the execution of the mission.

3.3.3 Software Technology Needed for an AEF CAP Environment

Current planning tools have only begun to tap the potential of advanced information system technologies. Some of the emerging approaches that will provide the basis for satisfying AEF planning needs are described in the following paragraphs.

- **Intelligent Planning Tools.** An AEF operates on a very constrained timeline, possibly with only a few hours to develop and validate a plan. The planning tools will have access to an ever-expanding amount of data, including previously developed plans, results of previous AEFs, TPFDDs, transportation resources, weather, etc. If the planning tool is to be more than a repository of resources and schedules, it needs to have a model of what constitutes an AEF. This will enable the tool to take plan fragments and partial inputs from a planner and automatically generate feasible courses of action. As modifications to a plan are made, the planning tool will continuously check for feasibility. Finally, as the plan is executed, unexpected problems, scheduling delays, or changes in the external environment will require a dynamic replanning capability.

  A variety of technologies have been or are being developed to support intelligent planning. Programs at DARPA include JFACC After Next, Planning and Decision Aids, and Advanced Logistics Planning. Advanced planning tools incorporating artificial intelligence technology have been a major Rome Laboratory (RL) program for some time and have yielded a number of important tools that are now in use.

- **Building and Testing Complex Systems of Systems.** Current Air Force planning capability already includes a large number of independently developed tools. In the future, this proliferation of tools will only get worse as a combination of legacy systems, commercial off-the-shelf (COTS), and new developments must be integrated to form an overall planning capability. Much of today's technology for composing and integrating systems is still rather *ad hoc*. The result is that adding new components or making changes to the software frequently takes many months to debug and validate. There is no quick solution for this problem, but some promising technologies are emerging. These include model-based checking, software architecture definition languages, and template-based software development paradigms. The DARPA program in Evolutionary Development of Complex Systems (EDCS) is addressing some of these problems and is very relevant to AEF planning problems.

- **Collaboration Technologies.** People productivity is critical to performing time-constrained AEF planning tasks. Intelligent planning tools as described above can assist the planner substantially. Equally important is the need to increase the performance of the planners as they interact with each other and with the planning tools. Interactive white boards and video conferencing technologies will allow planners to interact with shared data from geographically distributed locations. But the real challenge to making the collaboration more effective is to ensure that the planners have the right information for the task they are performing. The DARPA program in Intelligent Collaboration and Visualization is developing many of the technologies needed by an AEF. This includes being able to extract semantically relevant information from multiple data streams, virtual situation rooms, experience on demand, information sharing across time, semantic multicasting, etc. These individual projects all are geared to making the planners more effective while working as a team in a dynamically changing environment.

4.0 Minimum Bare-Base AEF Package

Part of the Lean Sustainment Panel's task has been to challenge the conventional wisdom about deployment timelines and footprints. In Volume 1, we summarize the results of an attempt to define the true minimum package of personnel and materiel needed to establish a 30-fighter operation at an undeveloped forward base. This section provides more details of that analysis.

The approach was to take the AEF IV deployment to SWA as a basis for comparison, estimate the additional resources that force would have required if bedded down at an austere site, and compare these to an AEF built from the ground up on the basis of minimizing deployed people and cargo. Our list was compiled and refined through dialog with experienced specialists in the various functional areas, many of whom have recent experience in SWA AEFs and other deployed operations.

4.1 Factors Affecting Minimum Bare-Base Logistics Support

It must be emphasized that a single, rigorous side-by-side comparison is impossible, because thousands of detailed assumptions about the mission and beddown site, not to mention the expert judgments and opinions of individual planners, affect the outcome. However, our objective was to estimate the order of the reductions that might be possible with a truly "lean and mean" force, and in this we believe we have succeeded. Our pared-down force becomes far more realistic under the assumption that the beddown site is supported by a RCC as described in Section 1.4, and it is feasible only under the assumptions of deployment with full mission support kits (MSKs), dependable priority resupply, rapid replacement of casualties and the sick, and similar measures to keep the forward base fully operational.

The following are some of the factors affecting the true minimum level of logistics support at a bare base:

- **Quality of Life.** The supported CINC and JFACC, guided by applicable regulations and policies and the exigencies of the situation, must establish the quality-of-life standards to be provided to AEF personnel, including
  - **Shelters and Environmental Control Units (ECUs).** Under benign weather conditions, support personnel can survive without tentage or other shelters and ECUs ("sleeping under the wings"). Aircrews require climate-controlled crew rest quarters. The assumed shelter level has some impact on airlift (because environmental control units are heavy) and a substantial impact on power production (since air-conditioned quarters double the electric power requirement per person). Even in undeveloped countries, however, hotel accommodations may be available near airfields that can support AEF operations.
  - **Hot Food.** Long experience has shown that after about three days, field rations (meals ready to eat, MREs) become so unpalatable that personnel stop eating enough to maintain adequate calorie intake, especially under sustained heavy labor. The personnel and equipment to provide one or two hot meals a day are a modest burden which the theater may well elect to support.
  - **Basic Amenities.** Deployment and erection of existing Harvest Falcon/Eagle kits takes longer than the assumed duration of an AEF operation. However, like hot food, the availability of shower/shave facilities, access to long-distance phone lines, and other amenities have a growing impact on morale and efficiency after a few days. Depending on the nature of the contingency, the CINC may decide to deploy additional personnel support resources.

- **Refueling.** Factors such as local availability of specification-compliant jet fuel and the use of a hot pit refueling operation (where aircraft taxi to a common refueling point) vs. a larger number of fuel trucks to service aircraft on the ramp can make as much as a 3:1 difference in the short tons of equipment that must be deployed to support refueling. Also, current field refueling equipment, especially 50,000-gallon bladders, is such that at least 24 hours is required to set up a fuel-mixing and -dispensing operation at a bare base. The Air Force has some experience with refueling directly from KC-135s or from transports fitted with fuel bladders ("bladder birds"), but no current arrangements are really satisfactory.
- **Vehicles.** Most deployment plans assume that general-purpose vehicles (cars, panel trucks, forklifts, etc.) can be rented locally at the beddown site. If this is not true, multiple C-141 equivalents of airlift are required to move the 20 or more vehicles needed to run a base and flight line.
- **Force Protection.** Depending on the assumed threat, the force protection package can vary widely. A minimum security police unit is about 44 personnel with small arms and radios. A more typical package is about 120 personnel with vehicles and other equipment. As the level of threat rises, intrusion and chemical/biological agent sensors, crew-served weapons, shelters and decontamination equipment, armored cars, and other heavy equipment could be required.
- **Water.** Each person consumes 12 gallons per day of water, almost all of it potable. Reasonably clean local supplies can be made drinkable with reverse-osmosis water-purification units (ROWPUs). If this is not feasible, and the site in question must be used anyway, flying in bottled water for 500 people consumes roughly a C-141 load per day.
- **Flight Operations Support.** Airfield lighting and arresting gear, navigation aids, and other requirements for flight operations must be deployed if not available at the beddown site.

Our analysis is based on the following assumptions:

- The force comprises a "CENTCOM Model"[27] with 12 air-superiority fighters (F-15Cs or F-16Cs), 12 ground-attack fighters (F-15Es or F-16Cs) and 6 fighters (F-16CJs) for suppression of enemy air defenses. The force is tasked to generate 70 sorties per day, including night operations. All air-ground munitions are expended on each attack sortie, but most air-to-air missiles and 20-mm cannon ammunition are returned unexpended. Staffing is based on the munitions and consumables demanded by F-15Es, which is higher per sortie than that of F-16s.
- Fuel is delivered by aerial refueling for the first 24 to 48 hours until a refueling capability is established at the beddown site. That capability consists of a hot pit refueling operation, supplemented by limited R-9 fuel trucks for topping off. (This minimizes the deployed footprint at the expense of reduced flexibility in turning jets for repeated sorties.)
- Maintenance is staffed for 1.5 12-hour shifts. The Minimum Flight-Essential Maintenance concept is implemented. Aircraft not repairable under this concept are immediately replaced and may be designated for cannibalization. Load crews are staffed on the basis of staggered launches of four-ship formations. No maintenance-intensive munitions (e.g., the AGM-65 Maverick) are used.
- Critical item resupply begins 24 hours after force beddown and continues daily.

[27] Draft AFI 110-XXX, "Rapid Reaction Air Expeditionary Forces."

- Most general-purpose vehicles, packing materials, and other common items are locally purchased or rented. However, two all-terrain forklifts are deployed.
- A realistic force protection package comprising 118 troops (similar to that deployed in AEF IV) is required; a smaller team (44 troops) is included in the absolute minimum case, trading increased risk for reduced airlift.
- A Harvest Eagle (HE) kit may be deployed during the AEF period, but is not included in our numbers. (HQ USAF/ILEOR provided the Panel with the listing of a tailored HE kit to support 550 people and requiring approximately nine C-141 loads to transport.)

It also is important to define some characteristics of the assumed beddown site. Our bare base has only a runway, taxiways, and ramp adequate to support transport and fighter operations, a local water supply that can be purified by ROWPUs, and a local threat environment requiring only a basic security contingent. Other essentials, if not locally available, can be lifted in at the expense of a greatly increased airlift burden. As discussed elsewhere in this report, fuel for the assumed force and sortie tempo (70 sorties per day) could be flown in by five to seven C-17s using the center wing tank or by various transports with flight deck bladders. Whether an AEF actually would be sent to such a demanding location may be questionable, but we wanted to probe the worst case. This sustainment lift is not included in our numbers for a deployment package.

4.2 Minimum Bare-Base AEF Logistics Package

It proved useful to compile our AEF on the basis of two fundamental sets of assumptions. One is that nothing be taken that is not literally essential to generating sorties. This list, labeled “Package 1,” omits, for example, two crash/fire/rescue (CFR) trucks, a mobile barrier for arresting damaged aircraft, and a field kitchen to give the troops a break from field rations. It also strips flightline gear, shelters, and other essentials to the bone. Such a force would be considered only in a really dire emergency, but it anchors the spectrum on the low end.

Our second list, labeled “Package 2,” adds the items just listed, provides enough personnel to allow for illness, injury, and occasional sleep, and includes a full readiness spares package (RSP) kit and other items. This larger package obviously requires more net airlift, but does not affect the first sortie timeline because much of the cargo comes in during the first days of the operation, by which time the need for shelter, showers, hot food, and more support equipment becomes acute in the real world of field operations. This is the list that forms the basis for our “Minimum Bare-Base Package.”

Both lists contain the same aircraft, crews, command-and-control resources, climate-controlled crew rest shelters, and other operational content. We stress that these are hypothetical lists that would have to be validated in field exercises and experiments before being used as the basis for organizational and operational planning. However, every person and item of materiel has been critically examined and found to be necessary to support a fighter flight line generating 70 sorties per day.

Table H-4 tabulates the emergency and realistic minimum cases. Personnel and cargo are broken out into airfield operations, force protection, fighter operations, maintenance, munitions, and aerial port. Planning factors (weight and length) for major equipment items are listed. Cargo is estimated either in C-141 equivalents or in pallets. Depending on the item, the basis for estimating C-141 equivalents may be gross weight (22.5 short tons per load), length of the cargo deck, or number of pallets (13 per load). The estimates are conservative for cargo, and therefore we have not added airlift requirements for personnel, who would be distributed on aircraft according to required order of arrival and available space.

Table H-4. *Absolute Minimum and Realistic Personnel and Materiel Requirements for a 30-Fighter AEF*

			Package 1				***Package 2***			
			Cargo				*Cargo*			
ITEM	Weight (short tons)	Length (inches)	#	C-141s	Pallets	*PAX*†	#	C-141s	Pallets	*PAX*†
Airfield Operations										
Command staff/WICP	35*			2		35		2		53
NAVAIDS				0.5		4		0.5		4
Mobile barrier	20.5			-		-		1		4
Airfield lighting	7.7			0.3		2		0.3		2
Power production				1		2		1.5		3
Sweepers	4.3	190*	1	0.3		4	2	0.7		6
P-10 fire/rescue	3	200*	1	0.3		15	1	0.3		24
P-19 fire truck	3.8	200*	-		-		1	0.3		
P-20 ramp patrol	3	200*	-		-		1	0.3		
Misc. vehicles	4*	190*	5		10	8	8		16	12
Tents w/ ECUs					1				2	
Shower/shave, etc.					-	-			3	2
Medical					1	2			2	4
MREs					4				2	
Initial depl. kitchen					-	-			8	6
Miscellaneous‡					4	8			6	12
Civil engineering					3	35			7	49
Force Protection				0.5		44		1.5		118
Fighter Operations										
Crew					2	60			2	60
Crew chiefs					3	30			3	30
Asst. crew chiefs					1.5	15			3	30
Life support					1	2			1	4
Munitions loaders					0.5	12			1	18
Refuelers					0.5	15			0.5	20
R-9 fuel trucks	11.2	230*	3	1			6	2		
Fuel storage/handling§										
MB-2 or 4 tugs	5.2	200	2				3			
MJ4 bomb loaders	3.5	182	3				3			
-10 air conditioners	.7	106	4				6			
-60 power/oil carts	1.8	121	3				4			
MEP6 generators	4	164	1				2			
NF2 light stands	1.1	106	7				9			
MC7 air compressor	1.5	131	1				1			
Subtotal				2				3		
Stands					4				4	
Jacks					1				1	
Ladders, tow bars, etc.					4				6	
Liquid N_2 cart	1.2	129	1				1			

Table H-4. *Absolute Minimum and Realistic Personnel and Materiel Requirements for a 30-Fighter AEF (continued)*

			Package 1				***Package 2***			
			Cargo				*Cargo*			
ITEM	Weight (short tons)	Length (inches)	#	C-141s	Pallets	*PAX*[†]	#	C-141s	Pallets	*PAX*[†]
Stands					4				4	
Jacks					1				1	
Ladders, tow bars, etc.					4				6	
Liquid N_2 cart	1.2	129	1				1			
Liquid O_2 cart	0.5	90	1				1			
Hydraulic cart	1	120	2				2			
Subtotal					4				4	
Misc. AGE**					3				5	
Misc. vehicles				1		6		2		8
Misc. eqpt. pallets					8				10	
Misc. personnel pallets					3				5	
Maintenance										
Specialists/Supervisors					1	13			2	26
RSP kits	2.4	210	1				3			
Engine on trailer	2.3	154	1				2			
4000/3000 stacked crane	0.3	214	1				1			
Subtotal				0.5				2		
Misc. equipment					8				12	
Munitions										
Specialists					2	52			3	68
Bobtails	3.9	178	3				5			
MC-2 low pacs			1				2			
Loaded MHU141 trailer	3.2	140	10				14			
Loaded MHU110 trailer	3.2	140	6				10			
Subtotal				1.7				2.7		
Munitions assembly Conveyer on MHU110			1		1		1		1	
Tanks/racks/adapters/ pylons (TRAP)					6				8	
MC-7 compressor	1.5	131	1		1.5		1		1.5	
All-terrain forklifts	13.2		1	0.5			2	1		
NF-2 light stands	1.1	106	2		2		2		2	
Aerial Port										
TALCE/airhead				4		16		4		16
AMC ops support				1		32		1		32
Aerial port operations					1	21			1	21
TOTALS				16.6	97	433		26.1	137	632
Total C-141s				24				36.6		

Notes:
* Estimated.
† Passengers.
‡ Sanitation, messing, mortuary, other BOS.
§ Bladders, pumps, filters, etc.
** Tank dolly, engine oil spectroscopy unit, etc.

The analysis shows 24 C-141 loads and 433 people for Package 1, and 36.6 C-141s and 632 people for Package 2. Note that these totals include roughly 5 C-141 loads and 69 people associated with the aerial port who would be essential but are not always accounted for in estimating deployment requirements. Package 2 — passengers and cargo for the lead unit deploying to a bare base — compares closely with an independent estimate performed by Air Staff logistics planners.

The preceding table represents our best estimate of what can be done to pare a deployment package using today's systems, equipment, procedures, and policy. When the full AEF concept and technology improvements described in this study are implemented, major additional reductions will become feasible. These include:

- Reducing the deployed wing command staff to 10 or fewer people and four pallets of equipment, as allowed in the distributed JFACC concept
- The smaller deployed footprint, improved shelters and environmental units, advanced power production, and other advances to reduce the personnel, equipment, and supply requirements for base operations and support
- Required routine maintenance for aircraft like the F-22 and the Joint Strike Fighter; an engine durability improvement program would be another important contribution, but is not assumed in this analysis
- The deployed cargo, reduced roughly by half through use of lightweight, multifunction support equipment
- The required transportation and loading equipment for advanced munitions, shipped as all-up rounds, eliminating the munitions build-up function.

When these reductions are taken into account, the minimum bare-base package drops to an estimated 460 people and 27 C-141 loads while retaining the safety and operational capability features of Package 2. We refer to this projected package as an Optimized AEF. Table H-5, repeated from Table 2 of Volume 1, compares today's Minimum Bare-Base Package and tomorrow's Optimized AEF Package to our best estimate of what was actually deployed on AEF IV, using data from the Air Mobility Command and the participating fighter wings. Not surprisingly, there are discrepancies between these two sources, but the cargo estimates, which dominate required airlift, agree fairly well. To allow comparison of equivalent packages, we have added an estimate of personnel and cargo to the AEF IV numbers to account for pre-existing base facilities at the beddown site. Given the uncertainties, the comparison can be taken only as approximate, but it does support the contention that a substantial reduction in personnel and cargo is possible.

Table H-5. *Comparison of Optimized AEF Package to Minimum Bare-Base Package and Estimated Equivalent AEF IV Package*

	Recent (AEF IV)			Achievable Now		SAB AEF	
	Deployed Personnel	Deployed Cargo (C-141s)	Pre-positioned Cargo (C-141s)	Deployed Personnel	Deployed Cargo (C-141s)	Deployed Personnel	Deployed Cargo (C-141s)
Initial Combat Capability	541	16.0	15.8	264	20.9	158	13.0
Force Protection	113	2.7	0.0	118	1.5	118	1.5
Base Operations & Support	576	0.4	14.5	184	9.1	116	7.4
Aerial Port	120	7.0	0.0	69	5.1	69	5.1
Subtotals	1,350	26.1	30.3	632	36.6	460	27.0

Total Cargo (C-141s)	56.4	36.6	27.0
Total Deployed Personnel	1,350	632	460

5.0 Infrastructure Considerations

Improvements in the organization, procedures, and provisioning of deployable forces must be matched by a global infrastructure that allows them to execute rapid worldwide deployments. One major dimension of this involves command and control capabilities such as communications and navigation; the report of the C^2 Panel discusses this in detail. Here, we are concerned specifically with logistics facilities and processes. Although much reduced from Cold War levels, the overseas presence of the Air Force remains a vital element of national strategy. The Panel found that modest extensions of the remaining bases and adjustments to forward-positioned materiel can have large payoffs for rapid, global AEF employment.

5.1 Regional Contingency Centers

Our analysis, agreeing with common sense, shows that the ultimate limitation on response time of an AEF comes down to mass through distance — the time and transport needed to move aircraft, supplies, support, and personnel from their home station to a forward base. One obvious approach is to have a worthwhile fraction of the cargo already in place or nearby. We have examined various ways to accomplish the desired reduction in transportation requirements without making it unaffordable.

Various kinds of prepositioning have been used in past decades to prepare for the presumed likelihood of war against known opponents, chiefly the Warsaw Pact, in known places. Today, the Air Force maintains extensive prepositioning of equipment and supplies at developed bases in places such as Southwest Asia and Korea and expects to draw on war reserve materiel (WRM) stocks from regional warehouses. However, the cost of stocking such centers and the continuing expense of caring for their contents — many of which must be exercised, inspected, repainted, and otherwise maintained — makes it impractical to do this everywhere an AEF might be needed. Even if such prepositioning could be afforded, the time to withdraw equipment from storage, prepare and ship it, and set it up at an operating base puts such support well past the AEF period of an operation and makes it instead an option for sustainment of a prolonged operation.

Instead, the AEF concept put forward in this study combines the ability to operate a force with minimal support for at least the first week using a limited but ubiquitous network of forward supply positions. We have termed these Regional Contingency Centers, and they have proved upon examination to have a number of advantages:

- They allow reduced ton-miles per day of airlift to supply an AEF at an austere forward base.
- Each provides a preplanned location for quickly building up a regional main operating base (MOB) should the contingency warrant it.
- They would be a logical element of programs such as Partnership for Peace and of normal U.S. presence in a friendly nation.

An RCC, in our concept, is not a prepositioning site in the familiar sense. Instead, it is a high-quality airfield, in a strategic location, at which certain advance facility preparations have been made and which provides secure, static (unattended) storage of heavy materiel likely to be needed in a contingency. Then only unrefueled theater airlift sorties would be required to move stored materiel to a forward base. The idea is similar to things that have been tried in the past in USAFE and PACAF. It is similar in some respects to the global Forward Supply Location network of the Air Mobility Command.

To be a candidate, an airfield would have to have the following characteristics:

- Location within 1,500 nmi, eventually 2,000 nmi, of likely beddown sites for AEFs in the region. These are the approximate unrefueled mission radii of the C-130 and C-17, which will be used to provide intratheater airlift.
- Excellent pavements, including a strong runway of 8,000 feet or longer and a ramp with high maximum on ground (MOG) to allow multiple transports to be loaded and unloaded simultaneously.
- Assured local supplies of aircraft and vehicle fuels and lubricants, potable water, and, ideally, other consumables such as food and medical supplies. Available local rental of vehicles, material-handling equipment, and the like would be a plus.
- Assured storage for bomb bodies, preserved engines, and other items in static storage. This presumably would involve physically secure warehouses, alarms, and contracted security services.
- Assured access in time of crisis. This is a diplomatic issue to be worked out early and often. An RCC would be worse than useless if the host nation denied its use in a contingency.

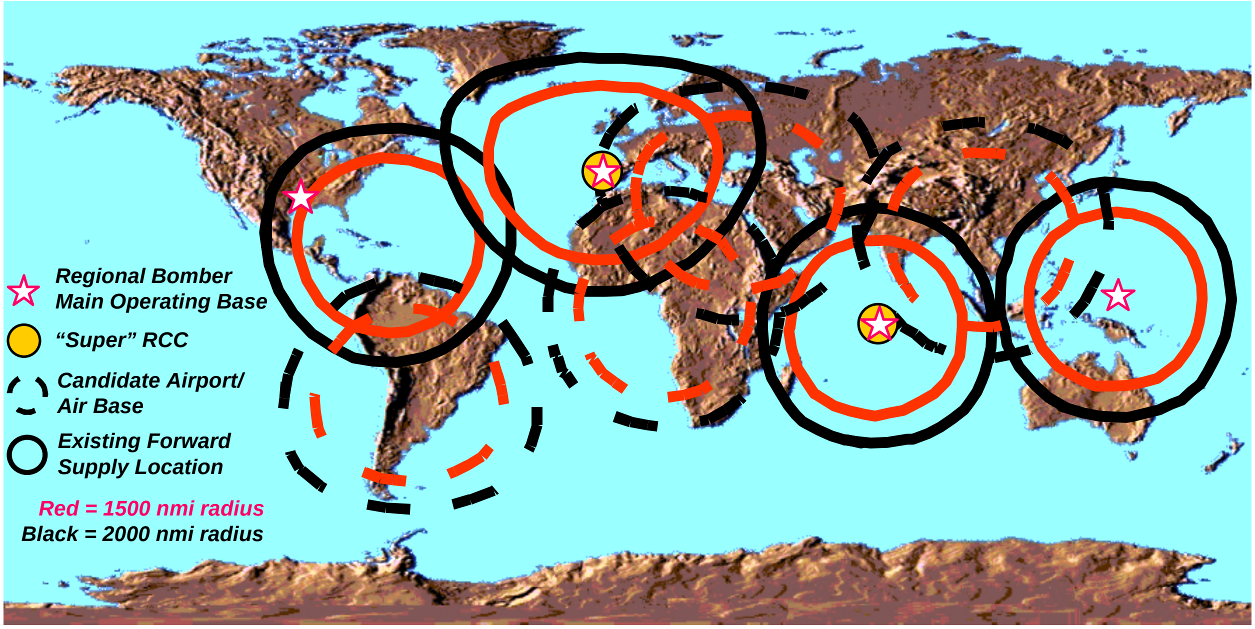

Figure H-9. *A Notional Set of Eight RCCs, Half at Existing Bases, Shows Good Global Coverage*

As a basic reasonableness check, we have picked a set of RCC locations as shown in Figure H-9. Half are existing U.S. bases; the others are commercial airfields. We did not consider allied air bases in this quick look, and there has been no attempt to evaluate the diplomatic feasibility of places such as Asuncion, Paraguay, and Utapao, Thailand. It is quite likely that more thorough analysis will lead to a different set of locations. However, the map shows that, especially with the 2,000-nmi C-17 radius, most beddown sites of interest would be covered by this number of RCCs. Two of the sites are marked "Super RCC." The idea here is to preposition a much more complete set of equipment, including things such as vehicles and generators that require regular maintenance. With only two such sites, a strategic airlift sortie could quickly move such cargo to a closer RCC or direct to a forward base. The map also shows the locations of the bomber MOBs, which are discussed in the next section.

The airfields likeliest to meet these conditions are existing U.S. bases, major civilian airports, and air bases of allied nations. Under normal conditions, an RCC location owned by a host nation would logically be a major site of U.S. military presence in the country and could be combined with existing DoD offices or other facilities to secure a permanent U.S. presence. Development of the RCC could be part of a program to help an ally develop its infrastructure and might be coordinated with other foreign aid. Depending on the bilateral relationship, some form of rent or other fee for use might be required. It also would be essential to negotiate a binding agreement regarding use of airfield facilities, especially ramp space. Recent experiences in SWA have shown that competition with commercial operators and misunderstandings with airport management can be very real problems.

It would be highly desirable to make advance preparations that facilitate upgrading the RCC to a full MOB in a contingency. If the geopolitical situation warrants it, additional supplies and equipment could be rotated to an RCC. For example, UAVs with ISR payloads could be sent in anticipation of a short-notice requirement for intelligence preparation of a battlespace. If the contingency goes away, all that would be lost is some transportation cost. More substantially, it would be very valuable to pour the concrete and otherwise prepare to set up a jet engine intermediate-maintenance (JEIM) facility, especially a test cell with its noise suppresser. Other preparations could include planning for building space to be used to house intermediate-level maintenance, medical facilities, and other functions in the event the RCC winds up supporting a major operation. An analysis of WRM distribution and storage might show that at least some materiel would be better sited at one or more RCCs rather than the current regional depots.

5.2 Regional Main Operating Bases for Bombers

As analyzed elsewhere in this report, bombers provide an attractive option for getting bombs on target quickly, either for a single strike or as the opening move of a campaign. To be fully effective, the bomber force needs three regional MOBs with facilities, support equipment, and munitions prepositioned to support operations in Europe and Asia. South America can be covered from CONUS bases. In a contingency, a bomber slice, typically four or six ships, would launch from its CONUS base, deliver the first strike, and recover to the appropriate MOB. Considering their facilities and prior experience in their use, the preferred bases, shown in Figure H-9, are Anderson AFB on Guam, Diego Garcia, and Moron AB, Spain.

Table H-6 uses data supplied by logistics planners at the Eighth Air Force to show the status of munitions and equipment to support B-52 and B-1 operations for three or seven days at each MOB. One reason for choosing these bases is their excellent pavements and facilities, which thus are not an issue. The data show that Anderson and Moron have reasonable bomb stocks, but Diego does not. Only Anderson has in place mission support equipment, and not a complete set; the other bases have none. It is essential to the concept that the shortfalls in the table be made good, and that overall problems with spares shortages similarly be fixed. It also might be advantageous to preposition some elements of RSP kits, which are typically much larger for bombers than for fighters. Then use of a bomber slice in an AEF would be a matter of packing up approximately five C-141 equivalents of RSP and other cargo and support personnel (equivalently, a C-5 and a C-17) to receive the bombers inbound from the target and set up the flight line for sustained sorties.

Table H-6. *Stocking Shortfalls at Proposed Regional Bomber Main Operating Bases*

B-1 6-Ship Slice					
	Required, 3 Days	*Required, 7 Days*	*On Hand, Moron*	*On Hand, Diego*	*On Hand, Anderson*
Munitions					
CBU-87	162	378	1,092	0	5,236
CBU-89	N/A	N/A	0	0	670
MK-82	453	1,058	10,640	0	57,626
Flares & squibs	388	907	0	0	0
Chaff & squibs	2,592	6,048	0	0	11,415
Munitions-Handling Equipment					
6K forklift	2		0	0	0
40-ft trailer	3		0	0	0
10-ton tractor	2		0	0	0
MJ40 loader w/ conversion RAM	6		0	0	0
Scissor for MJ40	1		0	0	0
Mission Support Equipment					
B-1B towbar	1		0	0	0
MB-2	1		0	0	0
Oil service cart	3		0	0	0
Hydraulic cart	2		0	0	0
Liquid nitrogen cart	2		0	0	0
Bobtail	2		0	0	0
ACE air conditioner	1		0	0	0
4000 trailer	1		0	0	0
3000 trailer	2		0	0	0
60-ton axle jack	1		0	0	0
A/M32A-95	1		0	0	0
Fuel tank trailer	1		0	0	0
B-52 6-Ship Slice					
Munitions					
CBU 87	144	336	1,092	0	5,236
MK 82	270	630	3,107	0	57,626
M-117	270	713	2,983	0	28,694
Flares & squibs	576	1,344	3.667	0	16,347
Chaff & squibs	576	1,344	0	0	11,414
Munitions-Handling Equipment					
MHU-83 bomb lift	1		0	0	0
MJ-1 bomb lift	1		0	0	0
Mission Support Equipment					
A/M32-95	1		0	0	0
GOX cart	1		0	0	0
MA3 air conditioner	1		0	0	1
MC7 air compressor	1		0	0	0
Engine trailer	1		0	0	1
H-1 heater	1		0	0	1
Liquid oxygen cart	1		0	0	1
MC-1A Hi Pac	1		0	0	1
MC-2A Lo Pac	1		0	0	1
NF2 Liteall	1		0	0	1
ABDR trailer	1		0	0	0
Jacking manifold	1		0	0	0

6.0 Airlift

Several important aspects of airlift for AEF, including the value of activating the C-17 center wing tank (CWT) and the need to improve C-5 dispatch reliability, are dealt with in Volume 1 and in the Technology Thrusts Appendix in this volume. Here, we present some additional data, mainly in graphical form, that may be useful in dealing with AEF airlift planning and evaluation. Figure H-10 is a summary of the payload-range characteristics of current transport aircraft, based on average planning loads, which are somewhat conservative. With the center wing tank, the C-17 approaches the capability of the C-5 for extreme-range missions. Table H-7 expands this comparison with detailed planning factors for each aircraft type. Table H-8 provides more information on the capability of the C-17 in ferrying fuel to a forward base. Table H-8 tabulates the number of sorties to deliver various combinations of cargo and offloaded fuel at various ranges with and without the CWT. This data can be used with an estimated daily fuel and supplies requirement to compute the number of sorties needed to sustain an operation. We estimate that a 30-fighter force flying two sorties per aircraft per day can be supplied with fuel by five to seven C-17 sorties. While less attractive than a local fuel supply, this is not a prohibitive lift burden, at least for the initial AEF period, and would buy time for more permanent fuel supply arrangements to be made.

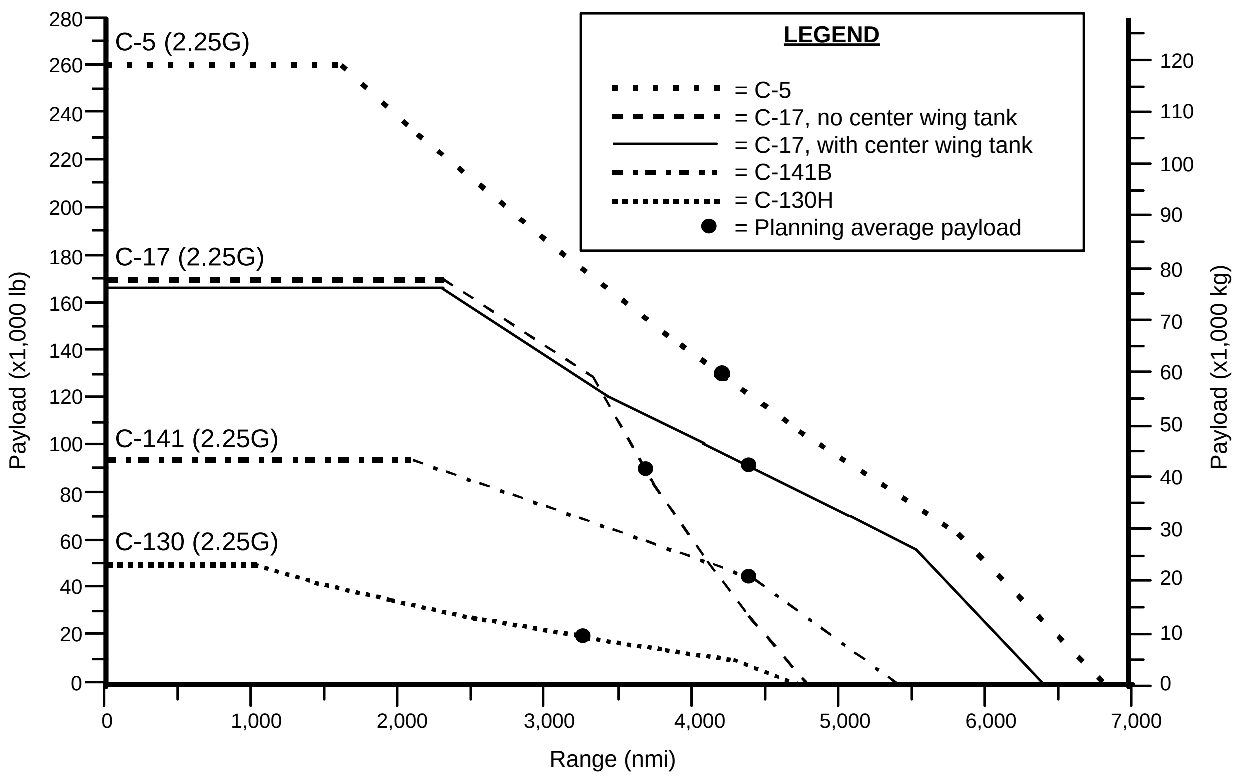

Figure H-10. *Payload-Range Characteristics of Airlifters*

Table H-7. *Airlifter Planning Data*

PARAMETER	C-5	C-17	C-141	C-130	KC-10	KC-135R
Max gross weight	769,000	585,000	323,000	155,000	590,000	322,500
Operating weight	374,000	278,500	151,000	85,000	250,000	120,000
Max landing weight w/o waiver	635,850	N/A	257,500 or 75,000 fuel	N/A	436,000	200,000
Runway length/width/taxiway	6,000/148/75	3,000/90/50	6,000/98/50	3000/80(i)/ 30	7,000/148/75	7,000/148/75
Max fuel	332,000	184,000 (j)	153,300	62,126	355,472	203,288
Fuel burn — 1st hr./cruise	35,000/ 25,000	24,000/ 16,000	16,000/ 12,000	5,000/5,000	18,000/ 15,000	12,000/ 10,000
Overhead fuel	30,000	22,000	16,000	10,000	25,000	25,000
Customer charge rate — FY 98	$12,605	$7,025	$5,349	$3,972	$8,131	$4,051
Max passengers/over water	73/73	102/102	200/151 (b)	90/74 (a)	65/65	54/54
Allowable cabin load (ACL)	65 ST	45 ST	22.5 ST	10 ST	30/40 ST	15/35 ST
Cargo door dimensions (w/h) Fwd. Aft.	228" x 162" 228" x 114"		123" x 109"	119" x 108"	96" high	134" x 91"
Max Pallets	36	18	13	6	22	6
Max Pallet Height	96" (d)		96" (c)	96" (c)	90"	
Max RSS Height	156" (d)	148"/162" (d)(e)	108" (d)	108" (d)		
COMMON CONFIGURATIONS						
C-1		54 PAX/ 11 pallets	7 SWS or 11 AFS/12 pallets	RSS	Configs. by letter (f)	No configs.
C-2		54 PAX/RSS	98 SWS/ RSS	6 pallets	B-14 PAX/ 22 pallets	57 PAX max
C-3		18 pallets	13 pallets		D-69 PAX/ 16 pallets	6 pallets/ about 15 ST
CP-1	73 PAX/ 36 pallets	(h)	47 AFS/CP (g)/8 pallets	42 PAX/ 1 pallet		20 PAX w/ pallets
CP-2	73 PAX/SS		101 AFS/CP/ 3 pallets	15 PAX/ 5 pallets		
CP-3	73 PAX/ mix of pallets & RSS		86 SWS/CP/ 1 pallet	31 PAX/ 4 pallets		
P-1		102 PAX/ 4 pallets		90 PAX		
P-2			143 AFS/CP/ 2 pallets			

Notes:

a. Overwater PAX of 74 assumes crew of 6.
b. Assumes crew of nine.
c. Can be increased with special loading.
d. May require special loading.
e. Can be increased to 162".
f. Contact XOOX for non-std. configurations.
g. Add 5,000 lb. for comfort pallet.
h. CP1 M (estimates) 96 PAX/6 ST; 90 PAX/8 ST; 84 PAX/10 ST; 78 PAX/12 ST; 72 PAX/14 ST; 66 PAX/16 ST; 60 PAX/18 ST.
i. Non-assault operations.
j. Without center wing tank.

AFS = Aft-facing seats
CLS = Centerline seats
CP = Comfort pallet
RSS = Rolling stock, floor loaded
ST = Short tons
SWS = Sidewall seats

Table H-8. *C-17 Capability to Airlift Fuel to Forward Bases*

	No CWT						***With CWT***					
Range (nmi)	Fuel avail. (lbs.)	Fuel burned (lbs.)	Cargo dlv'd	Fuel Dlv'd	C-17 Sorties (fuel)	C-17 Sorties (cargo)	Fuel avail. (lbs.)	Fuel burned (lbs.)	Cargo dlv'd	Fuel dlv'd	C-17 Sorties (fuel)	C-17 Sorties (cargo)
500	138,000	37,000	169,000	100,000	2	1	135,000	37,000	169,000	98,000	7	1
500	181,000	37,000	127,000	144,000	5	2	248,000	37,000	58,000	211,000	4	3
1,000	138,000	74,000	169,000	63,000	11	1	135,000	74,000	169,000	61,000	12	1
1,000	181,000	74,000	127,000	107,000	7	2	248,000	74,000	58,000	174,000	4	3
1,500	138,000	112,000	169,000	26,000	26	1	135,000	112,000	169,000	24,000	29	1
1,500	181,000	112,000	127,000	69,000	10	2	248,000	112,000	58,000	136,000	5	3
2,000	171,000	149,000	169,000	22,000	31	1	173,000	149,000	132,000	24,000	29	1
2,000	181,000	149,000	127,000	32,000	21	2	248,000	149,000	58,000	99,000	7	3
2,500	N/A	N/A	N/A	N/A	N/A	N/A	212,000	186,000	93,000	26,000	27	2
2,500	N/A	N/A	N/A	N/A	N/A	N/A	248,000	186,000	58,000	62,000	11	3
3,000	N/A	N/A	N/A	N/A	N/A	N/A	248,000	224,000	50,000	25,000	27	3
3,000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

7.0 Deployment Base Operability

Many factors affect the ability of a deploying force to operate satisfactorily at an austere forward base. Increasing reliance on electronics demands uninterruptible, high-quality AC power, which may not be available from local utilities. In many parts of the world, a reliable supply of potable water is a serious problem, and flying in bottled water adds a major airlift requirement to the operation. Pavements will often require repair or upgrading, even if not damaged by attack. The complexity of airbase operations arises from the practice of independently provisioning multiple functional units: operational command and control cells, maintenance control elements, maintainers, bomb builders, bomb loaders, fuelers, civil engineers, etc. In the quest for highly agile AEFs with minimum deployed footprint, big advantages could accrue from considering forward airbase infrastructure and operations as a *system* to consolidate functions, personnel, and equipment and to exploit opportunities for common, multifunction equipment.

Personnel support represents a special challenge, as the Environment Appendix makes clear. Most of our current inventory of shelters and other personnel support is old, in poor condition, and not designed for rapid shipment and erection. Some improvements may be possible by buying advanced commercial items. However, this can be taken too far; there is, for example, no commercial equivalent of a collapsible shelter that is chemically impervious and can sustain positive pressure for group protection from chemical and biological agents. Some threat environments may require rapid installation of protection against small arms fire, mortar rounds, and other munitions. Even during the minimally supported AEF phase of an operation, crew rest quarters with sound isolation and temperature control are required. Items such as a new field kitchen that consumes only eight pallet positions with its generator and can be erected in a few hours by six people can make a big difference, compared to field rations, in the endurance and morale of troops working long hours under bare-base conditions. The Panel found that the whole area of keeping operational and support personnel safe, healthy, and productive with minimum deployed materiel deserves a fresh look.

Technologies that may be a part of this AEF airbase system include portable beddown assessment and planning tools (perhaps including real-time survey and simulation capability) such as the Manportable Pavement Assessment Tool, mobile phones and radios (including SATCOM and an intelligent, programmable communication controller), a quick-install JEIM engine test stand, use of transport aircraft to "truck in" fuel when local availability or quality is inadequate, and use of commercial vehicles to perform ground support functions. The general principles are to reexamine traditional ideas about equipping a bare base; get rid of every possible piece, especially peculiar vehicles; and capitalize on new technologies to reduce size and weight and to increase the functionality of base operations materiel.

For many years, the Air Force laboratory program in air base operability has been a major source of new technologies in these areas, not only for the military but for commercial industry. Examples range from high-shear-strength pavements to improved fire protection. After FY 97, budget constraints will lead to cancellation of all these programs except fire protection. This means that future equipment will have to come from commercial sources (which have no incentive to solve uniquely military problems), from the other Services, or from other nations.

The following paragraphs discuss base operability areas in more detail.

7.1 Bare-Base Power

Power is now provided by diesel generators, which have efficiencies of about 25 to 35 percent (Figure H-11) and have high noise and thermal signatures. The low efficiency translates into excessively high fuel consumption; the need to employ diesel fuel or gasoline means that two fuels (diesel fuel and aircraft fuel) must be transported to the base and maintained separately. An attractive alternative is to develop a technology that not only circumvents the low thermodynamic efficiency of an internal-combustion engine (ICE) imposed by the Carnot Theorem, but that also operates on aircraft fuel. Reformed hydrocarbon fuel cells would seem to meet these requirements, but they too have some less-than-ideal characteristics (notably their low power densities and high thermal signatures). The available technologies, which partially or wholly meet these requirements, are summarized below.

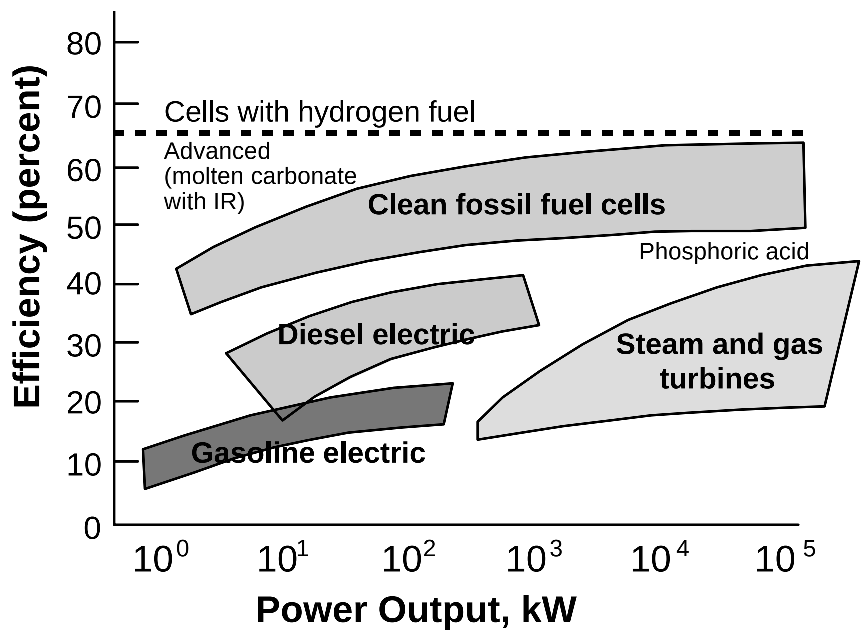

Figure H-11. *Efficiency vs. Power Output for Potential Bare-Base Power Systems*

7.1.1 Advanced ICE/Electric Generators

Continuous progress is being made in high-power-density, lightweight ICEs, with their development driven by both the automobile industry and the general aviation industry. These engines might be used as sources of bare-base power when combined with lightweight generators. Among these are Stirling cycle engines, turbocharged Otto cycle engines, and rotary (Wankel) engines. The latter two are available commercially and have proven to be exceptionally reliable. Although they are only modestly efficient (25 to 35 percent), they possess very high power densities (greater than 1,000 watts per liter) and are somewhat fuel flexible. Stirling cycle ("external combustion") engines are attractive because of their relatively high efficiency and because of their great fuel flexibility, but these attributes have not caused them to replace Otto cycle engines in the automobile industry.

7.1.2 Adiabatic ICE/Electric Generators

The development of advanced ceramics has raised the possibility of "adiabatic" internal-combustion engines, in which no cooling is employed. This raises the source temperature very high, such that thermodynamic efficiency also is very high (greater than 50 percent). Such an engine might operate on JP-8 aircraft fuel, perhaps with octane-modifying additives, and hence would partially satisfy the constraints identified above. However, even with the advanced ceramics that are on the horizon, these engines are likely to be maintenance-intensive and in any case would still have high noise and thermal signatures. These systems therefore are long-term possibilities.

7.1.3 Wind Generators and Solar Cells

Both of these options are conceptually attractive because the fuel is "free." However, both systems have low energy density, are subject to the whims of the weather, and are not inexpensive on a pound-per-kilowatt basis. Furthermore, both are feasible only in conjunction with some energy storage system (e.g., secondary batteries, supercapacitors, flywheels, or compressed air) if power is to be available on demand (when the wind is not blowing or the sun is not shining). As shown in Table H-9, the available energy storage technologies that might be employed in these scenarios have low specific energies and/or low specific powers. While the performance characteristics of batteries and other energy storage technologies are improving continually (see Figure H-12), the current systems (generator and storage) all yield excessively large "footprints" when specified for peak demand.

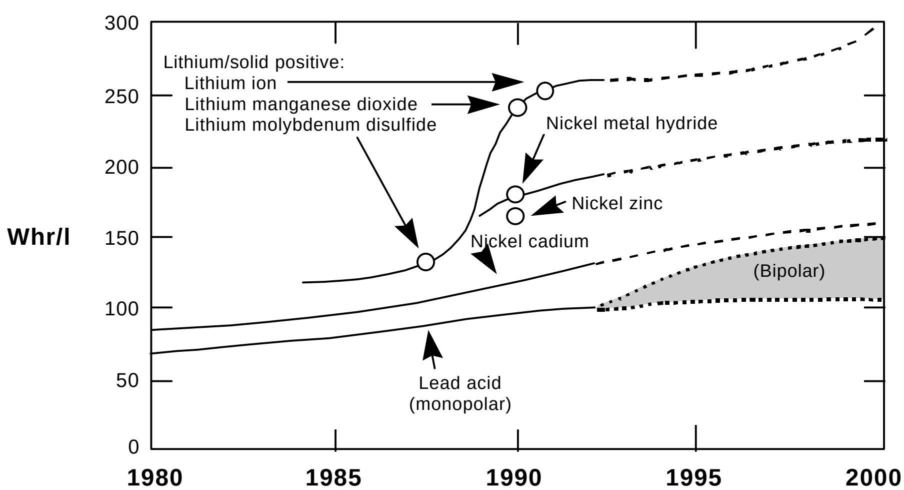

Figure H-12. *Battery and Supercapacitor Technology Trends*

Table H-9. *Energy, Power, and Cycling Characteristics of Potential Bare-Base Power Systems*

	Specific Energy (Whr/kg)	Specific Power (W/kg)*	Energy Density (Whr/l)	Cycle Life†
Supercapacitor	<10	<600	—	—
Li/Solid Polymer Electrolyte	250	100-400	400	<150
Ni/Hydrogen	65-80	600-900	<100	30,000+
Ni/Metal Hydride	80-100	1,000+	180-200	
Ni/Cadium	40-60	600-900	100	10,000+
Lead/Acid	30-50	600-900	110	30,000+
Flywheel	20‡	Very High	—	—
APU	70	<100	—	Very Large

* Typical values.
† Cycle life decreases with increasing depth of discharge.
‡ Scales with rotational velocity and rotational moment of inertia.

7.1.4 Reformed Hydrocarbon Fuel Cells (RHFCs)

Fuel cells convert chemical energy directly into electrical energy via electrochemical reactions (see Figure H-13) and hence are not subject to the limitations of Carnot's Theorem, as are ICEs. Indeed, from a thermodynamic viewpoint, the efficiency of an "electrochemical energy converter" is given by the formula:

$$\varepsilon = \Delta G/\Delta H$$

where ΔG and ΔH are the Gibbs ("free") energy change and enthalpy change of the cell reaction. For an H_2/O_2 fuel cell operating under standard conditions (gas pressures of one atmosphere, T = 25°C), the efficiency calculated as the electrical energy output (given by ΔG°) divided by the heat input (ΔH°) is 83 percent (entry three in Table H-10), which is roughly double that of an ICE powered by a typical hydrocarbon fuel (decane, Table H-10). Practical efficiencies of various fuel cells (with losses due to electrode polarization and IR heating) commonly exceed 50 percent (see Figure H-11).

The principal problem of hydrocarbon fuel cells (HCFCs) is that the hydrocarbon is too stable electrochemically to be used directly. Thus, the fuel must be "reformed" to produce hydrogen:

$$C_nH_{2n+2} + nH_2O \rightarrow nCO + (2n + 1)H_2$$

The hydrogen must be separated from the co-produced carbon monoxide. While reformer technology has advanced steadily over the past two decades, the complexity and specific demands of reformers (e.g., water) greatly degrade the attractiveness of hydrocarbon fuel cells for bare-base applications. For example, one "demonstration" 100-kW unit consisting of a reformer, a phosphoric acid fuel cell (PAFC), and associated controls (an "entire package") is projected to occupy a volume of 160 cubic feet (2,622 liters) and to weigh 7,000 pounds (3,182 kilograms). Thus, the power density and specific power are 38.1 W/l and 31.4 W/kg, respectively. These numbers may be compared with those for typical ICE-powered generators and auxiliary power units (APUs) of greater than 100 W/l and greater than100 W/kg. The great advantage of HCFCs is that they readily operate on aircraft fuel, which at first sight obviates multiple fuel types on site. However, diesel and/or gasoline, in addition to aircraft fuel, almost always will be required for the multiple transportation systems that will be employed, so the "single fuel" argument may be moot.

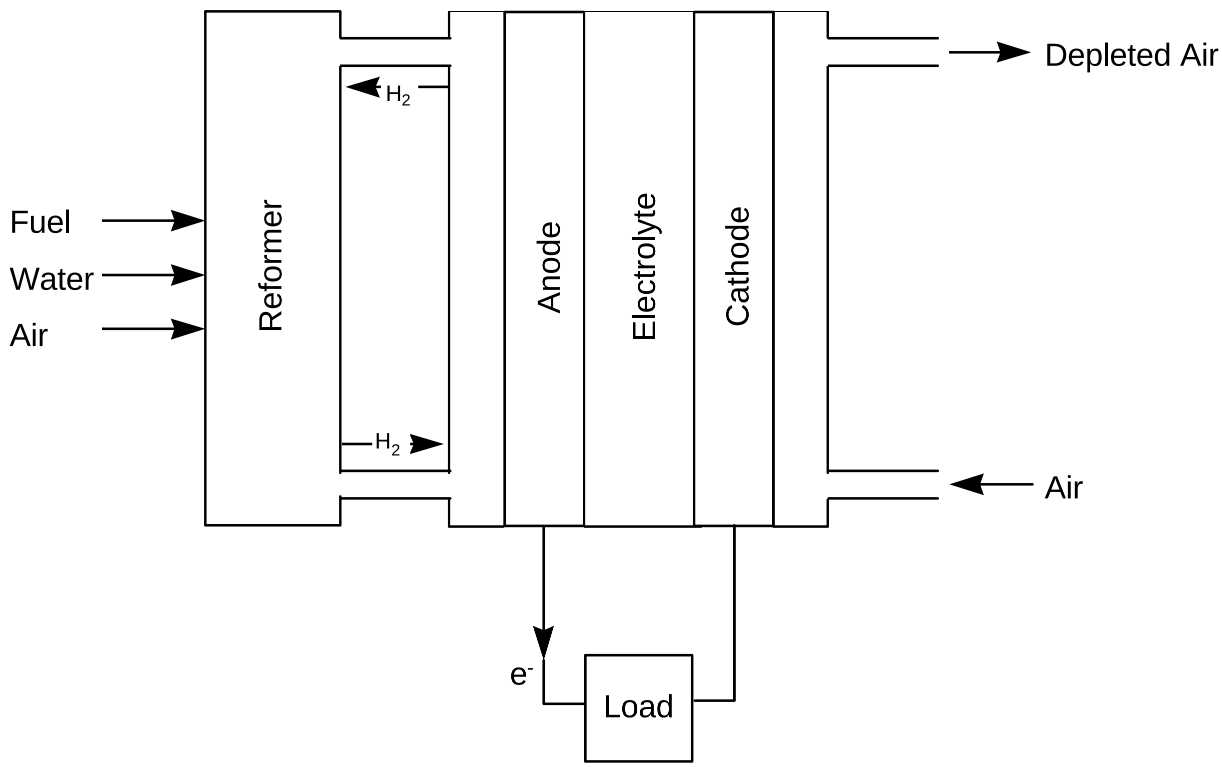

Figure H-13. *Schematic of a Reformed Hydrocarbon Fuel Cell. Note that the electrolyte might be phosphoric acid, molten carbonate, concentrated alkali, or a proton exchange membrane, depending on the technology.*

7.1.5 Direct Methanol Fuel Cells

Considerable progress has been made in recent years in devising fuel cells that employ methanol (CH_3OH) or other partially oxygenated fuels directly without the need for reforming (Figure H-14). Current efforts to develop this technology, which would greatly simplify the power cell, involve the development of better (and lower-cost) electrocatalysts and the development of systems that operate under conditions where the need for (expensive) catalysts is greatly reduced. Thus, work is now under way to develop proton exchange membranes (PEMs) that will operate at temperatures above 200°C, where the electrochemical oxidation of methanol is sufficiently fast that noble metal (e.g., platinum) catalysts may not be required. If this technology can be perfected, it promises to yield power densities and specific powers considerably higher than those obtainable from HCFCs (perhaps by a factor of two or three), but they would require an additional fuel on-site.

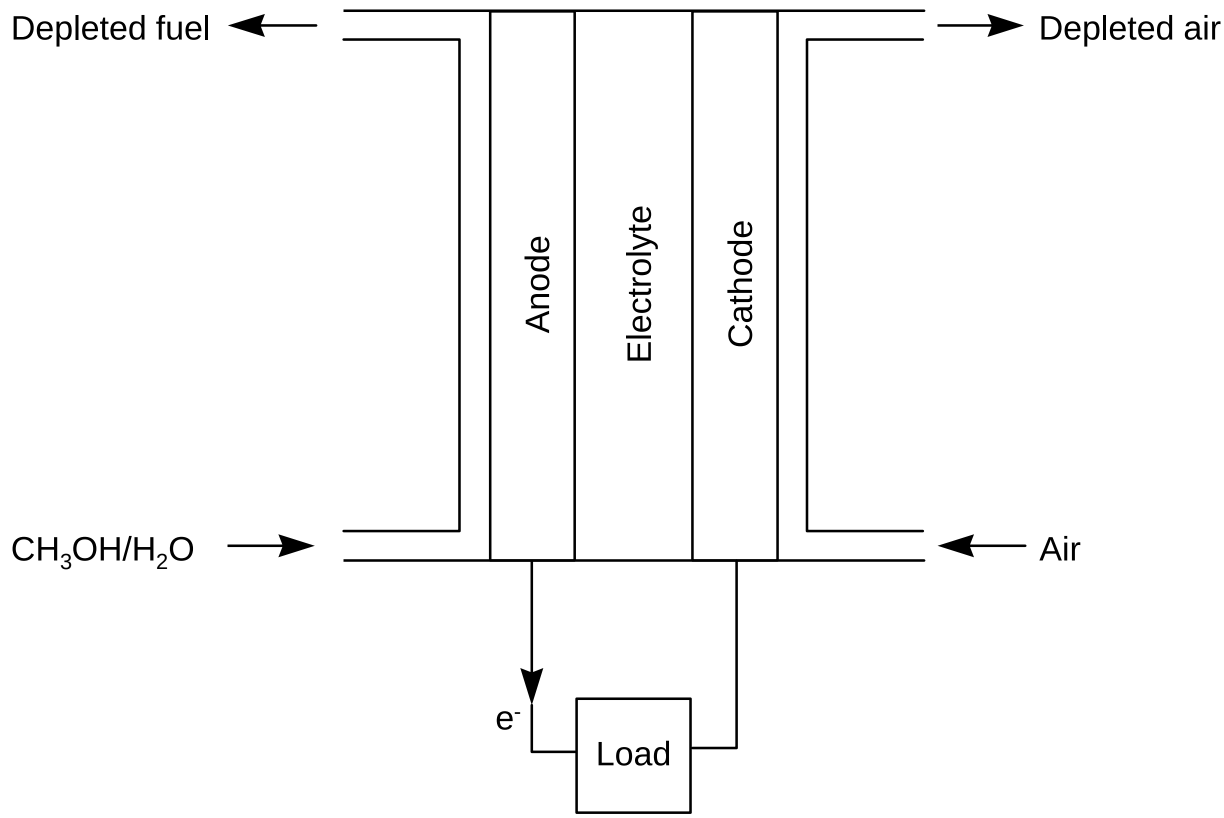

Figure H-14. *Schematic of Direct-Fueled Methanol/Air Fuel Cell. Note that the electrolyte might be phosphoric acid or a proton exchange membrane, depending on the technology.*

7.1.6 Metal-Air Fuel Cells

Although commonly overlooked, metal-air fuel cells (commonly misnamed “metal-air batteries”) offer some significant advantages over other systems — notably in terms of the fuel characteristics, low flammability, ambient temperature operation (low IR signature), quiet operation (low noise signature), and, in most cases, benign emissions (the exception being BeO). The philosophy here is that the “fuel” is simply a medium for storing and transporting energy from some primary source (e.g., from a power plant within CONUS) to a point of application (the bare base) when needed during operation. Thus, the most advantageous fuel is that with the highest energy density (Whr/l), and in this regard metals such as zinc, silicon, and aluminum all meet (Zn) or greatly exceed (Si, Al) the performance characteristics of a hydrocarbon (Table H-10).

Of the metal/air systems summarized in Table H-10 and shown schematically in Figure H-15, only Al-air and Zn-air have been explored to any significant extent. Zn-air, in particular, has shown great promise and now is being considered for electric vehicles and small “Honda-type” generators. Aluminum-air “batteries” were extensively researched in the early 1980s as power sources for electric vehicles, but were largely abandoned because of the high fuel cost ($3.50 to $5.00/gallon equivalent for gasoline) associated with the need to use specialty alloys (to inhibit hydrogen evolution), and because of the cell potential loss due to the existence of a mixed potential. Silicon has not yet been explored, in spite of its excellent energy density (21,090 Whr/l compared with 9,741 Whr/l for the hydrocarbon decane) and its modest cost (see Table H-11). Note the relatively favorable fuel cost of aluminum and silicon on a dollars-per-kWhr basis, but even these are significantly more expensive than a hydrocarbon (decane) fuel cell when used in an ICE, after correction for the theoretical efficiency of conversion.

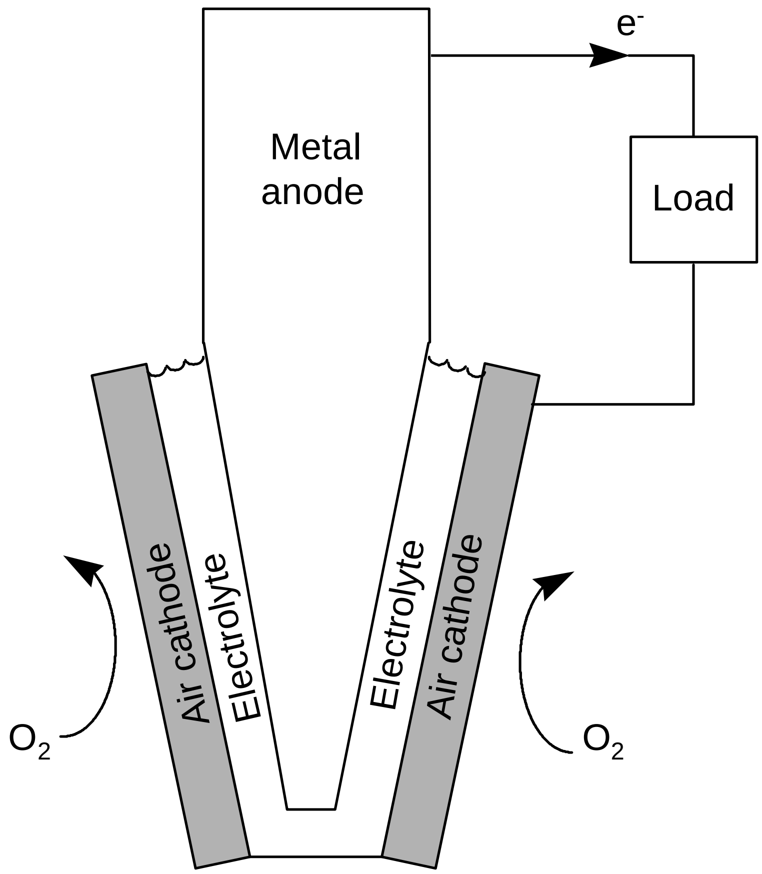

Figure H-15. *Schematic of a Metal-Air Fuel Cell. Note the wedge configuration, which allows for uniform consumption of the metal anode. Other designs employ slurries of metal particles as the fuel.*

7.1.7 Comparison of Systems

Because of the lack of detailed design information on systems that, in some cases, are little more than concepts, a quantitative comparison among the potential base power systems reviewed above is not possible. However, it is possible to draw broad conclusions based on how well competing technologies might meet specific needs and performance goals. Based on the most likely AEF scenarios, the desirable properties of a base power system are ranked in Table H-12 on a scale of 2 (least important) to 10 (most important) for a spectrum of AEF missions. In Table H-13, we list the various attributes of each technology and rate each attribute on a scale of 0 (worst) to 10 (best) based on the data. The two sets of numbers are then multiplied to yield scores that can be used to rate one technology against another.

Table H-10. *Thermodynamic Parameters for Potential Metal-Air Fuel Cells*

		kJ/mol oxide		Theoretical Efficiency	Absolute	
Fuel	Cell Reaction	ΔG^o_R	ΔH^o_R	ε	Specific Energy (Whr/kg)*	Energy Density (Whr/l)*
Al	$2Al + \frac{3}{2} O_2 = Al_2O_3$	-1582.4	-1675.6	0.94	8,146	21,994
Be	$Be + \frac{1}{2} O_2 = BeO$	-578.1	-607.3	0.95	17,823	33,151
H_2	$H_2 + \frac{1}{2} O_2 = H_2O(l)$	-237.2	-285.8	0.83	3,658	329@P= 1000atm
Li	$2Li + \frac{1}{2} O_2 = Li_2O$	-561.9	-598.5	0.94	11,246	5,960
Mg	$Mg + \frac{1}{2} O_2 = MgO$	-569.4	-601.7	0.95	3.942	6,859
Si	$Si + O_2 = SiO_2$	-856.5	-910.9	0.94	8,470	21,090
Zn	$Zn + \frac{1}{2} O_2 = ZnO$	-320.8	-350.7	0.92	1,363	9,677
Decane	$C_{10}H_{22}$ + 15.5 O_2 = 10 CO_2 + 11 H_2O	---	-1632.3	---	13,343	9,741

* Based on kg and l of metal. The specific energy (SE) is calculated from SE=0.2778 ΔG°_R/M (Whr/kg) where ΔG°_R (J/mol) is the standard Gibbs energy change per mol of metal consumed in the reactions written above and M is the metal atomic weight.

Table H-11. *Approximate Fuel Costs*

Fuel	Dollar/unit*	Normalized Cost (dollar/kg)	Theoretically Available Specific Energy (Whr/kg)	Fuel Cost (dollar/kWhr)
Al	$0.70/lb	1.54	7,657	0.20
Be	$300/lb	660.00	16,932	39.00
H_2	$3.14/kg†	3.14	3,658	0.86
Li	$80/kg	80.00	10,571	7.57
Mg	$1.60/lb	3.52	3,745	0.94
Si	$0.70/lb	1.54	7,962	0.19
Zn	$0.66/lb	1.45	1,254	1.16
Decane	$1.50/U.S. gallon	0.543	4,670	0.12

* *Minerals Yearbook, Vol. 1*, Metals & Minerals, U.S. Bureau of Mines, U.S. Dept. of the Interior, 1994.
† Taken as approx. $0.80/100 ft^3.

Table H-12. *Ranking of Desirable Properties for Bare-Base Power Supplies*

Property	Ranking	Comments
Power density/energy density/specific power	1 (10)*	The most valuable commodity for an AEF is low volume, which translates into a high power density (W/l) for the converter and a high energy density for the fuel. Because the volume of the fuel scales inversely with the energy density of the fuel, the energy density of the fuel becomes increasingly important with increasing length of operation.
Fuel type	2 (8)	Avoiding the need to transport a specialty fuel is considered important logistically. Therefore, systems that operate on JP-8 or diesel (which will be present for other systems, such as trucks) are preferred.
Low IR signature	3 (5)	While important in order to avoid IR-homing weapons, low IR signature is considered of lower importance than fuel type and power density/energy density for the typical AEF mission. This is particularly so for well-defended bases where the threat of enemy air operations is minimized.
Efficiency	4 (2)	Higher efficiency means less fuel that needs to be transported to the base. However, the practical efficiencies of the various conversion technologies may offset this advantage.

* Number in parentheses indicates the importance of the property to a spectrum of AEF missions, 1 being most important.

Table H-13. *Comparison of Bare-Base Power Sources*

Power Source	Power Density (W/l)	Attribute Specific Power (W/kg)	IR Signature	Fuel Type*	Fuel Energy Density (Whr/l)	Efficiency (%)	Comments
Advanced ICE generators	>1,000 (10)*	>200	High (2)	G/D (8)	3500 (3)	25-30 (6)	Lightweight ICE's currently available
Adiabatic ICE generators	>1,000 (10)	>200	High (2)	D (8)	3500 (3)	>50 (10)	Long term — requires new ceramics
Wind/solar/battery	<20 (0.1)	<20	Low (10)	—	v. low (0.1)	>50 (10)	Intermittent & unreliable — requires battery; fuel is free
Reformed hydrocarbon fuel cells	<40 (3)	~ 30	High (2)	Any hydrocarbon incl. A/C fuel (10)	2,000 (2)	>50 (10)	Reformer required
Direct methanol fuel cells	>100 (5)	>100	Moderate (6)	Methanol (4)	2,000 (2)	>50 (10)	No reformer required
Metal-air fuel cells	>100 (5)	>100	Low (10)	Metal (2)	8,900 (Zn)-19,825 (Si) (10)	>50 (10)	Very-high-energy-density fuels

* G = gasoline, D = diesel.
Number in parentheses rates the attribute of a given property for a given technology on a scale of 0 (worst) to 10 (best).

The six technologies as ranked form three groups:

- Group 1 (highest):
  - Advanced ICE generators
  - Adiabatic ICE generators
  - Metal-air fuel cells
- Group 2 (middle):
  - Reformed hydrocarbon fuel cells
  - Direct methanol fuel cells
- Group 3 (lowest):
  - Wind/solar/battery

Of Group 1, the only currently available systems are advanced ICE generators, although one metal-air fuel cell (Zn-air) is at the small prototype stage. Reformed hydrocarbon fuel cells (Group 2) are highly developed and have been operated by natural gas utilities and electric utilities for many years, albeit as fixed installations. Direct methanol fuel cells are still in the research phase, with the principal challenge being the development of electrode and/or electrolyte materials that will permit the oxidation of methanol at a high enough rate to yield useful power densities. Finally, the attributes of wind and solar power are such that we do not envisage their being employed as the principal source of bare-base power, although they may find specialty applications (e.g., in communication and remote monitoring systems).

In light of the above analysis, it is evident that the short/intermediate-term (0 to 10 years) needs for base power are probably best met by advanced ICE generators operating off diesel fuel or perhaps even aircraft fuel. If the IR signature issue becomes more important than has been recognized in Table H-12, then the development of ambient-temperature metal-air fuel cells may be the long-term (beyond 10 years) solution to the portable-power problem.

7.2 Water

The existence of a good water supply is vital to successful AEF operations. Water is used in a wide variety of processes, including cleaning, cooling, and drinking. The existence of water-borne diseases, such as typhoid, dysentery, and cholera, particularly in tropical zones where many AEF operations might be expected in the years to come, makes the existence of clean water essential if the forces are to retain combat effectiveness. Most places on earth have access to water, but in many cases it is unfit for human consumption because it is contaminated with bacteria, parasites, or minerals (from subterranean brackish water, sea water, or mineral spring water). Available technologies can render all of these sources suitable for drinking. Indeed, technologies exist that permit recycling of human waste and that process waste water, greatly alleviating the need to transport water to the base from outside sources. Some of these technologies are briefly reviewed below.

7.2.1 Chemical Treatment

The oldest method and the one most commonly used by the military for “purifying” water contaminated with bacteria and parasites is chemical treatment. A variety of chemicals are used, ranging from “chlorine” (e.g., hypochlorites) to hydrogen peroxide. These chemicals are effective against a broad spectrum of biological contaminants but do not address the problem of inorganic salt (NaCl) contamination. Nevertheless, because of its ease of application, even at the individual level chemical treatment will likely remain a principal method of producing safe drinking water from contaminated freshwater sources.

7.2.2 Distillation

This age-old technology (Figure H-16) is effective in producing safe drinking water from salt water and has been used by the military in a variety of missions. In its most common form, it suffers the disadvantage of requiring a fuel source (hydrocarbon or electric power) to boil the water, which renders it dependent on these commodities on-site. In specific locations, solar distillation systems are practical and are capable of producing large volumes of fresh water, depending on the size of the solar array.

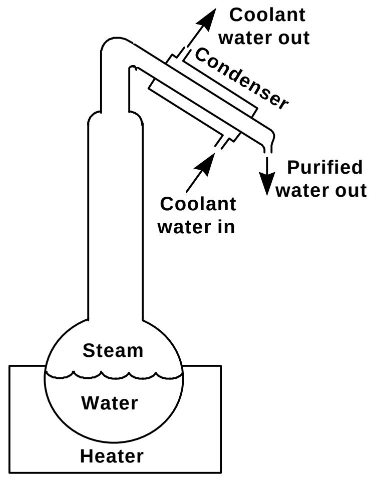

Figure H-16. *Schematic of a Water-Distillation Apparatus*

7.2.3 Ultrafiltration

Recent advances in hollow-fiber filters that are capable of removing micron and nanoscale particles have rendered ultrafiltration highly effective at removing bacteria and parasites from fresh water sources and hence in producing safe drinking water (Figure H-17). However, the system requires a power source for pressurization, it will not desalinate brackish water or sea water, and it must be backwashed frequently to assure efficient operation.

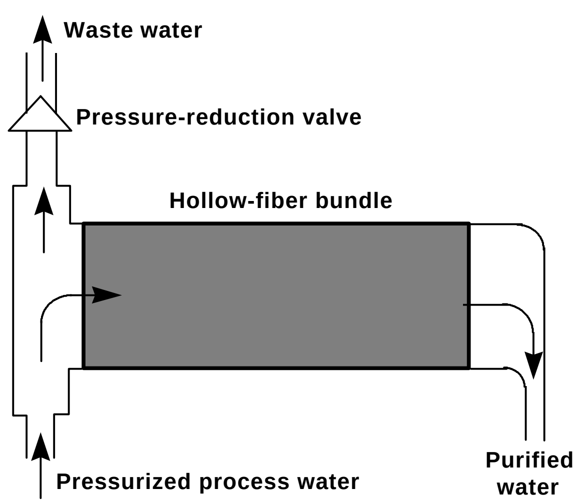

Figure H-17. *Schematic of an Ultrafiltration Water-Purification Process Using a Hollow-Fiber Filter*

7.2.4 Reverse Osmosis

This technology, which has its basis in the field of irreversible thermodynamics, has revolutionized water treatment, because it is capable of producing drinking water from salt-contaminated sources without the need for distillation. The technology makes use of a semipermeable membrane, which allows for the passage of water but not of salt, under the influence of a pressure gradient (Figure H-18). Portable units are available that produce tens of thousands of gallons of fresh water daily. At the other end of the scale, small, hand-pumped units that produce a few liters per day also are available at relatively low cost. Indeed, these units have been credited with saving the lives of a number of shipwrecked sailors.

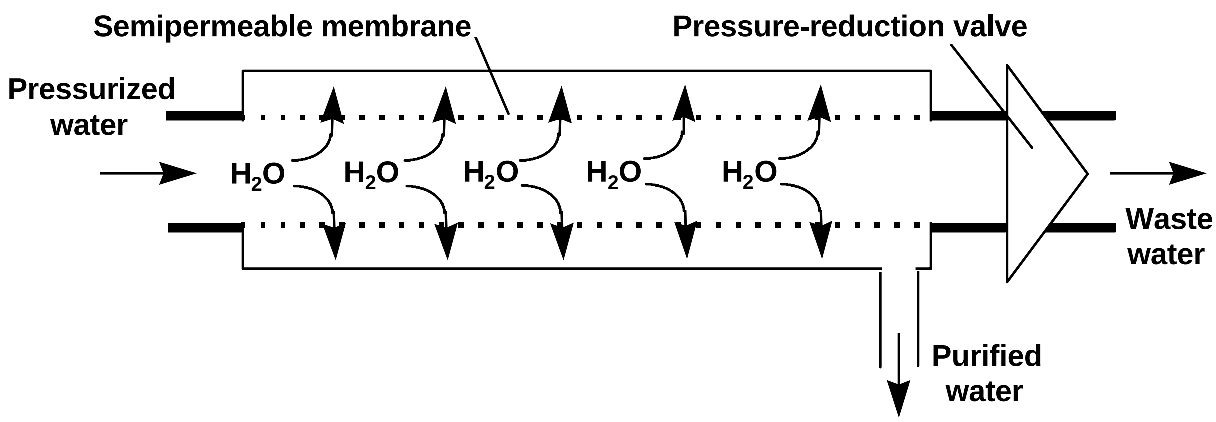

Figure H-18. *Schematic of a Reverse-Osmosis System Employing a Semipermeable Membrane. Note that the membrane will pass water but not an electrolyte such as salt (NaCl).*

7.2.5 Electrolysis/Recombination

The electrolysis of water produces hydrogen at the cathode and oxygen at the anode; the elements then may be recombined to produce pure water (Figure H-19). Electrolysis units require raw water of good conductivity (e.g., sea water) and a source of electrical energy. Generally, they are not competitive with reverse osmosis or even distillation, but they may sometimes be preferable because they also produce oxygen (and hydrogen), which are useful commodities for specific applications (e.g., welding).

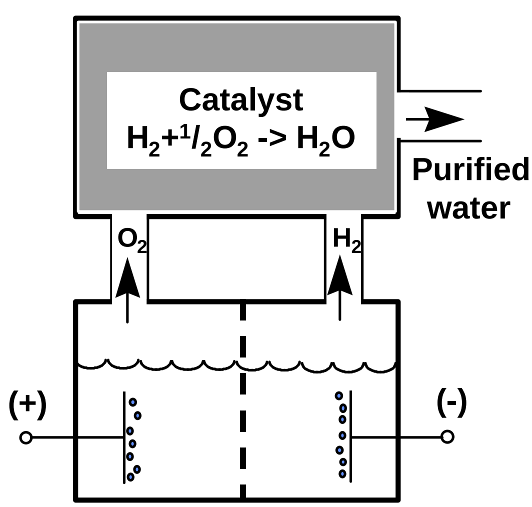

Figure H-19. *Schematic of an Electrolysis/Recombination Water-Purification System*

7.2.6 UV Radiation

A wide variety of biological (BW) agents are susceptible to UV (and shorter-wavelength) radiation. Although the exact mechanism(s) by which radiation interacts with living organisms (including bacteria, viruses, spores, and various other multicellular species) is subject to some controversy, the photon energies that are effective in killing the organisms (greater than 3 eV) are sufficient to produce photolytic species from water, including water inside the cells. The species include strongly oxidizing entities such as O_2, H_2O_2, and OH^-, as well as reducing entities such as O_2^-. The purification method is simple, in that the water is simply irradiated by an intense UV source. Appropriate sources are available commercially, but they do require power. Also, UV irradiation is considered ineffective against most chemical warfare (CW) agents.

7.2.7 Methods to Combat CW/BW Contamination

A particularly important class of contaminants is CW/BW agents. These range from molecular entities (e.g., VX, sarin, mustard) to viral agents (Dengue fever) to microbial agents (e.g., anthrax). The larger microbial particles can be removed effectively by ultrafiltration or neutralized by chemical treatment, but the smaller viral and molecular particles are not so easily removed. Because many of the smaller entities may pass through semipermeable membranes, it should not be assumed that reverse osmosis will be effective in removing them unless specifically demonstrated. However, most if not all of these contaminants can be destroyed by a combination of heat and high oxidizing potential, with the latter being achieved chemically (e.g., by the addition of hydrogen peroxide) or electrochemically (using porous anodes). Oxidative distillation, in which steam from boiling water in the presence of oxygen is passed through a platinum catalyst bed at elevated temperatures (700 to 900°C) prior to condensation (see Figure H-20) is a particularly effective way of removing resilient organic contaminants. Even more resilient organics (including VX) may be effectively destroyed under supercritical conditions (T>374.15°C) using a process known as supercritical water oxidation (SCWO). This process, which is scalable over a wide range of outputs, is now at the advanced pilot plant stage with full commercialization slated for the near future. While SCWO has been developed to destroy resilient organics in a closed-cycle system, it is equally proficient in producing pure water when operated in the once-through mode. The Joint-Service Agent Water Monitor (JSAWM, E15) will be a useful tool for detection of CW/BW agents in water supplies and will greatly enhance an AEF's ability to operate in an austere environment when water quality is unknown. CW/BW threats are examined in detail in Volume 3 of this study.

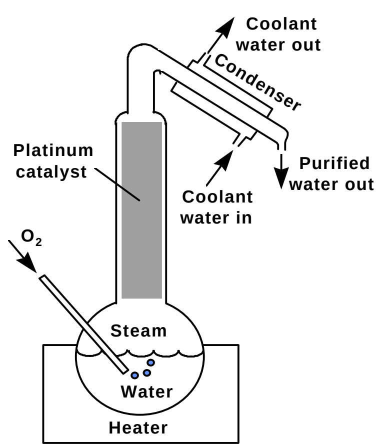

Figure H-20. *Schematic of an Oxidative Distillation System for Purifying Water Containing Organic Compounds*

In summary, a variety of technologies are available for producing safe drinking and process water during AEF operations. The most effective appear to be a combination of chemical treatment with ultrafiltration and reverse osmosis, which are capable of dealing with most contaminants, with the possible exception of some CW/BW agents. However, technologies (e.g., oxidative distillation, SCWO) also are available for producing pure water from almost any contaminated water supply, but only with the expenditure of energy.

7.3 Runway and Ramp Repair

The development of effective runway-cratering munitions, as well as the threat from conventional bombs, requires that any AEF have the ability to quickly repair runways and other pavements in order to maintain uninterrupted flight operations. While major repairs will require heavy equipment (bulldozers, backhoes), the repairs can be greatly aided by the use of advanced materials.

The repair of a cratered runway essentially involves the re-creation of the underlying base (crushed rock, aggregate) and the pavement. Re-creation of the base, including compaction, is basically a physical process of crushing damaged runway material and mechanically compacting it to the desired density. Repair under normal conditions would then pave the damaged area with concrete or asphalt, but both of these “conventional” materials require considerable setting times (typically several days) to achieve full strength. What is needed is a paving material that achieves full strength in a matter of 1 or 2 hours after being put in place.

The most effective way of addressing this problem is to use reinforced “synthetic” paving materials, consisting of fiberglass or Kevlar reinforcement/aggregate bonded with fast-setting synthetic resins (e.g., epoxies). Appropriate catalysts can reduce the setting time to a matter of minutes or hours, rather than days as for conventional cements. A critical need is for an appropriate reinforcing material; we believe that a great opportunity exists in this regard for “multiple-use” materials, whereby the reinforcing material might be derived from containers that were used to transport materiel to the base.

At this point, the Panel must express surprise and dismay at the Air Force’s decision to greatly reduce or eliminate the civil engineering budget. The responsibility for runway repair (and other construction and repair functions) clearly should fall upon the civil engineers, who must be an essential component of any AEF. Runway repair, in particular, is a highly skilled engineering activity, because it requires the matching of available materials with the expected loadings of operation. Thus, military aircraft differ widely with respect to their runway loadings; the F-16 has a particularly heavy loading. Failure of the repairs to meet the required loadings could very well compromise the operation.

7.4 Toxic Material Cleanup

Toxic materials, ranging from oils to halogenated hydrocarbons (e.g., solvents), will be employed in all phases of AEF operations. Furthermore, as the result of adversary action, assets may become contaminated with CW/BW agents, and it may be necessary to remove the contaminants from the surfaces or even destroy the assets along with the contaminating agents. A variety of techniques have been developed, which depend on the nature of the threat. These techniques are as follows.

7.4.1 Chemical Decontamination

Many CW/BW agents are readily neutralized using chemical decontamination. For example, BW agents are normally susceptible to high oxidizing potentials that may be achieved by using “chlorine” (hypochlorite) solutions, hydrogen peroxide (H_2O_2), or some other oxidizing agent. These solutions may be applied as a spray or fog, and decontamination is best carried out in a central facility to permit collection and control of the effluent. CW agents can be treated in the same way, but a common chemical strategy is to hydrolyze the molecule. For example, VX readily undergoes base hydrolysis to produce phosphonates, among other compounds, which, although inactive from a physiological viewpoint, need to be destroyed before the effluent can be discharged into the environment. In any event, chemical decontamination requires a source of water and transportation of the decontaminating agent to the base. Possibly the most important need is sensors that not only can detect the presence of CW/BW agents but also can be used to determine when decontamination is complete. These sensors must be accurate and easy to use in the field, and the results must be readily interpretable by personnel who are only marginally skilled in their use. While considerable progress has been made in developing such sensors, much has yet to be done to produce wide-spectrum sensors that have the desired dynamic ranges. This is further discussed in the chapter on chemical threats in Volume 3 of this study.

7.4.2 UV Irradiation

BW agents in particular are susceptible to UV irradiation, especially in the presence of moisture. The mechanism of decontamination probably involves the photolysis of water (*in vivo* and *ex vivo*) to produce species such as -OH, O_2^-, and H_2O_2. In any event, relatively low-cost, high-efficiency UV lamps are readily available and easily transported on AEF missions. Note, however, that decontamination is "line of sight" and hence may not be effective on heavily soiled surfaces or within crevices in equipment. Furthermore, a multi-kW power source must be available at the site of decontamination. With regard to CW agents, UV irradiation will be effective only if the agent absorbs photons with UV energies and if the exited state undergoes some reaction that modifies the molecule and hence renders it physiologically inactive.

7.4.3 Plasma Decontamination

In this technique, the material to be decontaminated is exposed to a plasma (ionized gas, such as O_2) that is produced by an electric discharge. Destruction of the agent probably occurs by thermal processes, although the existence of atomic species (e.g., oxygen atoms) also may be important. This technique, like SCWO, requires a reactor and hence is restricted in the materials and forms that can be treated. Plasma decontamination has been shown to be effective for destroying a variety of materials (including CW/BW agents and propellants), but the method is energy-intensive and may not be best suited for AEF operations.

7.4.4 Supercritical Water Oxidation

In SCWO the toxic substance is oxidized by molecular oxygen or hydrogen peroxide in aqueous media at supercritical temperatures ($T > 374.15°C$, but typically >500°C) and at elevated pressures (typically 3,000 to 6,000 psi) in a closed cycle. The advantage of the technique is that under these conditions (low density and dielectric constant), organic substances that normally are immiscible with water at ambient temperature are completely miscible with water at supercritical temperatures. High conversion efficiencies (greater than 99.999 percent) are commonly achieved even with the most resilient waste (e.g., CCl_4). The greatest problem with the method when operating on halogenated waste is corrosion, but corrosion may be greatly reduced by neutralizing the acid produced by hydrothermal oxidation of the waste. However, because of the low solubility of salts in supercritical water, salt precipitation within the reactor may become a severe operational problem. SCWO is being extensively developed by the Navy for shipboard use and by the Army for the destruction of CW agents and propellants. Portable units have been developed, but they are energy intensive and their utility at an AEF base requires careful analysis in terms of the economics and logistics.

Of the techniques outlined above, the best method of on-site decontamination is chemical, with decontaminants chosen to counter the threat that is experienced. Chemical decontamination is effective and the decontaminating chemicals often can be transported to the base in “dry” or “concentrated” form to minimize volume. The chemicals also frequently have long shelf-lives, so they may be stored in rear depots for years prior to use. Application equipment (spray guns, foggers, decon tents, etc.) must be transported to the staging base, but these are generally low-weight, low-volume items.

For destruction of bulk toxic materials (lubricants, solvents, propellants, etc.), the preferred technique is SCWO. However, the most important issue, which must be decided case by case, is whether it is logistically (and perhaps politically) preferable to transport the cleanup unit to the staging base or to transport the waste (on return flights) to a rear, fixed facility. Note that the “footprint” for a unit that will decontaminate 1 liter per hour is on the order of 100 cubic feet and would weigh approximately 3,000 lbs.

7.5 Base Decoys

For AEF operations, it may not be possible to select assets that do not emit radiation and hence do not represent a target for an adversary’s precision weapons. For example, bare-base power in the near term will almost certainly be provided by advanced ICE generators, which are strong IR emitters. Reformed hydrocarbon fuel cells have been proposed as alternatives, but they too are IR emitters, and they have large footprints because of their low power densities (~ 30 W/l, which is less than a third of that of advanced ICEs). Metal-air fuel cells, which operate at or near ambient temperature, would seem to offer significant advantages in low IR signature and high power density, but they require a specialty fuel (metal or metal alloy) to be transported to the base. Radiofrequency (RF) emitters also will be present and may provide targets for a sophisticated adversary.

Considerable protection from these threats might be achieved by deploying IR and RF decoys to deflect homing missiles from critical assets. These decoys would be of low cost, would emit with spectral characteristics identical to the asset to be protected, and would be agile, in that the spectral characteristics could be changed to reflect the temporal characteristics of the actual systems. The decoys and the assets might be moved regularly to confuse satellite surveillance systems. Although it is believed that decoys can provide significant protection from precision homing weapons, we believe that the long-term solution lies in developing power sources that do not emit to any significant extent in the first place.

7.6 Field Armor

Scenarios can be envisioned in which considerable armor will be required to protect assets at staging bases. Protection might be required against direct enemy action such as air strikes or against terrorist operations. History has shown that the most vulnerable assets are fuel and munitions, and that ignition of these can cause considerable collateral damage that may significantly compromise operations. Given modern weapons systems (IR- and RF-homing missiles), and recognizing their proliferation to potential adversaries, the threat of rapid, devastating strikes against a staging base by an enemy using precision-guided weapons should not be ignored. While it is almost impossible to armor a specific target against a direct strike, the judicious choice of armor material and configuration may do much to reduce collateral damage. These threats are further discussed in the chapter on terrorism in Volume 3 of this study.

Lightweight armor that is effective against small arms fire and shrapnel can be fabricated from Kevlar or perhaps from more recently developed “rigid-rod” polymers, such as PPO, PBZ, and PBT (these fibers were developed under AFOSR sponsorship). The armor can be fabricated in various forms; some could be fabricated into containers. These containers could be used to ship material to the base and then be employed as armored storage facilities for munitions, fuel, and personnel. Additionally, portable armor in the form of Kevlar or Kevlar/ceramic blankets should be transported to the base to provide added protection for critical assets. Because this armor is portable, it may be moved around during the mission to protect specific assets as their value changes.

7.7 The Impact of Outsourcing

As a means of reducing operational costs to free resources for modernization, DoD and the Services are moving aggressively to outsource functions that do not directly involve combat operations. This includes many logistics functions that are essential to base support both at home and while deployed. Examples include transportation and vehicle maintenance, civil engineering, and supply. The Panel is concerned that if the elimination of organic capability in these areas is not countered by assured availability of contractor services on the timelines, at the locations, and under the threat and living conditions of AEF operations, the whole AEF concept may be seriously compromised. Recent steps to increase Red Horse deployable civil engineering forces are encouraging; however, we believe that any outsourcing action that eliminates Air Force personnel and equipment that otherwise would be required and available for deployment must require contractors to accompany a deploying force or make equivalent provisions to instantaneously procure the equivalent support at the beddown site.

8.0 Reliability and Supportability Issues

The ability to deploy to and operate from undeveloped forward bases is strongly impacted by both the support required to generate sorties and that associated with operating the beddown site. Improvements in the intrinsic reliability and maintainability of deployed weapon and support systems directly reduce the personnel and support equipment needed. Moreover, in current operations, a rule of thumb is that two to three support personnel are required for every individual directly involved in carrying out the mission. Clearly, rethinking maintenance practices and assumptions about support functions at beddown sites is an important area to consider in reducing the deployment footprint of an AEF. In this section, we expand on the discussion of reliability and supportability issues in Volume 1 and highlight a number of specific concerns and possible corrective actions.

8.1 Mission-Capable (MC) Rates

The Panel examined key maintenance indicators such as total non-mission-capable supply (TNMCS), non-mission-capable maintenance (NMCM), and cannibalization rates. We believe this is a serious problem. When the Panel visited the 347th Fighter Wing at Moody AFB, the wing's F-16s were consistently showing MC rates in the range of 70 percent, vs. the Air Combat Command standard of 85 percent. The B-52s of the 2nd Bomb Wing at Barksdale AFB, which today are prime candidates for AEF missions, have recent MC rates as low as 52 percent and have gone for months without critical spare parts, most of which are contractor-repaired items.

The MC picture has deteriorated over the past few years. During Operation Desert Shield/Desert Storm, the following statistics were typical for the F-16 fleet:

- MC rates in the high 80s — and as high as 92 percent in some cases
- NMCM rates around 4 percent
- NMCS rates around 5 to 6 percent

Today, the MC rate averages around 80 percent and goes as low as the 70 percent figure cited earlier, while NMCS rates are around 8 to 10 percent, and NMCM rates average around 10 to 12 percent with a high of 14 percent.

For the F-15 fleet, including home base operations and recent AEF deployments, MC rates run around 80 percent, down from 85 percent in Operation Desert Shield/Desert Storm. Trends in NMCS and NMCM rates are similar to those for the F-16.

MC rates are deteriorating rapidly as a result of (at least) the following factors:

- NMCM rates have worsened as a result of continuing high operations tempo, due largely to deployments. This increases demand for scarce parts, accelerates age-related system problems, degrades training of support personnel, and puts the logistics system in an endless catchup mode.
- NMCS continues to go downhill because the logistics system is not delivering to the flight line the spares to meet even the rather low MC goals on which the budget is based. This is due in large part to the fact that depot obligation authority (OA) is constrained and is not optimally applied to fix the units really needed in the field.

Although even these lower-than-desired MC rates would not prevent the generation and deployment of the sorts of AEF packages considered in this study, there is a major concern over the impact on the force left behind. Since a wing will deploy its best aircraft and the fullest possible MSK, even if only a fraction of its aircraft leave, the remainder will be disproportionately non-mission-capable (NMC) and may lack critical support items. This certainly will impair routine training, and it could become serious if the contingency grows, requiring rapid deployment of additional packages or, even worse, if additional contingencies arise in other places.

The net effect of chronic spares shortages and low MC rates is that the Air Force actually possesses a useful force significantly smaller than its nominal inventory. This is made even worse by the fact that a unit returning from deployment takes weeks to return to fully combat-ready status as a result of accumulated deficits in training, spares, maintenance, and other areas. The budgets and processes involved in delivering spare parts and supplies, qualified technicians, and reliable systems to the flight line have a huge impact on the operational capability of the force.

8.2 Engine Reliability

The situation with respect to low reliability of current F-100 and F-110 series engines, and the lack of a good understanding of the mechanisms contributing to high cycle fatigue, was summarized in Volume 1. It suggests that the mean time to failure of the engine in the F-117 without an afterburner is roughly twice that of the same engine with reheat. “On-wing” times in the range of 50 to 200 hours mean that a steady stream of replacement engines must be fed to a fighter AEF operating at high-sortie tempo. Moving to “on-demand” engine maintenance and eliminating inspections and other scheduled maintenance at forward bases will help. However, measures to fundamentally improve engine reliability would yield great benefits to the high-performance aircraft of an AEF.

The Panel believes that a systematic evaluation of the benefits of modestly detuning these engines is very important. Attempts in the past to “turn down the wick,” exchanging some performance, typically at the upper right corner of the aeroperformance envelope, for reduced failure rates, have produced reliability gains. Until a thorough program is implemented to understand failure mechanisms and develop modifications to deal with them, such a compromise may be the best way to reduce the engine support burden of an AEF.

A recent report[28] dealing with the CFM-56 family of commercial transport engines stated that a systematic effort to identify, diagnose, and correct failure modes had more than doubled the on-wing time, from around 5,000 or 6,000 hours to more than 12,000 hours. Recognizing that afterburning fighter engines experience stresses far beyond those of airliner engines, we nevertheless find this suggestive of the power of an engine improvement program.

Future engines like the F-119 use even higher combustor and turbine temperatures and count on advanced metallurgy to achieve a still greater thrust-to-weight ratio, allowing supersonic flight without afterburner. To ensure that these advances do not lead to reliability problems, it is essential to have a realistic qualification program that exposes the design to the stresses of real operations and includes plans to fix the problems that surface. The Panel understands that funding for this could not be found in the current tight budget. We are concerned that the F-22 and the Joint Strike Fighter may have engine problems and post-production fixes that will cost more than a good up-front qualification and durability program.

8.3 Focused Reliability and Maintainability (R&M) Improvements

R&M modifications to existing aircraft frequently are expensive to develop and install, and current budget rules require that a clear return on investment in terms of reduced direct support costs be proven before funds are provided. This often is too hard to do, especially for aircraft with a decade or less of planned remaining service life. No credit is given in these calculations for the combat value of higher aircraft availability. Moreover, such modifications compete with funding for spare parts and other contributors to aircraft MC rates. Nevertheless, the Panel believes that carefully chosen R&M projects can have important AEF payoffs, especially as a greatly reduced force structure is called upon to service diverse and global short-notice taskings, making it important that the greatest possible number of aircraft be able to deploy and sustain high-sortie tempos. Again, a commercial benchmark recently was reported.[29] Concerned with the impact of MD-11 transport reliability on customer service, Federal Express formed a "Trijet Reliability Team" with the goal of boosting dispatch reliability (DR) to 99 percent from a starting point of 97 to 98 percent. Through systematic evaluation of problems contributing to deviations from scheduled departure, the team has defined specific fixes (such as a change to the battery-charging system), with the result that fleetwide DR now approaches the goal and exceeds industry averages.

We did not attempt to compile a comprehensive list of candidate R&M upgrades to the current fleet. One example brought up repeatedly during our field visits concerns the secondary power system of the F-15. Another, discussed elsewhere, is an improvement in the DR of the C-5. We believe that if the Air Force is serious about the AEF concept, a serious attempt should be made to identify availability-limiting problems and to prioritize whatever funding is available in such a way as to maximize fleetwide MC rates under realistic conditions of deployed operations at austere bases.

The highest benefit/cost ratios for R&M efforts occur when the efforts are made at the beginning of system development. Emphasis should be given to keeping future weapon systems, such as the F-22, the JSF, and the CV-22, compatible with AEF operations at austere sites. AEF supportability metrics should be evaluated by the programs' supportability design teams. These evaluations should include impact on the AEF footprint for a wide range of AEF operational scenarios, in which the aircraft must operate in a mixed force, in addition to the basic scenarios. High value should be placed on lessening the need for ground

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[28] *Aviation Week and Space Technology*, 16 June 1997, pp. 127-9.

[29] Ibid., pp. 123-4.

equipment, use of common ground equipment, elimination of maintenance above O-level at the AEF site, and rapid regeneration. Another critical need, as advanced, low-observable aircraft become mainstays of AEF operations, is the development of durable signature treatments and repair procedures for them.

The need for oxygen and nitrogen service carts can be minimized by using an On-Board Oxygen Generating System (OBOGS) and an On-Board Inert Gas Generating System (OBIGGS). To eliminate the carts altogether is desirable, so technology solutions for other uses, such as nitrogen pressurization of landing gear struts, would be valuable.

Tires are one of the largest consumption items with current fighters; F-16 tires must be changed as often as every 5 to 8 cycles, and F-15s get about 20 to 24 landings per set. In addition, high tire pressure, especially from the F-16 nose wheel, can rapidly degrade the kind of pavements likely to be encountered at undeveloped bases. Tire designs and materials to give AEF aircraft high-use (say 50-cycle) tires, preferably including high flotation and run-flat capability as well, would materially reduce the support burden while deployed.

Bound printed Technical Orders (TOs) should be replaced by computerized TOs, perhaps including real-time Time-Critical Technical Order (TCTO) instruction and automated updates via cellular phones or other wireless data channels. Electronic data and intelligent troubleshooting aids are especially important to the minimum AEF support concept described in this report because crew chiefs will be called upon to do virtually all organization-level repairs, with only minimal support from specialists. A host of other measures, from eliminating external access ladders to better avionics to built-in diagnostics, have been identified that would contribute to aircraft supportability and thus to sortie generation while deployed.

Conventional incandescent cockpit lighting causes both visual problems for aircrews (especially incompatibility with night vision goggles), and a recurring maintenance burden. Replacement with electroluminscent (EL) lighting, as documented in an Air Force Lesson Learned, substantially improves reliability (mean time between maintenance rises to around 10,000 hours), saves weight, reduces maintenance costs, and solves a number of pilot vision problems. EL sources are suitable for cockpit panel and flood lights as well as external formation lights. Such a modification is an example of the kind of focused R&M improvement that would enhance the effectiveness and supportability of Air Force weapon systems under deployed operational conditions.

8.4 Lean Logistics and Reachback

Lean Logistics (LL) has been extensively documented[30] and is accepted by the Air Force as a central element of force support. Logistics reachback for minimum AEF deployed footprint is predicated on the responsive spares support that LL is supposed to deliver. However, while budgets have been adjusted downward on the basis of assumed savings, the concept has never been completely implemented. Cutting the spares inventory without taking the commensurate measures to assure availability of spares in the field is a recipe for degrading, not improving, MC rates. The Panel urges that the following LL issues be addressed:

- **Contractor Repairs.** The Contractor Repair Enhancement Program (C-REP) is intended to produce the same kind of reductions in repair turn times for contractor-repaired items as the Depot Repair Enhancement Program (D-REP) has begun to demonstrate for organically repaired units. However, contract delivery schedules routinely allow 90- to 180-day repair times, which are utterly incompatible with LL. Especially for older aircraft such as the B-52,

[30] *Preliminary Pipeline Analysis of AEF Deployments*, Synergy, Inc., and Dymond Associates, 5 March 1997.

the number of contractor-repaired critical items in short supply is a significant constraint on the aircraft's ability to participate in AEFs.

- **Time-Definite Transportation.** LL relies on fast, predictable shipment times both for retrograde movement of failed items from the field to the repair center and for forward movement of serviceable items to the engaged forces. As transportation resources are finite, an effective priority scheme is essential. At some points in Desert Storm, so many shipments were awarded top priority that the effect was to give priority to nothing. Our field visits turned up repeated problems ranging from high-priority small packages getting lost in normal-priority pallets to critical materiel held up in host nation customs. The lack of in-transit visibility is widely recognized as a serious problem, but achieving ITV is far from a solution to the problem of managing shipment priority. If the transportation system does not ensure that mission capability (MICAP) and other urgent shipments move quickly and on determined schedules, no amount of repair-cycle speedup will solve the problem.

- **Rapid Fabrication.** The age of many of our systems is such that maintaining spares of every part that could fail is impractical, while the original sources of supply for many parts have vanished. Where possible, reverse engineering and substitution of an available part is the preferred approach, but sometimes it is impossible. In these cases, the ability to rapidly and affordably fabricate small quantities (often, one) of a mechanical or electronic part may be the only way to restore an aircraft to mission capability. High-quality computer-aided engineering tools, coupled to modern rapid prototyping methods, can improve the ability of depots and their contractors to deal with these cases.

- **Improved Demand Forecasting.** Simple linear extrapolations of past consumption are known to be poor predictors of future demand,[31] but the Air Force lacks a good tool for this purpose. This is especially serious in a climate where limited budgets for spares and repairs make it urgent that funds be used as effectively as possible. In FY 97, all five Air Logistics Centers (ALCs), through a combination of inaccurate forecasting and external controls on the use of their repair funds, ran out of obligation authority for repairs by the end of the third quarter. A better system for analyzing and predicting spares demand is extremely difficult to develop but is urgently needed, together with the switch to responsive demand-pull supply to meet operational needs.

- **Continuous Improvement.** The original LL concept assumed that field experience and analysis would provide the basis for continuous refinement of processes, inventory levels, and other parts of the spares pipeline. This has yet to be embraced in a serious and systematic way. Modern logistics are too complex to assume that any strategy will be optimum for very long. Rigid systems for computing levels, planning repair rates, and using alternative shipment channels should give way to a living, adaptive approach based on optimizing operationally relevant metrics such as fleetwide MC and cannibalization rates.

- **Corrections to Funding Policy.** Depots operate under a variety of budget and expenditure constraints that give incentives to make decisions inimical to combat effectiveness. One of these is that depots have incentive to produce replacement parts to fill holes in aircraft, because the stock fund rules allow them to "sell" these items and receive credit. However, the same rules provide no incentive to fill holes in RSP kits, exacerbating low fill levels and all the ensuing distortions to the supply process. The adoption of presumed best business

[31] Capt Mark A. Abramson and Capt Harry A. Berry, "Applying Neural Networks to Demand Forecasting," *Air Force Journal of Logistics*, Vol. XX, No. ¾, Summer/Fall 1996, pp. 1-4.

practices within Air Force logistics has had a number of such unintended consequences that need to be fixed.

8.5 Lightweight/Multifunction Support Equipment

A ride down any Air Force flight line demonstrates the result of decades of acquisition of single-function, sometimes aircraft-unique aerospace ground equipment and other support gear. While this can be coped with at a developed base, AGE represents a significant portion of the required airlift to set up operations at an austere site. Moreover, AGE is a significant support burden in its own right, with repair, calibration, corrosion control, and other maintenance required. Designs that fit more than one function into a unit and that exploit advanced composites, solid-state electrical power control, and other approaches to reduce weight and improve durability would have high payoffs for AEFs.

As one example, the F-22 and, presumably, other future aircraft will use hydraulic systems with operating pressure well above that common in today's aircraft, leading to the acquisition of modified hydraulic carts. Although cost has been kept down by adopting the same cart chassis, a peculiar configuration nonetheless results. At a minimum, these carts should be able to service both F-22 and inventory aircraft. An even more attractive alternative has emerged in the Modular Aircraft Support System (MASS) program, described in the Technology Thrusts appendix; it can reduce the total number of carts by using a single power cart for several functions.

8.6 Point-of-Use Delivery

AEF operations almost always will require the delivery of significant quantities of cargo to locations that may not have good airfields. Even when airfields are available, MOG limitations on the number of transports that can be unloaded can make airdrop a valuable auxiliary means of delivery. In short, airdrop of cargo directly to the end users may be far superior to landing, offloading, and trucking of that same cargo. In Bosnia, the lack of precision airdrop systems in a threat environment, which required transports to remain above desired drop altitudes, significantly reduced the effectiveness of the operation and caused important cargo to fall into the wrong hands. A robust point-of-use delivery capability would be a valuable adjunct to overall AEF capabilities.

The required technology is mature and available, as recent demonstrations have reaffirmed.[32] With further development of deceleration schemes and shock-absorption packaging, even cargo currently considered too delicate to airdrop can be accommodated. The Panel believes that for a modest investment spread over several years, the Air Force can acquire a precision airdrop system that usefully expands the ability to execute AEF missions.

8.7 Management of Scheduled Maintenance

A key element of Minimum Flight-Essential Maintenance is that no scheduled maintenance is performed at forward bases. This means that deployment-eligible units must implement rigorous management of such activities as aircraft phase inspections to ensure that primary aircraft are not due such maintenance. Careful long-term planning of the flow of aircraft through periodic depot maintenance (PDM), phase, avionics calibration, and other scheduled maintenance can ensure that a unit stays ahead of the timeline and can generate an appropriate deployment package when called upon.[33] Beyond this, the Air Force could

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[32] *Aerospace America*, December 1996, p. 9.

[33] AFLMA analysis by SMS John Drew.

realize major benefits by switching from the current phase inspection concept to an isochronous scheduling concept as employed by many airlines, which both minimizes the time a tail number is out of service and allows more efficient organization and use of scheduled maintenance resources.

9.0 Cost Estimates

The Panel has tried to identify and, where possible, assess the costs associated with our recommendations. Many of these do not involve investment in assets, but would carry operational costs. For example, prepositioning tankers and transports for rapid AEF response could entail additional temporary duty expenses and personnel costs. These costs are impossible to quantify, but would be a consequence of reposturing the Air Force for rapid, global expeditionary operations.

Other recommendations do entail expenditure for additional assets or for improvements to weapon and support systems. However, many of these involve deficiencies in the ability of the Air Force to execute its mission as a whole, and thus are not uniquely associated with implementation of the AEF concept. Perhaps the outstanding example is the need to improve C-5 departure reliability.

Setting these two areas aside as not constituting AEF “bills to pay,” we are left with a number of logistics recommendations associated with AEFs that will, if adopted, produce such bills. In the following paragraphs, we address four specific areas where dollars would be required and attempt to analyze the investments involved.

9.1 Provisioning for Independent Slices

As described in Volume 1, this study has concluded that Air Force units eligible for AEF tasking should be organized in sub-squadron slices for greater flexibility in rapidly tailoring and deploying a force to meet a specific contingency. To be effective, such slices must be able to operate autonomously, at least for a limited period, without crippling the ability of the planes and people left at home to conduct other operations and training. This leads to the recommendation that these wings be provisioned to deploy some number of independent slices, meaning that equipment, spare parts, and other essential assets must be available to support geographically split operations. In particular, items that currently are authorized in numbers too small to be shared among operating sites must either be supplemented with more stock or made available from other sources. This idea, to be feasible, must be put into effect in a way that keeps the cost affordable. The Panel therefore has taken an initial look at the required assets, the associated costs, and strategies to minimize the required funding.

The resources associated with deploying a 30-fighter AEF are tabulated in some detail in Table H-4. Similar lists could be compiled for packages involving bombers, transports, medical teams, etc. The materiel specifically associated with operation and sustainment of an aircraft package includes vehicles, AGE, munitions buildup and transportation gear, personnel support items, airfield operations equipment, and command and control assets. Most of these are available in sufficient numbers to allow split operations or can be locally purchased or rented. We assume that some additional inventory would be required, but with individual items costing from a few thousand to a few hundred thousand dollars, the associated expense per wing is not excessive and could, moreover, be distributed over several budget years.

A potentially difficult cost problem in implementing independent slices is spare parts — the content of RSP kits. Today, the Air Force Materiel Command’s Weapon System Management Information System (WSMIS) computes kit levels using the Aircraft Sustainability Model (ASM). Inputs include a Direct Support Objective for each supported aircraft type, specifying the number of aircraft required to be MC at the end of the planned operating period plus assumptions about demand rates, resupply times, and other factors. Kit cost is dominated by predicted consumption during the first 5 days or so of an operation; cost is not proportional to the assumed duration.

Current kits are based on sortie rates in the Warfighting Master Plan, Volume 5 (WMP-5), on 30 days of operations with no resupply, on extensive cannibalization, and on a 65 percent MC rate after 30 days. These contrast with this study's concept of a 7-day AEF, timely resupply from CONUS and regional bases, and the need for very high MC rates (on the order of 90 percent) due to limited numbers of deployed aircraft. The ASM assumes that the operation is divided into an initial surge period, followed by a longer period at much lower sortie rates. It attempts to take account of the fact that demand depends on both total flight hours and number of sorties. However, it suffers from the problem common to all such models: that forecasting demand under combat conditions is virtually impossible. Hence, the model is somewhat biased toward conservative estimates to increase the chances that spares will be available when needed.

We have explored this subject with the Logistics Management Institute, which developed the ASM and performs ongoing RSP analysis. Current RSPs cost on the order of $7 million to $30 million for an 18-aircraft package. Perversely, RSP cost can go up when computed for a small number of aircraft, because fewer tail numbers can be allowed to be non–mission capable and therefore used for cannibalization. Expensive avionics spares dominate the cost. Kit costs are somewhat inflated because they contain "non-optimized" levels for items that units insist be included even though demand for them is not predicted by the model. As an example, there are $9.3 million worth of such items in the F-15E kit regardless of estimated demand.

If the current rules for computing RSP assets are applied, provisioning a squadron to deploy multiple independent slices is massively unaffordable, entailing acquisition costs two or three times those of existing assets. It could easily cost $50 million to $100 million per wing to do this. Another complicating factor is that RSP is not truly deployment stock because units live out of their kits to meet peacetime tasking in the face of declining system reliability and shortfalls in peacetime operating stocks (POS) that lead to lack of spares at the flight line. When deployed, units routinely make heroic efforts to get RSP fill levels up to some reasonable level, which usually is still well below 100 percent. This often entails robbing POS, meaning that any aircraft left behind are grossly undersupported. It also means that units fiercely resist any suggestion of separating RSP assets from units, since this is seen as undermining their ability to operate in peacetime.

A fundamentally different approach to supporting deployed forces is clearly required. That approach must include:

- Implementation of the full LL concept to make spares available and allow responsive satisfaction of actual demand during an operation. In addition, LL-based resupply and acquisition of replacement assets should address the shortfalls in POS to allow units to stop robbing their RSP and thus be better prepared for short-notice deployment. Many current holes in kits and airplanes could be filled by timely repair of boxes already in the depot pipeline.
- Immediate establishment of daily priority airlift to forward bases when a deployment starts so that MICAP spares demand can be met in 24 hours or less; this will be greatly improved by the use of RCCs as in-theater storage and issue points for critical items.
- Limited procurement of additional assets where this is unavoidable, including both RSP stocks and other items in a full MSK that units do not currently possess in numbers adequate for split operations. These buys must consider the unique spares requirements of various aircraft types and configurations, e.g., those associated with LANTIRN or HARM Targeting System–equipped F-16s.
- Better coordination among units to facilitate filling deficiencies in a deploying unit's inventory from other units where this is the best economic and operational solution to such problems. However, degrading the readiness of the rest of the force to support an AEF should be a last resort.
- Deployment of spare aircraft, which may be used for cannibalization, or assured rapid replacement of aircraft broken beyond the repair capability of Minimum Flight-Essential Maintenance with additional aircraft deployed from the rear. This will allow high MC rates to be maintained without exorbitant increases in RSP.
- RSP levels for deployments should be computed on the assumptions of reasonable cannibalization or aircraft replacement at the beddown site, daily resupply, and a Direct Support Objective that allows at least one aircraft per slice to be non–mission capable at the end of the operational period.

A small number of centralized or regional/theater mission support kits not assigned to any specific unit and based on providing spares and support equipment not readily available from unit stocks could enhance the global deployability of the force. Such assets would be, in effect, an enhancement of War Readiness Materiel, but would have to be maintained and managed in such a fashion that rapid movement to a forward base is assured. They could be rapidly rotated to an RCC or beddown site when a developing contingency warrants. Deploying units would know in advance what regional assets were available and could further pare and tailor their own RSP. Careful analysis, backed up by experiments and exercises, is needed to optimize this acquisition. The associated cost will certainly be far below that involved in a brute-force application of the current provisioning system.

9.2 Regional Contingency Centers

It is impossible to quantify the cost of the RCC concept, but at least the elements of that cost can be identified. First, there would be the initial and recurring expense of securing access to the site and its facilities. This might be reduced by combining the RCC program with others as discussed earlier. There would be additional up-front expense to establish the secure storage facility and some recurring cost for its oversight. Most of the materiel to be stored is already possessed and needs only to be moved. If the kind of facility preparations discussed in the previous paragraph prove feasible, their one-time cost must be included. Thus the RCC cost is mainly nonrecurring, while recurring costs might be shared with other U.S. Government activities in the country. The expense could be spread over time as budgets dictate, since nothing requires that the whole RCC network be implemented at once.

9.3 C-17 Center Wing Tank

Activation of the C-17 CWT has been shown to offer very useful new options for supporting deployed operations. A rough order-of-magnitude cost estimate is $25 million nonrecurring to develop the modification and $800,000 per aircraft to install during aircraft production. Retrofits would be more expensive, but since the entire fleet would not need this option, it would be sufficient to introduce the CWT into the new aircraft assembly flow at some point.

9.4 Bomber Main Operating Bases

As noted in Volume 1, the 2nd Bomb Wing and PACAF spent two years restoring Anderson AFB on Guam to readiness for B-52 operations, a capability that proved vital to the success of Desert Strike and allowed the bomber package to deploy with limited transport sorties. The other proposed bomber MOBs, Diego Garcia and Moron, require no significant facility upgrades to be similarly ready. Prepositioning of RSP and support equipment would reduce the required airlift for deployment. Shortfalls were tabulated in Section 1.4. In any event, the associated costs are not believed to be large, but validated operational plans calling for these bases to be used in this fashion for AEF missions would be needed. Eventually, we expect the B-1 and, in some situations, the B-2 to step into the AEF bomber role. Both of these systems have large support footprints, and an analysis must be conducted of the optimum facility upgrades and prepositioning to implement the study's AEF concept with these weapon systems before they assume such tasking.

10.0 Findings

The Lean Sustainment Panel arrived at the following findings.

- The missions examined in the study are basically feasible today from the logistics standpoint, but meeting the desired response times is problematical.
  - Deployment for 7 to 10 days of an AEF package such as 30 fighters, 6 bombers, or 12 transports is supportable with current assets.
  - Current operational thought is dominated by preparations to deploy to developed bases with extensive prepositioning of materiel for long times (90 days or more).
  - A response time of 24 to 48 hours would be hard to meet today, especially for missions to unprepared beddown sites.
  - Deploying units would need full MSKs and dependable 24-hour resupply for MICAP items.
  - Airlift of fuel, water, and other basics must be provided if not locally available.
  - Low mission-capable rates would not preclude deployment of an initial AEF, but could become a factor if the contingency expands or if additional AEFs need to be generated while the first one is under way.

- The responsiveness of the force is limited today by numerous process deficiencies associated with planning and execution of deployed operations.
  - Tools, databases, and procedures for planning and executing tactical operations, mobility operations, logistics functions, force protection, and other key activities are not well integrated; each functional area works largely in isolation with non-interoperable legacy tools.
  - The JOPES, which currently is used for any joint planning, is a theater-level, deliberate-planning environment that is poorly suited to contingency action planning.
  - Collection and maintenance of detailed, current data on potential beddown sites generally is lacking.
  - Reachback is problematical due to lack of reliable communications for transmitting requests and of fast, time-definite transportation for delivery of priority materiel.
  - Mismatches between the cargo and personnel to be deployed and the transportation stream dispatched to move them are commonplace, producing what is often referred to as "TPFDD turbulence"; this results in large measure from lack of discipline in the processes of tasking units, sourcing the requirements of an operational order, and preparing for deployment.
  - Coordination among lead and supporting units constituting a composite force is inadequate and largely *ad hoc*, leading to multiple problems with transporting too much or too little of essential resources.

- Deployment of an AEF typically has a disproportionately adverse impact on the remainder of the force; 20 wings of tactical inventory do not constitute 20 wings of employable air power.
  - Low mission-capable rates and chronic spares shortages mean that extensive cannibalization will be used to generate the deployable aircraft.
  - The MSK of the deploying force will be filled at the expense of operations at the home base, impacting training and readiness.
  - Training of both flight crews and support personnel will be degraded; training virtually stops while a force is deployed, and the absence of many experienced personnel curtails training at the home base. As much as 2 months may be required after return from deployment to bring all personnel back up to fully ready status.
  - Phase inspections and other scheduled maintenance accumulates during a deployment, and the deficits must be made good when the force returns.

- The primary constraint on the time to carry out a deployment is associated with aircraft movements, not with packing up and launching the deploying force.
  - Driving factors include the time to position tankers and transports to erect the air bridge and the time to ferry deploying aircraft to the operational theater.
  - Time to obtain diplomatic clearance, including overflight permission, is routinely encountered as a major schedule limiter.
  - Preparation of the beddown site, especially if initially undeveloped, can significantly impact the time to delivery of the first sortie; this may include pavement repair or upgrading, installation or repair of navigational aids and airfield lighting, and arrangements for local supply of fuel, water, and other essentials.

- Bombers offer a logistically feasible option for a fast first strike.
  - The AEF concept requires fully developed and provisioned regional bomber main operating bases, presumably Anderson, Diego Garcia, and Moron; lack of validated operations plans limits the ability to fund these base build-ups.

  - Defended target airspace may require fighter escort unless long-range standoff precision weapons are employed.
  - 24-hour response time requires some level of alert status for prime aircraft, crews, and support personnel.
  - Shortages of critical spares are a long-standing concern; generating a bomber force involves extensive cannibalization today.

- Inadequate C-5 departure reliability is a concern in achieving the goal of global AEF capability.
  - The C-5 is the transport of choice in many situations, both for long range and to reduce total required sorties; C-5s represent a large fraction of available airlift for the foreseeable future.
  - The relevant metric is DR, not just mission-capable rates, because of the problems caused by blocking ramps and runways when a C-5 breaks down, especially at smaller beddown sites.
  - The problem is not dominated by a single failure mode; the most prominent failures involve power plants, landing gear, and hydraulics.
  - A targeted program to correct as little as two-thirds of the failures in the top eight categories contributing to departure deviations could raise overall DR to around 98 percent without an unaffordable attempt to completely correct reliability shortfalls.

- Many AEF logistics problems are being worked out effectively, and the organizations and individuals responsible deserve credit.
  - Systems such as LOGCAT, IDS, and JPA/JPT will largely correct the deficiencies in crisis action planning tools as they are rolled out.
  - Many other initiatives, such as Lean Logistics, Readiness-Based Leveling, and the Global Transportation Network, also will make important contributions to AEFs.

- Lean Logistics still is not fully implemented, and the consequences for AEF operations may be serious.
  - The D-REP has made progress in reducing organic repair times, but the corresponding C-REP has made little difference to date; repair contracts still routinely allow 90- to 180-day response times, which are totally incompatible with LL.
  - Lack of adequate tools for predicting spares demand leads to bad depot decisions about allocating the limited repair resources that are available, exacerbating overall spares shortages. The inherent unpredictability of demand makes the power of LL to optimize the pipeline and improve response to actual operational needs all the more critical.
  - Reliable, fast, time-definite transportation both for retrograde movement of failed items and forward movement of replacement parts still is not adequate.
  - Funding policies such as the current allocation of the depot surcharge give field commanders an incentive to make poor decisions.

- Focused investments to correct specific reliability problems and sustainment drivers could have major payoffs for AEF operations.
  - Advanced munitions such as the Small, Smart Bomb would make AEFs more efficient and responsive by reducing the required sustainment lift and sortie count.

- Many current systems have well-known failure modes that limit availability and increase support requirements; historically, funding for such modifications has been hard to sustain because of rules requiring near-term payback in pure cost-of-support terms, with no credit for improved combat capability.
- Replacement of current heavy, single-purpose ground equipment with modular, multipurpose designs using advanced materials and electronics would both reduce deployment cargo and save maintenance manpower.
- Better packaging and material-handling equipment (e.g., all-weather storage bins made of advanced composites) to complement the current 463L pallet system would facilitate rapid deployment and save airlift.
- Spares and repairs accounts are chronically underfunded, meaning that even with perfect logistics processes the mission-capable rates of the fleet will be limited and thus that only a fraction can be employed at any given time.
- Activation of the C-17 center wing tank would create new options for long-range delivery and for delivering fuel to beddown sites without local sources.

• Proliferation of aircraft-unique support systems hinders deployed operations.

  - Single-purpose maintenance information systems, test equipment, and other items increase costs and add to deployment cargo.
  - As one example, the Integrated Maintenance Information System was developed to be a common hand-held maintenance aid, but was evolved by different system program offices into a collection of aircraft-specific versions; the Air Force has no effective mechanism for optimizing overall fleet affordability and supportability through use of common support systems.

• Cuts in the Base Operability Technology program have eliminated the primary (sometimes the only) source of technologies that are central to the AEF concept of global operations from austere bases.

  - After fiscal year 1997, only fire protection remains active as a technology-development area.
  - This forces reliance on commercial products, other Services, or other countries for power production, advanced shelters, water purification, and other essential functions.

• *Additional Observations.* The Panel noted the following facts, which are of concern both to AEF operations and to the health of the Air Force in general.

  - Low-observable aircraft present additional challenges when operated at forward bases; current aircraft such as the F-117 and B-2 require shelters and special maintenance procedures, neither of which is compatible with austere beddown sites.
  - Decisions are required during the initial (7- to 10-day) AEF period if operations are to persist or grow in scope. Additional sustainment for aircraft support, quality of life, force protection, and other functions must start to flow on roughly the third day of the operation.
  - Low engine reliability is a continuing concern, especially for AEF operations from undeveloped bases. This can be managed with an adequate flow of spare engines, preferably through a regional repair center.
  - Consumable items (stock code XB-3), which are managed by the Defense Logistics Agency, represent a large fraction of the spares demand associated with MICAP

maintenance problems. Although DLA's responsiveness has shown improvement in recent years, the situation is far from satisfactory.

– As many as two-thirds of the Harvest Falcon and Eagle kits for establishing base operations at undeveloped sites are in poor to unserviceable condition. While this is not an issue for the initial period of an AEF, it could hamper the ability of the Air Force to quickly set up a fully operational main base at a bare site.

11.0 Recommendations

The Panel's primary recommendations were integrated into those of the overall study in Volume 1. In this section, we present, in roughly priority order, the specifically logistics-related actions that have emerged from our work and that we believe are important — in some cases vital — to the success of the AEF concept. The Panel's recommendations on specific technology developments have been merged into the report of the Technology Panel. For each recommendation, we offer an office of primary responsibility (OPR), a suggested completion date, and one or more metrics to assess completion.

11.1 Near-Term Actions

- Correct the process disconnects that impede rapid planning and execution of AEF operations.
  - Replace traditional logistics planning with employment-driven planning as described in Section 1.2.
  - Complete the development and fielding of tools and databases, including LOGCAT, IDS, and JLP, to replace JOPES in crisis action planning situations.
  - Institutionalize integrated, collaborative planning and execution monitoring processes to ensure that execution plans are complete and feasible from the viewpoints of all involved functions and that promote an orderly, efficient deployment sequence (eliminating TPFDD turbulence).
  - Develop and maintain, using the STEP/BCAT tool set, an accurate and comprehensive database on potential beddown sites in areas of interest for AEF operations.
  - Provide communications priority and reliable, time-definite transportation, both forward and retrograde, to make logistics reachback feasible.
  - Ensure that actions to outsource support functions include assured provisions for providing the equivalent at deployed locations and on AEF timelines.
  - Reexamine current equipment and procedures for supporting personnel at austere bases, seeking opportunities to improve safety, comfort, and productivity while reducing weight and maintenance.

OPR: Since this requires action by all major commands and many Air Staff directorates, the recommended OPR is the Air Force Chief of Staff (CSAF).

Completion Schedule: Initial fielding of all process corrections in 2 years; complete institutionalization in 3 years.

Metrics: Tools and processes in use at all levels of all major commands.

Ability demonstrated in exercises to complete crisis action planning in 4 hours, employ logistics reachback effectively, and meet AEF deployment timelines.

Beddown site database developed, and structured updating process in place.

- Organize AEF-eligible wings for rapid, flexible assembly of composite forces from a mix of independent and dependent slices.
  - For each mission design series (MDS), determine the optimum size of a slice, based on ability to train and operate independently or as an element of a larger force.
  - Establish and provide MSK levels, including theater assets not uniquely assigned to a wing, to allow a 24-aircraft squadron to deploy two independent slices to geographically separate locations, and subsequently one dependent slice to join an independent slice.
  - Establish procedures, training, and exercises to ensure that slices from multiple wings can rapidly cohere in a composite force, efficiently coordinate deployment planning between lead and supporting units, and smoothly transition to a longer-term or larger-scale operation if necessary.

OPR: Air Combat Command.

Completion Schedule: First two ACC wings provisioned and trained for split operations in 2 years; all AEF-tasked wings provisioned and trained and theater MSK assets in place in 4 years.

Metrics: Wings have on hand or available from the supported theater the MSK assets for split operations with at least two independent slices.

Ability demonstrated in exercises to rapidly assemble and effectively operate composite forces from the first day of a contingency.

- Posture the mobility forces to support accelerated AEF timelines.
  - Plan for prepositioned tankers on 4-hour response call at strategically located staging bases.
  - Plan for a predetermined transport stream to begin arriving at aerial ports of embarkation 4 hours after a deployment order.
  - Explore ways to use Air National Guard and Reserve Component mobility forces in AEF deployments.

OPR: AMC, to work with U.S. Transportation Command to plan for rapid AEF deployment.

Completion Schedule: One year.

Metric: Ability demonstrated in exercises to erect the air bridge and deploy an AEF on the desired timeline.

- Make the Rapid Response AEF (RAEF) a top Battlelab priority, preferably a Mitchell Demonstration, with emphasis on logistics, force protection, command and control, and other support functions.

OPR: ACC.

Completion Schedule: Initial demonstration in 1 year, complete demonstration in 2 years.

Metric: RAEF processes and procedures validated in Battlelab demonstrations and in exercises.

- Implement austere maintenance procedures at AEF beddown sites.
  - Implement Minimum Flight-Essential Maintenance as defined in Volume 1.

- Prepare prime deployable aircraft in such a way that no scheduled maintenance falls due during an operation.
- Provide in-theater back shops for engines, specialized avionics, etc., with 24-hour response to requirements at beddown sites.

OPRs: HQ USAF/IL should develop the appropriate implementing instructions; ACC, USAFE, and PACAF should incorporate these instructions in training, exercises, and operations.

Completion Schedule: One year.

Metric: Austere maintenance practices incorporated in Air Force instructions, validated in exercises, and implemented in AEF-eligible wings.

- Implement regional infrastructure improvements.
  - Analyze locations, coordinate with Department of State, and implement Regional Contingency Centers as defined in Section 1.4.
  - Provision Anderson AFB, Diego Garcia, and Moron AB (or other suitable European base) as bomber main operating bases.

OPR: Secretary of the Air Force, with assistance from the Air Staff and regional major commands.

Completion Schedule: Start with upgrading of existing bases; phase in additional centers over a period of not more than 5 years.

Metric: RCCs established, stocked, and provided with facilities for rapid upgrading to theater main operating bases.

- Finish the implementation of Lean Logistics.
  - Push the Contractor Repair Enhancement Program to get repair-cycle times for critical items down to 5 days or less, with flexibility to assign priorities depending on current requirements of engaged forces.
  - Develop and implement demand-forecasting tools that allow effective use of depot resources.
  - Grade depot support on the basis of operational measures of merit, e.g., mission-capable rates of supported weapon systems.

OPR: AFMC.

Completion Schedule: Revise repair contracts and depot practices within 2 years.

Metrics: Demonstrated pipeline times that meet the Lean Logistics Master Plan.

Depot repair planning provides the materiel to maintain NMCS rates at or below major command standards for an entire fiscal year.

- Make selected investments with high payoff for AEF capability.
  - Complete and procure Small, Smart Bomb and other advanced munitions plus fuses that allow shipment of all-up rounds to a forward base.
  - Activate the C-17 center wing tank.
  - Develop an affordable approach to improve C-5 departure reliability by making the feasible corrections of the top failure causes.

- Develop modular, multipurpose, lightweight ground equipment.
- Detune engines for increased on-wing time at acceptable performance decrease.
- Develop lightweight, affordable, multipurpose containers for rapid packing and open-air storage of materiel.
- Analyze chronic reliability and maintainability problems in the current fleet and fund modifications to correct those with high leverage on AEF deployment and sortie generation, regardless of economic payback.

OPRs: HQ USAF/AQ with support from major commands on budget prioritization.

Completion Schedule: Varies, but most ideas could be implemented in 5 years or less.

Metric: Fielding of solutions to AEF deployment-limiting factors.

11.2 Mid- to Long-Term Actions

- Ensure that future aircraft (F-22, Joint Strike Fighter, VC-22) address the requirements of operation from austere bases.
  - Develop low-observable features that are durable and can be maintained in the field.
  - Maintain emphasis on high intrinsic reliability and fault tolerance, plus autonomy features that reduce the need for external support equipment.

OPR: HQ USAF/AQ, in coordination with AFMC and joint program offices.

Completion Schedule: Tied to the development schedules of the aircraft.

Metric: Achievement of the reliability and supportability goals in the operational requirements documents of each system.

- Pursue systems and features specifically to optimize global AEF response.
  - Increased ferry range for fighters.
  - Hypersonic strike/reconnaissance platform(s) for much less than 24-hour response without forward basing.
  - A global-range transport/tanker.

OPR: HQ USAF/AQ, coordinating overall Air Force positions.

Completion Schedule: Unspecified at this time.

Metric: At this time, inclusion of these considerations in Air Force long-range planning and budgeting.

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Annex to Appendix H

Acronyms and Abbreviations

Abbreviation	Item/Program/Tool	Description
2LM	two-level maintenance	System restoration through flightline replacement and depot repair of failed units, eliminating the intermediate level (back shops).
a/c	aircraft	
AAT	aircraft availability target	System that establishes RSP levels based on predicted demand and goals for MC rates.
ABAM	Aircraft Beddown Allocation Module	Theater-level planning tool for pavements, fuel/munition storage, etc.; feeds JPT.
ABDAR	Aircraft Battle Damage Assessment and Repair	Technology development for improved speed and accuracy in battle damage assessment and repair planning.
ABO	air base operability	
ACC	Air Combat Command	Owns CONUS fighter and bomber wings.
ACL	allowable cabin load	Maximum wartime loadout of a transport (weight, cube, seats, etc.).
ACN	aircraft classification number	A measure of the load imposed by an aircraft on a pavement.
ADAM	Aerial Port Documentation and Management System	ITV tool for tracking cargo and passengers through an aerial port.
ADP	automatic data processing	
ADVON	advanced echelon	Lead elements of a deploying force.
AECC	Aeromedical Evacuation Control Center	Theater focal point for evacuation requests and patient transport.
AEF	Aerospace Expeditionary Force	
AFI	Air Force Instruction	
AFLMA	Air Force Logistics Management Agency	
AFMC	Air Force Materiel Command	
AFOSR	Air Force Office of Scientific Research	
AFSC	Air Force Specialty Code	
AFWMPRT	Air Force Wartime Manpower/ Personnel Readiness Team	
AGE	aerospace ground equipment	Flightline generators, light stands, air conditioners, etc.
AIS	automated information system	
AIS	Avionics Intermediate Shop	Avionics back shop.
AL	Armstrong Laboratory	
ALC	Air Logistics Center	
ALCS	Airlift Control Squadron	Provides the core of a TALCE.

Abbreviation	Item/Program/Tool	Description
ALP	Advanced Logistics Planning	DARPA program to develop and demonstrate tools and protocols to control the logistics pipeline at all echelons.
AMC	Air Mobility Command	
AME	Air Mobility Element	Center within an AOR that tracks, coordinates, and directs air mobility assets; formed by an AMOS plus augmentation.
AMOS	Air Mobility Operations Squadron	Unit of an AMC NAF that provides core capability of an AME; the commander may become the DIRMOBFOR.
AMSOE	Automated Mobility Schedule of Events	Modeling tool for scheduling deployment timeline with arbitrary loads and transports.
AMX	Air Mobility Express	Wartime fast transportation support.
AOC	Air Operations Center	Command and control center for an AOR; manned by the Joint Force Air Component Commander's (JFACC's) staff.
AOR	Area of Responsibility	A theater of operations.
APCC	Aerial Port Control Center	Provides command and control for air transportation of passengers and cargo.
APOD	aerial port of debarkation	Airhead; receiving site for deployed passengers and cargo.
APOE	aerial port of embarkation	Departure site for deploying passengers and cargo.
APU	auxiliary power unit	
AREP	Aircraft Repair Enhancement Program	Improves PDM processes to reduce flow times and enhance responsiveness.
ASC	Allowance Standard Code	
ASHES	Automated Site Hazard/Explosives System	Information tools to support beddown planning for forces and associated explosive materials.
ASM	airspace management	Air traffic control and other aspects of safe, efficient air operations.
ASM	Aircraft Sustainability Model	The model used in the DO41 system to compute RSP levels.
ATAC-AF	Advanced Traceability and Control for Air Force	System using Air Force data and information systems to provide asset visibility through the repair/service pipeline.
ATC	air traffic control	
ATO	Air Tasking Order	Sortie-level execution and engagement order for theater air forces.
ATOC	Air Terminal Operations Center	
AUTODIN	Automated Digital Network	
AWACS	Airborne Warning and Control System	
AWP	awaiting parts	Usually means one or more missing SRUs for an LRU.

Abbreviation	Item/Program/Tool	Description
BADD	Battlespace Awareness and Data Dissemination	DARPA program to develop improved capability to develop a real-time situation picture for all force elements.
BAI	Backup Aircraft Inventory	Aircraft assigned to a unit as spares to allow DOC commitments to be met, allowing for scheduled maintenance and other demands.
BCAT	Beddown Capability Assessment Tool	Information tool to correlate resources available at beddown site with mission/deployment requirements.
BCS	bench check serviceables	Number of bench check serviceable items at a base.
BDS	Battlefield Distribution System	System using commercial and organic military transportation to expedite routing, handling, and accountability of assets.
BITS	Base Information Transfer System	Base-level network for communication among functions.
BLSM	Base-Level Systems Modernization	Program to upgrade legacy base-level logistics information systems.
BOS	base operations and support	Functions such as civil engineering, base transportation, etc., required to operate a base.
BSP	Base Support Plan	Part 1 supports advance beddown planning (automated by STEP); Part 2 gives details of all functions required to generate sorties (automated by BCAT).
BSPBT	BSP Browsing Tool	Part of STEP; supports access to EKB contents.
BSPC	BSP Committee	Representatives from the various base operations functions.
BSPCT	BSP Collection Tool	Automates data collection under STEP.
BW	biological warfare	
C^2	command and control	
C^3	command, control and communications	
CALCM	conventionally armed air-launched cruise missile	
CALM	Computer-Aided Load Manifesting	Tool used to automate the load-planning process; automates calculations of volume, weight and balance, etc.
CAMS/ REMIS	Core Automated Maintenance System/Reliability and Maintainability Information System	Current standard information systems for maintenance control and reporting.
CAP	crisis action planning	Process to select a COA and develop execution plans for a time-urgent contingency.
CBO	Contingency Base Ops	Base-level logistics functions at a deployed site.
CBR	California Bearing Ratio	Measure of the load-bearing characteristics of soils.
CCT	Combat Control Team	Assault zone team that directs and supports air delivery of forces.
CDF	Cargo Deployment Function	Base deployment work center for cargo.
CENTCOM	Central Command	

Abbreviation	Item/Program/Tool	Description
CFM	contractor-furnished materiel	
CFR	crash/fire/rescue	
Chalk	Derived from the practice of load planning on a chalkboard.	A specific transport aircraft to which a load of cargo and personnel can be assigned; a specific load plan.
CINC	Commander-in-Chief	
CJTF	Combined Joint Task Force	
CMOS	Cargo Movement Operations System	Used to create the manifest and support ITV of cargo and passenger movement; component of IDS.
COA	course of action	Top-level description of the way a campaign/operation will be carried out.
COMPES	Contingency Operations/Mobility Planning and Execution System	Information system supporting logistics, manpower, operations, and personnel functions at Air Staff, MAJCOM and base levels; AFM28-740; includes LOGPLAN.
COMPES-M	COMPES–major command level	
CONOPS	concept of operations	
CONUS	continental United States	
COTS	commercial off-the-shelf	
CRAF	Civil Reserve Air Fleet	Commercial transports available under contract for military lift operations.
C-REP	Contractor Repair Enhancement Program	Contractor complement of D-REP; implement LL, acquisition reform, and partnerships to speed the repair cycle — e.g., allow direct shipment between contractor and field location.
CRI	Consolidated Reparable Inventory	
CSAF	Chief of Staff of the Air Force	
CSI	Consolidated Serviceable Inventory	
CSS	Combat Supply System	Facilitates rapid fulfillment of deployed force supply needs from all available sources.
CSS	Contingency Support Staff	
CTAPS	Contingency Theater Automated Planning System	Integrates force-level (component-level) battle management, planning, dissemination, and execution phases of the air battle or other contingency in a joint environment.
CUP	Core UTC Package	
CW	chemical warfare	
CWT	center wing tank	
DAAS	Defense Automatic/Automated Addressing System	Standard gateway for information transfer at base and depot levels.
DARPA	Defense Advanced Research Projects Agency	
DCAPES	Deliberate and Crisis Action Planning and Execution System	Process improvement program for deployed operations; precursor to LOG-AID.
DCC	Damage Control Center or Deployment Control Center or Dedicated Crew Chief	

Abbreviation	Item/Program/Tool	Description
DDM	Distribution Drive Module	Part of EXPRESS.
DDR	Daily Demand Rate	Average daily requirement for a materiel item.
DeMS	Deployment Management System	Provides a deploying unit with the automated equipment resources to meet a tasking; implements LOGFOR and LOGPLAN functions; automates base-level process of tailoring UTCs, load planning, etc.; part of IDS.
DIFM	due in for maintenance	
DIRMOBFOR	Director of Mobility Forces	Reports to the JFACC or other Air Forces Commander (AFFOR).
DLA	Defense Logistics Agency	
DMD	Deployment Manning Document	Provides personnel resource information.
DMIF	Dynamic Multi-user Information Fusion	
DO35		Base-level supply/maintenance data system.
DO41		Tracks demand and levels for POS items; levels are driven by DSO.
DO87		Tracks demand and levels for RSP items; levels are set by AAT.
DOC	Designed Operational Capability	Statement of the required capability of a unit; specifies what is maintained for deployment and in what condition, including UTCs and time to move them; DOC status is reported through SORTS.
DPI	Deployment Process Improvement	Set of initiatives to improve key areas of deployment planning and execution.
DPT	Disaster Preparedness Team	
D-REP	Depot Repair Enhancement Program	Program to improve depot-level processes by aligning authority and responsibility in the materiel manager, reengineering processes, and applying operational metrics such as FMC rates and RSP withdrawals.
DR	dispatch reliability	
DRD	Deployment Requirements Document	
DRMD	Deployment-Required Manning Document	List of personnel and skills required by a deployment.
DSO	Direct Support Objective	Percent of aircraft still MC after 30 days of operations; determined by RSP support levels and cannibalization rates.
DSOE	Deployment Schedule of Events	Time-phased activity plan at base level by UTC for executing a deployment, including chalk sequence and work center flows.
DTEMP	Deployment Training and Education Master Plan	
DTS	Defense Transportation System	
EBO	expected back orders	Projected base-level requirements; to be minimized by RBL.

Abbreviation	Item/Program/Tool	Description
ECU	environmental control unit	
EDCS	Evolutionary Development of Complex Systems	
EKB	Employment Knowledge Base	Part of STEP; Oracle database of base-level logistics functions and capabilities.
EL	electroluminsecent	
EOC	economic order quantity	Traditional ordering criterion, being replaced/modified by flexible ordering under LL.
ERRC	Engine Regional Repair Center	Required to meet demand for serviceable engines in large-scale operations.
ESTA	En route Support Team Airlift	Transport for support at intermediate/staging bases.
EXPRESS	Execution and Prioritization of Repair Support Systems	System to optimize repair requirements based on RBL, RSP, and MICAP levels.
FDP&E	force deployment planning and execution	
FMSE	fuel mixing and supply equipment	Equipment and plumbing to mix additives, test fuel quality, etc., to ensure that specification-compliant fuel is provided to aircraft.
GCCS	Global Command and Control System	Standard DoD force control system; includes a family of standards to ensure interoperability of information systems.
GCSS	Global Combat Support System	Information system grouping based on modernizing legacy base-level systems onto a single platform compatible with GCCS.
GFM	Government-furnished materiel	
GIS	Geographic Information System	
GTN	Global Transportation Network	Allows efficient access to and transfer of network information among geographically distributed transportation databases; supports all transportation functions.
HARM	high-speed anti-radiation missile	
HCFC	hydrocarbon fuel cell	
HE	Harvest Eagle	
HPMSK	High-Priority Mission Support Kit	
ICE	internal-combustion engine	
IDO	Installation Deployment Officer	
IDS	Integrated Deployment System	Information tools to automate previously manual deployment process tasks; precursor to LOG-AID; currently being fielded.
IMDS	Integrated Maintenance Diagnostic System	System to generate status of maintenance and related items, including trends and analyses.
IPT	Integrated Product Team	
IREP	Intermediate Repair Enhancement Program	Program to improve use of limited available spares at the base level.
ISPA	Initial Strike Package Airlift	Transport for passengers and cargo constituting the first deploying forces.

Abbreviation	Item/Program/Tool	Description
ISR	intelligence, surveillance, and reconnaissance	
ITV	in-transit visibility	Desired capability to track cargo and passengers in shipment; one element of TAV.
JCALS	Joint Computer-Aided Acquisition and Logistics Support	Overall effort to improve acquisition and materiel support through modern information technology; includes multiple specific programs.
JCS	Joint Chiefs of Staff	
JDST	Joint Decision Support Tools	
JEIM	Jet Engine Intermediate Maintenance	Engine back shop.
JFACC	Joint Force Air Component Commander	Reports to the CINC or Joint Task Force Commander.
JFAST	Joint Flow and Analysis System for Transportation	JOPES application; simulates movement to analyze OPLAN and TPFDD movement requirements and support transportation planning.
JL-ACTD	Joint Logistics Advanced Concept Technology Demonstration	DARPA program to develop a logistics decision support tool for CINCs and CJTF Commanders.
JLME	Joint Strike Fighter Logistics Modeling Environment	Tools to assess logistics impacts of proposed conceptual designs and quantify relationships between affordability and combat effectiveness.
JLP	JPT Logistics Planner	Information system tools to support development of force requirements and beddown to execute an air campaign; outputs trigger activities at wing level.
JLP-M	JPT Munitions	
JLP-S	JPT Supply	
JLP-T	JPT Transportation	
JointSTARS	Joint Surveillance, Target, and Attack Radar System	
JOLT	Joint Office for Logistics Technology	
JOPES	Joint Operations Planning and Execution System	Legacy DoD command and control system for deliberate theater-level joint operational planning and execution monitoring.
JPAV	Joint Personnel Asset Visibility	The personnel element of JTAV.
JPT	JFACC Planning Tool	Information system tools to support planning optimal mixes of aircraft and munitions vs. specified targets; integrated with LOG-AID through an information interface.
JSAWM	Joint-Service Agent Water Monitor	
JTAV	Joint Total Asset Visibility	TAV for all Services and components.
JTAV	Joint Total Asset Visibility	
JTCC	Joint Transportation Corporate Information Management Center	Transportation Command activity to improve information processes and overall management.

Abbreviation	Item/Program/Tool	Description
LAD	Log Anchor Desk	Foundation of the JL-ACTD; demonstrates decision support tools of a common logistics picture for a CINC, CJTF Commander, and staffs; Army-oriented with little Air Force functionality. Includes multiple tools.
LANTIRN	Low-Altitude Navigation and Targeting for Night	
LCN	Load Classification Number	Current parameter used to specify the load-bearing characteristics of flexible and rigid surfaces.
LES	Leading-Edge Services	Enhancements to the GCCS.
LIMFAC	limiting factor	
LIS	Logistics Information Systems	
LL	Lean Logistics	Air Force initiative to reduce costs and improve support by optimizing the repair pipeline.
LOC	Logistics Operations Center	Monitors, controls, and expedites movement and repair of tankers and transports in the AOR.
LOCIS	Logistics Control and Information Support	Assessment of information requirements, flow, and use of current systems in core wing-level logistics functions.
LOG	logistics	
LOG-AID	Logistics Analysis to Improve Deployability	Requirements analysis tool to streamline the deployment process at the unit/base level.
LOG-CAT	Logistician's Contingency Assessment Tool	Program to improve unit-level deployment processes; includes STEP, BCAT, UTC-DTO and LOG-AID.
LOG-DET	Logistics Detail	Database of standard logistics elements.
LOGFAC	Logistics Feasibility/Analysis Capability	
LOGFOR	Logistics Forces Packaging System	Information system that provides standard logistics detail of equipment and materiel requirements of a UTC.
LOGFOR-B	LOGFOR–Base Level	
LOGMOD	Logistics Module	System that stores and produces manpower, personnel and materiel lists, load lists, packing lists, manpower requirement reports, and mobility personnel rosters for Air Force standard packages.
LOGMOD-B	LOGMOD–Base Level	
LogSAM	Logistics Simulation and Analysis Model	Base/weapon system–level tools for logistics planning and monitoring; simulates aircraft generation, scheduling, preflight, and postflight; calculates MC, TNMCS, NMCM rates and other measures of effectiveness.
LOI	Letter of Instruction	Part of the deployment notification to a tasked wing or unit.
LRU	line-replaceable unit	Box, module, or other item replaced at maintenance level 1 (flightline/organization-level).
LSA	Logistics Support Area	

Abbreviation	Item/Program/Tool	Description
MAAP	Master Air Attack Plan	Air campaign plan produced by JPT.
MAC	Munitions Assembly Conveyer	Trailer-mounted equipment for rapid munitions build-up.
MAJCOM	major command	USAFE, PACAF, and ACC, which have permanently assigned combat units.
MANFOR	Manpower Force Packaging System	
MANPER	Manpower and Personnel Module	Provides manpower and personnel data support to field commanders, including force requirements and projections, strength accountability, and replacement requirements.
MANPER-B	MANPER–Base Level	Information system that provides details of personnel requirements of a UTC.
MARC	Mobile Air Reporting and Communications	Transportable (expandable shelter) module for TALCE C^3.
MASS	Modular Aircraft Support System	Technology development program for modular support equipment to reduce deployment transportation requirements.
MC	mission-capable	Alternatively, FMC = fully mission capable, PMC = partially mission capable.
MCC	Mobility Control Center	
MDS	Mission Design Series	Designation of a weapon system family.
MEFPAK	Manpower and Equipment Force Packaging	
MFEM	Minimum Flight-Essential Maintenance	
MHE	material-handling equipment	Forklifts, K-loaders, etc.
MICAP	Mission Capability	Denotes a maintenance/supply problem that makes an airplane NMC.
MILSTRAP	Military Standard (Transportation) Reporting and Accounting Procedures	AR 320-50; DOD 4140.39.
MILSTRIP	Military Standard Requisitioning and Issue Procedure	AFR 400-3.
MISTR	Management/Maintenance of Items Subject to Repair	
MOB	main operating base	
MOG	maximum on ground	
MRE	meals ready to eat	
MSC	Mission Support Cell	Element of an AME.
MSF	Mobility Support Forces	
MSK	Mission Support Kit	Includes RSP, support equipment, and other things required to support deployed operations.
MTW	major theater war	
NAF	Numbered Air Force	Organizational level below major command and above wing.
NCA	National Command Authorities	
NMC	non-mission-capable	

Abbreviation	Item/Program/Tool	Description
NMCM	non-mission-capable/maintenance	
NMCS	non-mission-capable/supply	
NRTS	not reparable this station	
NSN	National Stock Number	
O&ST	order and ship time	
OA	obligation authority	
OBIGGS	Onboard Inert Gas Generation System	A unit that uses a molecular sieve to generate N_2 from air, eliminating the need for liquid nitrogen storage and the associated support equipment and servicing time.
OBOGS	Onboard Oxygen Generation System	A unit that uses a molecular sieve to generate O_2 from air, eliminating the need for liquid oxygen storage and the associated support equipment and servicing time.
OJCS	Office of the Joint Chiefs of Staff	
OPLAN	Operations Plan	
OPORD	Operations Order	
OPR	Office of Primary Responsibility	
OPS	operations	
OPSMOD	Operations Module	
OPTEMPO	operations tempo	
OT&P	Operational Tasking and Priorities	Information system tools to integrate applications at all echelons and consolidate information for transmission to GCCS.
PAA	primary aircraft assigned	Number of aircraft assigned to a unit (obsolete term).
PACAF	Pacific Air Forces	Air component of Pacific Command.
PAFC	phosphoric acid fuel cell	
PAX	passengers	
PCN	Pavement Classification Number	Measure of load-bearing strength of a pavement.
PDF	Personnel Deployment Function	Base deployment work center for personnel.
PDM	Periodic Depot Maintenance	Scheduled major maintenance/modification of weapon systems at depot level.
PEM	proton exchange membrane	
PERSCO	Personnel Support for Contingency Operations	
PMAI	Primary Mission-Assigned Aircraft	Aircraft assigned to a unit to meet its DOC statement.
PMEL	Precision Measurement Equipment Lab	Calibration facility for test equipment and instruments.
POD	port of debarkation	
POE	port of embarkation	
POL	petroleum, oil, and lubricants	Fuel, oil, hydraulic fluid, and other required aircraft fluids.
POS	Peacetime Operating Stock	Items and levels intended for normal peacetime operations.
PRU	Personnel Readiness Unit	

Abbreviation	Item/Program/Tool	Description
PSI	Parts Supportable Inventory	
R&M	reliability and maintainability	
RAEF	Rapid Response Aerospace Expeditionary Force	
RAMPCO	Ramp Control Officer	
RAMS	Rapid-Assembly Munitions System	Obsolete term for what is now called MAC.
RBL	Readiness-Based Leveling	Centralized, global asset allocation/distribution based on system performance and parts availability; eliminates base-level computations and uses readiness criteria.
RCAPS	Remote Consolidated Aerial Port System	ITV tool for cargo and passenger manifesting.
RCC	Reception Control Center	
RCC	Regional Contingency Center	Proposed forward supply location for reduced deployment cargo lift and rapid establishment of a MOB.
RDA	Requirements Development and Analysis	JOPES application; creates, modifies, and deletes TPFDD requirements.
RDD	Required Delivery Date	Time when a UTC must arrive in theater.
RDO	Redistribution Order	
READY	Resource Augmentation Duty	Program used to select and notify mobilization augmentees.
RF	radiofrequency	
RIPDAT	Reparable/Serviceable Item Pipeline Data Analysis Tool	Prototype program under LL to support metrics analysis for the Air Force logistics system.
RL	Rome Laboratory	
ROWPU	reverse-osmosis water-purification unit	Equipment for water purification.
RPU	Reception Processing Unit	
RSP	Readiness Spares Package	(Formerly War Reserve Spares Kit, WRSK); unit-level deployable spare parts and materiel kit.
S&M	Scheduling and Movement	JOPES application; creates, modifies, and deletes air/land/sea transportation schedules, tracks missions, and generates reports.
SBSS	Standard Base Supply System	Base-level system for requisitions, stock tracking and other supply functions.
SCaDViz	Stock Control and Distribution Visibility	
SCWO	supercritical water oxidation	
SOE	Schedule of Events	TPFDD timetable with departure and arrival dates.
SOR	Statement of Requirements	
SORTS	Status of Resources and Training System	Readiness reporting system; units are rated C-1 (fully ready) to C-4 (not ready) based on ability to execute DOC tasking.
SPO	System Program Office	
SRAN	Stock Record Account Number	

Abbreviation	Item/Program/Tool	Description
SRU	shop-replaceable unit	Card or other item internal to an LRU, replaced at maintenance level 2 (back shop) or 3 (depot).
SSD	Systems Support Division	
SSN	Social Security number	
STAMP	Standard Ammunition Package	Predefined lot of munitions, packaged for shipment.
STEP	Survey Tool for Employment Planners	R&D project for a multimedia tool to collect data on potential beddown locations into a central knowledge base for rapid access by functional area planners.
SWA	Southwest Asia	
TAA	Theater Assembly Area	
TACC	Tanker/Airlift Control Center	Command post for global Air Mobility Command operations.
TALCE	Theater Airlift Control Element	Personnel and equipment (including C^3 and MHE) to control and facilitate aircraft movement through an airhead; mirrors airlift wing organization.
TALO	Theater Airlift Liaison Officer	Advises Army units on airlift.
TAV	Total Asset Visibility	The ability to accurately track the location and quantity of spares and other key materiel at all organizational levels; currently very limited.
TBMCS	Theater Battle Management Core Systems	Information tools for theater-level command and control.
TC-AIMS, TC-AIMS II	Transportation Coordinator's Automated Information for Movement System	
TCTO	Time Compliance Technical Order	Defines an action such as a problem fix that must be completed on a specified schedule; may limit an aircraft's deployability.
TICARRS	Tactical Interim CAMS/REMIS Reporting System	
TNMCS	total non-mission-capable/supply	
TO	Technical Order	Basic technical data document.
TPFDD	Time-Phased Force and Deployment Data	Listing of UTCs to be deployed and their dates of arrival; includes an SOE.
TRANSCOM	Transportation Command	
TRAP	tanks, racks, adapters and pylons	Gear required to hang munitions, etc., on aircraft.
TUCHA	Type Unit Characteristics File	Database of details needed for deployment planning.
UAV	Unmanned Aerial Vehicle	
UDM	Unit Deployment Manager	
UE	Unit Equipment	Number of aircraft assigned to a unit.
UIC	Unit ID Code	Identifies the unit assigned to provide a given UTC.
ULN	Unit Line Number	
USAFE	United States Air Forces in Europe	Air component of European Command.
USTRANS-COM	U.S. Transportation Command	
UTC	Unit Type Code	Description of a unit of deployable resources.

Abbreviation	Item/Program/Tool	Description
UTC-DT	UTC Development and Tailoring	Advanced software to enhance the speed and accuracy of UTC development and tailoring.
UTC-O	UTC Optimization	Development of a support tool to optimize cargo loading on one or more pallets.
UV	ultraviolet	
WAA	wartime aircraft activity	
WAAR	WAA Report	
WCCS	Wing Command and Control System	Tools to automate/integrate wing-level command and control processes.
Whr/l	watt-hours per liter	
WIP	work in process	Assets in process at depot.
WL	working level	Sum of CSI and WIP assets.
WMP	War and Mobilization Plan	
WMP	Warfighting Master Plan	
WOC	Wing Operations Center	Deployed command post.
WRM	War Reserve Materiel	Harvest kits and other supplies and equipment in storage for use in a contingency.
WSMIS	Weapon System Management Information System	Basic information system used by AFMC for logistics planning.

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Annex A to Volume 2

Executive Summary from Volume 1

When the Chief of Staff and the Secretary of the Air Force tasked the Air Force Scientific Advisory Board to

> *". . . conduct an intense examination of Air Expeditionary Force operations and to recommend to the Air Force opportunities and options for enabling the Air Force to fulfill the training, deployment, sustainment and employment performance it requires to conduct air expeditionary operations . . ."*

they foresaw the possibility of the Air Force offering increased and valuable military options to the United States. Current Air Force core competencies and near-term technological advances provide the foundation for significant enhancements in both operational capability and responsiveness. This report provides a roadmap to fielding new options for Air Force expeditionary operations.

The Scientific Advisory Board Committee defined *Aerospace Expeditionary Forces* (AEFs) as follows:

> ***Aerospace Expeditionary Forces are tailorable and rapidly employable air and space assets that provide the National Command Authority and the theater commanders-in-chief with desired outcomes for a spectrum of missions ranging from humanitarian relief to joint or combined combat operations.***

In the course of this study, the Committee visited personnel ranging from crew chiefs to commanders, from Mountain Home Air Force Base, Idaho to Tazar, Hungary, and gathered information that leads to the belief, relative to today, that an AEF can

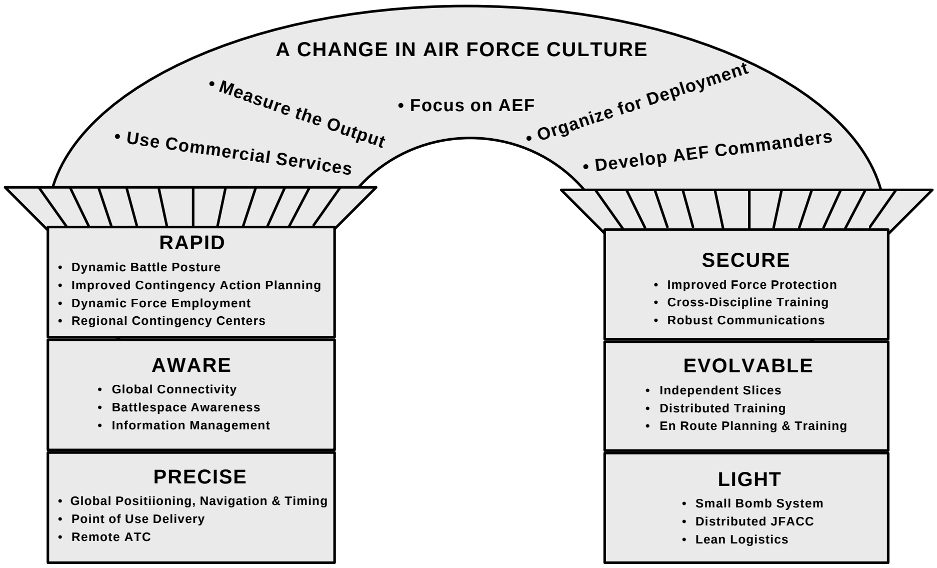
- Respond in less than half the time currently needed, with less than half the airlift, with less than one-third the people forward, to unprepared locations throughout the world
- Operate about an order-of-magnitude more effectively, consistent with other commander-in-chief (CINC) requirements, and with relatively small marginal cost to the current Air Force program and in the near future

Fielding the envisioned AEF will require that the Air Force adopt new operational concepts, new organizational structures, new approaches to training, and new equipment. But most importantly, the AEF is a different culture and the Air Force will have to make the appropriate cultural changes to be successful in this venture.

Taken together, the new approaches will allow the AEF to control the operating tempo of the battlespace by consistently operating with shorter time cycles than the adversary, proactively preparing the battlespace for operations, creating windows of opportunity for AEF exploitation, and inflicting surprise and shock on the adversary. The anticipated result will be a quicker, more efficient achievement of the AEF's objectives with smaller size forces, less support forward, and fewer casualties.

The tremendous leverage created by rapid response to virtually any situation expands the capability of decision makers to influence situations worldwide. Deterrence will be accomplished, in many cases, simply because an AEF exists and the world knows the U.S. has the capability to deliver substantial firepower anywhere in the world within 24 hours. The ability of the AEF to reduce employment timelines to a little more than the flight time from the U.S. to the area of operations provides flexibility to decision makers that has never existed in the past.

The AEF is a giant step forward from today's expeditionary operations, yet it stems from the same core competencies of the Air Force: air and space superiority, global attack, rapid global mobility, precision engagement, information superiority, and agile combat support. The AEF has the potential to provide both a new military capability to the U.S. and a revalidation of the historical basic strengths of the Air Force. The AEF will succeed primarily through fundamental cultural changes in the way the Air Force is organized, trained and equipped.



Keys to the AEF Vision

The essential cultural changes necessary to make an AEF successful include focusing decisions within the Air Force on AEF capabilities, developing commanders who can effectively lead the diverse components of an AEF, organizing the Air Force for rapid deployment, relying upon commercial services (particularly communications), and establishing a continuous self-measurement system based upon desired outcomes.

This new Air Force culture will be technologically enabled by advances in speed of response; understanding of the environment via better use of sensors and connectivity; clear understanding of friendly, enemy and neutral locations and the ability to deliver to precise locations; minimal forward equipment; improved security of forces; and the capability to rapidly assemble and evolve into the right force at the right time. Because the AEF will be used in a variety of scenarios, the Committee identified a spanning set of possible scenarios and subjectively tested the concept against this set. The scenarios used are

- Combat operations mission similar to AEF IV
- Separate combatants mission similar to Bosnia
- Show-of-force mission similar to F-15 fly-overs in Korea
- Counterproliferation mission similar to the Israeli raid on the Iraqi nuclear facility
- Humanitarian relief mission similar to Rwanda
- Battlespace awareness mission

In every scenario and by every relevant measure, the Committee believes the new AEF provides greater (or occasionally equal) capability compared to today's force. One feature of the AEF is that it is easy to test. After a plan is developed to implement the AEF, the Air Force Chief of Staff and the CINCs can and should regularly use no-notice exercises to validate and test the effectiveness of the concept.

To enable this operational vision of Aerospace Expeditionary Forces, the Committee believes AEF implementation needs to be joint and must be integrated appropriately across the other U.S. Military Services, defense-related agencies, and with allies of the U.S. Full implementation of the specific recommendations below will result in a tailorable and rapidly employable Air Force that provides the National Command Authority and the theater commanders-in-chief with desired outcomes for a spectrum of missions ranging from humanitarian relief to joint or coalition combat operations.

Recommendation Relating to the Joint Approach to AEF Implementation

- The Air Force should ensure that requirements are incorporated for an improved AEF capability into national readiness source documents such as DoD Strategic Guidance, Defense Planning Guidance, Joint Chiefs of Staff Strategic Planning and Operational Requirements documents (e.g., Vision 2010), and CINC Integrated Priority documents and joint operational plans.

Recommendations Relating to Operational Characteristics

- The Air Force should organize, train, and equip for deployment and employment of slices (small independent packages) of fighter, bomber, unmanned air vehicle (UAV), tanker, intelligence, surveillance and reconnaissance (ISR), airlift forces, and compatible support slices with an Initial Operating Capability in two years.
- The Air Force should fund the development of munitions with more effectiveness per round and requiring less airlift, such as the Small Bomb System and Low Cost Autonomous Attack System (LOCASS); integrate them on current and planned bombers, fighters, and UAVs; and procure sufficient numbers of the munitions.
- The Air Force should develop the means to do rapid planning, execute employ/deploy mission profiles,[34] and support operational forces from distributed locations, with minimal forward forces, using en route planning, a distributed command center for the Joint Force Air Component Commander, and demand-pull logistics. This concept must be consistent with a minimum forward footprint (people and materiel).
- The Air Force should establish Regional Contingency Centers, implement lean logistics, implement the AEF "Minimum Flight Essential Maintenance" concept, and complete the development and deployment of common operational logistics planning software such as Logisticians' Contingency Assessment Tools (LOGCAT).
- The Air Combat Command (ACC) should be the Air Force lead to work with all relevant DoD and Civil agencies and the Force Protection Battlelab to develop and field effective, highly deployable detection, protection (including nonlethal systems), and decontamination systems for biological, chemical, and laser threats.

[34] "Employ/deploy mission profiles" means that the deploying aircraft (and/or UAVs) conduct a mission at the end of their deployment before landing at their recovery base(s).

Recommendations Involving Information as a Key Enabler

- The Air Force must develop and integrate affordable command and control (C^2) and information systems necessary to find, fix, track, target, and engage any target of interest in the world. This entails establishment of the following:
  - Global Grid system
  - Information management, control, and distribution system
  - Dynamic battle planning tools and systems
  - Geospatial and temporal reference battlespace integration into all AEF platforms, sensors, and weapon systems
  - Maximum integration of commercial systems into AEF-relevant information systems

Recommendations Relating to Instilling a New Air Force Culture

- The Air Education and Training Command (AETC) should provide education and training from the classroom to the field that inculcates the AEF philosophy in all members of the Air Force.
- The Air Force should develop, adopt, and continuously track metrics on AEF performance. Furthermore, Air Force inspections must be revised to reflect the AEF concept and scoring must be consistent with these AEF metrics.

Recommendations Relating to Research and Development, Experiments, and Demonstrations

- The Air Force should perform experiments, both field and Advanced Concept Technology Demonstrations (ACTDs), in command, control, and information, lean sustainment, and force protection as discussed in Chapter 4 of this report.
- The Air Force Materiel Command (AFMC) should ensure that, as part of the SAB annual Science and Technology (S&T) quality review of the Air Force Research Laboratory (AFRL), investments are made that underwrite the AEF concepts described herein.
- The Air Force should place high priority on Research and Development (R&D), particularly in the following areas:

  Near to Mid Term

  - Anti-jam and differential Global Positioning System (GPS) (on-orbit and in user equipment)
  - Information management, access, and distribution
  - Network access management (communications)
  - Remote air traffic control (GPS related)
  - Engine reliability and maintainability (e.g., high cycle fatigue)
  - Embedded diagnostics for engines and avionics with inflight reporting
  - Improved chem/bio masks and detection systems
  - Reachback expertise for medical and maintenance diagnoses (telemedicine, telemaintenance)
  - Communication systems to ensure all forms of “in-transit visibility”
  - Affordable integration of military and commercial satellite systems
  - Distributed and embedded training

  Mid to Far Term

  - Lasers and high power microwave weapons and defensive systems
  - Hypersonics (engines, endothermic fuels, materials, etc.)
  - Space structures (e.g., lightweight structures, deformable optics)

– Reusable launch vehicles

Realizing the New AEF

The Committee envisions Aerospace Expeditionary Forces to be tailorable and rapidly employable air and space forces that provide the NCA and the CINC with the option to produce the desired outcomes for a range of possible missions the country may be called upon to undertake. The full realization of this AEF depends upon the synergistic combination of the many changes to people, systems, and concepts described throughout this report. However, many advances (particularly organizational, planning, and training) can be made relatively rapidly and inexpensively in the near term. The Air Force should undertake these improvements immediately. The Air Force should assure that funding priorities appropriately consider program/system contributions to making the force more expeditionary.

In its travels and meetings, the Committee developed a renewed appreciation for the creativity, initiative, and enthusiasm of the operational Air Force — a group many of the Committee had previously had little opportunity to investigate and understand. While several key recommendations of this report revolve around cultural changes — and cultural changes are often the most difficult ones to effect — the AEF concept is one the people of the Air Force want to make happen. *They* can succeed in providing this new and valuable military capability to the U.S.

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Annex B to Volume 2

Terms of Reference

USAF Scientific Advisory Board 1997 Study on
United States Air Force Expeditionary Forces

11 February 1997

BACKGROUND: The majority of U.S. Air Force and other DoD operations since the end of the Cold War have been limited-objective, non-Major Regional Conflict (MRC) activities (Operation Desert Storm being the primary exception). There have been many of them and they typically lasted a long time, with infrastructure often at a premium. The number of simultaneous operations precluded any one of them being able to count on all the support services the Air Force has for that single event. The likelihood of having months to organize, plan, and deploy has grown increasingly smaller. The need to conduct operations quickly, in austere environments, with a minimum of support and support infrastructure has become the norm.

For more than forty years the Air Force operated out of a robust peacetime infrastructure at home and, most importantly, abroad. This has changed significantly since the breakup of the Soviet Union. The capability to quickly deploy and fight "lean and mean," while a strength of the Air Force in the past, must be "reengineered" today. At the Fall CORONA in October 1996, General Fogleman and his senior Air Force leaders developed a strategic vision for the Air Force. The strategic vision, *Global Engagement: A Vision for the 21st Century Air Force*, charts a path into the next century as an Air Force team within the joint team. Global Engagement is based on six core competencies: *air and space superiority, global attack, rapid global mobility, precision engagement, information superiority,* and *agile combat support.* One aspect of the *global attack* core competency is described as follows:

> "The Air Force has developed and demonstrated the concept of an Air Expeditionary Force (AEF) rapidly deployable from the United States. This expeditionary force can be tailored to meet the needs of the Joint Force Commander, both for lethal and non-lethal applications, and can launch and be ready to fight in less than three days. The Air Force will develop new ways of doing mobility, force deployment, protection, and sustainability in support of the expeditionary concept."

> "Air Force power projection and presence capabilities today are a complementary mix of long-range and theater aircraft, based in the United States and forward-based. The Air Force has relied heavily in the past on the elements of that mix that were permanently forward-based overseas. Currently, the Air Force is increasing the role of expeditionary forces to maintain its global engagement capability. In the future, capabilities based in the continental United States will likely become the primary means for crisis response and power projection as long-range air and space-based assets increasingly fill the requirements of the Global Attack core competency."

STUDY PRODUCTS: Briefing to AF/CC and SAF/OS in October 1997. Report completion by December 1997.

STUDY CHARTER: The goal of the 1997 SAB Summer Study is to conduct an intense examination of AEF operations and to recommend to the Air Force opportunities and options for enabling the Air Force to fulfill the training, deployment, sustainment, and employment performance it requires to conduct air expeditionary operations. Specifically, this study will examine/suggest

- Likely context/constraints for the warfighting elements (e.g., deploy to a specified set of scenarios, meet an operational tasking within a specified time, sustain the tasking with stream resupply for the necessary time, or operate in a specified environment [such as chemical and biological])
- Interoperability and joint service compatibility requirements
- Minimum warfighting elements that need to be forward deployed and deployed infrastructure requirements
- Minimum support facilities required for what length of time
- Minimum system support required, including Battle Management (BM)/C^3ISR
- Concept of operations for logistics, supplies, and support (such as information systems)
- Core expeditionary forces and scenario-dependent supplemental forces
- Recommended investments to support force capabilities
- Security and security system requirements
- Training and training system requirements

SUGGESTED PANEL STRUCTURE

Operational Context and Training Panel. Identify relevant scenarios, describe operational concepts, determine system requirements for deployment and operations, define shortfalls, establish minimum force structure. Define infrastructure for the AEF Battlelab. Define potential organizational structures for AEF.

Technology Thrusts Panel. Identify current technology applications that support expeditionary operations. Establish linkage between shortfalls and technology developments. Identify high-leverage technology investments. Develop investment recommendations and associated costs.

Lean Sustainment Panel. Establish logistics and maintenance concepts (building on AF/ILX concepts) such as reach-back that allow the tasks to be performed at a fraction of the current deployment cube. Define shortfalls and recommend solutions.

Environment (Chemical and Biological and Force Protection) Panel. Identify human factor requirements such as protective gear and operational alternatives for conducting operations in a chemical and biological environment. Define force protection and security concepts. Define potential organizational changes, investment options, and other factors required to accomplish this portion of the AEF mission.

Command, Control, and Information Panel. Tailor top-level BM/command, control, communications, and intelligence (C^3I) architectures (building on the SAB C^2 Vision Study) to support ops concepts.

Identify shortfalls in current systems (in deployability, latency, interoperability, targeting, mission planning, currency, capability, opsec, etc.) and recommend solutions to identified shortfalls.

Integration and Cost Assessment Panel. Integrate and coordinate other panel efforts to develop a coherent program. Identify costs of current and alternative AEF concepts. Establish an affordable approach to the AEF mission.

STUDY MEMBERSHIP

Study Chair	Dr. Ronald P. Fuchs
Senior Advisor to Study Chair	General Michael P.C. Carns, USAF (Ret)
Operational Context and Training Panel Chair	Maj Gen John A. Corder, USAF (Ret)
Command, Control, and Information Panel Chair	General James P. McCarthy, USAF (Ret)
Technology Thrusts Panel Chair	Dr. Robert R. Rankine, Jr., Maj Gen, USAF (Ret)
Environment Panel Chair	Dr. Valerie J. Gawron
Lean Sustainment Panel Chair	Dr. John M. Borky
Integration and Cost Assessment Panel Chair	Dr. William C. Miller
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SAB Executive Officer	Lt Col James F. Berke

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Office of the Secretary of Defense

USD (A&T)	Under Secretary for Acquisition and Technology
USD (A&T)/DSB	Defense Science Board
DARPA	Defense Advanced Research Projects Agency
DISA	Defense Information Systems Agency
DIA	Defense Intelligence Agency
BMDO	Ballistic Missile Defense Organization

Other Air Force Organizations

AFMC	Air Force Materiel Command
– CC	- Commander, Air Force Materiel Command
– EN	- Directorate of Engineering and Technical Management
– AFRL	- Air Force Research Laboratory
– SMC	- Space and Missile Systems Center
– ESC	- Electronic Systems Center
– ASC	- Aeronautics Systems Center
– HSC	- Human Systems Center
– AFOSR	- Air Force Office of Scientific Research
ACC	Air Combat Command
– CC	- Commander, Air Combat Command
– ASC^2A	- Air and Space Command and Control Agency
– 366th Wing	- 366th Wing at Mountain Home Air Force Base
AMC	Air Mobility Command
AFSPC	Air Force Space Command
PACAF	Pacific Air Forces
USAFE	U.S. Air Forces Europe
AETC	Air Education and Training Command
– AU	- Air University
AFOTEC	Air Force Test and Evaluation Center
AFSOC	Air Force Special Operations Command
AIA	Air Intelligence Agency
NAIC	National Air Intelligence Center
USAFA	U.S. Air Force Academy
NGB/CF	National Guard Bureau
AFSAA	Air Force Studies and Analysis Agency

U.S. Army

ASB	Army Science Board

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U.S. Navy

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J8	Force Structure, Resources and Assessment

Other

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