The Anti-Access Threat and Theater Air Bases

by

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Executive Summary

The Department of Defense (DoD) in its 2001 Quadrennial Defense Review (QDR) concluded that the "anti-access" threat—the complex mix of political, geographic, and military factors that could prevent or delay US forces from deploying to a combat theater—is the dominant strategic challenge confronting future US power-projection operations in regions of potential conflict, particularly in Asia.

To analyze the seriousness of this challenge, this paper focuses on one key aspect—the potential vulnerability of theater bases for land-based fighter aircraft. American combat air power, provided primarily by the United States Air Force (USAF), plays a critical and growing role in US power-projection operations. Over the next two to three decades, Defense Department combat aircraft plans are focused on modernizing the fighter force. Should emerging anti-access threats undermine theater fighter base viability, future US military operations could be jeopardized.

To conduct this analysis, this report addresses four key related issues:

- What are the basing and logistical requirements for land-based fighters in future combat operations?
- To what extent do these kinds of bases (and supporting logistics) exist?
- How vulnerable are these bases to political access problems and to emerging military threats?
- What potential counters are available to minimize these threats?

This report suggests that over the long run, the combined uncertainties raised by political factors, logistics, and emerging military threats mean that the combat power of the land-based fighter force may be significantly constrained in supporting US power-projection operations in an anti-access environment. To hedge, the Defense Department should adjust its current combat aircraft modernization plans, which focus primarily on the acquisition of fighter aircraft, to increase spending on systems less reliant upon forward bases.

The issues raised in this analysis have broader strategic implications for the US military as a whole. Reliance on large, fixed facilities in the theater of operations is much more than an Air Force issue. Given the growing role of air power forces in US military operations, constrained USAF fighter operations would increase the vulnerability of joint forces to military threats and decrease overall force effectiveness. Army, Navy, and Marine forces are dependent upon forward ports, airfields, and bases in the theater to conduct combat operations. Many of these forces must engage adversaries at much shorter distances than land-based fighters, thus exposing them to even greater risk from anti-access threats. The susceptibility of these force elements to emerging anti-access threats may differ from land-based fighters due to force characteristics, logistical requirements, and basing modes, but should be analyzed in similar detail to guide decision-making on future force posture and force modernization priorities.

Summary Results

What Are the Basing and Logistical Requirements for Land-Based Fighters in Future Combat Operations?

Taking into account the inter-related factors of aircraft characteristics, aircrew fatigue, combat mission profiles, aerial refueling requirements, sortie rates, and aircrew to aircraft ratios, land-based fighters typically will require bases within 1,000 to 1,500 nautical miles of enemy borders to conduct effective operations.

Based on historical requirements, five theater bases would be required for each Aerospace Expeditionary Force (AEF), which contains approximately two traditional wings of fighters. The Vietnam conflict required almost six AEF equivalents; the Gulf War around five; Serbian operations about two.

Forward-based fighters must be supplied with munitions and fuel to conduct sustained operations. Depending on aircraft type, each deployed aircraft would consume three to eight tons of current-generation weapons per day (though these requirements will decrease with future weapons) and about double that tonnage in fuel. Depending on the base, the United States may need to deploy additional equipment to support operations.

To What Extent Do These Kinds of Bases (and Supporting Logistics) Exist?

Overall numbers of developed airfields increased dramatically around the world following World War II under the impetus of two main drivers: Cold War imperatives and commercial air traffic growth. Base infrastructure development was most concentrated in Europe, Northeast Asia, and the Persian Gulf. In most of Asia, the emerging focus of current Pentagon planning, the basing infrastructure is less developed. Analysis of the global airfield data base[1] illustrates that Asia contains only about 14 percent of the world's airfields. Half of these are located in the developed nations of Australia, Japan, and South Korea. As the Defense Department recently concluded regarding Asia "the distances are vast….The density of US basing and en route infrastructure is lower than in other critical regions. The United States also has less assurance of access to facilities in the region."[2]

Experience from numerous conflicts, notably the 1967 and 1973 wars between Israel and Arab states, has demonstrated the critical role hardened aircraft shelters play in reducing vulnerability to air base attacks. Fifty-two bases in Asia—about 18 percent of the total—field a total of 1,412 hardened aircraft shelters. At first glance, this large number would appear sufficient to house US deploying fighters, but availability is likely to be lower for several reasons. Reflecting 50 years of preparation for war, almost half (641) of the total shelters in Asia are concentrated in South Korea. Employing these bases to conduct operations other than for South Korea's defense raises uncertainties; South Korea may be reluctant to get engaged, while the bases could come under heavy attack from North Korea should a conflict widen. Most of the other shelters are located in Japan (107

[1] Data base does not include airfields in Russia, China, or North Korea.

[2] Donald Rumsfeld, *Quadrennial Defense Review Report* (Washington DC: Office of the Secretary of Defense (OSD), September 30, 2001), p. 4.

shelters); Taiwan (203 shelters), India (229 shelters) and Pakistan (176 shelters)—an average of about 180 per nation, sufficient to shelter a single AEF. But the total number available for use could be reduced by several factors. Are these widely separated bases located in the right position for the conflict? Will the nation support combat operations from its soil by US aircraft? Finally, each nation fields substantially more combat aircraft than shelters. Accordingly, the host nation would need to expose more of its own aircraft to attack in order to shelter US aircraft. All this suggests that the number of shelters available for use will be lower than the total and in a larger-scale conflict, significant numbers of US fighters could have to deploy to unhardened bases.

Regarding logistics, forward-deployed aircraft require fuel and munitions to operate from host nation airfields. Aviation fuel could be readily available; if not, fuel is a fairly fungible commodity that, with sufficient time, could be provided to the fighting force. Fuel production, storage, and distribution facilities would, however, remain vulnerable to attack. Supplying munitions has historically been the most challenging logistical task, but advances in munitions technology offer the potential to increase radically US flexibility in supporting deployed forces.

How Vulnerable Are These Bases to Political Access Problems and To Emerging Military Threats?

Political Anti-Access Threats to Forward Bases

Although the number of airfields has increased around the world, the USAF's overseas basing posture has declined because of changing strategic circumstances, budgetary pressures, and internal opposition from host nations. To employ forward bases and air space, the United States will need political support from host countries. Political access problems have erupted in almost every contingency and conflict in which the United States has engaged since World War II. The United States has powerful economic, diplomatic, and military cards to play in securing access—and has employed these cards successfully in many crises. But historical evidence also demonstrates that on many occasions, difficulties in obtaining political access to airspace and bases has constrained US power-projection capabilities.

The attitude of host countries regarding access in future crises is difficult to predict, raising significant uncertainties regarding the basing and employment of combat aircraft. The United States can bring enormous pressure to bear on a host country to accept US forces, but success, as has been seen in numerous crises, cannot be guaranteed.

Military Threats to Theater Bases

Deep-Strike Systems

Many potential adversaries are increasing their emphasis on the procurement of ballistic and cruise missiles. Government intelligence forecasts anticipate adversaries possessing larger numbers of longer-range ballistic and cruise missiles. The proliferation of satellite navigation systems, submunition warheads, and re-entry vehicle guidance systems has the potential to increase dramatically ballistic missile accuracy and lethality. Long-range, land-attack cruise missiles, which offer even higher accuracy than ballistic missiles, continue to proliferate. In addition, the new

generations of ballistic and cruise missiles entering service can be fired from mobile launchers, which are much more difficult to locate and attack than fixed launch sites.

Multiple nations are placing commercial reconnaissance satellites into orbit that could provide adversaries with precision information to target their growing deep-strike arsenals. Commercially-based imagery can pinpoint the forward deployment and disposition of American and allied military forces in the region to facilitate the timing and effectiveness of enemy strikes. Attempts to control access to satellite imagery will prove increasingly difficult as the number of imagery sources grows.

Hardened military air bases are resilient entities. Historical evidence illustrates that large numbers of precision weapons would be needed to knock a hardened military air base out of commission for a substantial time period. The same does not hold true for less protected military and commercial airfields. At unhardened airfields, aircraft parked on ramps, fuel stocks, and munitions would be vulnerable to the new threats. Capabilities to restore runways, electrical power, and fuel supplies would be less resilient than at hardened military airfields.

Toward the end of the Cold War, the USAF found it could not afford to ensure the survivability of its air bases in Europe. The sheer mass of anticipated Soviet attacks had the potential to overwhelm available passive and active defenses. The future ballistic and cruise missile threat has different characteristics: less mass but much greater precision. These weapons are less threatening to hardened facilities and runways than traditional strike aircraft, but potentially more devastating against aircraft parked in the open, fuel facilities, and munitions storage areas.

Special Forces Attacks

Since 1942, special forces worldwide have conducted 645 separate attacks on airfields to destroy over 2,000 aircraft on the ground. Special forces pose a growing potential threat because of the proliferation of more accurate stand-off weapons, which increases the perimeter US forces must defend. The most worrisome threats include precision munitions for mortars (which would enable attackers to hit high value targets with a small number of rounds); long-range, large caliber sniper rifles (which could be used against high-value aircraft to knock out key components); and anti-tank rockets (which could be used to penetrate aircraft and personnel shelters).

Weapons of Mass Destruction

Weapons of mass destruction (WMD) employed against an air base have the potential to disrupt the flow of US forces into a region, degrade combat sortie generation rates, and kill large numbers of US personnel. A nuclear strike could obviously knock a base out of action. US forces are trained to operate in a chemical or biological environment, but the presence of such substances could slow the pace of operations.

US policy is to deter WMD use with the threat of retaliation. This policy apparently succeeded in the 1991 war with Iraq. The United States would also, as was seen in the Gulf War, attempt to destroy an adversary's weapons, research facilities, and means of delivery to reduce the threat to US and allied forces. The Gulf War highlighted the multi-faceted difficulties confronting such operations.

The presence of WMD raises two key access-related issues:

- Allies may be deterred from granting access to US forces in order to prevent WMD employment on their soil.

- An adversary possessing WMD is bound to make a US decision-maker reflect carefully about placing aircraft and thousands of US personnel in harm's way on forward air bases.

Are There Potential Counters to Anti-Access Threats?

Political initiatives

The United States should engage as wide an array of nations as possible to increase the chances of obtaining access when needed. Nonetheless, history illustrates that the unpredictability of the location and nature of future conflicts will make it difficult to forecast the attitude of host country when access is needed.

Infrastructure Development (Base Development, Pre-Positioning)

To augment the current basing infrastructure in Asia, developing additional hardened facilities would be an option; however, one that will take time. Developing a similar network of facilities in Western Europe and the Persian Gulf took decades of sustained effort. Unfortunately, Asia's vast size combined with the range limitations of fighter aircraft demands enormous prescience in predicting accurately the general location of future conflicts. Given such vast distances, the United States could expend enormous resources on base infrastructure development and "get it wrong."

The high cost is also a significant complicating factor. Trying to hedge bets by conducting base development in multiple locations would cost tens of billions of dollars. The cost of base development just in Saudi Arabia—a single country with a much smaller land mass compared to Asia—was estimated at over $30 billion in current year dollars. Even with this significant investment, most US aircraft were forced to park in the open during the 1991 Gulf War. Developing hardened bases in Europe was even more costly and, by the end of the Cold War, still insufficient to protect many deployed USAF aircraft.

Dispersal

Dispersing the force across more airfields would be an obvious counter to reduce vulnerability at unprotected airfields. To implement such dispersal concepts, the USAF would need to invest more heavily in its support structure. Dispersal proposals developed during the Cold War were constrained because of the significant costs of expanding the support structure (more ground support equipment, maintenance personnel, and base security) and reconfiguring all aircraft (to improve their capability to operate from austere fields). Dispersing the force would also require access to more airfields at a time when the US is concerned about gaining access to sufficient bases using traditional concentrations of aircraft.

Suppress Anti-Access Threats Rapidly

The USAF currently plans to employ the B-2 and F-22 force, working in conjunction with carrier air power and naval surface combatants and submarines, to neutralize enemy mobile air defense system; strike enemy airfields (to eliminate enemy aircraft); shoot down enemy aircraft; hunt down mobile enemy ballistic and cruise missiles; knock out WMD production and storage facilities; and, if necessary, deal with enemy ground offensives. Because of the small size of the USAF "access insensitive" force and the size of the job, such operations could take a considerable amount of time, particularly if an adversary conceals its missile forces until US forces begin deploying (and thus constitute a more lucrative target).

Large Manmade Islands

In the 1990s, the Office of Naval Research sponsored a science and technology program on what was termed the Joint Mobile Offshore Base (JMOB)—a large floating structure capable of handling land-based aircraft and providing logistical support. Such bases would greatly increase US flexibility in deploying aircraft forward, but may also present an opponent with an attractive target. The cost of a single JMOB was estimated at about $6 billion, but the concept currently has no ardent supporters in the Pentagon.

Active Defenses

Active defenses could help alleviate concerns if they become effective, but uncertainty remains whether US missile defense systems, once fielded and deployed, can reliably defeat enemy ballistic missiles. Indeed, a primary reason these weapons are proliferating is the difficulty of defending against them. Cruise missiles also pose challenges. If successfully detected, cruise missiles can be engaged successfully by a variety of platforms, but maintaining defenses constantly on alert would strain the deployed force and reduce US offensive capabilities. Overall, an adversary could probably overcome US defenses by fielding sufficient numbers of missiles to conduct massed volleys; some missiles would probably get through to inflict damage on forward bases.

Base Outside the Range of Threat Systems

If adversaries can threaten US bases within 1,500 nautical miles, fighter operations over extended ranges become less viable and call into question current US aircraft modernization policies. Long-range systems would increase US basing options and decrease the number of enemy systems that can attack US bases. But a new long-range system will take time to develop. Air Force estimates do not envision a new long-range system entering service for another 20–30 years, while the economic and political challenges involved in developing and fielding a new system are substantial. For the near to medium term, Air Force options include expanded purchases of stand-off weapons, additional B-2 procurement, adding refueling capabilities to the proposed Unmanned Combat Air Vehicle (which would not have the pilot fatigue issues that constrain the mission radii of fighter aircraft). The Defense Department could also consider increasing reliance on maritime forces such as aircraft carriers, surface combatants, and submarines.

Conclusions

The requirement to base fighters within 1,000 to 1,500 nautical miles of an adversary raises three key issues:

- Can the United States count on getting access to forward bases? Trends here appear negative. The US peacetime, foreign basing posture has declined precipitously since the Cold War. US long-term presence has stimulated indigenous opposition, and access constraints continue to bedevil combat operations. Predicting the attitude of host nations regarding access in a future crisis remains difficult.

- Will adversaries deploy sufficient numbers of long-range ballistic and cruise missiles to threaten forward bases? Longer-range weapons are more expensive than shorter-range variants, which raises an adversary's cost of fielding large numbers. But ignoring this threat does not seem acceptable. Over the long-term, the United States would be placing a significant portion of its combat capability at risk. Analysis of potential counters to make forward bases less vulnerable—hardening, dispersal, and missile defense—indicates that these may be imperfect and possibly unaffordable solutions. The USAF reached a similar conclusion at the end of the Cold War regarding air base survivability in Europe. Perhaps the USAF's Global Strike Task Force in combination with maritime forces will prove successful in neutralizing an adversary's deep-strike systems, but the small size of the USAF's access insensitive force combined with the magnitude of the operational tasks it must achieve causes concern. It also raises some difficult problems regarding logic for the USAF. If these small forces can succeed in this most difficult and challenging set of tasks, what is the justification for the rest of the force? Why not simply increase the size of the access insensitive force to increase the chances of success and use these for the duration of the campaign?

- What will be the effect of adversaries possessing WMD? The threat of WMD strikes would appear to reduce both allied willingness to host US forces and US decision-makers' willingness to risk deploying forces.

To project power, US forces relying on forward bases require success in four areas: an adequate base infrastructure, responsive logistical support, political approval from host nations, and effective counters to enemy threats. If one of these factors is missing, US power-projection capabilities will be compromised. The problem facing the United States is that even a high probability of success in each factor results in an overall low probability of success. For example, with a 90 percent chance of succeeding in each area, only a 65 percent overall probability of success results (90 percent X 90 percent X 90 percent X 90 percent = 65 percent) In short, these combined uncertainties suggest that over the long term, the land-based fighter force could be significantly constrained in supporting US power projection operations.

In the 2001 QDR, the Defense Department noted the importance of "hedging" strategies to cope with assumption failures or unanticipated developments. Over the past 30 years, the USAF "hedged" by allocating on average two-thirds of each modernization dollar to short-range combat aircraft and one-third to long-range combat aircraft. Current plans, however, change these ratios from 2:1 to 30:1 in favor of short-range forces more dependent upon forward bases. The political problems,

logistical issues, and military threats posed to forward air bases individually raise challenges, but the uncertainties and risks induced by all these factors together in future conflicts suggest that the Defense Department leadership should re-evaluate these plans to meet the goal of projecting decisive power promptly in future anti-access environments.

I. Introduction

The Department of Defense (DoD) in its Quadrennial Defense Review (QDR) has concluded that the "anti-access" threat—the complex mix of political, geographic, and military factors that could prevent or delay US forces from deploying to a combat theater—is the dominant strategic challenge confronting future US power-projection operations in future conflicts, particularly in Asia.[3]

To analyze the seriousness of this challenge, this paper focuses on one critical aspect—the potential vulnerability of theater bases for land-based fighter[4] aircraft to anti-access threats. American combat air power, provided primarily by the United States Air Force (USAF), plays a critical and growing role in US power-projection operations. Over the next two to three decades, Defense Department combat aircraft plans place the highest priority and investment emphasis on modernizing the fighter force. Should emerging anti-access threats undermine theater fighter base viability, future US military operations could be jeopardized.

In 1997, Congress commissioned a distinguished group of strategists and retired senior military generals known as the National Defense Panel (NDP) to conduct a review of US military strategy in conjunction with the ongoing Quadrennial Defense Review. Chaired by Philip Odeen, the NDP[5] formally laid out what would become known as the "anti-access" threat by stating:

> The cornerstone of America's continued military preeminence is our ability to project combat power rapidly and virtually unimpeded to widespread areas of the world. Much of our power projection capability depends on sustained access to regions of concern. Any number of circumstances might compromise our forward presence (both bases and forward operating forces) and therefore diminish our ability to apply military power, reducing our military and political influence in key regions of the world. For political (domestic or regional) reasons, allies might be coerced not to grant the United States access to their sovereign territory. Hostile forces might threaten punitive strikes (perhaps using weapons of mass destruction) against nations considering an alliance with the United States….

[3] See Donald Rumsfeld, *Quadrennial Defense Review Report* (Washington DC: Office of the Secretary of Defense (OSD), September 30, 2001). The report states that "projecting and sustaining US forces in distant anti-access or area-denial environments and defeating anti-access and area- denial threats" is one of the Defense Department's six key operational goals driving the need for transformation. Ibid. p. 30. Many of the other operational goals are related, such as protecting forward bases and the homeland from attack, conducting persistent tracking of enemy threat systems that can threaten US theater forces, and leveraging information technology and new concepts to conduct more effective joint operations. The QDR notes regarding future regions, "In particular, Asia is gradually emerging as a region susceptible to large-scale military competition. Along a broad arc of instability that stretches from the Middle East to Northeast Asia, the region contains a volatile mix of rising and declining regional powers. The governments of some of these states are vulnerable to overthrow by radical or extremist internal political forces or movements. Many of these states field large militaries and possess the potential to develop or acquire weapons of mass destruction. Maintaining a stable balance in Asia will be a complex task. The possibility exists that a military competitor with a formidable resource base will emerge in the region." Ibid., p. 4.

[4] I use the term "fighters" to refer to single- or dual-engine combat aircraft. I prefer this word to the term "tactical aircraft," or TACAIR, which was favored during the Cold War, because both land-based and sea-based "tactical" aircraft have been employed to strategic effect.

[5] See *Transforming Defense: National Security in the 21st Century* (Washington DC: DoD, December 1997). Panel members included Ambassador Richard Armitage, General Richard D. Hearney (USMC, Ret), Admiral David E. Jeremiah (USN, Ret.), Robert M. Kimmitt, Dr. Andrew F. Krepinevich (USA, Ret.), General James McCarthy (USAF, Ret.) Dr. Janne E. Nolan, and General Robert W. RisCassi (USA, Ret.).

> Even if we retain the necessary bases and port infrastructure to support forward deployed forces, they will be vulnerable to strikes that could reduce or neutralize their utility. Precision strikes, weapons of mass destruction, and cruise and ballistic missiles all present threats to our forward presence, particularly as stand-off ranges increase. So, too, do they threaten access to strategic geographic areas. Widely available national and commercial space-based systems providing imagery, communications, and position location will greatly multiply the vulnerability of fixed and, perhaps, mobile forces as well.
>
> At the same time, constraints on forward-basing (i.e., infrastructure outside the continental United States: ports, installations, prepositioned equipment, and airfields) and advanced technologies threaten to impede our access to key regions.[6]

Debate over the NDP's conclusions has dominated strategic policy ever since. Defense Department opinions are divided on the severity of this threat.

The Air Force argues that problems related to gaining political access to bases are overstated. General John Jumper, as commander of USAF forces in Europe, stated in late 1998 that: "Access is an issue until you begin to involve the vital interests of the nation that you want and need as a host. Then access is rarely an issue."[7] During a Congressional hearing on the access issue in March 1999, General Joseph Ralston, the Vice Chairman of the Joint Chiefs, observed: "If we stay engaged with our allies, we will have access when we need it."[8]

In terms of military threats, the Air Force had traditionally argued that air bases were extremely difficult to knock out of action. The USAF shifted its position to claim during the 2001 QDR that a stealth strike team composed of F-22s and B-2s could quickly degrade military anti-access threats to enable the safe deployment of other land-based fighters and joint forces.

In general, the Air Force position is that sufficient air bases are available to support operations around the world; political issues surrounding base access can be overcome; and military threats are overstated and can be suppressed quickly. This position is reflected in current Air Force combat aircraft modernization planning, which is focused almost exclusively on procuring fighter aircraft[9] for the next two to three decades.[10] A new, long-range, strike system less dependent on forward

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[6] Ibid., pp. 12–13.

[7] See "The Access Issue," *Air Force Magazine*, December 1998.

[8] General Ralston's testimony is contained in the hearing of Senate Armed Services Subcommittee on Airland Forces, March 10, 1999.

[9] See Section II for an analysis of the potential effective combat radii of fighter aircraft.

[10] The Air Force plans to procure 295–339 F-22 air superiority fighters, 1,763 Joint Strike Fighters (JSFs), the Unmanned Combat Air Vehicle (UCAV), which is similar to a fighter in combat radius, and possibly a medium-range attack variant of the F-22. To afford these programs, the Air Force reduced the size of the B-1B force and rejected initiatives by OSD to restart the B-2 bomber production line. These plans are a substantial break with past USAF investment strategy. Historically, the USAF has balanced its combat aircraft modernization investment resources between long-range bombers and short-range fighters. Over the past 30 years, the Air Force invested two-thirds of each combat aircraft investment dollar in fighter modernization and one-third in bomber modernization; current plans envision an investment ratio closer to 30:1 in favor of fighters. See Appendix I for USAF investment history and Williamson Murray, *The United States Should Begin Work on a New Bomber Now* (Washington, DC: The Cato Institute, March 2000) for an analysis of future spending plans.

bases will not be fielded for another two to three decades.[11]

The Navy takes the opposite viewpoint. For decades, the Navy has argued that political access problems underpin the requirement for aircraft carriers. In 1990, for example, the Navy released a briefing chart to Congress to make this point. The chart contrasted the 40-year operational career of an aircraft carrier compared to the history of Wheelus Air Force Base (AFB) in Libya over the same time frame. The carrier participated in numerous operations around the world and was constantly upgraded with new aircraft. In contrast, Wheelus was activated in June 1948, supported USAF bomber deployments and the Lebanon operation in the 1950s, but was evacuated following the 1969 coup in Libya that brought Khadaffi to power. In 1986, the USAF bombed its former base during Operation Eldorado Canyon.[12]

The Navy has consistently maintained this message in its public policy statements. In commenting on the Air Force's inability to get permission to launch its fighters from Saudi Arabia and Turkey to attack Iraq in September 1996, a Navy official stated: "The Air Force has been castrated. With an aircraft carrier, you get 4.5 acres of Americana with no diplomatic restrictions on when and what you can fly."[13] More recently, the Navy has placed heavier emphasis on the military vulnerability of forward bases. As the Chief of Naval Operations, Admiral Jay Johnson, stated in 1997: "Over the past ten years, it has become evident that proliferating weapon and information technologies will enable our foes to attack the ports and airfields needed for the forward deployment of our land-based forces."[14] An recent Navy-sponsored MIT study states baldly: "…major ground formations and air expeditionary forces will face serious military constraints on their ability to deploy to major contingencies because the ports and airfields that they now depend on will simply not be viable."[15] In the 2001 QDR, the Navy position briefing argued that forward-deployed naval forces were critical to defeating anti-access threats, enabling land-based air and ground forces to move to the theater. During Afghanistan combat operations, numerous naval officers pointed out (usually on background to reporters) how forward basing constraints had relegated the Air Force fighter force to the sidelines.[16] Echoing this theme, the Secretary of the Navy, Gordon England, in testimony to the Senate in 2002, stated:

> Naval forces of the 21st century will continue to offer secure sea bases from which our sailors and Marines will be able to operate both in peace-

[11] Developing and fielding the B-2 bomber took approximately 20 years of sustained effort. Recent Air Force analysis conducted in 2000 concluded that current technology was insufficiently mature to support development of a long-range strike system with capabilities better than a B-2. Accordingly, bomber modernization would have to wait another decade until the technological picture had changed to support development of a more advanced system. Adding in two decades of development, testing, and procurement means a new system will not enter service until 2030 at the earliest.

[12] The Air Force regarded the Navy slide as a serious attack on land-based air power forces. The author was on the Air Staff at the time and was tasked to develop an Air Force counter for circulation in Congress.

[13] John Mintz, "Navy, Air Force Compete to Hit Iraq," *The Washington Post*, September 12, 1996.

[14] Admiral Jay Johnson, "Anytime, Anywhere: A Navy for the 21st Century," *United States Naval Institute Proceedings*, November 1997, p. 49.

[15] Owen R. Cote, Jr., *Assuring Access and Projecting Military Power Abroad* (Boston, MA: MIT Security Studies Program, 2001).

[16] In Operation Enduring Freedom, carrier-based fighters delivered 43 percent of precision-guided weapons, bombers delivered 46 percent, land-based fighters about 10 percent. Bombers also delivered over 7,000 unguided weapons. See William Arkin, "Weapons Total from Afghanistan Includes Large Amount of Cannon Fire," *Defense Daily*, March 5, 2002.

> time and wartime alike. Such bases will offset the restrictions caused by sovereignty issues, which increasingly limit or impede our national strategies, especially during crises.[17]

The Office of the Secretary of Defense embraced the National Defense Panel's conclusions and has emphasized the perils posed by emerging anti-access threats as a key reason to transform the US military. As the recent QDR report laid out: "projecting and sustaining US forces in distant anti-access or area-denial environments and defeating anti-access and area-denial threats" is one of OSD's highest priority operational goals.[18] As Afghanistan operations highlighted the problems political access, distance, and limited infrastructure posed to US forces, Deputy Secretary of Defense Wolfowitz remarked on November 14, 2001:

> Although our access to Afghanistan has improved steadily and most recently spectacularly, we have been forced by circumstances to operate from very great distances, and this against an enemy whose active efforts to deny us access have met so far with little success. It's only a shadow of what a more determined, more advanced enemy could do.[19]

This study's objective is to provide a perspective on the seriousness of the anti-access threat to theater air bases. The analysis addresses four key related issues:

- What are the basing and logistical requirements for land-based fighters in future combat operations?
- To what extent do these kinds of bases (and supporting logistics) exist?
- How vulnerable are these bases to political access problems and to emerging military threats?
- What potential counters are available to minimize these threats?

The reliance on large, fixed facilities in the theater of operations is more than an Air Force issue. Given the growing role of air power forces in US military operations, constrained USAF fighter operations would increase the vulnerability of joint forces to military threats and decrease significantly overall force effectiveness. Army, Navy, and Marine forces are also dependent upon forward ports, airfields, and bases in the theater to conduct combat operations. Accordingly the issues this analysis raises have broader implications for the US military as a whole.

[17] Gordon England, Transcript from Senate Armed Services Committee Hearing, Feb, 14, 2002.

[18] Rumsfeld, *Quadrennial Defense Review Report*, p. 30.

[19] Paul Wolfowitz, remarks at the Fletcher Conference, Ronald Reagan Building and International Trade Center, November 14, 2001.

II. Context

Debate over air base vulnerability to political and military threats has emerged episodically in public and internal debates since World War II. Cold War efforts focused primarily on the military threat. In the early 1950s, Albert Wohlstetter led a team at the newly formed RAND Corporation, an Air Force "think tank," that conducted an extensive analysis of the USAF's planned force and basing posture. To conduct nuclear-strike missions, the Air Force planned to deploy approximately 1,700 medium-range bombers to 70 forward bases around the periphery of the Soviet Union. Once deployed, the bombers would be refueled and armed to make ready for nuclear strikes. Wohlstetter's analysis, entitled *Selection and Use of Strategic Air Bases*, concluded that the Air Force plan was extremely vulnerable to a Soviet nuclear offensive blow and instead recommended locating the force in the United States and using overseas bases primarily for ground refueling upon the opening of hostilities.[20]

Wohlstetter's team noted that a force based in the continental United States (CONUS) supported by aerial refueling was the optimal solution but was very costly. The startling conclusions of vulnerability, however, led the Air Force's Strategic Air Command (SAC) to embrace moving toward a force comprised of CONUS-based, long-range bombers supported by aerial refueling to maximize warning times and minimize vulnerability.[21]

The USAF's Strategic Air Command was the Air Force's dominant element during the 1950s and 1960s, while the Tactical Air Command, which was responsible for the fighter forces, played a secondary role. The policy shift under the Kennedy Administration from massive retaliation to flexible response led to a growing emphasis on fighter aircraft to provide a conventional "pause" in the event of a Soviet invasion of Europe. Fighters were critical for securing air superiority and conducting conventional interdiction and close air support missions in the European theater. Whereas the ratio of fighters to bombers in the 1950s stood at only 2:1, under the influence of flexible response (and the increasing demands of the Vietnam conflict), fighter/bomber ratios by the end of the 1960s stood at 8:1.[22] Growing numbers of fighter pilots began to rise in seniority to challenge the "Bomber Barons" who had dominated the Air Force since World War II. By the mid-1990s, the so-called "Fighter Mafia" had achieved dominance in the general officer ranks.[23]

At the outset of the 1967 Arab-Israeli War, Israeli Air Force (IAF) fighters and medium bombers conducted a devastating pre-emptive strike against the Egyptian Air Force that brought base vulnerability to the fore once again. At 8:45 a.m. on June 5, 1967, Israeli fighter-bombers struck simultaneously against nine Egyptian bases in a successful surprise attack. The Israelis strafed, bombed, and rocketed the Egyptian aircraft on the ground, then closed the runways with a rocket-

[20] A. J. Wohlstetter, F.S. Hoffman, R. J. Lutz, and H. S. Rowen, *Selection and Use of Strategic Air Bases*, R-266 (Santa Monica, CA: The RAND Corporation, April 1954).

[21] Fred Kaplan, *The Wizards of Armegeddon* (New York: Simon and Schuster, 1983), pp. 85–110.

[22] For an overview of these changes, see General Richard E. Hawley, (USAF, ret,) "Back to a Bomber-Centric Attack Force," *Strategic Review*, XXIX, No. 2, Spring, 2001, pp. 41–48.

[23] Of the 283 serving Air Force generals in 1995, 60 percent had fighter experience, while only 10 percent had bomber experience. Of the 10 four star generals, nine had fighter experience, none had bomber experience. See Andrew Krepinevich, *The Air Force of 2016* (Washington, DC: CSBA, 1996), p. 19.

assisted runway penetrating weapon called the "dibber" to keep the Egyptian Air Force aircraft trapped at the bases. Within an hour, the Egyptian Air Force has lost more than one hundred aircraft. The IAF fighters recovered, rearmed, and launched additional attacks. Within five hours, 300 aircraft—half of the Egyptian Air Force—had been destroyed.[24] The IAF also struck Syria, Jordan, and Iraq to destroy a total of 400 aircraft during the first day of combat.[25]

The Israeli strikes prompted widespread concern over the vulnerability of main operating bases and, in response, the United States and its North Atlantic Treaty Organization (NATO) allies launched an extensive program to improve base survivability, particularly in the European theater. Initiatives included "hardening" the bases by constructing protective shelters (known as TAB-Vs in the USAF) for aircraft, maintenance gear, and pilots; increasing the number of operating surfaces; pre-positioning rapid runway repair (RRR) capability;[26] and increasing the number of potential bases overall (the collocated operating base program) to reduce force concentration. The USAF extended these efforts to bases in Korea and Japan. Several other nations followed suit. In the 1973 Arab-Israeli War, IAF fighters attacked Arab air bases, but were far less effective in destroying aircraft on the ground and closing runways because of the shelters and runway repair equipment.[27] Iraqi air bases in the 1991 Gulf War featured many of these improvements, such as multiple operating surfaces and hundreds of aircraft shelters distributed across 17 military air bases. [28]

Several nations went beyond the USAF and its European allies in implementing "base operability" programs. The NATO shelters in Europe were primarily aimed at preventing damage from blast and fragments and could not protect against a direct hit by a general purpose or penetrating bomb.[29] Saudi Arabia installed highly advanced shelters, which featured much thicker walls and roofs, on some of its bases. The shelters were also built with blocking walls to prevent an opponent from delivering weapons against the shelter doors. Iraqi bases developed in the 1980s also featured much thicker walls than USAF and NATO shelters. Probably Israel, Switzerland, and North Korea conducted the ultimate hardening efforts. The Israelis constructed extensive underground facilities to minimize vulnerability. These shelters provided important operational security advantages as well; aircraft could be prepared for missions below ground and then brought to the surface to launch (giving minimal intelligence tipoffs to adversaries of impending operations).[30] The Swiss and North Koreans developed hardened mountain bases. The Swiss facilities, housed in man-made granite caverns, are designed to allow maintenance crews to repair, fuel, and arm aircraft inside the base, and to permit the aircraft to actually begin takeoff rolls from *inside* the mountain.

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[24] Lon Nordeen, *Fighters over Israel* (New York: Orion Books, 1990), pp. 66–72.

[25] John Kreis, *Air Warfare and Air Base Air Defense, 1914–1973* (Washington, DC: Office of Air Force History, 1998), pp. 317–19.

[26] Rapid Runway Repair for a single base requires a substantial amount of material: a tractor trailer, front end loaders, dump trucks, concrete cutting saws, a water truck, pre-cast concrete slabs, and several hundred tons of gravel, concrete, and sand. See John Halliday, *Tactical Dispersal of Fighter Aircraft: Risk, Uncertainty, and Policy Recommendations* (Santa Monica, CA: The RAND Corporation, 1987), p. 27.

[27] Ivan Rendall, *Rolling Thunder: Jet Fighter Combat from World War II to the Gulf War* (New York: The Free Press, 1999), p. 194.

[28] *Gulf War Air Power Survey, Volume III, Part 2: Effects and Effectiveness* (Washington, DC: HQ USAF, 1993), p. 101.

[29] Halliday, *Tactical Dispersal of Fighter Aircraft: Risk, Uncertainty, and Policy Recommendations*, p. 17.

[30] Rendall, *Rolling Thunder: Jet Fighter Combat from World War II to the Gulf War*, p. 236. For example, the Osirak reactor raid was launched from the Etzion air base near Eilat in part because of its underground facilities.

Figure 1: F-117 outside Advanced Aircraft Shelter, Khamis Mushait Air Base, Saudi Arabia

Courtesy of Aero Graphics, Inc. The two Saudi shelters shown above are far superior to the ones the United States built in Europe and the Far East during the Cold War. Two F-117s could be housed per shelter space. On the right, observe the thickness of the shelter walls and rock layer on the top (to deflect penetrating weapons); on the left, note the blocking wall to prevent weapons from hitting the shelter doors.

Other nations, notably Sweden, believed that hardening was fruitless and opted instead to disperse their aircraft across a large number of bases to reduce vulnerability.[31] The Swedes developed a variety of dispersed operating surfaces (primarily portions of the national highway system) spread over large geographical areas; mobile maintenance, refueling, and rearming facilities; and aircraft designed specifically to operate in a dispersed fashion.[32] The Royal Air Force (RAF), to a more limited extent, pursued a similar policy with its small Harrier aircraft force.[33] Upon mobilization, RAF engineers would construct an initial set of aircraft "hides." The Harriers would then deploy to these sites. Meanwhile, the engineering teams would construct additional sites to increase the number of potential operating locations and complicate an enemy's attack planning.

During the 1970s and 1980s, the USAF and its NATO allies took the air base threat extremely seriously, investing tens of billions of dollars in air base operability programs. The RAND Corporation developed highly detailed computer models, known as TSAR and TSARINA, to calculate the effects of air base attacks on sortie generation rates.[34] In the mid-1980s, the USAF conducted a

[31] Christopher Bowie, *Concepts of Operations and USAF Planning for Southwest Asia*, R-3125-AF (Santa Monica, CA: The RAND Corporation, 1984).

[32] For example, Swedish fighters tended to have high flotation landing gear (to reduce runway strength requirements), thrust reversers (to shorten landing distances), and a variety of enhancements to ease maintenance requirements. See Richard Bitzinger, *Facing the Future: The Swedish Air Force, 1990–2005*, R-4007-RC (Santa Monica: The RAND Corporation, 1990), and Christopher J. Bowie, et.al, *Trends in the Global Balance of Airpower*, MR-4781/1-AF (Santa Monica, CA: The RAND Corporation, 1995), p. 90.

[33] One RAF Air Marshal remarked to the author in the 1980s that the small number of operational Harriers (roughly 5 percent of the RAF's combat inventory) was an accurate reflection of the RAF's attitude toward dispersed basing concepts.

[34] See Donald E. Emerson, *TSAR and TSARINA: Simulation Models for Assessing Force Generation and Logistics Support in a Combat Environment*, P-6773 (Santa Monica, CA: The RAND Corporation, 1982). Most of the results of these simulations are classified and were incorporated into large scale theater combat simulations conducted at RAND in 1980s.

multi-week exercise called Salty Demo at Spangdahlem Air Base to evaluate the effectiveness of air base operability measures. Runway sections were blown up to demonstrate RRR techniques; power and communication losses were simulated along with chemical weapons and special forces attacks. The exercise demonstrated that by augmenting the base with additional equipment and personnel and conducting extensive training, air operations could be sustained in the face of runway attacks (though sortie rates would be greatly reduced). The exercise also highlighted that chemical attacks would greatly reduce combat capability.[35]

During the mid-to-late 1980s, new concerns were raised about the increased threat to European air bases raised by longer-range Warsaw Pact strike aircraft and tactical ballistic missiles. USAF planners evaluated the consequences of an initial missile strike to close the runways and disrupt operations followed by thousands of Warsaw Pact aircraft delivering weapons against the bases.[36] Other threats included fuel-air explosives and Soviet Special Forces attempting to kill pilots in their homes, poison base water supplies, and cut electrical power supplies to the base.[37]

In the face of the growing threat, the USAF attempted to make air base operability a mission area at the same level of importance as air superiority, interdiction, and airlift. The USAF installed ground personnel protective shelters, protected communications and power lines, developed new chemical suits, and expanded airfield camouflage, concealment, and deception techniques. As Tidal W. McCoy, who spearheaded efforts to increase the emphasis on air base operability, noted, the outcome of the simulated attacks had been "a shock" to the Air Force.[38] At best, uncertainty remained over forward base viability under sustained conventional and chemical strikes. RAND computer simulations conducted in the early 1980s indicated that Warsaw Pact strikes against USAF bases in Europe in the first week of hostilities would cut sortie generation rates by almost 40 percent and destroy 40 percent of deployed aircraft.[39] Another group of RAND analysts stated in the mid-1980s: "In Europe, main operating bases (MOBs) and support equipment previously thought survivable may become extremely vulnerable."[40]

When the Air Force released its massive final Salty Demo report in the late 1980s on the range of initiatives that needed funding to minimize European base vulnerability, the total program cost was ultimately deemed unaffordable as defense budgets began to decline following the peak of the Reagan defense buildup. Some equipment was purchased in the wake of Salty Demo, such as the

[35] Author's interview with Major General Lawrence Day (USAF, Ret.), February 27, 2002. Also see John T. Correll, "Fighting under Attack," *Air Force Magazine*, October 1988, for an account of the exercise and Air Force initiatives in response.

[36] Author's interview with Dr. James Wendt, OSD PA&E, February 11, 2002. Dr. Wendt extensively analyzed such threats using the TSAR/TSARINA models while at RAND in the 1980s. Also see Price Bingham, "Fighting from the Air Base," *Air Chronicles*, 1987, p. 1 for a description of the potential Warsaw Pact concept of operations.

[37] Author's interview with Tidal W. McCoy, former Assistant Secretary of the Air Force for Readiness Support, February 13, 2002.

[38] Ibid.

[39] Don Emerson, *USAFE Airbase Operations in a Wartime Environment* (Santa Monica, CA: The RAND Corporation, October 1982), pp. 9, 16. The RAND calculations assumed three Warsaw Pact raids per base over seven days. Of the 120 deployed aircraft, the attacks destroyed 50. The USAF force could have generated 1,075 sorties in that period without air base attack; with the raids, the sortie potential dropped to 675.

[40] M.B. Berman, et al., *Integrating Basing, Support, and Air Vehicle Requirements: An Approach for Increasing the Effectiveness of Future Fighter Weapon Systems* (Santa Monica, CA: The RAND Corporation, 1985), p. v.

mobile arresting gear that remains in the USAF inventory today, but nothing on the scale recommended by the Air Force report. The Soviet Union's collapse seemed to deflate USAF interest and concern over the air base operability issue. Air base operability investment declined as the pressure on the Central Front evaporated and what had been almost a cottage industry in the 1980s largely disappeared by the mid-1990s.

In 1995, the DoD released its Congressionally mandated Heavy Bomber Study, which provided insights into military thinking and concepts of operations in evaluating the planned mix of combat air forces. The study, conducted by the Institute for Defense Analyses, included "all the planning assumptions that the Department uses to size the Bottom-Up Review forces and that the Department is currently using in defense planning guidance."[41] All cases analyzed assumed base access and a mature basing infrastructure. As its base case, the study assumed 14 days of warning and unmolested deployment of hundreds of fighter aircraft into the theater. Even in the surprise scenario, a substantial number of fighter aircraft were assumed available in the theater for operations before hostilities started.[42] Some offline analysis was conducted on the effects of potential chemical or "kinetic" strikes against forward air bases; overall, the estimated decreases in sortie rates were overshadowed by the large numbers of aircraft that the study assumed could be rapidly deployed to the theater.[43]

Today, Air Force civil engineers still conduct annual training on base recovery and "bare base" operations. However, the USAF believes that current adversaries would have enormous difficulty attacking a US base in the face of US air defense capabilities. This conclusion reduced the need for the passive defenses and base recovery capabilities pursued during the Cold War when facing the massive threat posed by the Soviet Union. Emphasis has been placed on chemical and biological agent detection and protection, though concerns remain about the adequacy of funding and debate continues on the seriousness of the chemical threat in particular.

An emerging paradox is apparent from this brief history. The USAF took air base vulnerability seriously enough in the 1950s to reshape radically its force structure. The Air Force also spent tens of billions in the 1970s and 1980s to minimize theater base vulnerability. In the end, the USAF found competing program priorities and the potency of the Soviet threat made the required investment unaffordable. However, as recent force structure decisions have increased reliance on forward bases, the USAF seems to have discounted concerns over air base vulnerability, primarily because no opponent currently appears capable of mounting a serious threat. The focus of debate now revolves around performance and survivability in the air against enemy aircraft and surface-to-air missile (SAM) systems, while ground performance and survivability appears to be largely ignored.

[41] Kurt Guthe, "A Precisely Guided Analytic Bomb: The Defense Department's Heavy Bomber Force Study," *Comparative Strategy*, 16, 1997, p. 70.

[42] Ibid., p. 84.

[43] Ibid., p. 83. The study assumed a loss of 66 percent of fighter sorties the first week, 50 percent the second week, and 33 percent the third week.

III. What Are the Basing and Logistical Requirements for Land-Based Fighters in Future Combat Operations?

How close to an adversary do USAF fighters need to be based? Given this topic's importance to the subject at hand, the following section first provides some detail on fighter combat radius and required operational base locations. The rest of this section then discusses USAF deployment operations and the number of bases expeditionary air forces require to conduct combat operations.

This analysis concludes that USAF fighter forces must be situated within 1,000 to 1,500 nautical miles (nm) of an adversary's borders. A fighter aircraft's potential combat radius is a fairly complex topic, but in general, it is limited by the physical stresses on the aircrew, who must sit for long periods in cramped cockpits, operational considerations, aerial refueling requirements, and sortie generation capability.

Unrefueled fighters can typically operate with combat radii of around 350–500 nautical miles.[44] However, fighter range can be extended significantly by aerial refueling. During the Gulf War, for example, F-117s and F-111Fs routinely flew combat missions roughly five hours long and approximately 900–1,000 nautical miles in radius.[45] F-15Es flying from the United Kingdom during operations against Serbia in 1999 flew missions over the same sorts of distances.[46] Other fighter aircraft have flown even longer sorties using more aerial refueling. F-15Cs manning combat air patrol stations over the Iran-Iraq border during the 1991 Gulf War flew missions 10 hours in length, as have fighters in Northern Watch operations over Iraq. In extreme cases, using extensive refueling, fighters can fly even longer missions. For example, two F-117s flew from the United States to strike Panama in 1989 for an estimated mission radius of 2,400 nautical miles. The F-111 raid on Libya launched from the United Kingdom involved an exhausting 14 hour mission flown over a 2,700 nautical mile radius.[47] More recently, an F-15E conducted an even longer 15 hour mission during Operation Enduring Freedom in Afghanistan. But such missions, as will be explained below, are the exception, not the rule, and cannot be sustained for long.

Long-endurance missions are physically exhausting. A fighter cockpit gets chilly as the aircraft "cold soaks" for long periods in the low temperatures experienced at high altitude. Bladder relief

[44] Unrefueled combat radius is the distance an aircraft can fly and then turn around and return to its originating base. F-16 typical unrefueled typical mission radius is about 350 nautical miles; F-15 typical mission radius is about 500 nautical miles. See David A. Shlapak, et al., "Global Access: Strategy 2000," *Air Force Journal of Logistics*, XXIV, No. 2, Summer 2000. The F-22 offers a 600 nautical mile unrefueled combat mission radius according to the Secretary of the Air Force. The JSF fighter is expected to have a combat mission radius of about 650–700 nautical miles. See "Roche Envisions Close Air Support F-22," *Defense Week*, July 1, 2002, p. 6.

[45] Calculated by computing the distance from the F-117 and F-111 bases (Khamis Mushait and Taif respectively) to Baghdad.

[46] Air War over Serbia Fact Sheet (Washington, DC: HQ USAF, January 2000). Basing data from Kosovo/Operation Allied Force After Action Report (Washington, DC: DoD, January 2000), p. 12.

[47] Colonel Robert Venkus (USAF, Ret.), *Raid on Qaddafi: The Untold Story of History's Longest Fighter Mission by the Pilot Who Directed It* (New York: Saint Martin's Press, 1992).

must be conducted sitting down and bowel movements must be avoided.[48] Fighter aircrews must sit on hard ejection seats[49] and are unable to get up and move around (as in larger transport and bomber aircraft). Because of this, feet, legs, and the lower body start to go numb over time. Imagine, for example, flying on a commercial flight from the United States to the Far East in chilly air sitting on a hard uncomfortable surface and being unable to get up and stretch or go to the restroom for the entire flight. Colonel Robert Venkus, one of the key planners in the 1986 Libya raid, explains the physical challenges facing fighter pilots using the following analogy:

> If the comparison makes sense, it may help the reader imagine just how stressing Operation El Dorado Canyon was to its Air Force fighter participants. Imagine you are on a round-trip night drive from your home to a destination six hours distant; Chicago to St. Louis is one such journey that comes to mind. Your car is a small sports model, something like a Porsche or a Corvette. You must wear a tight-fitting jump suit and a three-pound helmet the entire time. To complete the trip in minimum time, fuel is pumped by hose from an accompanying tanker truck. Once in the car and on the road, there is no stopping—refueling must be done on the go at normal cruise speeds (excellent 'formation driving' skills are required; tailgating for several hours is a necessity). After six hours and nearing your destination, you must leave your friendly tanker and accelerate to near-maximum speed for a brief period during which the residents of your destination attempt to destroy you and your vehicle with all the firepower at their command. After that brief hair-raising experience, you must find your fuel truck in the dark again, and retrace the entire six-hour journey back to the starting point. Of course, the entire trip is done with the top up and the windows closed—no standing or turning around—and without access to roadside facilities. Like your Air Force counterparts, you may carry one or two 'piddle packs,' plastic containers that are difficult to use when standing and nearly impossible to use accurately sitting down. You finally reach home again a full fourteen hours after starting your journey; only then can you open the car door and leave the tight confines of the cockpit. [50]

To help, the Air Force issues aircrews pharmaceutical "go pills" (Dexedrine), which can be taken if needed. Reportedly, two-thirds of USAF aircrews used Dexedrine at least once during the Gulf War.[51] But after flying such long missions, fighter aircrews will be physically exhausted and may require assistance to stand up and exit the aircraft. Typically, pilots fly such long endurance missions during a deployment to a forward base—USAF aircrews routinely deploy from the CONUS to the Persian Gulf on 15 hour missions. On long-distance combat missions, however, the pilot must also be mentally and physically prepared to engage in combat. Accordingly, official Air Force policy is that fighter aircrews should not exceed 12 hours per day on flight duty, which starts when aircrews report for mission briefing and ends at engine shutdown.[52] Typically, mission preparation, briefing, taxi, and landing consumes two hours of that time (using optimistic assumptions). This

[48] Before launching on long missions, aircrew follow special diets.

[49] Ejection seats have hard cushions to minimize damages to aircrew spines in an ejection. If a soft cushion were used, during an ejection the cushion would compress and then impart a strong jolt to the spine that could cause severe injuries to the occupant.

[50] Venkus, *Raid on Qaddafi: The Untold Story of History's Longest Fighter Mission by the Pilot Who Directed It*, p. 110.

[51] Glenn McGregor, "Fatigue Dogged US Pilots," *Vancouver Sun*, June 3, 2002.

[52] See Chapter 9 in *Flying Operations: General Flight Rules*, Air Force Instruction 11-202, Volume 3, (Washington, DC: Office of the Secretary of the Air Force), February 9, 2001. The regulation is available electronically at [http://afpubs.hq.af.mil/pubfiles/af/11/afi11-202v3/afi11-202v3.pdf].

results in 10 hours' flying time for maximum mission duration. These same constraints would affect all aircraft with a fighter-style cockpit, such as the JSF and a proposed, longer-range, ground-attack variant of the F-22.

Fighter aircraft on average cruise at about 450 knots true ground speed—about 7.5 nautical miles per minute.[53] A ten hour mission thus translates into a total range of 4,500 nautical miles and a maximum radius of 2,250 nautical miles. These are impressive distances—roughly the equivalent of conducting operations from the east coast of the United States against the west coast. For another perspective, 2,250 nautical miles is 750 nautical miles longer than the distance from Kuwait to central Afghanistan via the Persian Gulf.

But just being able to range the enemy border is not sufficient. Assuming that targets lie about 400 nautical miles deep in enemy territory—a typical Air Force strike mission requirement—fighter bases must at most be located 1,850 nautical miles from an enemy border. But prudent planners would want to operate from bases a bit closer to increase operational flexibility. Increased fuel consumption during combat (afterburner use dramatically increases fuel consumption rates), increasing potential penetration depths, and increasing the potential to loiter when required before engaging in combat are all significant factors. For example, in all recent conflicts—Iraq, Serbia, and Afghanistan—US bombers and fighters have often had to loiter near the conflict area to await the appearance of ground targets or enemy fighters. Each hour of loiter decreases fighter combat radius by 225 nautical miles. At the extreme, fighter bases could be located 1,850 nautical miles from the enemy border, but sound operational concerns would dictate moving closer.

Extended-range fighter operations require substantial aerial refueling support, which adds another reason to locate fighter bases closer to enemy terrain. The Air Force calculates that a flight of four highly fuel-efficient F-22s flying a combat radius of 1500 nautical miles would require two KC-135R tanker sorties; at 2000 nautical miles, three KC-135R sorties; and at 2500 nautical miles (almost the distance flown by the F-111Fs in Operation Eldorado Canyon in 1986) four KC-135R sorties (one per fighter).[54] Estimating tanker requirements is a fairly complex business given all the parameters (such as location of tanker bases, tanker sortie rates, and differing aircraft fuel consumption rates), but using the preceding data as a rough metric, fighters flying 10 hours would each need about three quarters of a tanker sortie. A force the same size as the USAF deployed in the Gulf War with each fighter flying 10 hours would need about 550 tanker sorties,[55] 150 tanker sorties *more* than the daily average total tanker sorties flown by the USAF during combat in that conflict.[56] Tankers have emerged as a critical resource for a wide range of operations and will be needed to support airlift, bomber, naval, and reconnaissance operations all at the same time. In the Gulf War,

[53] Although the F-22 has "supercruise" capability—the ability to fly at Mach 1.6 without requiring afterburners—it is much more fuel efficient at high subsonic speeds. Accordingly, F-22s would fly at high subsonic speeds to achieve maximum range.

[54] Briefing chart entitled "Extended Range F-22 Operations," Quadrennial Defense Review Office, HQ/USAF, 2001. The calculations assume the tankers are based at the same base as the F-22s.

[55] In the Gulf War, the USAF deployed 731 fighters at the start of the conflict. Forces include all USAF fighters based in the Gulf and Turkey. Bombers, US Navy and Marine Corps assets, and allied fighters not included. See *Gulf War Air Power Survey, Volume V, A Statistical Compendium and Chronology* (Washington, DC: HQ USAF, 1993).

[56] See *Gulf War Air Power Survey, Volume III, Part 2: Support*, (Washington , DC: HQ USAF, 1993), pp. 181.

USAF land-based fighter aircraft consumed only about half the tanker offloads.[57] So the need to reduce tanker demand will dictate base locations closer than extreme range. The longer the range, the greater the tanker requirements.

As mission radii increase, sortie rate potential declines for other reasons. Each mission takes longer to execute and aircraft maintenance between each sortie may take more time (since the aircraft is flying longer and may develop more system failures). F-16s in the Gulf War, for example, typically flew shorter missions than F-117s and F-111s and maintained average sortie rates of around 1.5 (that is, on average each aircraft flew one and a half missions per day). The F-117s and F-111s, flying sorties 900–1,000 nautical miles in radii, sustained sortie rates of .77 and .89 respectively.[58] Increasing mission radii to 2,000 nautical miles (a 100 percent increase over what the F-117s and F-111s flew in the Gulf) or longer would obviously reduce potential sortie rates substantially. As range increases, combat potential decreases.

The constraints imposed by maximum flying hours per month ceilings (which are imposed to deal with cumulative fatigue) also reduce the number of sorties aircrews can fly, and thus combat potential. Current Air Force regulations state that aircrews are not supposed to fly more than 125 hours per month and 330 hours total over 90 days.[59] This would limit each aircrew to about a dozen ten-hour missions per month and 33 such missions every 90 days. At current aircrew to aircraft combat ratios, [60] this translates into a sortie rate potential of about half a sortie per day for each deployed fighter.[61] Wing commanders can agree to increase the ceilings in exceptional circumstances, but run the risk of accidents, mistakes, and combat losses due to aircrew fatigue. For example, press reports indicate that in the recent "friendly fire" incident that killed four Canadian soldiers, pilot fatigue and inadequate crew rest may have played a role.[62] For smaller deployed forces (say a few squadrons), the USAF can increase pilot to aircraft ratios to try to maximize sortie generation rates, but a large fighter force flying long missions over a sustained period (e.g., a few months) will almost certainly run out of aircrews and be forced to reduce sortie rates.

All these factors combine to suggest that USAF land-based fighters will need to be based within 1,000 to 1,500 nautical miles of enemy territory to provide air cover and strike targets several hundred miles beyond the adversary's borders. For bases located 1,500 nautical miles from the enemy border, refueling requirements will be very high and combat potential reduced.

Bombers can operate more efficiently at greater ranges than the fighter force (since their payloads, typically 5–10 times greater than fighters, make up for the reduced sortie rates caused by long range missions). Only the small force of stealthy B-2s can operate in advanced air defense environments (though daylight operations increase the risk of detection). According to Dr. Paul Wolfowitz,

[57] See Ibid, pp. 183–86. USAF fighters onloaded 393 million pounds of fuel out of the total 809 million pounds provided to receivers.

[58] Statistics drawn from *Gulf War Air Power Survey, Volume V: A Statistical Compendium and Chronology*.

[59] See Flying Operations: General Flight Rules, Air Force Instruction 11-202, Volume 3, Chapter 9.

[60] A typical aircrew to aircraft ratio in the USAF fighter force is 1.5:1.

[61] (1.5 X 330 hours)/90 days = 0.55.

[62] McGregor, "Fatigue Dogged US Pilots."

currently the deputy secretary of defense: "The B-1 bomber cannot operate effectively in combat environments where there is a serious anti-aircraft threat."[63] The aging B-52 is even less survivable. To allow these non-stealthy bombers to standoff outside enemy defenses, the Air Force possesses a small inventory of long-range Conventional Air-Launched Cruise Missiles (CALCMs) and plans to procure the Joint Air-to-Surface Standoff Missile (JASSM). The Air Force is modifying about 60 Air-Launched Cruise Missiles (ALCMs) per year into the conventional configuration. Planned eventual procurement quantity for the JASSM is 3,700 weapons, which would provide sufficient weapons to support about 168 total sorties—just over one sortie per B-1B and B-52 in the planned inventory.[64] For comparative purposes, bombers flew 1,741 sorties in the Gulf War,[65] 322 sorties in Serbia,[66] and, in the first three months, 701 sorties in Afghanistan.[67] The full buy of JASSMs will not be complete until around 2014.[68] The small JASSM inventory objective and slow buy rate is a result of the high cost of standoff weapons (the program unit cost for each JASSM is $815,000 in then-year dollars)[69] and Air Force priorities.

In sum, Air Force procurement plans indicate that for the next three decades, for conflicts of any significant size, the Service will require secure access to sufficient bases within 1,000 to 1,500 nautical miles of the theater of conflict to project power against an adversary equipped with modern air defense systems.[70]

To deploy fighters to these bases, the USAF employs an expeditionary force concept of operations. Ten percent of the overall force is forward deployed and replaced at regular intervals by units from the United States. To augment these forces or deploy to a new area, USAF fighter squadrons in the CONUS (or in an overseas theater) prepare for deployment during mobilization. Some units are held in higher states of readiness than others, and these units have priority in deployment planning. The Air Force constantly exercises its units to conduct these deployments and grades units in their Operational Readiness Inspections on their capability to deploy.

When notified to make ready for deployment, maintenance personnel set out support equipment on pallets at the parking ramps of home bases. Units typically deploy as squadrons or elements of squadrons. Though numbers vary depending on type of aircraft, for a squadron of 24 operational

[63] Paul Wolfowitz, Deputy Secretary of Defense, Prepared statement for Senate Appropriations Committee, Subcommittee on Defense, February 28, 2002.

[64] B-1Bs can carry 24 JASSMs; B-52s can carry 20 (assuming use of the external pylons). Sorties calculated by dividing 3,700 weapons by the average B-1B/B-52 load (22 weapons).

[65] *Gulf War Air Power Survey, Volume V: A Statistical Compendium and Chronology*, p. 346.

[66] Air War over Serbia Fact Sheet.

[67] Arkin, "Weapons Total from Afghanistan Includes Large Amount of Cannon Fire."

[68] See JASSM P-1 in USAF FY03 Procurement Budget.

[69] JASSM research, development, testing and evaluation (RDT&E) cost $874 million ($then year); JASSM procurement total is estimated at $2,138 million ($TY).

[70] Emerging air defense threats, notably advanced SAM systems employing silent operating concepts as employed by the Serbs in Operation Allied Force, make survivability of non-stealthy aircraft, such as F-15s, F-16s, B-1s, and B-52s, increasingly doubtful. The Air Force has concluded that stealth is essential for future operations. See, for example, "Air Force Separates F-22 Facts from Myths," Air Force Press Release, August 1999, which states that the F-15 will be too vulnerable to operate within 5–10 years. General Richard E. Hawley, the former head of Air Combat Command, stated in a seminar at the CATO Institute on October 17, 2001 that B-1Bs, even when equipped with advanced electronic countermeasures (ECM) and decoys, cannot survive in the face of modern threats.

combat aircraft, an average of about 500 personnel and 350 tons of equipment are needed.[71] The squadron loads its maintenance equipment, munitions gear, drop tanks, war reserves spares kits,[72] other equipment, and personnel onto airlift aircraft, which then fly to the designated forward combat base. A rough rule of thumb is that one C-17 transport sortie carries the support equipment for three deployed fighters. Newer aircraft, such as the F-22, are designed to require less support than current-generation aircraft—about half—to reduce airlift requirements.[73]

In a coordinated movement, the squadron's fighters launch from their home base, typically with a load of munitions and deploy to theater using aerial refueling. The tankers usually fly with the fighters to ensure that fuel is available at all times; as the fuel offload potential of the initial tanker decreases, a new tanker will join the formation en route to replace it. Using the tankers, the fighters can fly non-stop to the destination base; alternatively, the fighters can stop at an en-route base for ground refueling before launching again to reach the destination base.[74] At the forward operating location, the maintenance units mate up with the fighters to support flying operations in the theater.

Typically, a squadron can be available in the forward theater for initial combat operations within 48 hours or so of the deployment order. For example, Iraq invaded Kuwait on August 2, 1990. On August 6, King Fahd of Saudi Arabia requested assistance. By August 8, a single squadron of F-15Cs from Langley AFB was available for operations in Saudi Arabia. Seven days later, over 100 combat aircraft had been deployed; within a month, some 400 land-based fighters were available. The average rate was around 15 combat aircraft per day—a truly impressive, coordinated operation, especially given the distances involved.[75]

For sustained operations, substantial amounts of aviation fuel and munitions must also be prepositioned or transported to forward operating location. Depending on aircraft type, each aircraft could consume three to eight tons of weapons per day[76] (some future weapons will be lighter and decrease weight requirements—see below) and about double that tonnage in fuel. Additional gear may be required at the deployment site: runway lighting, firefighting vehicles, communications, power generation, messing facilities, sleeping quarters, latrines, and so on. The Air Force maintains a set of kits, known as Harvest Falcon, which can be used to bolster existing facilities or turn a "bare base" into a full operating base. Such kits were used extensively to support Gulf War operations.[77] In a recent exercise, 30 aircraft and 1,100 support personnel required about 1,000 tons of

[71] Christopher Bowie, et al., *The New Calculus: Analyzing Airpower's Changing Role in Joint Theater Campaigns*, MR-149-AF (Santa Monica:, CA The RAND Corporation, 1993), p. 75. Three squadrons typically comprise a wing.

[72] War Reserves Spares Kits (WRSK) are supposed to provide 30 days of spare parts for deploying units. Because of the difficulty of estimating spare demand and funding constraints, the WRSK rarely can meet this requirement.

[73] F-22s were projected to require only eight C-141B sorties per squadron, compared to 16 for an F-15C squadron. See Christopher J. Bowie, *Control of the Air and US National Security: The Case for the F-22* (Washington, DC: HQ USAF/SAF/OSX, 1991).

[74] For additional insights into refueling operations, see Michael H. Bednarek, *Alternative Concepts for Aerial Refueling of Deploying Tactical Fighters*, N-2960-AF (Santa Monica, CA: The RAND Corporation, 1990).

[75] *Gulf War Air Power Survey, Volume V: A Statistical Compendium and Chronology*, p. 53.

[76] An F-15E will typically carry four 2,000 pound weapons per sortie. If the aircraft fly two sorties a day, this equates to eight tons per day. For an F-15C, the air-to-air loadout weighs approximately three tons. Typical combat loadout for an F-16C is two 2,000 pound. weapons (or an equivalent weight of smaller weapons). See Bowie, *The New Calculus: Analyzing Airpower's Changing Role in Joint Theater Campaigns*, p. 75.

[77] *Gulf War Air Power Survey, Volume III, Part 2: Support*, p. 7.

bare base equipment (roughly 22 C-17 sorties).[78] In addition, the Air Force may need to devote substantial numbers of airlift aircraft to bring additional specialized equipment, such as rapid runway repair capability and mobile arresting gear, to less developed bases. Much of the Air Force's bare base equipment was employed to support joint Afghanistan combat operations from a wide range of undeveloped bases.

Combat aircraft alone cannot operate effectively without a full range of supporting aircraft. Surveillance and reconnaissance aircraft, such as the E-3A Airborne Warning and Control System (AWACS), the RC-135 Rivet Joint (which provides emissions and signals intelligence), the Joint Surveillance Target Attack Radar System (JSTARS), the Global Hawk theater surveillance unmanned aerial vehicle (UAV), the Predator tactical UAV, and the proposed Multi-Mission Command and Control Aircraft (MC^2A) are critical elements of the intelligence, surveillance, and reconnaissance (ISR) constellation used to identify and locate threats and targets. Aerial tankers are essential for extending aircraft mission radii and adding flexibility during employment operations. Helicopters conduct search and rescue, intra-theater movement, and special operations. Airlift assets move munitions, spare parts, and personnel. All these aircraft, many of which feature large multi-engine airframes, also require bases for parking, maintenance, and ground refueling.

Overall, then, how many bases would be required to support expeditionary air forces? Past operations provide some idea of the number of bases required.

- During the Vietnam War, when the air base infrastructure had been sufficiently developed by early 1967 to support large scale operations, the USAF deployed 839 "shooters" and 769 support aircraft (1,608 total aircraft) on 19 main operating bases, for an average base density of 84 aircraft per base.[79] Average shooter density was 44 aircraft per base.

- In the Gulf War, the USAF distributed 815 combat aircraft and 491 associated support aircraft (a total of 1,306 aircraft) across 24 separate bases, for an average base density of 54 aircraft per base.[80] Average shooter density was 34.[81]

[78] Paul Killingsworth, Lionel Galway, Eiichi Kamiya, Brian Nichiporuk, Timothy Ramey, Robert Tripp, and James Wendt, *Flexbasing: Achieving Global Presence for Expeditionary Aerospace Forces*, MR-1113-AF (Santa Monica, CA: The RAND Corporation, 2000), p. 32. Typical planning factor for a C-17 sortie is 45 tons.

[79] Numbers for combat and support aircraft are contained in *Southeast Asia Review* (Washington, DC: HQ USAF, Directorate of Management Analysis, February 1974). Numbers of bases are derived from *The United States Air Force in Southeast Asia, 1961–1973: An Illustrated Account* (Washington, DC: Office of Air Force History, revised 1984), p. 245.

[80] See *Gulf War Air Power Survey, Volume III, Part 2: Support*, pp. 253–59 for a summary of the theater bases employed and *Gulf War Air Power Survey, Volume V: A Statistical Compendium*, pp. 53, 613 for an overview of USAF combat aircraft deployed. Data includes Proven Force aircraft based in Turkey.

[81] The 815 combat aircraft were actually located on 14 air bases for an average base density of 58 shooters per base.

- In the Serbian conflict, the USAF fielded 232 combat aircraft and 298 support aircraft (a total of 530 aircraft) on 23 separate bases, for an average of 23 aircraft per base.[82] Average shooter density was about 10 per base, substantially lower than in the Vietnam or Gulf Wars.[83]

Based on this summary data and using the Gulf War as the model, for each available base, the United States can deploy about 34 shooters (and have sufficient space for required support aircraft). For each fighter wing of 72 aircraft (three squadrons) and associated support aircraft, the United States needs about two theater bases.

The Air Force currently conducts its planning on the basis of 10 Aerospace Expeditionary Forces (AEFs), each of which would contain on average approximately 150 shooters (about two traditional wings of fighters).[84] Accordingly, each AEF would require about five bases. The Vietnam conflict required almost six AEF equivalents, the Gulf War about five; Serbia over two.

[82] Aircraft data from Air War over Serbia Fact Sheet. Basing data from Kosovo/Operation Allied Force After Action Report, p. 32.

[83] Data has not been released on which bases contained combat aircraft, but the author estimates seven air bases contained combat aircraft for an average shooter density of 33 combat aircraft per base. The following theater bases probably supported combat aircraft: Incirlik (Turkey), Gioia (Italy), Aviano (Itally), Spangdahlem (Germany), Lakenheath (UK), Fairford (UK), and Ramstein (Germany).

[84] The USAF plans to maintain 20 fighter wings of 72 operational aircraft (1,440 total) and about 100 operational bombers for a total of 1,540 shooter aircraft. For purposes here, each deployed AEF would comprise on average about 154 combat aircraft. Actual numbers are complicated by the complexities of the USAF AEF plan, which features 10 AEFs and two Aerospace Expeditionary Wings (which augment AEFs depending on combat needs). See *Detail Concept Paper, Aerospace Expeditionary Forces (AEFs)* (Washington DC: HQ USAF/XOPF EAF Implementation Division, January 2000).

IV. To What Extent Do These Kinds of Bases (and Supporting Logistics) Exist?

USAF fighter aircraft require a mature base infrastructure (or infrastructure development) to execute sustained operations. As aircraft have increased in performance, power, and weight, their air base requirements have also increased. During World War I, many airfields were simply revamped cow pastures. During World War II, the Army Air Forces built or upgraded 568 airfields overseas. Many of these, reflecting increased aircraft weight, were surfaced with concrete, asphalt, or other materials (steel matting, stone, or coral).[85]

The constraints imposed by the air base requirements of high performance jet fighters were first seen during the Korean War, when newly-fielded jet fighters, such as the F-80 Shooting Star, could not operate off the less developed surfaces available in Korea. Accordingly, units flying F-80 jets had to transition back to propeller-driven F-51 Mustangs until the base infrastructure could be brought up to the standards required to handle the new jet fighters.[86] A similar problem was encountered by the Argentine Air Force and Navy in the conflict over the Falklands thirty years later. The limited number of runways on the Falkland Islands were inadequate to support Argentine Mirages, Super Entendards, and A-4 Skyhawks, which had to operate from the mainland at extreme range. This greatly limited their contribution to the battle.

Historically, the USAF has emphasized performance in the air over performance on the ground. Aircraft maneuverability, acceleration, payload, and range—all critical to aerial performance—are degraded by increased weight. But the capabilities to minimize air base requirements—high flotation landing gear to reduce runway strength requirements, strengthened landing gear to handle the shocks uneven surfaces induce, thrust reversers to reduce landing distance requirements,[87] alternative intake systems to reduce the dangers of damaging engines by sucking in stones and debris, increased aircraft self sufficiency (such as integrating munitions loading equipment into aircraft)[88], and Vertical/Short Takeoff and Landing (VSTOL) capability—all add weight and reduce in-flight aircraft performance.[89]

The Soviet Union traditionally placed greater emphasis on ground performance than the United States. Soviet air bases in eastern Europe, for example, typically had runways and parking ramps composed of small slabs of concrete, which resulted in fairly uneven surfaces and demanded "rough field" capability from combat aircraft. US planners also suspected that the Soviets planned to dis-

[85] *Gulf War Air Power Survey, Volume III: Part 2, Support*, pp. 1–2.

[86] Robert Futrell, *The United States Air Force in Korea, 1950–1953* (Washington DC: Office of Air Force History, 1981), p. 110–11.

[87] The European Tornado and Swedish Viggen both employ thrust reversers to shorten landing distances.

[88] The Swedish Air Force, for example, has munitions handling gear built into some of its aircraft's weapons loading pylons.

[89] See Halliday, *Tactical Dispersal of Fighter Aircraft: Risk, Uncertainty, and Policy Recommendations*, pp. 19–20.

perse to less developed airfields during conflict. The MiG-29 Fulcrum fielded in the 1980s, for example, featured large, low pressure tires to reduce runway strength requirements, a nose gear located to the rear to prevent spraying stones into the intakes, and an auxiliary intake system to minimize the potential for foreign object damage.[90] Analysts at the RAND Corporation suggested such an approach in the mid-1980s because of the growing military threat to European air bases and the paucity of developed military fields in other critical strategic regions.[91]

Although some of these proposals (increased electronic systems reliability and onboard oxygen generating systems) have been incorporated into modern combat aircraft, no current or projected USAF fighters are capable of conducting sustained operations from anything but "high performance" air bases—those equipped with strong, smooth runways, taxiways, and parking ramps. Uneven surfaces run the risk of collapsing landing gear struts. Operating and parking surfaces must be strong enough to prevent aircraft from cracking the pavement. These surfaces must also be kept clean to reduce the chances of aircraft ingesting foreign objects through intakes and destroying their engines.

In raw numbers, large numbers of such airfields are available. For fighter operations, the standard NATO airfield requirement was a runway measuring 8,000 feet by 150 feet. Such runway dimensions are cited by Lockheed as requirements for the F-22 and JSF.[92] Operations can be conduced from shorter runways—say 6,000 feet in length—with some additional risk[93] and potential reductions in fuel and munitions payload. Taking the shorter length as the requirement, the global airfield data base provided by the National Imagery and Mapping Agency reveals a total of 2,011 airfields with runways 6,000 feet by 145 feet[94] around the world (excluding China (PRC), North Korea, and Russia) that can support the Joint Strike Fighter (see Appendix II for country and regional details).[95] If planners demanded a minimum length of 8,000 feet, the number of potential airfields would shrink by about one-third.

The presence and distribution of these airfields around the world are the result of two main drivers: Cold War imperatives and commercial air traffic growth. At the close of World War II, the United States possessed about 2,000 bases of all types around the world. Within four years, total US bases had fallen to about 500 due to the pressures of demobilization, foreign pressure to turn over bases, and improved transport technology.[96] The U.S.-Soviet rivalry led both superpowers and their allies

[90] Price Bingham, "Operational Art and Aircraft Runway Requirements," *Air Chronicles*, 1988, pp. 9–10.

[91] See Berman, *Integrating Basing, Support, and Air Vehicle Requirements: An Approach for Increasing the Effectiveness of Future Fighter Weapon Systems*.

[92] Communication from Lockheed Martin Corporation to CSBA, April 26, 2001.

[93] For example, fighters might be damaged or destroyed if the aircrew tried to abort a takeoff after reaching high speed and could not stop in time.

[94] Many European runways are 148 feet in width, so the 150 foot requirement was decreased to 145 feet when sorting the data base to include these airfields.

[95] Analysis conducted on the Automated Air Facility Information File (AAFIF) published by the National Imagery and Mapping Agency, December 1997. Calculations assume minimum length of 6,000 feet, width of 145 feet, and Load Carrying Number (LCN) of 40 for JSF. A slightly larger number of airfields would be available for F-22 operations. The F-22 has a reduced LCN (which measures the load bearing capacity of the runway) of 32. LCN requirements for JSF and F-22 provided to CSBA by Lockheed Martin Corporation.

[96] James R. Blaker, *United States Overseas Basing: An Anatomy of the Dilemma* (New York: Praeger Press, 1990), pp. 21–32.

to invest heavily in air power forces and the required base infrastructure. The United States began construction at dozens of locations in the 1950s for SAC bombers around the periphery of the Soviet Union. The NATO air forces in the Central European theater alone deployed almost 250 squadrons of combat aircraft by the mid-1950s, all of which required adequate basing.[97] Typically these bases built upon the infrastructure left over from World War II—some even date back further to World War I. Similar base proliferation took place in the northern and southern regions in NATO (though Norway and Denmark passed legislation banning the permanent basing of foreign forces on their soil). Airfield development took place on the other side of the Iron Curtain as well. In the small area of East Germany alone, for example, the Soviets and East Germans possessed 40 military airfields.[98]

In 1966, France withdrew from the unified military command structure and demanded all US forces leave. This development shattered the US basing posture in Europe. French territory, which housed nine USAF air bases and numerous Army installations, provided critical strategic depth and lines of communication for US forces on the Central Front. This magnified the problems facing the USAF, which planned to augment its forward-based fighter forces with hundreds of additional aircraft from the United States to support the policy of flexible response. To accommodate these aircraft, NATO established the Collocated Operating Base (COB) program, which invested in support facilities and shelters for these reinforcing aircraft at allied bases throughout Europe. By 1984, the United States had developed agreements for employing over 60 COBs in Europe, with plans to develop similar agreements with Greece and Turkey.[99] Hardened shelter construction at these facilities, however, always lagged behind requirements because individual nations rarely met NATO infrastructure funding goals.

Similar infrastructure developments took place in the Far East. Because of the paucity of adequate airfields on the Korean peninsula at the start of the Korean War, USAF engineers constructed 9,000-foot airfields at four bases and built or upgraded 55 more bases in the theater.[100] These airfields in Korea and Japan formed the basis for supporting the USAF posture in the Far East during the Cold War. Many of the air bases (such as Kadena in Okinawa and Osan in Korea) were hardened in the 1970s and 1980s as well to reduce their vulnerability.

In the 1960s, the demands of the Vietnam war led to the establishment of eight major new airfields in Southeast Asia and the upgrading of 11 more. Six of these facilities in Thailand were lost in 1973–74 due to Thai opposition to US presence;[101] most of the remainder fell under the control of North Vietnamese forces following the collapse of South Vietnam in 1975. In the Persian Gulf, the United States built an airfield at Dahran in 1956, developed King Khalid Military City starting in 1965, and constructed several state-of-the-art bases beginning in 1974.[102] Concern over the threat

[97] Christopher J. Bowie, Mark Lorell, and John Lund, *Trends in NATO Central Region Tactical Fighter Inventories, 1950–2005*, N-3053-AF (Santa Monica, CA: The RAND Corporation, 1990), p. 4.

[98] Bingham, "Operational Art and Aircraft Runway Requirements," p. 9.

[99] Donald E. Lewis, Bruce W. Don, Robert M. Paulson, Willis H. Ware, *A Perspective on the USAFE Collocated Operating Base System*, N-2366-AF (Santa Monica, CA: The RAND Corporation, 1986), p. 5.

[100] *Gulf War Air Power Survey, Volume III, Part 2: Support*, p. 2.

[101] Adam Siegel, *Basing and Other Constraints on Land-Based Aviation Contributions to US Contingency Operations* (Alexandria, VA: Center for Naval Analyses, 1993), p. 9.

[102] *Gulf War Air Power Survey, Volume III, Part 2: Support*, p. 8.

to the Persian Gulf following the collapse of the Shah of Iran led to US support of additional base development in Saudi Arabia, Oman, and other Gulf nations in the 1980s.[103] Continued development of these facilities took place in the 1990s. More recently, the USAF has stood up 13 airfields in and around Afghanistan to support joint operations.[104]

Rivalries also stimulated the development of military airfields in other regions. Whereas the size of the US and allied NATO air forces peaked in the mid-1950s and declined to reach a steady state in the mid-1960s, developing nations such as India and Pakistan built up their forces more slowly after World War II to peak levels in the early 1990s.[105] China expanded its investment in air power in a similar fashion, increasing an inventory of 1,400 fighter aircraft in 1954 to a high of almost 4,500 aircraft by the mid-1980s.[106] These expanding fleets of aircraft required a corresponding growth in the military air base infrastructure.

The development of the jet airliner, starting with the British Comet and then the Boeing 707 and Douglas DC-8, led to a dramatic increase in numbers of commercial aircraft and consequent development of commercial airfields around the world. Figure 1 provides an overview of cumulative deliveries of both narrow-body and wide-body passenger airliners starting in the late 1950s and continuing through 1999. Over 17,000 commercial airliners have been delivered at an average rate of over 400 aircraft per year; about 14,000 (over 80%) are still in service today. Deliveries of these aircraft required the development of airfields and passenger terminals to support their operations.

Until the early 1980s, US and European carriers purchased the vast majority of commercial aircraft. At that point, developing nations, notably in the Far East, began purchasing an increasing number, but the market remained dominated by carriers in the United States and Europe. For example, the *total* narrow and wide-body commercial aircraft currently owned by the nations of South and East Asia—Pakistan, India, Malaysia, Singapore, Thailand, Indonesia, the Philippines, and China—totals 648 aircraft, about five percent of the world's total operational airliner fleet.[107] That total is also less than the number of aircraft owned by American Airlines alone (732) and just over the number owned by Delta (616) or United (600).[108] Not surprisingly, there is a natural relationship between national gross domestic product/national wealth and the number of jet airliners/supporting airfields nations own.

[103] See Bowie, *Concepts of Operations and USAF Planning for Southwest Asia*, pp. 12–22.

[104] "Peppe: Air Force Likely to Aim for Equal Capability in 10 AEFs," *Defense Daily*, June 5, 2002, p.5.

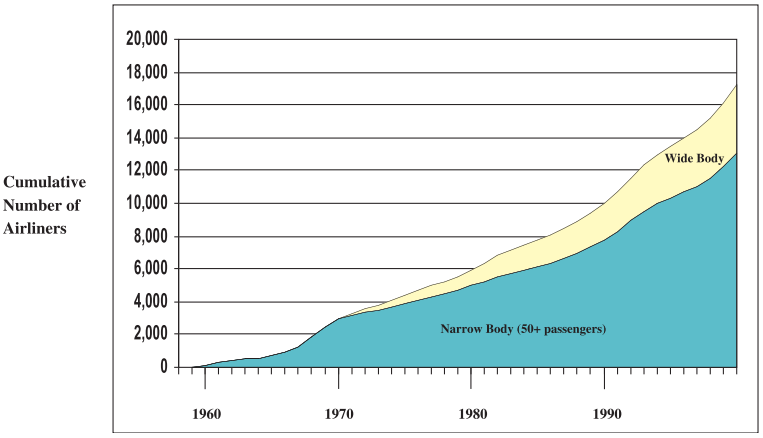
[105] See George K. Tanham and Marcy Agmon, *The Indian Air Force: Trends and Prospects*, MR-424-AF (Santa Monica, CA: The RAND Corporation, 1995).

[106] See Kenneth W. Allen, Glenn Krumel, and Jonathan D. Pollack, *China's Air Force Enters the 21st Century*, MR-580-AF (Santa Monica, CA: The RAND Corporation, 1995), p. 140.

[107] See airline data contained in "2002 Aerospace Source Book,", *Aviation Week & Space Technology*, January 14, 2002. In 2000, the active airliner fleet was approximately 14,300 aircraft according to Steve Bowling of Northop Grumman Corporation.

[108] "2002 Aerospace Source Book," *Aviation Week & Space Technology*, January 14, 2002.

Figure 2: Jet Airliner Production, 1958–1999



Graph based on information from the Back Information Services Database, 2002.

Table 1 illustrates the distribution of airfields capable of supporting JSF operations around the world that has resulted from a combination of the strategic and economic factors discussed above.[109] The majority of airfields are located in North America and Western Europe. For example, of the 2,011 total airfields in the world, almost half are found in these developed nations.[110] In less developed nations, the airfield infrastructure is substantially weaker, notably numbers of airfields, numbers of runways per airfield, and the critical area of ramp space. As one Air Force officer observed, "While there are many runways with adequate runway and weight-bearing capacity, most airports in third world regions do not have the ramp space to accommodate parking for an AEF-sized force."[111] Substantial changes to the number and quality of airfields in the developing world will require increases in the economic power of these nations (which is likely to take decades at best).

In the 1991 Gulf War and the 1999 Serbian conflict, the Air Force fought conflicts that erupted in areas where the basing infrastructure had been highly developed through deliberate US policy. Desert Storm forces employed bases built up starting in the mid-1970s to defend the Gulf against a Soviet invasion of Iran. Nonetheless, additional facilities had to be constructed over several months to handle the full force. For example, USAF engineers constructed two hard stands at Shaikh Isa air base in Bahrain, a new parking ramp at Al Minhad air base in the United Arab Emirates (UAE), weapons storage at Jeddah, a tent city at Riyadh, and a forward operating location at King Khalid Military City in Saudi Arabia.[112] Moreover, most US aircraft still had to park on unprotected ramps. USAF units in *Operation Allied Force* in 1999 employed the extensive European basing infrastructure that had been built up over a period of 40 plus years to support a NATO defense against the Warsaw Pact.

[109] Airfields selected can support a Joint Strike Fighter and must feature a runway 6,000 feet by 145 feet and an LCN of 40. For operations, most planners would prefer a runway at least 8,000 feet in length, which would reduce the numbers by about 30%.

[110] See Appendix II for details on individual nations and regions.

[111] LTC Michael Nowack, *The Air Expeditionary Force: Strategy for an Uncertain Future?* (Maxwell AFB, AL: Air War College, April 1999), p. 12.

[112] *Gulf War Air Power Survey, Volume III: Part 2, Support*, pp. 24–25.

Table 1: Airfields of the World (Excluding Russia, China and North Korea) with 6,000 X 145 Feet Operating Surfaces Capable of Supporting JSF Operations

Region	Airfields	Runways
Asia	278	314
Middle East/Persian Gulf	151	187
Western Europe (including Turkey)	388	454
North America	639	896
Rest of World	555	579
Global Total	**2,011**	**2,429**

Airfield data from the Automated Air Facility Information File, National Imagery and Mapping Agency, December 1997. See Appendix II for additional details.

Asia is the emerging focus of future DoD planning and concern. As stated in the QDR:

> In particular, Asia is gradually emerging as a region susceptible to large-scale military competition. Along a broad arc of instability that stretches from the Middle East to Northeast Asia, the region contains a volatile mix of rising and declining regional powers. The governments of some of these states are vulnerable to overthrow by radical or extremist internal political forces or movements. Many of these states field large militaries and possess the potential to develop or acquire weapons of mass destruction.
>
> Maintaining a stable balance in Asia will be a complex task. The possibility exists that a military competitor with a formidable resource base will emerge in the region. The East Asian littoral—from the Bay of Bengal to the Sea of Japan—represents a particularly challenging area.[113]

In terms of Asian basing, the QDR observes:

> The distances are vast…[and] [t]he density of US basing and en route infrastructure is lower than in other critical regions. The United States also has less assurance of access to facilities in the region. This places a premium on securing additional access and infrastructure agreements and on developing systems capable of sustained operations at great distances with minimal theater-based support.[114]

Data from the global airfield data base confirms these points. Overall, Asia contains 14 percent of the world's airfields (again, excluding Russia, China, and North Korea). In comparison, the North American continent—a substantially smaller geographical area (particularly when considering the oceans separating many areas in Asia)—contains 32 percent of the world's airfields, while Western Europe—which is even smaller in area—contains 18 percent.

[113] Rumsfeld, *Quadrennial Defense Review Report*, p. 4.

[114] Ibid.

In a crisis, deploying to hardened, regional, military air bases would be the Air Force's first choice. But hardened airfields are expensive facilities, particularly when equipped with shelters for aircraft, ground personnel, and pilots; munitions storage areas to minimize dangers from sympathetic detonations; fuel hydrant complexes to minimize refueling times; additional landing and recovery surfaces; and rapid runway repair capabilities. Because of the cost, nations, particularly less-developed countries with limited budgets, typically build military air bases with sufficient space to handle only their own air forces.[115] Moreover, few developing nations spend the large sums needed to build sufficient numbers of protective shelters; think of the slow progress the wealthy NATO nations made in trying to harden European bases. In Saudi Arabia, which had the financial resources to prepare elaborate additional facilities to house deploying US aircraft, large numbers of US and allied fighters had to park out in the open during Operation Desert Shield/Storm.

Hardened airfields (see Table 2 below)—that is, those possessing shelters to protect fighter aircraft on the ground from attack—represent a significant percentage of overall airfields in both Europe (25 percent) and the Middle East/Persian Gulf (37 percent). In Asia, the percentage stands at 18. Moreover, the total number of hardened airfields (52) is lower than in the smaller geographic areas of the Middle East/Persian Gulf (56) and Western Europe (95).

Overall, average base density in Asia is substantially lower than in either Europe or the Middle East/Persian Gulf. Table 3 shows the average number of airfields and hardened air bases per million square nautical miles of area. Airfield density in Asia runs about 1/3 to 1/4 that of the other two regions; hardened airfield density stands at about 1/5 that of Europe or the Middle East/Persian Gulf.

The fifty two bases in Asia—about 16 percent of the total—field a total of 1,412 hardened aircraft shelters (each shelter can typically house one fighter). At first glance, this large number would appear sufficient to house US deploying fighters, but availability is likely to be lower for several reasons. Reflecting 50 years of war preparations, almost half (641) of the total shelters in Asia are concentrated in South Korea. Employing these bases to conduct operations other than their primary purpose—South Korea's defense—raises uncertainties. South Korea may be reluctant to get engaged, while the bases could come under heavy attack from North Korea should a conflict widen. Most of the other shelters are located in Japan (107 shelters), Taiwan (203 shelters), India (229 shelters), and Pakistan (176 shelters)—an average of about 180 per nation, sufficient to shelter a single USAF Aerospace Expeditionary Force. But the total number available for use could be reduced by several factors. Are these widely separated bases located in the right position for the conflict? Will the nation support combat operations from its soil by US aircraft?[116] Finally, each of these nations fields substantially more combat aircraft than shelters.[117] Accordingly, the host nation would need to expose more of its own aircraft to attack in order to shelter US aircraft. All this suggests that the number of shelters made available for use will be lower than the total and in a larger-scale conflict, significant numbers of US fighters will have to deploy to unhardened bases and/or park on unprotected ramps.

[115] Exceptions to this, as noted above, include Europe and the Persian Gulf.

[116] See Section IV for additional discussion.

[117] Japan fields 297 combat aircraft and 107 shelters, Taiwan fields 482 combat aircraft and 203 shelters, Pakistan fields 353 combat aircraft and 176 shelters, and India fields 738 combat aircraft and 229 shelters. For combat aircraft force levels, see *The Military Balance 2001–2002* (London: International Institute for Strategic Studies), 2001.

Table 2: Airfields of the World with a Focus on Asia (Excluding China, North Korea and Russia)

	Airfields	Runways	Hardened Airfields	Number of Shelters
Asia	278	314	52	1,412
Middle East/Persian Gulf	151	187	56	1,217
Western Europe (including Turkey)	388	454	95	2,410
North America	639	896	1	2
Rest of World	555	579	46	711
Global Total	**2,011**	**2,429**	**250**	**5,752**

	Airfields	Runways	Hardened Airfields	Number of Shelters
North East Asia				
Japan	62	68	6	107
South Korea	20	25	12	641
Totals	82	93	18	748
Southeast Asia/Pacific				
Australia	30	35		
Brunei	1	1		
Guam	2	3		
Indonesia	18	19		
Laos	1	1		
Malaysia	5	5		
Marianna Islands/Guam	3	4		
Marshall Islands	2	2	1	4
Myanmar	16	16		
New Zealand	5	6		
Papua New Guinea	1	1		
Philippines	12	14	1	5
Singapore	3	4	3	29
Taiwan	10	14	7	203
Thailand	15	16	3	18
Vietnam	3	5		
Totals	127	146	15	259
Central Asia				
Afghanistan	3	3		
Bangladesh	4	4		
Burma	3	3		
India	43	46	12	229
Kazakstan	2	2		
Kyrgyzstan	2	2		
Pakistan	9	11	7	176
Sri Lanka	2	2		
Tajikistan	1	1		
Uzbekistan	2	3		
Totals	69	75	19	405

Airfield data from the Automated Air Facility Information File, National Imagery and Mapping Agency, December 1997. Airfields must possess operating surfaces measuring 6,000 feet by 145 feet and LCN of 40 to support JSF operations. Most shelters typically can house a single fighter aircraft. See Appendix II for more data.

Table 3: Base Density in Three Regions

Region	Airfields per million sq. nm	Hardened airfields per million sq. nm.
Asia	15.4	2.9
Middle East/Persian Gulf	37.8	14.0
Western Europe (including Turkey)	55.4	13.6

Airfield data from the Automated Air Facility Information File, National Imagery and Mapping Agency, December 1997 divided into author's estimate of regional areas. Middle East/Persian Gulf estimated at 4 million square nautical miles., Western Europe at 7 million square nautical miles, Asia at 18 million square nautical miles. Asia regional area does not include Russia.

Basing at unprotected facilities raises numerous issues. Few airfields in the developing world offer the sort of ramp space major airfields in the developed world provide. Without hardened facilities, deployed aircraft become more lucrative targets. The presence of the large, relatively unprotected ammunition and fuel stores required to support combat operations also heightens vulnerability (see Section IV for additional discussion).

The United States must provide responsive logistical support to forward-based aircraft at less developed facilities. Logistical requirements can be daunting when deploying to unprepared facilities. To move 30 USAF combat aircraft to Qatar in 1997, for example, the support tonnage requirements for personnel, munitions, force protection, vehicles, and the like amounted to 4,000 short tons (approximately 90 C-17 loads)—about 133 tons (3 C-17 loads) per deployed combat aircraft.[118] An F-15E squadron of 24 aircraft requires almost 400 tons of jet fuel per day; the combat aircraft of a single AEF almost 2,500 tons per day.[119] A larger force combined with support aircraft increases fuel requirements substantially. During the Gulf War, the USAF aircraft in theater alone consumed on average over 37,000 tons of fuel per day.[120]

Aviation fuel is an inherently fungible commodity. At most airfields, some stocks would be available and, with sufficient time to arrange transport, additional supplies could be provided to the fighting force. To increase local supplies of fuel would require building fuel storage stocks in theater, relying on local refineries, and/or laying pipelines. Building sufficient fuel storage stocks in theater is expensive—roughly $165 per barrel stored (in fiscal year (FY) 2002 dollars) and would not prove timely unless done before a conflict.[121] Local refineries are an attractive fuel source (and were used extensively in the Gulf War), but also represent vulnerable targets. Pipelines can be laid expeditiously using mooring buoys for tankers and temporary pipelines. Overall, fuel can be supplied, but concerns over the vulnerability of this highly flammable substance cannot be ignored. World War II efforts to protect fuel supplies with hardening and dedicated firefighting units met with little success.[122] Destruction of fuel storage at a base would bring operations to halt until new supplies could be arranged.

[118] Killingsworth, Galway, Kamiya, Nichiporuk, Ramey, Tripp, and Wendt, *Flexbasing: Achieving Global Presence for Expeditionary Aerospace Forces*, p. 33.

[119] Bowie, *Concepts of Operations and USAF Planning for Southwest Asia*, p. 45.

[120] *Gulf War Air Power Survey, Volume III, Part 1: Logistics* (Washington, DC: HQ USAF, 1993), p. 14.

[121] Bowie, *Concepts of Operations and USAF Planning for Southwest Asia*, p. 47.

[122] Edmund Dews, *POL Storage as a Target for Air Attack: Evidence from the World War II Allied Air Campaigns against Enemy Oil Installations* (Santa Monica, CA: The RAND Corporation, 1980).

Supplying munitions is also an extremely challenging logistical task. Just over a week's worth of current-generation weapons for three AEFs weighs about 20,000 tons—about the weight of the entire 82nd Airborne Division with three days of fuel, ammunition, and food.[123] Because of the weight and the demands on the air transport force, airlifting munitions is typically avoided except in emergencies. A single C-17, for example, could bring in about 80 tons of weapons[124]—only enough to support 20 F-15E sorties. Pre-positioning aircraft munitions is always the favored policy, but runs into three significant problems:

- As with base development, presciently predicting conflict location is difficult.

- "Preferred" munitions—typically the most advanced weapons—often cannot be pre-positioned overseas unless the US government has agreed to sell such weapons to the country in question. The reason is that in the case of a revolution or dramatic shift in strategic orientation, the weapons could fall into unfriendly hands and be used against US forces and allies (not to mention the risk of compromising advanced US technology).

- Pre-positioning preferred weapons at multiple locations is costly—in essence, the United States must purchase stocks for each theater. However, institutional pressures under budget constraints have historically increased the temptation to raid the relatively fungible munitions accounts. In the Serbian and Afghanistan conflicts, stores of preferred weapons were quickly depleted because of inadequate peacetime stocks. Pre-positioning at multiple locations also would require greatly increasing overall preferred munitions stocks and allocating even more resources to munitions procurement. To date, success in increasing munitions procurement accounts on a sustained basis has been limited.

A compromise solution is to employ pre-positioning ships, as was done effectively in the Gulf War. These ships can be stationed within a few days' sailing of potential conflict areas and loaded with preferred weapons. Upon warning or conflict outbreak, the vessels can then steam to the region and offload the weapons for transport to regional bases. These weapons can then be used until sealift from the CONUS or other theaters can bring additional munitions to the region.

Pre-positioned ships do suffer from some drawbacks. The vessels would constitute a very lucrative target in port, transit, and docking (basically, losing the ships would eviscerate deployed force capabilities). In addition, the weapons must be offloaded from the ship in a port and then moved to the bases in question, which reduces responsiveness. Handling large quantities of explosive materials offers some challenges (for example, locating sufficient trucks and qualified drivers in a foreign country) and errors run the danger of causing pyrotechnic catastrophes and weapons loss. If bases are located far from the sea, this can further complicate transport issues and reduce responsiveness. For example, supplying weapons to the new US air base at Bishkek in Kyrgyzstan, which lies landlocked approximately 1,000 nautical miles from the Arabian Sea, poses some interesting logistical issues.

[123] Bowie, *The New Calculus: Analyzing Airpower's Changing Role in Joint Theater Campaigns*, p. 75.

[124] This assumes maximum load. Airlifters typically tend to "cube out"—that is, cargo volume takes up all available space—before they "weight out." With munitions, airlifters typically "weight out." Operational considerations, however, often result in reduced airlift payloads.

On the positive side, technological developments will ease the logistical challenges involved in supplying munitions:

- Some preferred weapons, notably the Joint Direct Attack Munition (JDAM) and the family of laser-guided bombs (LGBs), consist of standard bomb bodies fitted with guidance kits. Accordingly, inexpensive bomb bodies could be pre-positioned in multiple locations and the guidance kits airlifted to the bombs. Such weapons increase the potential for low-cost distributed pre-positioning.

- Using precision weapons may greatly reduce munitions requirements while increasing combat effectiveness. During Operation Desert Storm, precision weapons accounted for only seven percent of total weapons employed. In Kosovo, that figure increased to 35 percent. Even greater percentages were seen in various punitive strikes in the 1990s[125] and in Afghanistan operations, the percentage increased to approximately 60 percent.[126] In Desert Storm, US forces expended over 227,000 weapons[127] against approximately 42,000 aimpoints.[128] Future campaigns may generate equal or greater numbers of aimpoints, while requiring fewer weapons overall.

- Precision enables the use of smaller, lighter weapons, since increased accuracy can reduce the need for explosive power. The Air Force is currently developing the Small Diameter Bomb (SDB), which will weigh around 250 pounds.. The 227,000 weapons employed in the Gulf War amounted to 84,000 tons in weight (about 1,050 C-17 loads).[129] Attacking the same number of aimpoints (42,000) using SDBs would only amount to 5,250 tons of weight (about 66 C-17 loads)—over an order of magnitude in weight reduction.[130] Smaller weapons cannot be used against the full range of targets (for example, hard and deeply buried facilities), but would increase greatly the Air Force's capability to airlift weapons and expand deployment flexibility.

For operations in Asia, the basing infrastructure is sparse. The United States has fought five major conflicts since World War II: Korea (North East Asia), Vietnam (Southeast Asia), the Gulf War (Southwest Asia), Serbia (Europe), and Afghanistan (Central Asia). The basing infrastructure was inadequate in three of the four Asian conflicts—Korea, Vietnam, and Afghanistan—to support large-scale, sustained, fighter operations and required substantial development in all three cases. Because of the patterns in airfield development, basing infrastructure constraints are likely to characterize any future operations involving China, Southeast, Central, and South Asia. A significant number of shelters are available overall, but hardened airfield density, distribution, and availability in Asia indicates that USAF fighters are probably going to have to rely in large part on less mature and unprotected airfields.

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[125] Michael Vickers, "Revolution Deferred: Kosovo and the Transformation of War" in *War Over Kosovo* ed. Eliot Cohen and Andrew Bacevich (New York: Columbia University Press, 2001), p. 195.

[126] See Arkin, "Weapons Total from Afghanistan Includes Large Amount of Cannon Fire."

[127] *Gulf War Air Power Survey, Volume V: A Statistical Compendium and Chronology*, pp. 553–54.

[128] *Gulf War Air Power Survey, Volume II, Part 2: Effects and Effectiveness* (Washington DC:HQ USAF, 1993), pp. 26.

[129] Data provided to author in 1993 by SAF/OSX, Headquarters, USAF. C-17 sortie counts assumes maximum weight. If payloads had to be reduced because of distance and/or refueling constraints, the number of sorties required would increase.

[130] C-17 load calculation assumes maximum weight.

Providing responsive logistical support to these forward bases is critical. The USAF has extensive experience in providing fuel to bare bases (most recently in Afghanistan), though the set up times required are likely to degrade responsiveness. Fuel vulnerability remains a concern. In past operations, munitions tended to be the most challenging logistical issue. The advent of guidance kits for general purpose bombs should ease pre-positioning problems, while the Small Diameter Bomb offers the potential to increase radically USAF flexibility in supporting deployed forces with munitions. The challenge of providing logistical support depends heavily on the size of the force deployed. The larger the force, the more challenging the support task.

V. How Vulnerable Are These Bases to Political Access Problems and to Emerging Military Threats?

Political Access Issues

While the world's basing infrastructure expanded under the previously discussed stimuli, the USAF overseas basing posture eroded due to budgetary, strategic, and foreign pressures. In 1965, the USAF possessed 70 bases in 25 countries. By 1975, the total had fallen to 58 in 19 countries, and to 46 in 17 countries by 1985. The latter numbers actually understate the true total, since the collocated operating base program in Europe added an additional 60 or so bases, while the U.S.-supported base development program in the Gulf made additional sites potentially available. Following the end of the Cold War, the USAF overseas basing infrastructure fell precipitously. By 1995, roughly five years after the end of the Cold War, the USAF basing posture stood at 15 bases in only 10 countries.[131] The collocated operating base program languished, reducing the number of potential sites. Overall, the data indicates that USAF peacetime foreign basing and access has declined, particularly following the end of the Cold War. The question is whether the declining posture will continue, stabilize, or reverse.

The United States needs to gain political approval from foreign nations to use their bases and airspace whether USAF forces are based overseas in a conflict area or in the CONUS. The general US policy goal is to develop strong relations with host countries to minimize the threat of political access problems. The Air Force and the other Services conduct regular operations and exercises around the world with a variety of nations to increase foreign familiarity with US forces. In the 2001 Quadrennial Defense Review, the DoD stated its plans to develop expanded basing plans to deal with East Asia. The Secretary of the Air Force was instructed to develop formal plans to increase contingency basing options in the Pacific and Indian Oceans.

Continued presence does run the risk of contravening US policy objectives by causing frictions over the long term. As one wag noted: "Divorce proceedings are when you learn that you really have to know someone in order to hate them." A key factor in the decline of USAF overseas presence was indigenous political opposition to US bases. The presence of US forces in Europe during the Cold War stirred local resentment, even in the case of such close allies as the United Kingdom and Germany, particularly over jet noise and damage US forces caused during exercises. After NATO formed, members Norway and Denmark passed legislation banning the peacetime basing of foreign forces on their soil.

In the Philippines, anti-colonial sentiment and local resentment against the side effects of US presence (e.g., prostitution, crime) led to closing of the vital naval and air force facilities on these

[131] Data taken from the annual almanac issue of *Air Force Magazine* for each respective year. As defined, a major installation is an Air Force base that serves as a self-supporting center for Air Force combat, combat support, or training operations. Units of wing size or larger operate the installation with all land, facilities, and support needed to accomplish the unit mission.

islands and a withdrawal of US forces in the early 1990s. Similar pressures led to planned US withdrawal from Panama. In Okinawa, crimes committed by US personnel against local civilians has led to continuing pressure for US forces to leave. Saudi Arabia, long uncomfortable with US presence since the Gulf War, recently signaled it may ask the United States to withdraw. In addition, a goal of Osama bin Laden's terrorist activities is to eliminate US presence in Saudi Arabia. Similar concerns were raised following the conflict in Afghanistan regarding potential problems that could arise from a long-term US presence in Pakistan, Afghanistan, Kyrgyzstan, and other nations in South and Central Asia. US presence over the long term could form a natural rallying point for Islamic and nationalist opponents and US bases could emerge as a target for terrorists attacks (as has already occurred in the Persian Gulf).[132]

Foreign bases from which US aircraft operate in peacetime are also subject to continuing constraints and pressures, even from close allies, and access rights can be a pressure point in negotiations. For example, the United Kingdom is one of the United States's closest allies and has traditionally been very supportive of US use of the UK's Diego Garcia atoll in the Indian Ocean. During Trident nuclear submarine contract negotiations in the 1970s, however, the United Kingdom sought a more favorable deal than the United States was offering. The US government balked, only to begin encountering numerous difficulties in conducting operations at Diego Garcia. Once the United States agreed to the British position on the Trident, the United Kingdom agreed to a less fettered use arrangement for Diego Garcia.[133] This encounter is not atypical of base access issues.

Political access issues have been present in many of the crises and military operations the United States has engaged in since World War II. Constraints typically depend on the type of mission the United States wants to conduct. Airlift, refueling, surveillance missions and naval port visits are typically easier to gain approval from host country, since these are far less threatening than offensive strike operations. For example, in May 1966, the Thai government stated that it would only allow B-26K night attack aircraft to be based in Thailand if the USAF changed the designation to A-26K, since the term "bomber" was deemed too highly charged compared to "attack."[134] More recently, the USAF decided not to arm the Global Hawk theater surveillance UAV to minimize future access problems. As an Air Force spokesman noted: "The U-2 and Global Hawk have a lot of access because everyone knows they're not combat aircraft."[135] In various crises during the 1990s in the Gulf, nations that were reluctant to support strike missions were willing to support refueling and surveillance missions.

The degree of threat to the host country also plays an important role. General John Jumper, as commander of USAF forces in Europe, stated in late 1998 that: "Access is an issue until you begin to involve the vital interests of the nation that you want and need as a host. Then access is rarely an issue."[136] His argument highlighted the changed attitude of the Gulf States following Iraq's invasion of Kuwait, when these nations requested military support from the United States. Previously, these nations had been reluctant to permit a large-scale US presence on their soil.

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[132] William Arkin, "US Air Bases Forge Double-Edged Sword," *The Los Angeles Times*, January 8, 2002.

[133] Information provided to the author by a former NSC official involved in the negotiations.

[134] Colonel James Rotramel (USAF, Ret.), A-26 historian.

[135] "Global Hawk UAVs to Remain Unarmed," *Aviation Week & Space Technology*, April 15, 2002, p. 20.

[136] See "The Access Issue."

To gain access, the United States has powerful cards to play in terms of prestige, power, and money, as illustrated by the following historical episodes:

- After the decision to send supplies via airlift to Israel during the 1973 Yom Kippur War, Portugal stalled in granting the United States use of the critical airfield at Lajes in the Azores. Portugal was concerned about antagonizing the Arab states and sought military aid in return. Secretary of State Henry Kissinger recalls in his memoirs of drafting "a Presidential letter of unusual abruptness that refused military equipment and threatened to leave Portugal to its fate in a hostile world." Within a few hours, Portugal granted unconditional transit rights.[137]

- During the 1980s, the United States exercised similar power to gain access to Pakistan to support Afghanistan against occupying Soviet forces; in return, the United States agreed to pay Pakistan over $7 billion in return for access.[138]

- Following the terrorist attacks on the United States in September 2001, the United States issued seven demands to Pakistan, including unrestricted access to Pakistani airspace and bases. The request was granted almost immediately. In return, the United States has pledged $800 million in aid, assistance in eliminating the country's $3 billion foreign debt, and reconsideration of the previously blocked F-16 sale.[139] Previous US sanctions over the Pakistani nuclear program that blocked the provision of credits, military sales, economic assistance, and loans to the Pakistani government have apparently been eliminated.

These successful negotiations illustrate that obtaining access can be costly. To cite a few examples, the United States agreed in 1987 to pay Turkey $569 million per year in military aid in exchange for base access; in 1990 to pay $345 million per year to Greece (until US facilities were closed), and in 1991 to pay the Philippines $200 million per year for a "base related compensation package."[140] A recent British history of US overseas base policy made a telling observation: "But in no instance, apart from the use of her own colonial possessions, has the United States had an entirely free hand in negotiating overseas basing rights. On the contrary, some host nations, conscious of the importance of their strategic position, have been able to exercise the tyranny of the weak by driving an ever harder bargain for the facilities on offer."[141]

Other historical episodes illustrate that negotiations over political approval can have inherently uncertain outcomes because of differences in perceptions, policies, and objectives of the United States and its potential allies. The following examples provide a sampling of past Air Force access problems (the other Services have encountered similar difficulties):

- In Operation Blue Bat, the 1958 movement of US forces into Lebanon, several nations (Greece, Austria, and Switzerland) refused overflight rights to US aircraft transporting Army forces from Germany to Turkey. Saudi Arabia refused to permit related USAF operations at the US air

[137] Henry Kissinger, *Years of Upheaval* (Boston, MA: Little, Brown and Co., 1982), p. 520.

[138] *Background Notes: Pakistan*, Washington DC: Department of State, 2000.

[139] Judy Keen, "Bush Lauds New Partnership with Pakistan," *The Washington Post*, February 14, 2002.

[140] Christopher Sandars, *America's Overseas Garrisons: The Leasehold Empire* (Oxford: Oxford University Press, 2000), pp. 280 (Turkey), 268 (Greece), 125 (Philippines).

[141] Ibid., p. 318.

base at Dahran.[142]

- In 1966, France withdrew from the unified military command structure and shattered the US basing posture in Europe. French territory, which housed nine USAF air bases and numerous Army installations, provided critical strategic depth and lines of communication for US forces on the Central Front. This loss and the potential uncertainties surrounding France's contribution in a future conflict greatly undermined NATO capabilities to mount an effective defense.

- In the 1973 airlift to Israel, all US NATO allies, with the exception of Portugal (which buckled, as noted before, under heavy US pressure), refused to grant the United States access to bases to support the operation. These same NATO nations and Spain refused overflight access to US airlifters. USAF fighters based in Italy were prohibited from providing escort to US airlifters, requiring US Navy carrier aircraft to assume this role.[143]

- In 1973–1974, six US bases in Thailand were shut down due to local opposition.[144]

- In the 1986 raid against Libya, France and Spain refused permission for overflights by USAF F-111s launching from the United Kingdom, almost doubling mission length and adding considerably to the operation's complexity.[145]

- In 1992, USAF and USN forces evacuated the key facilities of Clark Air Force Base and Subic Bay, respectively, in the Philippines after many years of growing indigenous opposition to the US presence.[146]

- Following September 1995 air strikes against Bosnia, Italy refused permission to base F-117s at Aviano air base for subsequent missions. The Italians were irritated over their limited diplomatic role in peace negotiations and used access rights to improve their negotiating position.[147]

- In the September 1996 Irbil crisis, when Iraqi forces attacked the Kurds in northern Iraq, Saudi Arabia and Turkey refused permission to conduct offensive operations from their soil with the 100 USAF fighters based in those nations. Jordan refused to permit the United States to deploy 30 fighters to that nation.[148] The location was also outside the range of carrier-based aircraft.[149]

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[142] Siegel, *Basing and Other Constraints on Land-Based Aviation Contributions to US Contingency Operations*, pp. 13–14.

[143] Ibid., pp. 17–18.

[144] Ibid.

[145] See David C. Martin and John Walcott, *Best Laid Plans: The Inside Story of America's War against Terrorism* (New York: Harper and Row, 1987) and Venkus, *Raid on Qaddafi: The Untold Story of History's Longest Fighter Mission By the Pilot Who Directed It*.

[146] See Sandars, *America's Overseas Garrisons: The Leasehold Empire*, pp. 105–26 for an overview of US and Philippine government negotiations over these two bases.

[147] Daniel Williams, "Italy Seeks Bigger Role on Diplomatic Stage; Rome Uses Bosnia as Leverage to Boost Status, but Internal Troubles Hamper Effort," *The Washington Post*, October 11, 1995. Details on the strike operations can be found in Craig Covault, "Air Power Alters Bosnia Equation," *Aviation Week & Space Technology*, September 4, 1995.

[148] Jeff Harris and R. Jeffrey Smith, "Why Clinton's Response Fell Far from the Site of Saddam's Aggression," The Washington Post, September 4, 1996.

[149] "Missiles Had to Travel Far, Saudi Arabia and Turkey Refused to Let Air Bases Be Used in Attack," *Orlando Sentinel*, September 4, 1996.

Accordingly, the United States was forced to use cruise missiles launched from bombers and ships to strike unrelated air defense sites in southern Iraq. The cruise missiles did little damage to the heavily bunkered targets. Access problems continued to bedevil the United States in the aftermath. Kuwait agreed to host eight F-117 strike aircraft, but delayed in permitting US Army force deployments, causing additional diplomatic embarrassment.[150]

- In the December 1998 Desert Fox strikes against Iraq, half of the forward-based USAF fighters in the Gulf—about 60 in number—could not be employed because of objections from Saudi Arabia and the United Arab Emirates. Combat aircraft operating from Kuwait and Oman took part in the operation. However, Saudi Arabia and the UAE did allow support operations, such as tanker refueling sorties.[151]

- During the 1999 Serbian conflict, concerns grew that internal divisions over the air war in Italy, which housed the crucial base at Aviano, might force a stand down of air operations. Violent protests took place at various air bases in Italy.[152] Five days after the start of operations, Italian authorities insisted to General Wesley Clark that unless the coalition focused its air power efforts against the Serbian forces conducting atrocities in Kosovo, Italy would shut down access to its facilities. Clark accordingly acceded to Italian concerns and focused the air campaign against the Serbian ground forces,[153] which in turned triggered frictions between Clark and his Joint Force Air Component Commander over the proper employment of air power. During the operation, France also denied use of its air space for UK-based B-52s carrying cruise missiles, forcing the bombers to fly around Spain and up through Mediterranean to deliver their weapons.[154]

- In 1999, US forces began withdrawing from Panama as part of the agreement to return control of the canal to the Panamanian government.

- In September 2001, Saudi Arabia signaled that it might not permit the United States to employ its new command and control center at Prince Sultan air base to direct offensive air operations.[155] A few months later, the Saudi government floated rumors that Riyadh might ask the United States to remove its forces and personnel.[156] Recent press reports have indicated that the

[150] Neil MacFarquhar, "Mideast Coalition Shows Strain; Kuwait Puts US Plan on Hold; White House Says Saddam Has Yet to Meet Terms of Ultimatum," *The New York Times*, September 16, 1996.

[151] Douglas Jehl, "No Strikes from Saudi Soil: About 60 US Fighters Grounded," *The New York Times*, December 19, 1998.

[152] William Booth and Sarah Delaney, "While Accepting Refugees, Italy Is Divided over Kosovo," *The Washington Post*, April 14, 1999.

[153] Author's interview with senior official at Supreme Headquarters Allied Powers Europe (SHAPE), February 28, 2002.

[154] General John Jumper, "Global Strike Task Force: A Transforming Concept, Forged by Experience," *Aerospace Power Chronicles*, Spring 2001.

[155] Vernon Loeb and Dana Priest, "Saudis Balk at US Use of Command Post; Powell Seeks Reversal of Policy; Refusal Could Delay Airstrikes at Terrorists," *The Washington Post*, September 23, 2001.

[156] David B. Ottaway and Robert G. Kaiser, "Saudis May Seek US Exit; Military Presence Seen as Political Liability in Arab World," *The Washington Post*, January 18, 2002.

United States is planning to move the facility to Qatar to reduce dependency on the uncertain position of Saudi Arabia.[157]

These historical examples illustrate that forecasting the attitude of host country/countries in future crises will remain a risky proposition. The United States can bring enormous pressures to bear on a host country, yet success cannot be guaranteed. Foreign nations may have very different views on the seriousness of the crisis than the United States They may be reluctant to escalate the crisis by permitting the deployment of US forces or may not want to be perceived as aligning with the United States (and triggering local and regional opposition). USAF capabilities have been undermined by access problems in numerous contingencies, when lack of political support severely compromised potential US offensive options.

Previous Air Force arguments downplaying the seriousness of access have focused on threat perceptions; if a nation is threatened, it will grant access. Since September 2001, however, the United States has emerged as a threatened nation and has begun laying plans to conduct offensive operations against several nations, notably Iraq. Support from regional allies critical to such operations has been less than enthusiastic, at least in public. If host nation and US interests fail to align, obtaining political support and access will be far more difficult.

Overall, political access issues raise enormous uncertainties regarding basing and employing combat aircraft in foreign nations. The uncertainties are highlighted by the response of the commander of the Pacific Air Forces, General William Begert, to a question regarding progress in expanding Air Force basing arrangements in Asia:

> The distances in the Pacific are daunting and we don't have a lot of strategic lily pads, at least not in enough places. What we need is over-flight clearances that come quickly, blanket over-flights are better than case-by-case over-flights. What we need is access to bases in order to get to where we are going. We have critical bases in places like Guam and Kadena [and] Singapore. There are other places that we are exploring and looking at. Very frankly, India is attractive, depending on where you want to go and what it is that you want to do.
>
> I didn't talk about Thailand, but the Thailand infrastructure in Southeast Asia that many of us remember is still there and still very good and in fact they are very good, quiet allies and have been throughout Enduring Freedom. Those bases are very useful to us in Thailand. But in terms of opening new Air Force bases and putting additional force structure in, I don't see a lot of extra force structure laying around the Air Force not doing anything right now…. What I am trying to do is get access to as many places that will allow us in for when we need to get the job done and then work those over-flight clearances, country by country, as much as we can.[158]

In the final analysis, can the United States count on getting political access and "blanket over-flight" rights? General Begert's remarks only highlight the uncertainties involved.

[157] "USA Looks to Expand Bases in Oman and Qatar," *Jane's Defence Weekly*, April 17, 2002.

[158] Comments by William Begert, Commander, Pacific Air Forces, at Air Force Association meeting in Orlando, Florida, February 14, 2002.

Military Threats

Three main threats confront USAF fighter forces at forward bases: Conventional, deep-strike (ballistic and cruise missiles) systems, special forces, and weapons of mass destruction (WMD).

Deep-Strike Systems

Manned aircraft have been the traditional tool nations employed to conduct deep-strike operations. Historically, when developing nations have employed these forces, particularly when confronted by modern Western air power, they have fared very poorly in combat. North Korean aircraft suffered a very poor exchange ratio against US forces and never could seriously threaten US ground forces or US air bases. The Vietnamese enjoyed better success in the air, at least until US air combat training was revised, but could not mount air strikes against US air bases in South Vietnam. The Israeli Air Force consistently drubbed Arab air forces; Iraqi aircraft suffered a similar fate during the 1991 Gulf War at the hands of coalition forces. The same held true for Serbian combat aircraft in 1999. Building and employing manned aircraft in effective offensive operations is an extremely complex and expensive task that, to date, has only been successfully achieved by a handful of developed nations. For example, in 1967 the Israeli Air Force conducted a series of highly successful air base attacks against its Arab foes. Just two years earlier the Indian Air Force had attempted a similar attack against Pakistani air bases that proved far less successful.[159]

Unmanned systems, however, can be employed to good effect by less experienced and sophisticated military forces. As this author noted in a previous publication; "Once a ballistic or cruise missile is fired, it really does not matter who pressed the trigger—a Western professional or an untrained conscript. The weapon will proceed to the target area subject to the system's capabilities and reliability constraints."[160] In Western thinking, ballistic and cruise missiles are typically not considered cost-effective for sustained warfighting, since the loss of the air vehicle on each sortie makes the cost per aimpoint extremely high (compared to aircraft which can be reused). But because investment in manned aircraft has proven so disappointing in terms of military return, ballistic and cruise missiles appear to be the most effective option for developing nations to gain a useful deep-strike capability. As the National Air Intelligence Center noted: "Missiles are much less expensive than acquiring and maintaining a world-class air force competitive with US military aviation."[161]

Ballistic missiles were first used in combat in World War II. The Germans fired approximately 3,000 V-2 missiles at the United Kingdom and on the European continent—the firing rate ranged from 15 to 26 missiles per day.[162] The Soviet Union derived the SCUD ballistic missile from the V-2 and SCUDs have proliferated widely—the Soviets are thought to have exported from 5,000–10,000 of these weapons and many nations now have the capability to produce SCUDs. During the Iran-Iraq War of the 1980s, the two opposing nations fired approximately 600 ballistic missiles at each other. Iraq reached a rate of fire of 11 per day (and was capable of building three ballistic

[159] Tanham and Agmon, *The Indian Air Force: Trends and Prospects*, p. 30.

[160] Bowie, et. al., *Trends in the Global Balance of Airpower*, p. 83.

[161] *Ballistic and Cruise Missile Threat*, NAIC-1031-0958-98 (Wright-Patterson AFB: National Air Intelligence Center, 1998), p. 1.

[162] David Irving, *The Mare's Nest* (London: William Kimber and Co., 1964).

missiles a day). Iraq launched a total of 361 missiles against six Iranian cities, killing and injuring 8,000 Iranians.[163] During the 1991 Gulf War, Iraq fired 88 missiles at the Gulf nations and Israel. Though the SCUDs were relatively ineffective in military terms, the US inability to defend effectively against ballistic missiles apparently triggered growing emphasis on these weapons:

- China currently produces the CSS-2 (1,500 nautical mile range), CSS-3 (2,800 nautical mile range), CSS-4 (7,000 nautical mile range), and CSS-5 (800 nautical mile range) missiles. China has begun deploying solid-fueled CSS-6 (300 nautical mile range) and CSS-7 missiles (150 nautical mile range) to replace its older systems; 200 CSS-7 ballistic missiles have been deployed at two bases opposite Taiwan. The missiles are mounted on mobile launchers and housed in hardened underground facilities.[164] China is reported to have plans to deploy some 650 such missiles opposite Taiwan by 2005.[165] In July 1995 and March 1996, China fired a total of ten CSS-6 ballistic missiles into the waters near Taiwan to underscore dramatically its dissatisfaction with Taiwanese policies.

- North Korea has deployed approximately 500 SCUD variants (with ranges of 150–300 nautical miles) and can produce 4–8 per month.[166] North Korea has also developed several medium-range ballistic missiles with much longer ranges (800–3,000 nautical miles) and relies upon export of missiles and missile technology for hard currency.

- Iran, relying on Chinese assistance, has constructed a facility east of Tehran to build short-range missiles and purchased approximately 600 SCUD variants from North Korea. Iran can now build SCUDs indigenously.[167] One estimate places the current Iranian ballistic missile inventory at 500 missiles (195 SCUD Bs, 150 SCUD Cs, and 50 shorter range systems).[168] Iran has tested the Shahab-3 (with a range of 700 nm that could threaten Israel) and has announced plans to begin production.[169] Mounted on mobile launchers, the Shahab-3 will be housed in five separate underground bunker facilities.[170] Iran is also reportedly working on the Shahab-4 (with a range of 3,000 nautical miles that could reach Western Europe, including the United Kingdom).[171]

- India has deployed two variants of the short-range Prithvi missile (with ranges of 100 nautical miles) and has tested the Agni II with a range of 1,600 nautical miles. A 2,700 nautical mile range variant is also under development.[172]

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[163] Mark Hewish, "Ballistic Missile Threat Evolves," *Jane's International Defense Review*, October 2000.

[164] Bill Gertz, "China Places Second Missile Base Near Taiwan," *The Washington Times*, March 15, 2001.

[165] Bill Gertz, "China Prepares for War with US over Taiwan," *The Washington Times*, November, 15, 2000.

[166] See *2000 Report to Congress: Military Situation on the Korean Peninsula* (Washington, DC: OSD), September 12, 2000 and Hewish, "Ballistic Missile Threat Evolves."

[167] Ibid.

[168] "Turkey: Iran Starting Production of Shahab-3 Missile," *Jerusalem Post*, May 15, 2002.

[169] Ibid.

[170] *Jane's Strategic Weapon Systems* (London: Jane's Information Group, 2002), p. 92.

[171] Keith Payne and Robert Rudney, "The Unique Value of Ballistic Missiles for Deterrence and Coercion," *Commission to Assess the Ballistic Missile Threat to the United States* (Washington, DC: OSD, 2000) and Rober Shuey, *Missile Survey: Ballistic and Cruise Missiles of Foreign Countries* (Washington, DC: Congressional Research Service), February 10, 2000, p. 23.

[172] Hewish, "Ballistic Missile Threat Evolves."

- Pakistan has developed ballistic missiles with assistance from China and North Korea. The Hatf missile family comprises variants of the Chinese CSS-7 with ranges running from 150 nautical miles to 1,400 nautical miles. Pakistan has also developed several variants of the liquid-fueled Ghauri missile (with ranges of 700–1,300 nautical miles).[173]

- Saudi Arabia purchased and deployed 36 CSS-2 ballistic missiles from China with a range of 1,500 nautical miles. The missiles are maintained by Chinese personnel.

- Ballistic missiles forces are also fielded by Libya and Syria.

In his recently published memoirs, Lieutenant General Hazim 'Abd-al-Rassaq, the commander of Iraqi missile forces in the Gulf War, provides important insights into potential adversary thinking about these weapons.[174] Rassaq's memoirs make clear that these weapons offered Iraq an unprecedented capability—assured long-range strike capability against Iraq's enemies. The strategic value of these weapons, which allowed "the cancellation of borders," was not lost on Saddam Hussein or the Iraqi military. Judging from the growing numbers of missiles potential adversaries are fielding, the strategic potential has not been lost on other nations as well.

Iraq's careful preparation of these missile forces should also give pause to those tending to dismiss the threat. As Razzaq's memoirs illustrate, Iraq built up its missile forces following their use in the Iran-Iraq War to minimize their vulnerability and maximize their military effectiveness. Iraqi forces conducted their missile operations in a highly professional and coordinated manner. Iraq:

- indigenously developed mobile launchers and longer-range weapons;

- extensively used deception and camouflage;

- conducted continual exercises to minimize launch preparation times and to improve ability to fire mass volleys;

- developed chemical warheads and secure communications;

- coordinated operations with air defense and security forces; and

- prepared data on such targets as "…nuclear reactors, military and chemical factories, air bases and air ports, naval bases, and targets that give support to the enemy military effort."[175]

This careful preparation frustrated coalition attempts to destroy the Iraqi missile force—Razzaq claims that he lost neither a single launcher nor crewman from his three rocket brigades during the conflict and was sufficiently confident in his security measures that he allowed his 10 year-old son to press the firing button during two of the launches.[176] Coalition air forces flew 2,400 Scud strike

[173] Ibid.
[174] LTG Hazim 'Abd-al-Razzaq, *Forty Three Missiles on the Zionist Entity*, FBIS Translation, October-November 1998.
[175] Ibid.
[176] Ibid.

and Scud patrol sorties to suppress the missile threat. On 42 occasions, patrolling aircraft spotted a launch plume, leading to eight attacks. But overall, coalition forces failed to destroy any Scud launchers.[177] Other nations observed the advantages provided by Iraqi missile mobility and operating procedures. Almost all of the newly developed ballistic missiles deployed by China, Iran, Pakistan, and India are mobile.[178]

Although Scud effectiveness during Desert Storm was of limited military effectiveness—owing to poor accuracy—satellite navigation systems, re-entry vehicle guidance systems, and submunitions could potentially increase dramatically missile lethality. US experience from the Gulf War indicates that precision weapons increases overall force effectiveness by an order of magnitude or more. The problem is that such effectiveness increases are now available to potential adversaries.

Modern guidance techniques (such as GPS-derived launcher position) can make ballistic missiles far more accurate than previous generations. However, these missiles will still not be as accurate as precision-guided weapons or cruise missiles since the warhead follows a ballistic trajectory after motor cutoff. This may change if new generations of warheads are deployed. For example, the Russians and Indians are negotiating over the sale of an electro-optical seeker for India's ballistic missiles which would greatly improve missile accuracy. The optical seeker warhead employs a previously photographed target image (provided by aircraft or satellites) stored in its guidance computer, against which it compares imagery from the on-board target seeker. The warhead vehicle is fitted with fins for maneuvering during the final phase of the warhead's engagement; accuracy for the Russian system is estimated at about 60 feet.[179]

If the Chinese adopt such technologies, Mark Stokes, a former USAF air attaché to Peking serving in OSD, noted: "Breakthroughs in ballistic missile terminal guidance over the next five to 10 years could be devastating not only for the PRC's neighbors, but also for US forces operating in the Pacific."[180] A recent report states that China is developing a radar-based terminal guidance system for its medium-range missile force similar to that developed for the US Pershing II missile in the 1980s (which featured a circular error probable of 164 feet).[181]

Cruise missiles offer another attractive, deep-strike system for developing nations. Although Germany employed cruise missiles on a large scale basis by Germany in World War II (the V-1 "Buzz Bomb"), these weapons did not begin to proliferate widely until Egyptian patrol boats sank the Israeli destroyer *Eilat* with Styx cruise missiles in the October 1967 War. About 75,000 of these weapons can now be found in naval inventories around the world. Anti-ship cruise missiles pose a formidable anti-access threat to surface ships because they fly at low altitudes with low radar cross sections (and when fired in mass volleys can potentially overwhelm fleet defenses).

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[177] Christopher J. Bowie, *Destroying Mobile Ground Targets in an Anti-Access Environment* (Rosslyn, VA: Northrop Grumman Analysis Center, January 2002), pp. 2–3.

[178] Payne and Rudney, "The Unique Value of Ballistic Missiles for Deterrence and Coercion."

[179] Douglas Barrie and Simon Sardzhyan "Russian Seeker Sale May Undermine MTCR: System Would Improve Accuracy of Indian Missiles," *Defense News*, March 26, 2001.

[180] Mark Stokes, "Space, Theater Missiles, and Electronic Warfare: Emerging Force Multipliers for the PLA Aerospace Campaign," in *Chinese Military Affairs: A Conference on the State of the Field* (Washington, DC: Fort McNair, October 26–27, 2000).

[181] Center for Defense and International Security Studies, *National Briefings: China* (United Kingdom: Lancaster University, 2001).

Adapting these anti-ship weapons to the land-attack role offers one path to potential adversaries seeking to strike at long ranges. However, recent analyses indicate that the most dangerous weapons could be cruise missiles derived from unmanned aerial vehicles (such as target and reconnaissance drones) or small kit aircraft.[182] These relatively low cost weapons can provide substantial range and payload. Before the Gulf War, Iraq had constructed several cruise missiles based on converted trainer aircraft and reconnaissance drones.[183]

Currently, nine countries indigenously manufacture land-attack cruise missiles with ranges of 60–500 nautical miles, which could further spur proliferation.[184] For example, India recently revealed that it had successfully developed the PJ-10 cruise missile (with a range of 175 nautical miles) in cooperation with Russia. The weapon can be fired from a mobile launcher.[185] India is developing two other land-attack cruise missiles, including the *Lakshya*, which can carry a 1,000-pound payload 300 nautical miles. Indian designers are also exploring fitting the *Lakshya* system with a more advanced turbofan engine, which would increase its range.[186] Iran is constructing a cruise missile production facility and working with North Korea on other cruise missile projects.[187] US intelligence officials revealed in the fall of 2001 that China had also successfully tested a land-attack cruise missile and noted that in fielding such weapons "the threat to US forces will increase over the next decade."[188]

Cruise missiles are less expensive than ballistic missiles and can also be launched from mobile launchers, which are more difficult to locate and attack than ballistic missile launchers because the launch is typically not a "high signature" event. Using GPS-guidance, cruise missiles can achieve much higher accuracy than ballistic missiles (since they can receive satellite signals all the way to target impact). In addition, such weapons can be difficult to defend against, particularly if equipped with stealth technologies.[189]

Precision weapons require precision intelligence. During the Cold War, such capabilities were only available to the two superpowers. In the very near future, high-resolution commercial remote sensing satellites will provide imagery and intelligence over large geographic areas to any paying customer.[190]

The Falklands/Malvinas conflict in 1982 provides a glimpse into the potential impact. As the Royal Navy task force sailed south, the British reported their concern to the United States that low-resolution, LANDSAT satellite data would reveal the position of the British fleet.[191] Newer generation

[182] Dennis Gormley, *Dealing with the Threat of Cruise Missiles* (London: International Institute for Strategic Studies, Adelphi Paper No. 339, 2001).

[183] Ibid., p. 27.

[184] "Analyst Warns of Increasing Foreign Interest in Cruise Missiles," *Inside Missile Defense*, April 18, 2001.

[185] "India Plans Broad Arms Deals with Russia, Worth $3 Billion," *Defense News*, October 22–28, 2001.

[186] Ghormley, *Dealing with the Threat of Cruise Missiles*, p. 25.

[187] "Analyst Warns of Increasing Foreign Interest in Cruise Missiles."

[188] "Chinese Missile Test," *The Washington Times*, September 7, 2001.

[189] See Dennis Gormley, *Cruise Missile Proliferation: Threat, Policy, and Defenses* (Washington, DC: Carnegie Endowment for International Peace, October 9, 1998).

[190] An overview of this topic can be found in Yahya A. Dahqanzada and Ann M. Florini, *Secrets for Sale: How Commercial Satellite Imagery Will Change the World* (Washington, DC: Carnegie Endowment for International Peace, 2000).

[191] Information provided to author by a senior US government official.

satellites offer much higher resolution, which would expose a greater range of operations to observation. During recent combat in Afghanistan, the Pentagon purchased all imagery of Afghanistan from the US commercial Ikonos satellite, which offers one-meter resolution, to prevent other nations and entities from getting this valuable intelligence resource. Other imaging satellites operated by companies in France, Israel, and India do not currently offer such resolution, but will in the future.[192] In addition to these suppliers, Canada, Russia, China, and possibly Pakistan, South Korea, and Australia could also provide high resolution imagery in the future. Analysts at the Carnegie Endowment who studied the issue in depth concluded that the growing number of potential providers will make attempts to control access to this imagery "bound to fail."[193]

Accordingly, a future adversary will almost certainly see large-scale American troop movements (similar to the famous "left hook" of the Gulf War), naval vessels, and "beddown" locations of fighter and support aircraft. Using commercially based imagery to pinpoint the forward deployment and disposition of American and allied military forces in the region, adversaries could conduct more effective attacks. As Rudy De Leon stated when he was deputy secretary of defense, satellite imagery distribution during conflict "is, I think, the central challenge of the 21st century."[194]

What could such deep-strike systems, when coupled with overhead surveillance capabilities, mean for US forward air base survivability? US thinking on airfield vulnerability is based on the experience of the European front in the Cold War, which involved massed waves of Warsaw Pact strike aircraft delivering unguided bombs. RAND simulations, for example, typically examined the effects of bombs hitting various airfield locations; a large proportion of the weapons used in such simulations did not hit any key facilities. However, the sheer scale of these attacks—thousands of strikes within a few days—would have severely degraded NATO air operations and few in the USAF were confident about air base survivability in Europe.

In Desert Storm, coalition air forces began using precision-guided weapons in large numbers against selected key facilities on Iraqi air bases. In 1999, USAF B-2s employed precision weapons against the runways and taxiways of a Serbian airfield; the same technique was employed against an Afghan fighter base in 2001. Additional precision strikes hit shelters, hangars, and other key facilities. These recent attacks provide an insight into the future: accurate weapons will increase the potential vulnerability of airfields by allowing adversaries to strike accurately critical facilities and areas.

A recent RAND study postulated an alarming scenario involving more accurate and lethal weapons. RAND noted that a *single* medium-range, Chinese-developed CSS-6 ballistic missile using modern guidance techniques (but not a guided warhead) equipped with submunitions had a high probability of destroying almost four squadrons of fighters (96 aircraft) parked in the open using standard spacing (see Figure 4). Submunition warhead technology is many decades old. For example, the Chinese began developing such a warhead for their ballistic missiles in 1976.[195]

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[192] "US Military Buys Rights to Satellite Pictures of War Zone," *Dow Jones International News*, October 16, 2001.

[193] Dahqanzada and Florini, *Secrets for Sale: How Commercial Satellite Imagery Will Change the World*, p. vii.

[194] "Commercial Satellites Pose Challenge to Military, De Leon Says," *Aerospace Daily*, September 25, 2000.

[195] Kurt Guthe and Keith Payne, "The Unique Value of Ballistic Missiles for Deterrence and Coercion: The Chinese Case," *Report of the Commission to Assess the Ballistic Missile Threat to the United States* (Washington, DC: Office of the Secretary of Defense, 1998).

Figure 3: Lethal Radius of CSS-6 Missile against Four Squadrons of F-15s Parked According to Normal USAF Spacing Guidelines

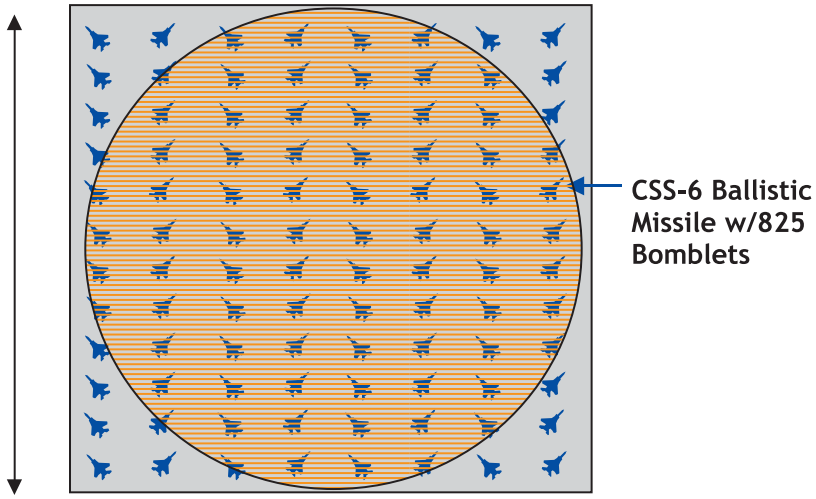

Figure based on information in John Stillion and David Orletsky, *Airbase Vulnerability to Conventional Cruise-Missile and Ballistic-Missile Attacks: Technology, Scenarios, and US Air Force Responses*, MR 1028-AF (Santa Monica, CA: The RAND Corporation, 1999), p. 14.

Looking at a broader scenario, the RAND analysts postulated an Iranian attack using a mix of ballistic and cruise missiles against four large bases housing US aircraft in the Gulf, assuming aircraft parked in the open and support personnel occupying tent cities. Cruise missiles attacked the ballistic missile defense sites near the bases (flying low and slow to evade radar detection), followed by a barrage of ballistic missiles armed with unguided submunitions to blanket the parking ramps and tent cities with explosives. Such an attack would have destroyed almost all aircraft parked at the four bases (which comprised 4 million square feet of ramp space) and killed large numbers of personnel. The number of weapons to execute this attack was surprisingly small: only 10–19 ballistic missiles and 2–4 cruise missiles per base/tent city complex. As the authors noted, "The combination of increased accuracy from GPS guidance and increased warhead efficiency is what decreases the number of missiles required to attack USAF air bases from hundreds to dozens." RAND estimated that for $1 billion in total investment, Iran could conduct four such attacks against the tent cities and up to 12 attacks against the parking ramps.[196]

Against airfields, an adversary equipped with ballistic and cruise missiles could employ a variety of attack strategies against US air bases:

- **Parking ramps:** At both commercial and military bases, parking ramps could form lucrative targets. Large support aircraft, such as airlifters and surveillance systems, cannot be sheltered at military bases and hence would be exposed to attack by submunitions delivered by ballistic missiles. At a commercial base, support aircraft and fighters could be destroyed. If aircraft are not properly separated on the ramp (which could occur if only a few bases are available), destroying a single aircraft could ignite others.

[196] Stillion and Orletsky, *Airbase Vulnerability to Conventional Cruise-Missile and Ballistic-Missile Attacks: Technology, Scenarios, and US Air Force Responses*.

- **Fuel:** Fuel storage facilities cannot be effectively hardened and would constitute a lucrative and extremely vulnerable target that could bring operations to a halt if hit. Pipelines leading to the airfield could also be struck. Though pipeline breaks could be repaired, such strikes would slow down aircraft refueling and hence degrade combat capability. During the 1985 Salty Demo air base operability exercise, the wing commander at the exercise base noted that no simulated attacks were conducted on the above-ground fuel storage area because "it would have shut down the wing."[197] No doubt the fuel supplies to the base could have been restored if the exercise had simulated such an attack, but sortie generation capability would have been substantially reduced.

- **Munitions:** Munitions storage facilities would also form an attractive target. At military bases, munitions are typically stored in clusters off base to prevent large-scale sympathetic detonations. But an explosion in a munitions storage facility is bound to slow down operations by raising concerns among munitions handling personnel who need to enter the area to move weapons to the aircraft. Finding an ideal storage location for weapons could be difficult at a commercial airfield. If the munitions are not stored properly (as was often seen during Operation Desert Storm), the potential exists for large scale sympathetic detonations that could damage facilities and totally disrupt operations.

- **Personnel:** Killing pilots and ground crew would quickly cut sortie rates, but requires excellent intelligence. In the 1980s, for example, the Soviet Union had developed plans to execute Swedish pilots in their homes during mobilization using Spetznaz teams. Traveling foreign "art dealers" gathered intelligence on the location of the pilots' homes, but the visits tipped off Swedish authorities on the plan.[198] At military bases, pilots would typically be housed in a hardened shelter. If it were possible to penetrate the bunker and kill the pilots, sortie generation capabilities would rapidly degrade. At an airfield without shelters, the pilots could be more vulnerable either at off-base housing or in tent cities. The same holds true for maintenance personnel. Nonetheless, the intelligence requirements to execute such an attack would be very demanding.

- **Power:** Strikes against electric generation plants, electrical grids, and transmission lines could degrade operations. Fuel cannot be pumped, avionics cannot be repaired, shelter doors cannot be opened, and communications can be disrupted. At military bases, most facilities have backup power generators, but these tend to be less reliable than main electrical supplies unless rigorously maintained and tested. During some air base operability exercises in the 1980s, for example, the Air Force found that back up generators would fail to start due to inadequate maintenance.[199] Conversely, during the 1985 air base operability demonstration at Spangdahlem, the commanding officer found the backup systems were highly reliable because they had been put in "tip-top shape" during the workup to the exercise.[200] In the Gulf War, problems occurred with the range of generators used at bare bases. Of the 90 large generators initially deployed, for example, only 16 were operational.[201]

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[197] Author's interview with General Lawrence Day (USAF, Ret.), February 27, 2002.

[198] Gordon McCormic, *Stranger than Fiction: Soviet Submarine Operations in Swedish Waters*, R-3776-AF (Santa Monica, CA: The RAND Corporation, 1990), p. 24.

[199] Interview with Tidal W. McCoy.

[200] Author's interview with Major General Lawrence Day.

[201] *Gulf War Air Power Survey, Volume III, Part 2: Support*, p. 12–13.

- **Water supplies:** Attacks aimed at cutting or poisoning water supplies were a major concern for the USAF during the 1980s in Europe. To respond, the United States would need to deploy pipelines, water purification facilities, and portable water storage tanks.

- **Aircraft Shelters:** Destroying aircraft in shelters can be a very effective means of degrading capabilities. The typical NATO shelters erected in the 1970s and 1980s did not offer protection against direct hits, so an accurate cruise missile with a modest warhead could probably penetrate and destroy the aircraft housed inside such shelters. Such weapons may not work against more protected shelters, such as the ones the Saudis built at Khamis Mushait that housed F-117s. Israeli attacks against Arab shelters in the 1973 conflict achieved poor results because Israeli weapons could not penetrate the thick walls.[202] With accurate weapons, it might be possible to physically strike the shelter doors and jam them in their tracks, thus trapping the aircraft inside. If numerous shelters are available, however, such attacks could consume many weapons (as is discussed below).

- **Hangars:** At a commercial facility, striking hangars has the potential to kill support personnel and destroy support equipment housed inside for aircraft maintenance. Over time, this can degrade force effectiveness by reducing the number of aircraft in commission.

- **Runways and taxiways:** Operating surfaces are probably an unattractive target for ballistic or cruise missiles. Aircraft-delivered general purpose bombs equipped with delayed action fuses can penetrate the surface and then "heave" the concrete after detonation. USAF B-2s employed such tactics in Serbian and Afghan airfield attacks. Specialized weapons can inflict even more damage. The Israelis employed such a weapon (the "dibber") in 1967. The United Kingdom deployed an even more potent submunition in its JP-233 munitions dispensers in the 1980s; France fielded the Durandel anti-airfield weapon in the same time period (which the United States subsequently adopted). To prevent aircraft from taking off using taxiways and shortened runway sections, multiple hits are required. Though ballistic missiles could possibly be used, their limited accuracy compared to cruise missiles would require large numbers to close an airfield. A specialized cruise missile could potentially be designed to "heave" runways, but development would be complex and difficult. In any case, damage to operating surfaces can be quickly repaired. Runway repair capabilities have become fairly widespread at military facilities, using either quick setting concrete or pre-stocked slabs. At military airfields, such attacks could certainly slow down operations, but would not likely bring them to a halt.

Hardened military air bases with base recovery equipment are resilient entities and considerably more difficult to degrade than unhardened airfields. Successful strikes would require large numbers of precision weapons to knock a military air base out of commission for a substantial period. In 1973, Israel turned to runway attacks because the IAF did not possess weapons capable of penetrating the thick Arab shelters. The Israelis used 12 F-4 Phantoms delivering unguided weapons against hardened Syrian bases, but observed that the Syrian fields "were again scrambling aircraft within less than an hour."[203] The IAF sustained the attacks, however, and observed that "the time between

[202] Kreis, *Air Warfare and Air Base Air Defense*, 1914–1973, p. 331.

[203] Eliezer Cohen, *Israel's Best Defense: The First Full Story of the Israeli Air Force* (New York: Orion Books, 1993), pp. 360–61.

the bombing of the runway and the return to operations increased."[204] Eventually, some Syrian pilots were forced to eject from their aircraft because of their inability to find an undamaged operating surface.[205] On the Egyptian front, runway repairs took from two to six hours (depending on the importance of the base) after Israeli attacks.[206] Despite flying hundreds of sorties against Syrian and Egyptian bases, the IAF was only able to destroy 22 enemy aircraft on the ground (compared to inflicting 400 ground losses in 1967).[207]

During the Gulf War, the alliance mounted a series of attacks against Iraqi operating surfaces to reduce the Iraqi Air Force threat. After a week of these attacks, the Iraqi Air Force "hunkered down" in its shelters to ride out the coalition attacks. In response, allied planners employed precision-guided weapons against the 600 or so shelters in Iraq. These strikes consumed substantial percentages of the limited number of precision-capable strike aircraft.[208] For the largest shelters—the so-called "Yugos" (built with assistance from Yugoslavia)—the newly fielded BLU-109 penetrating bomb body was the most effective weapon. Once the allies started destroying even the most protected shelters, the Iraqis reacted by flying some aircraft to Iran and dispersing aircraft in the open to complicate the allied targeting problem (destroying a shelter did not necessarily mean killing an Iraqi combat aircraft). Allied attacks destroyed an estimated 254 Iraqi aircraft (of 724 total) in shelters or on the ground.[209] The airfield attacks consumed a substantial portion of the coalition air effort. Overall, alliance air power conducted 2,990 strikes against Iraqi airfields, about 7 percent of the total strikes and roughly double the effort against any target class except for ground forces.[210]

During Operation Allied Force in 1999, USAF aircraft attacked a bunker facility at the airfield at Pristina in Kosovo. Following the conflict, the Serbs towed 11 MiG-21s out from the bunker (which had obviously not been penetrated) and flew the aircraft back to Serbia.[211]

Typically, more developed military bases house equipment to restore operating surfaces, sweep away submunitions, and restore power. So operations can be degraded, but probably not stopped. Nonetheless, such attacks could obviously be extremely damaging and disruptive. In the 1985 Salty Demo exercise, according to the official in charge of air base survivability, "the results…showed even a fairly moderate Soviet attack could reduce our ability to generate sorties. The degradation was especially severe in the first critical week of this demonstration."[212] An article on the exercise observed that:

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[204] Ibid., p. 361.

[205] Ibid.

[306] Kreis, *Air Warfare and Air Base Air Defense, 1914–1973*, p. 332.

[207] Nordeen, *Fighters over Israel*, p. 147.

[208] 40 percent of the F-111 strikes and around one-fifth of the F-117 strikes were devoted to these efforts over the next two weeks using 2,000 pound. laser-guided weapons. See *Gulf War Air Power Survey, Volume II, Part 2: Effects and Effectiveness*, pp. 387–93 for specific data on the F-117 and F-111F.

[209] Ibid., p. 156.

[210] Ibid., p. 341.

[211] See comments by General Charles Wald, USA, *DoD News Transcript*, June 11, 1999.

[212] Tidal W. McCoy, "Task One: Air Base Operability," *Armed Forces Journal International*, September 1987, p. 54.

Figure 4: Hardened Aircraft Shelters in Al Jaber Airfield, Kuwait

Source: *Gulf War Air Power Survey, Volume II, Part 2: Effects and Effectiveness*, p. 39. These impressive Kuwaiti shelters appropriated by the Iraqis surpassed anything the USAF had constructed in Europe or northeast Asia. Both of the two closest shelters in the picture were struck, blowing off their doors. Note the penetration hole in the top of the first shelter on the left, probably from a BLU-109B penetrating weapon.

> The results were a sobering demonstration of the synergistic chaos that ensues when everything goes wrong at the same time. Thirty-one percent of the base's personnel were casualties, half of them killed and nearly a third of the wounded were unable to return to duty. There was considerable damage to aircraft, vehicles, buildings, communications, and power systems…fires burned all over, and unexploded ordnance lay about everywhere. It was difficult to assess the damage accurately. Repair teams were short-handed and in some cases did not have the equipment and supplies they needed.[213]

The officer in charge of Spangdahlem Air Base at the time of the Salty Demo exercise, Major General Lawrence Day (USAF, Ret.), remarked: "We were impressed how much we learned going through it compared to what we thought we knew."[214] The attacks forced many changes in operational procedures and command responsibility. He also observed that given the scale of the attacks during the exercises (over 30 strikes per day): "We were impressed that we could fly at all given all the damage."[215] Day noted that his wing at Spangdahlem had been preparing for the exercise for a year and the base was augmented with some 1500 personnel and large amounts of heavy equipment (bulldozers, excavators, dump trucks, minesweeping armored vehicles) to deal with the attacks. Without such extensive preparation, training, and specialized construction equipment deployed, base recovery would have been far more difficult.[216]

[213] John T. Correll, "Fighting under Attack," *Air Force Magazine*, October 1998, pp. 50–52.

[214] Author's interview with Major General Lawrence Day.

[215] Ibid.

[216] Ibid.

Attacks against less developed airfields, which USAF expeditionary forces will probably have to employ in Asia, could be far more devastating. In the early stages of the Vietnam War, for example, USAF aircraft were concentrated at Da Nang, which raised concerns within the Pacific Air Forces (PACAF) about the force's potential vulnerability to a North Vietnamese air strike. PACAF planners feared an attacking force "could do extensive damage to parked aircraft on unrevetted hardstands, exposed fuel tanks, a large bomb storage area which greatly exceeded its maximum safe explosive content, and support facilities."[217] These same conditions could very likely exist during future USAF deployments to unhardened airfields. Aircraft parked on ramps would be vulnerable to a wide array of attacks.

At unhardened airfields, personnel would be far more exposed to lethal attacks. Fuel storage depots would probably be far more vulnerable. Munitions might be located fairly close to the airfield because of space constraints and the desire to reduce the security perimeter. Capabilities to restore runways, electrical power, and fuel supply would be far less resilient than at a hardened airfield. Unless specialized equipment was brought in before the attack (or present in the host country and brought to the site), recovery operations could be protracted. Without repair gear, base operations could be brought to a halt. Major General Lawrence Day observed that during the 1985 Salty Demo exercise, the repair equipment was so vital that he gave it priority for sheltering with aircraft. According to Day, losing an aircraft was one thing, losing a bulldozer ran the danger of shutting down the base.[218]

Given the length of time needed to develop systems and force structure, military planners have the difficult task of thinking over the long term. Currently, US planners are observing military developments by potential opponents and will need to consider how to best respond to those potential threats. As one well-known analyst noted regarding China: "…theater ballistic and land attack cruise missiles, supported by space-based reconnaissance, appear likely to emerge as a cornerstone of [People's Liberation Army] PLA warfighting early in the 21st century."[219] The numbers of ballistic and land-attack cruise missiles currently in operation number in the thousands, but the majority of these have fairly limited ranges. Over the next several decades, current trends indicate that thousands more of such weapons will likely be deployed with much greater range and potential lethality. As the National Intelligence Council recently commented:

> The trends in ballistic missile development worldwide is toward a maturation process among existing ballistic missile programs rather than toward a large increase in the number of countries possessing ballistic missiles. Emerging ballistic missile states continue to increase the range, reliability, and accuracy of the missile systems in their inventories—posing ever greater risks to US forces, interests, and allies throughout the world.[220]

[217] Kreis, *Air Warfare and Air Base Air Defense*, 1914–1973, p. 279.

[218] Author's interview with Major General Lawrence Day.

[219] Stokes, "Space, Theater Missiles, and Electronic Warfare: Emerging Force Multipliers for the PLA Aerospace Campaign."

[220] National Intelligence Council, *Foreign Missile Developments and the Ballistic Missile Threat Through 2015—Unclassified Summary of a National Intelligence Estimate* (Washington, DC: Central Intelligence Agency (CIA), 2002), p. 7 (electronic version).

Toward the end of the Cold War, the USAF found it could not afford to ensure the survivability of its air bases in Europe. The sheer mass of potential attacks appeared in danger of overwhelming available passive and active defenses. The future ballistic and cruise missile threat has different characteristics: less mass but much greater precision. These weapons are less threatening to hardened facilities and runways than traditional strike aircraft, but potentially more devastating against aircraft parked in the open, fuel, and munitions storage areas.

Special Forces

On March 8, 1994, Irish Republican Army (IRA) units fired four mortar shells through the open roofs of parked vans at runways in Heathrow Airport in the United Kingdom, which shut down air traffic and caused massive disruption throughout European skies. The IRA did not target aircraft, seeking disruption and publicity instead. A large British security sweep was launched and the airport reopened. Two days later, the IRA fired four more mortal shells from mortars buried in a trench and fired by remote control, causing continued disruption. After another extensive British search, Heathrow was reopened. Three days later, the IRA fired four more shells into the Heathrow terminal area. As the Times reported: "One security expert admitted last night within hours of the attack that no public space as large as Heathrow could possibly be completely sealed."[221]

More recently, Pakistani authorities discovered four remote-fire rockets aimed at American facilities in Karachi. Two of the rockets were aimed at the airport terminal; the other two at a hotel housing US personnel.[222] Rocket attacks have also been conducted against US personnel at the airfield in Kohst, Afghanistan.[223]

The experiences at Heathrow and Karachi provides a graphic illustration of the potential dangers posed by special forces and terrorists to air bases. A key study by Dr. Alan Vick of the RAND Corporation documented that since 1942, special forces using unsophisticated weapons have conducted 645 separate attacks on air bases. The most common objective in these attacks was the destruction of aircraft. Seventy-five percent of the attacks involved the use of standoff weapons (e.g., rockets, mortars, artillery). The attacks proved extremely difficult to counter and destroyed or damaged over 2,000 aircraft. The most extensive series of attacks occurred in Vietnam and Thailand, where North Vietnamese and Viet Cong special forces conducted 475 separate attacks, destroying 99 aircraft and damaging over 1,000. Indeed, more US aircraft were lost to these attacks than to enemy fighters (99 versus 62). In the November 1964 attack against the Bien Hoa airfield, the attacking force fired 83 rounds from six 81mm mortars into the airfield to destroy five (and heavily damage eight) B-57 medium bombers in 20 minutes.[224] The Vietnamese also mounted five separate "out of area" attacks against US aircraft based in Thailand.

[221] Stewart Tendler and Harvey Elliott, "Yard Launches Urgent Review of Security at Airport; Heathrow IRA Mortar Attack," *The Times*, March 10, 1994.

[222] Kathy Gannon, "Pakistanis Disarm Rockets Aimed at Coalition Facilities," *The Washington Post*, February 19, 2002.

[223] "Rockets Fired at US Base in Afghanistan," *Reuters News Wire*, May 2, 2002.

[224] Alan Vick, *Snakes in the Eagle's Nest: A History of Ground Attacks on Air Bases*, MR 553-AF (Santa Monica, CA: The RAND Corporation, 1995).

The problem raised by Dr. Vick and his colleague David Shlapak in subsequent work is that the potential threat posed by special forces has grown substantially through the proliferation of accurate standoff weapons, which greatly increase the perimeter that US forces must defend. The most worrisome threats include precision munitions for mortars (which would enable attackers to hit high-value targets with a small number of rounds), large caliber sniper rifles with effective ranges of almost a mile (which could be used against high value aircraft to knock out radars and avionics), and man-portable, anti-tank rockets (which could penetrate aircraft shelters).[225] As Dr Vick noted in his historical overview: "The centrality of airpower to modern warfare makes airfields even more tempting targets than they have been….If the historical experience is any indication, standoff threats [from special forces] will continue to pose a particularly daunting challenge."[226]

Weapons of Mass Destruction

Weapons of mass destruction or disruption—nuclear, biological, and chemical—continue to concern US policy makers. Iran, Iraq, North Korea, Libya, Syria, India, Pakistan, Russia, and China all field such weapons or seek to acquire them, as recounted in numerous reports from the Department of Defense, Congress, and various policy institutes.[227] In the 1997 Quadrennial Defense Review, DoD stated that "the threat or use of chemical or biological weapons...is a likely condition of future warfare, including in the early stages of war to disrupt US operations and logistics."[228]

A nuclear strike could obviously destroy any targeted air bases.[229] Employment of chemical or biological weapons could disrupt the flow of US forces into a region for a period of time and degrade combat sortie generation rates at targeted air bases. USAF personnel are continuously trained to operate in a chemical or biological environment, but the presence of such substances is bound to slow the pace of operations. If the base cannot be decontaminated through the actions of weather or other factors, or an adversary conducts follow-on strikes, operations could slow to a crawl.[230] Biological weapons use could have similar or even more disruptive results.

US policy is to deter the employment of such weapons through the threat of retaliation. During the Gulf War, the United States made it clear to Saddam Hussein through a variety of channels that if he employed weapons of mass destruction, the United States would respond effectively. The United States was deliberately vague on what form the response would take: Secretary of State James Baker told the Iraqi foreign minister that the US government might elect to change the Iraqi regime, Secretary of Defense Richard Cheney stated publicly that Israel might respond with nuclear strikes,[231]

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[225] David Shlapak and Alan Vick, *Check Six Begins on the Ground: Responding to the Evolving Ground Threat to US Air Force Bases*, MR-606-AF (Santa Monica, CA: The RAND Corporation, 1995).

[226] Vick, *Snakes in the Eagle's Nest: A History of Ground Attacks on Air Bases*, pp. xx-xxi.

[227] For a comprehensive overview, see William Cohen, *Proliferation: Threat and Response* (Washington, DC: OSD, 2001).

[228] William Cohen, *Report of the 1997 Quadrennial Defense Review* (Washington, DC: OSD, May 1997).

[229] For analyses of the impact of a nuclear detonation on a military airfield, see Greg Weaver and J. Dennis Glaes, *Inviting Disaster: How Weapons of Mass Destruction Undermine US Strategy for Projecting Military Power* (Washington, DC: AMCODA Press, 1997).

[230] See Weaver and Glaes, *Inviting Disaster: How Weapons of Mass Destruction Undermine US Strategy for Projecting Military Power* for an overview of potential chemical attacks on air bases.

[231] Rick Atkinson, *Crusade: The Untold Story of the Persian Gulf War* (New York: Houghton-Mifflin Co., 1993), pp. 86–87.

and General Colin Powell, chairman of the Joint Chiefs of Staff, drafted a warning to Iraq stating that the United States might choose to destroy every element of Iraq's industrial infrastructure and potentially flood Baghdad by striking dams on the Tigris and Euphrates rivers.[232] This policy apparently worked. Iraqi missile forces loaded chemical warheads before the Gulf War, but then switched to conventional warheads at Hussein's instructions.[233] The effectiveness of deterrence will depend on the situation. In most cases, an opponent would appear to have more to lose than to gain. But as General Charles Boyd (USAF, Ret.), when commenting on potential US offensive operations against Iraq following the attack on the Pentagon and World Trade Center, noted: "What deterrent is there on Saddam Hussein since we have told him his head is on a platter? We can never suppose he will do anything but use chemical or biological warfare."[234]

The United States would also, as was seen in the Gulf War, attempt to destroy an adversary's weapons, research facilities, and means of delivery to reduce the threat to US and allied forces. Unfortunately, successfully prosecuting such attacks offer enormous challenges. The United States discovered after the Iraqi conflict that Iraq's network of facilities proved much larger than initially estimated.[235] Most of the facilities remained unknown to US intelligence, and US forces proved unable to destroy Iraq's mobile missile delivery systems. These significant problems will continue to confronted US forces in conflicts against adversaries armed with WMD. Attacks against an adversary's WMD, if only partially successful, also run the risk of driving an enemy to employ these use before losing them.

The presence of such weapons during a conflict also raises two issues relevant to the access issue:

- Allies may be deterred from granting access to US forces in order to prevent employment of weapons of mass destruction on their soil.

- An adversary in possession of weapons of mass destruction is bound to make US decision-makers reflect carefully when considering whether or not to intervene in the first place. The need to place aircraft and thousands of US personnel in harm's way on forward air bases would be part of these deliberations.

[232] Colin Powell, *My American Journey* (New York: Random House, 1995), pp. 503–04.

[233] Razzaq, *Forty Three Missiles on the Zionist Entity*.

[234] Walter Pincus and Karen DeYoung "Anti-Iraq Rhetoric Outpaces Reality; Military Not Primed for New War Soon," *The Washington Post*, February 24, 2002.

[235] The United States believed the Iraqis had 23 WMD facilities. Based on UN inspections, the total came to around 252. See Robert W. Chandler and John Backschies, *The New Face of War* (Mclean, VA: AMCODA Press, 1998), pp. 216–22.

VI. What Potential Counters Are Available to Minimize These Threats?

To counter these threats, potential responses could include political initiatives to improve likelihood of gaining political access; base infrastructure development to minimize the dangers of military threats; operational counters; new sea-based concepts; and missile defense systems.

Political Initiatives

The United States should obviously attempt to engage as wide array of nations as possible in attempts to improve the chances of obtaining access when needed. The commander of USAF forces in Europe, General Gregory Martin, observed recently that many nations currently supporting US combat operations in Afghanistan had participated in US training conferences and operations, which greatly eased matters in obtaining access to air space and bases.[236] As laid out in the 2001 QDR:

> Security cooperation will serve as an important means for linking DoD's strategic direction with those of its allies and friends. DoD will focus its peacetime overseas activities on security cooperation to help create favorable balances of military power in critical areas of the world and to deter aggression and coercion. A particular aim of DoD's security cooperation efforts will be to ensure access, interoperability, and intelligence cooperation, while expanding the range of pre-conflict options available to counter coercive threats, deter aggression, or favorably prosecute war on US terms.[237]

Continued engagement of potential host nations is essential to obtaining access in a crisis. Nonetheless, history illustrates that the unpredictability of the location and nature of future conflicts makes it difficult to forecast the attitude of host country when access is needed. We should try our best to engage potential supporters, but uncertainty will continue to characterize the results, particularly if an adversary possesses weapons of mass destruction and/or a powerful deep-strike capability.

[236] As General Martin remarked at the Orlando Air Force Association meeting on February 14, 2002: "When we take a look at what we are doing in Europe, this is a typical year. About 40 percent of our people are engaged in some sort of training, exercise or partnership activities and about ten percent of our flying hour program is working in those nations that you see in the light-colored green. That pays off. When we started Operation Enduring Freedom, not many people realized that every 'Stan, except for Pakistan, and Afghanistan, is a Partnership for Peace member. That means that although they are in General Tommy Franks' AOR, they work with NATO and last May, most of them were at Ramstein at the Warrior Prep Center with General Franks, conducting a peace support operation with the senior leadership of their nations there. Now, isn't that something? And then when we needed over-flight rights from Turkmenistan or basing rights in Uzbekistan or Kazakhstan, those people allowed that to happen. That kind of contact is very, very important to us and that is something that our forward-deployed forces do, whether they are in the Pacific or in the Southern Hemisphere or in Europe. It is very important that we understand that makes a difference when we are in this global war."

[237] Rumsfeld, *Quadrennial Defense Review Report*, p. 20.

Base Infrastructure Development

To compensate for inadequate basing infrastructure, developing additional facilities before a conflict would be a logical course of action. Beginning construction of new facilities after the start of hostilities has not usually permitted the buildup of combat power quickly. During the Korean War, it took a year for USAF engineers to construct 9,000 foot runways at four bases.[238] In Vietnam, developing the base infrastructure to handle land-based fighters and support aircraft took 18 months of effort.[239] The base of Tuy Hoa, for example, took a team of 1,300 personnel about one year to build.[240] During this period, carrier-based naval forces provided about half the strike sorties flown in both North and South Vietnam until the base infrastructure was sufficiently developed to handle a larger quantity of land-based fighters.[241]

Similar timelines existed in Afghanistan. Following agreements developed in December, two months after the start of hostilities, US personnel began deploying to Manas airport near Bishkek, the capitol of Kyrgyzstan. The extensive development required to bring the base up to standards to support fighter operations was estimated to take four months.[242] Such timelines are not sufficiently rapid to provide prompt, decisive, combat power. Because of the lack of basing infrastructure within fighter range of Afghanistan targets, the United States had to rely primarily on carrier-based naval forces and bombers to provide striking power during offensive operations, which delivered over 90 percent of the total munitions during the first three months of operations.[243]

The above examples also do not include the time required to build hardened aircraft shelters. In the case of Europe and the Persian Gulf, this took decades of effort and was still insufficient to shelter all deploying USAF fighters.

To support future operations in Asia, the RAND Corporation has proposed "flexbasing," which uses three classes of operating facilities: large "core support" locations located on US territory (such as Guam), which could house large amounts of support material and munitions; forward support locations (which could house warehouses stocked with material); and forward operating bases in foreign nations (which would provide runways, fuel, water, ramp space, and possibly small stocks of munitions). Depending on the location of the conflict and the degree of access, airlift and ships can deploy logistical support from the core and forward support facilities to the forward bases—hence the name "flexbasing."[244]

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[238] Futrell, *The United States Air Force in Korea, 1950–1953*, pp. 394-5.

[239] *The United States Air Force in Southeast Asia, 1961–1973: An Illustrated Account*, p. 245.

[240] Bingham, "Operational Art and Aircraft Runway Requirements," pp. 5–6.

[241] Statistical data contained in C. Bernard Barfoot, *An Overview of CV TACAIR Operations in the Vietnam War*, CRM 94-152 (Alexandria, VA: Center for Naval Analysis, 1994).

[242] "Kyrgyzstan: Newspaper Analyses Presence of US Base in the Country," BBC Monitoring, January 20, 2002 and "US Air Force Boeing Jet Fighters to Arrive in Kyrgyzstan Soon—Kazaky Report," *BBC Monitoring*, January 13, 2002.

[243] Bombers and carrier-based fighters together flew 88 percent of the sorties and delivered 94 percent of the munitions. Bombers delivered 46 percent of the precision-guided weapons, carrier-based fighters 43 percent, land-based fighters about 10 percent. Bombers also delivered over 7,000 unguided weapons. Analysis derived from Arkin, "Weapons Total from Afghanistan Includes Large Amount of Cannon Fire."

[244] Killingsworth, et al., *Flexbasing: Achieving Global Presence for Expeditionary Aerospace Forces*, pp. 22–24.

Figure 5: A Perspective on Geographic Size: The United States Compared to Asia

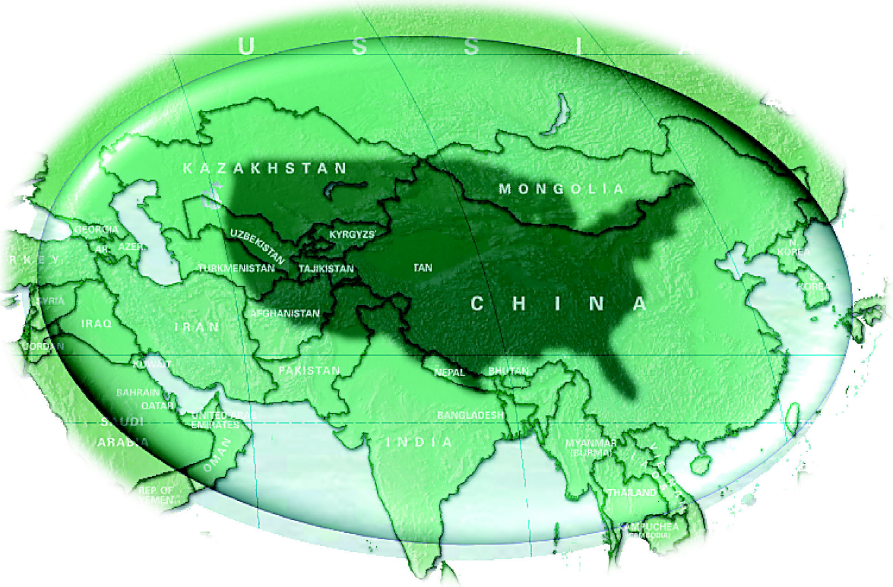


Illustration by LiveWireWeb.com.

The development of a similar network of facilities in Western Europe and the Gulf took decades of sustained effort. To develop a similar infrastructure in Asia could take even longer, since potential allies are much poorer. To reduce reliance on airfields vulnerable to deep-strike systems, developing additional hardened air bases would be critical. Such a policy paid enormous dividends in Operation Desert Storm. Unfortunately, the vast size of Asia (Figure 7 illustrates the general size of the region in comparison to the United States) combined with fighter aircraft range limitations requires prescience in predicting accurately the general location of future conflicts. Given such vast distances, the danger is that the United States could expend enormous resources on developing base infrastructure and "get it wrong."

The high cost is also a significant complicating factor. A single USAF air base in Europe was conservatively estimated to cost roughly $1.5 billion in current year dollars.[245] The cost of a single, hardened, aircraft shelter is approximately $4 million, meaning that shelters for a single AEF could amount to $600 million.[246] More sophisticated shelters could be even more expensive. The cost of base development just in Saudi Arabia—a single country with a much smaller land mass compared to Asia—was estimated to cost about $30 billion in current year dollars.[247] Even with this significant investment, most US aircraft were forced to park in the open. In Europe during the Cold War, the NATO nations spent substantially more on base operability, but this was still insufficient to provide protection for all USAF fighters. Trying to hedge bets by conducting base development in

[245] M.B. Berman with C. L. Batten, *Increasing Future Fighter Weapon System Performance by Integrating Basing, Support and Air Vehicle Requirements*, N-1985-1-AF (Santa Monica, CA: The RAND Corporation, April 1983), p. 1.

[246] Stillion and Orletsky, *Airbase Vulnerability to Conventional Cruise-Missile and Ballistic-Missile Attacks: Technology, Scenarios, and US Air Force Responses*, p. 31.

[247] The then-year dollar cost of the Saudi contracts let in the mid-1970s came to $14 billion. Current year dollars would be several times this amount. Robert G. Kaiser and David Ottaway, "Marriage of Convenience: The U.S.-Saudi Alliance," *The Washington Post*, February 11, 2002.

multiple locations could cost several times this amount. In the case of Saudi Arabia and NATO, the governments had the resources to fund most of this development themselves, but few countries in South, Central, and East Asia possess such wealth. Getting approval to invest US resources for overseas base development would raise additional challenges, since Congress is typically more supportive of investment in local bases than overseas bases.

Finally, even if planners succeed in all the above, the use of the bases remain subject to getting political approval from the host country, as highlighted by the current situation with Saudi Arabia.

Dispersal

If developing sufficient hardened military facilities proves too difficult for political and economic reasons, dispersing the force across a greater number of airfields would be an obvious counter to reduce vulnerability at unprotected airfields. An attacker would need to keep track of activity at more airfields; attacks on individual airfields would strike fewer aircraft; and overall, an opponent would have to deliver more weapons to destroy the same number of aircraft.

Conducting dispersed operations has been considered and evaluated many times in the past. The USAF explored such schemes in Europe during the Cold War. One concept, for example, evaluated dispersing fighters equipped with rocket-powered boosters (the so-called Zero Ejection Launch or ZEL system) in hardened shelters across numerous bases. The objective was to make it more difficult for the Soviets to conduct a successful pre-emptive strike.[248] In the end, the ZEL program was cancelled (in part because of the dangers posed by standing start, rocket-boosted take-offs). In the 1970s, the USAF initiated the collocated operating base program to increase the number of potential air bases in Europe and thus reduce force concentration and potential vulnerability. This program cost tens of billions of dollars. During the 1970s and 1980s, various proposals were developed to consider dispersed base operating concepts. The general idea was to employ the main operating base as a hub to support operations at dispersed locations to complicate the enemy targeting problem and reduce vulnerability. Distances to the dispersed operating locations (road sections and other operating surfaces) needed to be fairly short in order to minimize the logistical burden. The USAF believed that the Soviets might employ a similar concept.

The air forces that took this approach most seriously were the Royal Air Force and the Swedish Air Force (SAF). The RAF employed dispersed operating schemes using the VSTOL Harrier force. Engineering units would deploy from the main RAF base at Gutersloh in Germany to prepare a "hide site" and then move to another location to prepare another site. A small number of Harriers would launch from the main base to the hide site; another flight would depart when the next site was ready. The engineers would continue developing sites until the entire force could be dispersed—additional sites would provide additional basing options.[249] The British took advantage of the Harrier's VSTOL capability during the conflict over the Falkland Islands by deploying Harriers to a forward operating location on the main island. Argentina was unable to do the same because its fighter aircraft required adequate runways.

[248] See Leverrett G. Richards, *TAC: The Story of the Tactical Air Command* (New York: John Day Company, 1961), pp. 242–43.

[249] Information provided to the author by the Royal Air Force.

The United Kingdom only fielded a small force of Harriers; Sweden embraced dispersal for its entire force of combat aircraft. In 1990, the SAF fielded around 425 combat aircraft on 12 main operating bases, which had approximately two associated reserve bases for dispersal of the force in war. Each reserve base typically contained five separate runways (often parts of highways) spread over a large, 10 by 15 kilometer area to complicate the enemy targeting problem. Within this area, Swedish combat aircraft could be parked in camouflaged sites and tunnels.[250]

To implement such dispersal concepts, the USAF would need to invest significantly more resources in its support structure. Past dispersal proposals were constrained because of the significant costs of developing the support structure and reconfiguring all USAF aircraft to allow greater capability to operate from austere bases and to require less maintenance and support equipment. Both the RAF Harrier force and the SAF required substantial additional support equipment and personnel to conduct dispersed operations. Logistical support is more efficient when centralized. For instance, while only one person with a critical skill might be needed to service an entire wing of 72 aircraft at a single location, dispersing that same force in groups of four aircraft would require 18 people with that skill to ensure that support is present at each location. Detailed estimates indicate that double the number of maintenance personnel would be required to support a wing of 72 aircraft when dispersed into four groups as opposed to operating from a single base.[251]

Similar increases would be needed in ground support equipment, such as power carts, munition jammers, and towing vehicles. Adopting dispersed operations would also require allocating more resources to rapid runway repair capability, which would need to be spread over more bases. Given the threat posed by special forces, large numbers of base security personnel would be needed to protect each of the operating sites, further increasing personnel requirements. As noted by one author: "Relatively small, widely scattered groups of USAF maintenance personnel and pilots would be exceedingly inviting targets for terrorist or SOF [Special Operations Forces] attacks."[252]

Dispersing the force also would require access to a larger number of airfields at a time when the US is concerned about sufficient numbers of bases using traditional concentrations of aircraft. In addition, the dispersal concepts adopted by the RAF and the SAF featured the dispersed operating locations being located relatively close to main operating bases in order to minimize travel times for fuel, munitions, and support gear. The concepts developed for the USAF in the 1980s also envisioned similar proximities. This would be far more difficult to execute in Asia given the vast distances.

Another possible avenue, provided the complex and costly support issues could be worked out, would be for the USAF to acquire the VSTOL version of the JSF (which is currently only slated for the Marine Corps). With the VSTOL JSF, the USAF could develop an operating concept similar to RAF Harrier force provided sufficient additional resources were put into the support and force protection area. The availability of a high performance VSTOL aircraft also opens up some very interesting concepts for operating out of urban areas, which would greatly complicate an adversary's

[250] Bitzinger, *Facing the Future: The Swedish Air Force, 1990–2005*, pp. 24–25.

[251] See Berman, et al., *Integrating Basing, Support, and Air Vehicle Requirements: An Approach for Increasing the Effectiveness of Future Fighter Weapon Systems*, pp. 23–26.

[252] Stillion and Orletsky, *Airbase Vulnerability to Conventional Cruise-Missile and Ballistic-Missile Attacks: Technology, Scenarios, and US Air Force Responses*, p. 40.

targeting problem. Basing such aircraft in warehouses, shopping centers, underground parking facilities, etc., could allow the USAF to hide its fighters in the clutter of urban centers to make enemy targeting very difficult and reduce the dependence on fixed immovable runways.

On the negative side, basing in such areas would limit the use of airlift for resupply, require an extensive logistical support structure to provide fuel and weapons, and potentially increase vulnerability to special operations attacks. The USMC JSF uses a lift fan to achieve VSTOL performance; the extra weight, however, decreases internal fuel capacity, increases weight and complexity, and reduces unrefueled combat radii.

Rapidly Suppress Anti-Access Threats

To reduce the threat posed by enemy, deep-strike systems to forward operating locations, the US military could attempt to "defang" the enemy anti-access threat. General John Jumper, the chief of staff, argues that the new USAF concept of operations—Global Strike Task Force (GSTF)—is designed to do this. As he recently stated:

> The Global Strike Task Force is the kick-down-the-door portion of it. The kick-down-the-door portion of this deal does not win the war. It allows the things in that are going to win the war. So, in Global Strike Task Force, you are taking out those anti-access targets and creating the conditions for access. So the F-22s and the B-2s are going to come in there and take out the SA-10s, 12s and 20s, sweep anything from the skies. They are going to take out the shore batteries that can shoot at the ships over the horizon and they are going to do any sort of support of forces we might put in on the ground that are special forces. They are going to take care of the weapons of mass destruction, their storage, their transportation, and their launch points and then enable the persistence force to deploy forward.[253]

The "persistence force" is composed of the remainder of the fighter force, which deploys to forward bases once the anti-access threat has been neutralized. Global Strike Task Force was derived from the Global Reconnaissance Strike (GRS) concept, which envisioned a different force structure—one that relied on a larger force of long-range bombers and F-22s than the currently planned USAF force structure. The original GRS concept postulated using a long-range ISR constellation to provide targeting information, B-2s to deliver firepower at long-ranges from rear area bases, and multi-role F-22s to protect the B-2s and the ISR force (and strike targets when needed). The concept's advantage, according to its developers, was greatly reducing the forward theater footprint by only requiring a small number of F-22s operating forward. The rest of the F-22s would be based further back (occasionally touching down at forward bases to "gas and go"), while the larger B-2 force would deliver the lion's share of the firepower.[254] The Air Force claims that GSTF can do the same job without requiring substantial changes in planned force structure.

In GSTF, USAF access insensitive, power-projection capabilities would be comprised of 16 operational B-2s and three wings (216 aircraft) of F-22s supported by the ISR constellation of E-3As,

[253] General John Jumper, Air Force Association Orlando, February 14, 2002.

[254] See General Richard E. Hawley, Donald N. Frederickson, Michael B. Donley, and John R. Backschies, "Global Reconnaissance Strike," *Armed Forces Journal International*, June 2000, for an overview of the initial proposed concept.

RC-135s, MC^{2}As, JSTARS, Global Hawk, and Predator. The B-1B and B-52 force could augment this firepower until their limited cruise missile inventories were exhausted. In addition, assets from the other Services (submarines, surface ships, carrier-based E-2Cs and fighters) could contribute as well.

With the fielding of small, precision weapons, this smaller force could strike many more fixed aimpoints than is possible using current-generation weapons. However, larger numbers of aircraft would be needed to deal with the primary, enemy, deep-strike threats—ballistic and cruise missiles. These systems are mobile, which requires maintaining aircraft in the air near potential launch sites. Once cued by the ISR system, the attack aircraft would leave their current locations, penetrate, and deliver weapons capable of killing the mobile targets.[255] Such a concept reduces the chances of the ISR system losing the mobile target after initial detection/identification and minimizes the time available for mobile launchers to "scoot" after shooting. But to keep sufficient numbers of aircraft in the air at extended range near the battle area would require deploying a large fighter force. Assuming basing 1500 nautical miles from the conflict area and sufficient tankers to sustain ten hour missions, a wing of 72 F-22 Raptors could only keep six aircraft in the air near the battle area and ready to strike on a sustained basis.[256]

Moreover, a clever adversary would probably elect not to risk his mobile launchers until he had something worthwhile (e.g., concentrated US forces in theater) to attack. The Serbs, for example, used such an approach with their air defense systems in the 1999 war over Kosovo. They calculated correctly that the mere presence of air defense systems would force the United States to operate far less efficiently by always being forced to honor the threat. So an adversary may choose to husband his launchers in "hides" until USAF assets began deploying to forward bases, where the concentration of airlifters and fighters would be a lucrative target. This presents a troubling dilemma likely to slow dramatically the progress of future counter–anti-access operations: only US aircraft operating from long range are capable of attacking anti-access forces, but the enemy is unlikely to present his forces as targets until US theater-based forces are introduced.

Mobile launchers are not the only target—as General Jumper noted, WMD would be a prime target. Based on experience in Iraq, where the WMD target set proved to be an order of magnitude larger than initially thought, destroying enemy WMD facilities could prove very time consuming. US forces may have to also deal with a range of other tasks. Taken together, the small B-2 and F-22 force, working in cooperation with the older, less survivable B-1s and B-52s, carrier air power, and naval surface and subsurface combatants, would need to degrade the enemy mobile air defense system, strike enemy airfields (to eliminate enemy aircraft), shoot down air threats, hunt down mobile enemy ballistic and cruise missiles, knock out WMD production and storage facilities, and, if necessary, deal with an enemy ground offensive. Whether all these tasks can be done expeditiously with the small, access insensitive force remains a question, particularly if confronted by a patient and calculating adversary. Until such operations are completed, deployment of the large, persistence force must be deferred or limited.

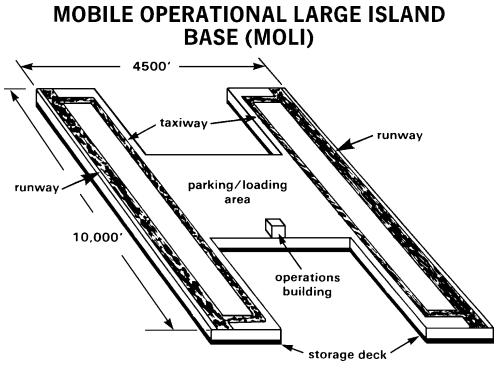
[255] For a more in-depth analysis, see Christopher J. Bowie, *Striking Mobile Ground Targets in an Anti-Access Environment* (Rosslyn, VA: Northrop Grumman Analysis Center, January 2002).

[256] Assumes 10 hour mission length and, due to monthly flight hour ceilings, a sortie rate of 0.5 per day. Each aircraft could remain four hours in the target area (the outbound and return legs would consume six hours), so the wing would need to launch sorties every four hours to maintain a constant presence. Since the wing could generate 36 sorties per day, this translates into six fighters on station in steady state operations.

Large, Man-Made, Floating Bases

In World War II, Winston Churchill became intrigued with the *HMS Habbakuk* project, which involved developing large "berg-ships" made of "pykrete" (sea water mixed with wood pulp and frozen) for basing aircraft and patrol vessels in the North Atlantic to counter the German submarine threat. The building material was named after the original concept developer, Geoffrey Pyke , who envisioned ice ships with a length of 4,000 feet, a width of 600 feet, and a depth of 130 feet that would be largely impervious to attack. A proof of concept ice ship was constructed measuring 60 by 30 feet on a Canadian lake. In 1943, Lord Mountbatten, then Chief of Combined Operations, took a block of pykrete to the Quebec Conference to gain support for the concept. Costs and technical problems combined with success against the German submarine force ended further interest in the project.[257] However, the notion of building large, powered islands to base aircraft and other combat forces has appeared episodically in military proposals since then.

Figure 6: RAND Floating Base Concept from the 1970s



Source: P.M. Dadant, *Improving US Capability to Deploy Ground Forces to Southwest Asia in the 1990s* (Santa Monica, CA: RAND, 1983, N-1943-AF) p. 17.

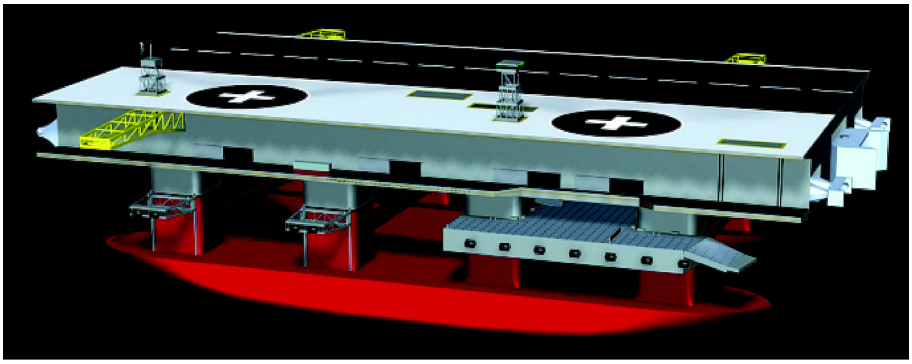
Technological advances in constructing large, concrete, oil-exploration platforms in the 1960s and 1970s combined with concerns over basing availability in the Persian Gulf led to renewed interest in the large, manmade islands in the late 1970s and early 1980s (see Figure 9).[258] The general notion was to build large sections out of reinforced concrete and link these sections together to build a large floating runway that could slowly steam to strategic areas. The floating island could house combat aircraft and pre-positioned equipment for ground forces. The size of the platform combined with its thick walls and deck made it largely invulnerable to conventional weapons. Overall technological risk was deemed fairly low, but so was DoD's interest. As one analyst noted, the project suffered from the "giggle factor."[259] Other issues included Service sponsorship (all four Services would need to provide funding and support) and potential vulnerability to nuclear strikes (the island would be a perfect target for a nuclear strike with low chances of collateral damage).

[257] George H. Pitt, "Pykrete—Ice Ships in the Rockies" [http://www.combinedops.com/Pykrete.htm].

[258] See, for example, P.M. Dadant, *Improving US Capability to Deploy Ground Forces to Southwest Asia in the 1990s*, N-1943-AF (Santa Monica, CA: The RAND Corporation, 1983).

[259] Personal communication to the author.

Figure 7: Proposed Joint Mobile Offshore Module



Source: McDermott International, Inc.

For oil tanker protection missions during Operation Earnest Will in the Persian Gulf, the Navy employed a smaller version by leasing two large barges to base Special Operations Forces.[260] In the early 1990s, Admiral William Owens, the vice chairman of the Joint Chiefs of Staff, asked the Defense Advanced Research Projects Agency (DARPA) to re-examine the mobile base concept. A design called the Joint Mobile Offshore Base (JMOB) was selected for further analysis by the Office of Naval Research (ONR). The JMOB was similar to the proposals in the 1970s, but offered reduced vulnerability by breaking the island into five separate, self-powered modules that could be connected and disconnected at sea. Each module, constructed of steel, would measure about 1,000 feet by 500 feet with a draft of 128 feet and could travel at a speed of 15 knots. When in position, the modules could link up, take on sea water for ballast and additional stability, but still steam at five knots. All five modules linked together would provide a runway nearly a mile long and 5 million square feet of storage space to house 3,500 vehicles, 150 aircraft, munitions, 20 million gallons of fuel, and 15,000 personnel.[261] A 1/60th scale model was developed for hydrodynamic tests. No significant problems were encountered in testing. The ONR also rated the JMOB as highly survivable,[262] though the concentration of US forces at such a base would appear to raise vulnerability concerns. The cost of a five unit JMOB was estimated at about $6 billion.[263] Current Defense Department interest in the JMOB concept is low.

Active Defenses

Part of the reason ballistic missiles continue to proliferate is the difficulty involved in destroying them before launch and defending against them after launch. The United States is currently engaged in a multi-billion dollar effort to develop defenses against theater ballistic missiles and intercontinental ballistic missiles. Efforts are also underway to upgrade defenses against the growing cruise missile threat, particularly low radar cross section weapons.

[260] This operation is mentioned in the website: [http://www.f4aviation.co.uk/Hangar/kiowa/oh58.htm]. Also see Michael Palmer, *On Course to Desert Storm: The United States Navy and the Persian Gulf*, (Washington, DC: Government Printing Office (GPO), 1992).

[261] "Joint Mobile Offshore Base" briefing from McDermott International, Inc. 1999.

[262] Author's interview with Admiral John "Bat" LaPlante (USN, Ret.), McDermott International, March 20, 2002.

[263] Ibid.

US efforts dealing with ballistic missile threats involve both the continental United States and overseas theaters; currently, all programs are considered as part of an integrated ballistic missile defense system. Ballistic missiles all fly a similar flight path: a boost phase (where the missile launches from the ground and accelerates to a speed and altitude to reach a target); a mid-course phase (where the missile or warhead is coasting toward the target); and a terminal phase (where the missile or warhead re-enters the lower atmosphere to strike its target). The length of these phases depends on the range. For theater ballistic missiles, the entire engagement time can take place within ten minutes or less.

The DoD has a set of programs to deal with each phase of the missile flight path. The Airborne Laser, the Space-Based Laser, and an undefined set of kinetic kill concepts are designed to kill the missile in boost phase. Two new programs—the ground-based midcourse system and the sea-based midcourse system—are aimed at striking the missile after boost phase. Finally, the Theater High Altitude Area Defense (THAAD) System, the Arrow Weapon System, and the upgraded Patriot PAC-3 program are designed to attack missiles and warheads in the terminal phase. Of these programs, the Airborne Laser, THAAD, Arrow, and PAC-3 are the most mature in terms of testing and performance.

For cruise missiles, the Radar Technology Improvement Program (RTIP), a high performance airborne radar, will provide early warning of low radar cross section cruise missiles, which can then be engaged by F-22s, other fighters, and the upgraded Patriot.[264] The RTIP will be mounted on the JSTARS aircraft, the proposed USAF MC^{2}A, and the Global Hawk UAV.

Defenses need to be present in theater to operate effectively, at least until space-based systems become feasible. The Airborne Laser can operate from rear area bases, so its airlift requirements are minimal. The ground-based terminal defense systems—PAC-3 and THAAD—must be deployed to the theater. This will require additional airlift. Two past exercises deployed Patriot units, which required moving about 275 tons of equipment (about six C-17 loads) and 100 personnel.[265]

Whether these systems, once fielded and deployed, can reliably engage enemy ballistic missiles is difficult to predict. The high speed of ballistic missiles requires tracking and engagement within tight time constraints. Intercontinental ballistic missiles fired at the United States from Eurasia provide roughly thirty minutes of warning and engagement times, but engagement times for theater ballistic missiles fired over shorter distances would be substantially shorter. Indeed, the difficulty of defending against ballistic missiles is one reason the weapons are proliferating. Moreover, these defenses will be required to defend a target 24 hours a day seven days a week for the duration of operations—an extremely demanding requirement. Cruise missiles, if detected, can be engaged successfully by a variety of platforms, but maintaining defenses on constant alert could strain deployed forces. In addition, devoting air combat resources to cruise missile defense would reduce US offensive capabilities.

Overall, an adversary could probably overcome even highly effective US defenses by conducting massed volleys; some missiles would probably get through to inflict damage on the base (thus

[264] "Intel, Anti-Stealth Part of Tanker Spinoff," *Aviation Week & Space Technology*, March 4, 2002, p. 43.
[265] Killingsworth, et al., *Flexbasing: Achieving Global Presence for Expeditionary Aerospace Forces*, p. 65.

cutting sortie production and consequently reducing cruise missile defense capability). In addition, over time, US terminal defense systems would run out of defensive missiles. Directed energy weapons and space-based assets may offer an eventual solution, but they are no doubt decades away from operational service.

Base Outside the Range of Enemy Threats

If enemy threats cannot be eliminated quickly, the Air Force would need to operate aircraft from bases outside the range of enemy threat systems. For the reasons described in Section II, fighter bases need to be located approximately 1,500 nautical miles from enemy territory at the maximum. If an adversary can threaten these bases, the Air Force should give strong consideration to shifting its combat aircraft modernization strategy toward systems that can conduct sustained, long-range strike operations more effectively.

Long-range systems increase basing options. As noted by the Scowcroft Commission in 1997: "The longer the range, the greater the number of potential bases that are available, and the greater number of countries available for negotiating access to bases."[266] But a new, long-range system will take time to develop. Air Force estimates do not envision a new, long-range system entering service for another 20–30 years, while the economic and political challenges involved in developing a new system are substantial.[267]

For the near to medium term, the USAF could procure larger numbers of cruise missiles to outfit the B-1 and B-52 force, purchase additional stealthy B-2 bombers, or work to add aerial refueling capability to the UCAV now in development. As noted previously, USAF conventional cruise missile inventories are currently marginal and the proposed JASSM buy is small. Conducting air campaigns using standoff weapons, which cost 40–100 times more than direct-attack weapons like JDAM, would be very expensive.[268] The high unit cost of these weapons could be reduced somewhat by increasing buy rates, but will still be substantially higher than direct-attack weapons. B-2s have already demonstrated their capability in two conflicts to strike at intercontinental ranges, but the Air Force opposed 2001 OSD efforts to restart the production line by citing concerns over B-2 survivability if engaged by enemy fighters in daytime.[269] The UCAV, as currently planned, features

[266] Brent Scowcroft, Richard Burpee, Jim Courter, William Hoehn, John Lenczowskie, and Donald B. Rice, *Final Report of the Independent Bomber Force Review Commission* (Washington, DC: House of Representatives, July 23, 1997).

[267] Vast resources would be needed to develop a large advanced techology aircraft. The B-2 development program, for example, cost $32 billion in FY 2000 dollars. Because long-range aircraft are larger than shorter-range aircraft and there is a strong correlation between unit cost and weight, the unit cost of a new-generation, long-range aircraft is likely to exceed previous generations, which would add signficantly to the political challenges of successfully fielding such an aircraft.

[268] See the P-1s in the FY 2003 DoD budget for various programs costs. JASSM program unit cost is $815,000 ($TY) compared to JDAM program unit cost of around $20,000 ($then year). Program unit cost of a Tomahawk Land-Attack Cruise Missile (TLAM), including support equipment costs, is $2,035,000 ($TY). TLAM procurement of 5,956 missiles is $9,910 million, support equipment costs are $2,215 million.

[269] See "Air Force Chief Opposes Purchase of More B-2s," *The Washington Post*, October 24, 2001 for an outline of the Air Force position. Another Air Force argument was that B-2s flying at high subsonic speeds were too slow to engage mobile targets, but this line of reasoning does not stand up to operational experience or analysis. B-2s played a key role in destroying relocatable targets during Serbian operations in 1999. Heavy bombers also struck reloctable targets in Afghanistan. For analysis of this issue, see Bowie, *Destroying Mobile Ground Targets in an Anti-Access Environment*.

a range similar to that of a fighter aircraft. However, because it does not have a pilot, UCAVs could fly very long endurance/range missions with sufficient refueling support, since the air vehicle is free of the constraints induced by pilot fatigue factors. The technical difficulties of refueling an unmanned aircraft are currently being explored by the Air Force and the Navy.

Should these options prove unattractive, the DoD could also move to increase reliance on maritime forces, such as carrier-based fighter aircraft and UCAVs combined with cruise missiles launched from surface and sub-surface combatants.

VII. Conclusions

The requirement to base fighters within 1,000 to 1,500 nautical miles of an adversary raises three key issues:

- Can the United States count on getting access to forward bases? Trends here appear negative. The USAF peacetime foreign basing posture has declined precipitously since the Cold War. US long-term presence has stimulated indigenous opposition and access constraints have continued to bedevil combat operations. Predicting the attitude of host nations regarding access issues in future crises remains difficult.

- Will adversaries deploy sufficient numbers of long-range ballistic and cruise missiles to threaten forward bases? Longer-range weapons are more expensive than shorter-range variants, which raises the cost of fielding large numbers. But ignoring this threat does not seem acceptable; over the long-term, the United States would be placing a significant element of its combat capability at risk. Analysis of potential means for decreasing base vulnerability—hardening, dispersal, and missile defense—indicates that these may be imperfect solutions and possibly unaffordable. The USAF had reached a similar conclusion at the end of the Cold War regarding air base survivability in Europe. Perhaps the USAF's Global Strike Task Force in combination with maritime forces will prove successful in neutralizing an adversary's deep-strike systems, but the small size of the USAF's access insensitive force combined with the magnitude of the operational tasks it must achieve gives reason for concern. It also raises some difficult problems regarding logic for the USAF. If these small forces can succeed in these most difficult and challenging tasks, what is the justification for the rest of the force? Why not simply increase the size of the access insensitive force to increase the chances of success and employ these for the duration of the campaign?

- What will be the effect of adversaries possessing weapons of mass destruction? The threat of WMD strikes would appear to reduce both allied willingness to host US forces and US decision-makers' willingness to risk deploying forces.

To project power, US reliance on forward bases requires success in four areas: an adequate base infrastructure, responsive logistical support, political approval from host nations, and effective counters to enemy threats. If one of these factors is missing, US power-projection capabilities will be compromised. The problem facing the United States is that even a high probability of success in each factor results in an overall low probability of success. For example, if the United States had a 90 percent chance of succeeding in each area, only a 65 percent overall probability of success results (90 percent X 90 percent X 90 percent X 90 percent = 65 percent). In short, these combined uncertainties suggest that over the long term, the land-based fighter force could be significantly constrained in supporting US power-projection operations.

As outlined in this report, the Air Force will probably be forced to deploy to unprotected airfields in future Asian conflicts. To operate from such bases, the USAF will confront potentially far more lethal strikes than it has faced in the past. To neutralize these threats, the United States must spend

substantial additional resources—tens of billions of dollars—on the best mix of the following options: widespread base development (notably hardening of facilities), logistics, production of small munitions, dispersal training and exercises, additional base security personnel, additional specialized equipment to deal with base attacks, additional airlift to bring in all this equipment and manpower, and possibly a different short-range combat force that exploits VSTOL technology. Few of these areas are funded adequately in current plans, if at all. And even if these counters are aggressively pursued, the land-based fighter force still runs the risk of being denied political access to bases and/or sustaining very lethal attacks.

In examining this issue, one is struck by analogies to the Army's recent experience in Task Force Hawk during the conflict over Kosovo in 1999. To support and protect 24 AH-64 Apache helicopters, the Army ended up developing the small airfield at Rinas, Albania using 667,000 square meters of rock fill and pouring 58 concrete landing pads, deploying 26,000 tons of equipment (including 20 vans for the tactical headquarters, twelve M-1 tanks, 42 Bradley fighting vehicles, 24 Multiple Launch Rocket Systems, and 37 utility helicopters), and 6,200 troops. [270] The USAF flew over 2200 airlift sorties delivering 27,000 tons of equipment to support the deployment.[271] This equipment and personnel were needed to support the engaged force and defend the base adequately against enemy missiles, artillery, and special forces. This same sort of elaborate infrastructure and protection could be required for forward-based fighter aircraft in the emerging security environment.

Deploying small numbers of aircraft to a theater is certainly "doable" and the forces that deploy should be as flexible and capable as possible (such as the multi-role F-22). Smaller numbers would allow airlift and sealift assets to provide proper support. Small numbers of fighters could also disperse to minimize their vulnerability. But small numbers will not provide prompt, sufficient combat power, particularly when dealing with a large power or peer competitor.

The USAF has demonstrated outstanding operational competence in a range of unforeseen and challenging conflicts in recent years. Perhaps the political access problems will not arise or will be handled successfully. Perhaps the missile threats forecast by government intelligence agencies will prove less lethal than anticipated. Perhaps numbers of offensive missiles will not continue to climb, or adversaries will not field sufficient numbers of longer-range weapons. Perhaps attacks will prove less devastating than computer simulations and modeling predict. Perhaps deployment of airfield repair equipment will enable USAF personnel to recover after a strike more rapidly. Perhaps the Air Force will be able to weave together a mix of long-range bomber and extended-range fighter operations using aerial refueling, dispersed basing, munitions deployment, and other responses to overcome the anti-access threat and deploy large numbers of fighters.

Although beyond the scope of this study, the developing threat to forward bases raises questions about the current course of US combat aircraft modernization policy. The emerging security environment places a premium on long-range forces less reliant on theater access at a time when the US plans to invest heavily in short-range, land-based fighters over the next two to three decades. Land-based fighter aircraft such as the F-22 and JSF clearly possess the capabilities to dominate hostile

[270] Vickers, "Revolution Deferred: Kosovo and the Transformation of War," p. 198.

[271] Air War over Serbia Fact Sheet. Basing data from *Kosovo/Operation Allied Force After Action Report*, p. 7.

skies. But eventually they must land, and it appears that insufficient attention has been paid to JSF and F-22 potential availability and survivability *on the ground*. The options for dealing with these developing threats will be expensive to implement. Furthermore, in the final analysis, even if implemented, these options do not provide high confidence that land-based fighter forces can be counted on to project sufficient, decisive, combat power quickly in an anti-access environment.

In the 2001 QDR, the Defense Department noted the importance of hedging strategies to cope with assumption failures or unanticipated developments. Over the past 30 years, the USAF hedged by allocating on average two-thirds of each modernization dollar to short-range combat aircraft and one-third to long-range combat aircraft. Current plans, however, change these ratios from 2:1 to 30:1 in favor of short-range forces more dependent upon forward bases.[272] The political problems, logistical issues, and military threats posed to forward air bases individually raise challenges, but the uncertainties and risks induced by all these factors together in future conflicts suggest that the Defense Department leadership should re-evaluate these plans to meet the goal of projecting decisive power promptly in future anti-access environments.

The issues raised in this analysis have broader strategic implications for the US military as a whole. The reliance on large, fixed facilities in the theater of operations is much more than an Air Force issue. Given the growing role of air power forces in US military operations, constrained land-based fighter operations could increase the vulnerability of joint forces to military threats and decrease significantly overall force effectiveness. Army, Navy, and Marine forces are dependent upon forward ports, airfields, and bases in the theater to conduct combat operations. Many of these forces must engage adversaries at shorter distances than land-based fighters, thus exposing them to even greater risk from anti-access threats. The susceptibility of these force elements to the issues raised in this report may differ from land-based fighters due to force characteristics, logistical requirements, and basing modes, but their susceptibility should be analyzed in similar detail to guide decision-making on future force posture and force modernization priorities.

[272] See Appendix I for USAF investment history and Murray, *The United States Should Begin Work on a New Bomber Now* for an analysis of future spending plans.

Appendix I: USAF Investment History (1970–1999)

The following table provides an overview of USAF investment patterns over the past three decades. Investment includes both procurement and system research and development.

$ Invested ($FY98)	1970s	1980s	1990s	Totals
Fighters	$67,300	$75,908	$38,013	$181,222
Bombers	$14,490	$69,364	$23,824	$107,678
Cargo	$7,968	$16,298	$24,636	$48,901
Other	$9,991	$16,797	$11,416	$38,204
Total	$99,749	$178,367	$97,889	$376,005
By Percentage				
Fighters	67.5%	42.6%	38.8%	48.2%
Bombers	14.5%	38.9%	24.3%	28.6%
Cargo	8.0%	9.1%	25.2%	13.0%
Other	10.0%	9.4%	11.7%	10.2%

Source: The data was drawn from "US Military Aircraft Data Book" series published by Data Search Associates. Multiple volumes were used to cover a wider span of time (1960–1999), including the "US Historical Military Aircraft and Missile Data Book." My thanks to Daniel Burg of Northrop Grumman's Air Combat Systems, who compiled this data. (Data listed in millions.)

Appendix II: Global Airfield Data Base

Summary analysis of National Imagery and Mapping Agency Automated Air Facility Information File dated December 1997. Airfield data for Russia, China, and North Korea are not included in these totals. Included airfields feature a runway measuring 6,000 feet by 145 feet with an Load Carrying Number of 40 (sufficiently strong to support a JSF). Increasing length requirement to 8,000 feet (a standard NATO airfield) to increase safety margins would reduce the totals by about one-third.

Shelter numbers in the data base contain many repeats. In analyzing the data base, the author attempted to count the shelters as accurately as possible.

	Airfields	Runways	Hardened Airfields	Number of Shelters
Asia	278	314	52	1,412
Middle East/Persian Gulf	151	187	56	1,217
Western Europe (including Turkey)	388	454	95	2,410
North America	639	896	1	2
Rest of World	555	579	46	711
Global Total	**2,011**	**2,429**	**250**	**5,752**

	Airfields	Runways	Hardened Airfields	Number of Shelters
North East Asia				
Japan	62	68	6	107
South Korea	20	25	12	641
Totals	**82**	**93**	**18**	**748**
Southeast Asia/Pacific				
Australia	30	35		
Brunei	1	1		
Guam	2	3		
Indonesia	18	19		
Laos	1	1		
Malaysia	5	5		
Marianna Islands/Guam	3	4		
Marshall Islands	2	2	1	4
Myanmar	16	16		
New Zealand	5	6		
Papua New Guinea	1	1		
Philippines	12	14	1	5
Singapore	3	4	3	29
Taiwan	10	14	7	203
Thailand	15	16	3	18
Vietnam	3	5		
Totals	**127**	**146**	**15**	**259**

	Airfields	Runways	Hardened Airfields	Number of Shelters
Central Asia				
Afghanistan	3	3		
Bangladesh	4	4		
Burma	3	3		
India	43	46	12	229
Kazakstan	2	2		
Kyrgyzstan	2	2		
Pakistan	9	11	7	176
Sri Lanka	2	2		
Tajikistan	1	1		
Uzbekistan	2	3		
Totals	**69**	**75**	**19**	**405**
Middle East/Persian Gulf				
Egypt	25	34	13	326
Iran	34	41	9	250
Israel	5	8	4	108
Iraq	16	19	9	178
Jordan	7	7	4	116
Kuwait	3	4	2	43
Lebanon	2	3	1	4
Oman	4	6		
Saudi Arabia	34	43	9	115
Syria	4	5	3	57
Yemen	5	5		
Bahrain	1	1		
Qatar	1	1	1	8
UAE	10	10	1	12
Totals	**151**	**187**	**56**	**1217**
Western Europe				
Belgium	10	12	5	126
Denmark	10	11	6	128
France	72	83	13	323
Germany	47	57	14	666
Greece	20	22	8	170
Iceland	3	5	1	15
Italy	39	43	5	87
Luxembourg	1	1		
Netherlands	12	17	7	186
Norway	15	17	7	133
Portugal	10	11	1	1
Spain	39	44	3	33
Sweden	18	19	4	20
Switzerland	2	4		
Turkey	31	33	16	380
UK	59	75	5	142
Totals	**388**	**454**	**95**	**2410**
North America				
Canada	90	122		
Mexico	46	52	1	2
USA	503	722		
Totals	**639**	**896**	**1**	**2**

Appendix III: Glossary

Acronym	Meaning
AAFIF	Automated Air Facility Information File
AEF	Aerospace Expeditionary Force
AFB	Air Force Base
ALCMs	air-launched cruise missiles
AWACS	advanced warning and control system
BLU-109	USAF hard-case penetrating bomb body
CALCM	conventional air-launched cruise missile
CIA	Central Intelligence Agency
COB	Collocated Operating Base
CONUS	continental United States
DARPA	Defense Advanced Research Projects Agency
DoD	Department of Defense
EAF	Egyptian Air Force
ECM	electronic countermeasures
FY	fiscal year
GPO	Government Printing Office
GPS	Global Positioning System
GRS	Global Reconnaissance Strike
GSTF	Global Strike Task Force
HMS	His/Her Majesty's Ship
IAF	Israeli Air Force
IRA	Irish Republican Army
ISR	intelligence, surveillance and reconnaissance
JASSM	Joint Surface-to-Air Standoff Missile
JDAM	Joint Direct Attack Munition
JMOB	Joint Mobile Offshore Base
JP-233	UK-developed airfield attack munitions dispenser
JSF	Joint Strike Fighter
JSTARS	Joint Surveillance Target Attack Radar System
LCN	Load Carrying Number
LGB	laser-guided bombs
MC2A	mission command and control aircraft
MOB	main operating base
NATO	North Atlantic Treaty Organization
NDP	National Defense Panel
NIMA	National Imagery and Mapping Agency
nm	nautical miles
ONR	Office of Naval Research
OSD	Office of the Secretary of Defense

PA&E	Program Analysis and Evaluation Office (in DoD)
PACAF	Pacific Air Forces
PLA	People's Liberation Army
PRC	People's Republic of China
QDR	Quadrennial Defense Review
RAF	Royal Air Force
RDT&E	research, development, testing and evaluation
RRR	rapid runway repair
RTIP	Radar Technology Improvement Program
SAC	Strategic Air Command
SAF	Swedish Air Force
SAM	surface-to-air missile
SDB	Small Diameter Bomb
SOF	Special Operations Forces
TAB-V	hardened aircraft shelters
TAC	Tactical Air Command
TACAIR	tactical aircraft
THAAD	Theater High Altitude Air Defense
TLAM	Tomahawk Land-Attack Cruise Missile
TSAR/TSARINA	computer simulation of air base operations under attack
UAE	United Arab Emirates
UAV	Unmanned Aerial Vehicle
UCAV	Unmanned Combat Air Vehicle
UK	United Kingdom
US	United States
USAF	United States Air Force
USAFE	United States Air Force Europe
USN	United States Navy
VSTOL	vertical/short takeoff and landing
WMD	weapons of mass destruction
WRSK	war reserves spares kits
ZEL	zero ejection launch