Aerospace Sanctuary in 2025:

Shrinking the Bull's-Eye

A Research Paper
Presented To

Air Force ***2025***

by

Col M. Scott Mayes
Maj Felix A. Zambetti III
Maj Stephen G. Harris
Maj Linda K. Fronczak
Maj Samuel J. McCraw

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Disclaimer

2025 is a study designed to comply with a directive from the chief of staff of the Air Force to examine the concepts, capabilities, and technologies the United States will require to remain the dominant air and space force in the future. Presented on 17 June 1996, this report was produced in the Department of Defense school environment of academic freedom and in the interest of advancing concepts related to national defense. The views expressed in this report are those of the authors and do not reflect the official policy or position of the United States Air Force, Department of Defense, or the United States government.

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Executive Summary

> There is nothing more difficult to take in hand, more perilous to conduct, or more certain in its success than to take the lead in the introduction of a new order of things.
>
> — Niccolo Machiavelli
> *The Prince*

Future technologies may allow a direct reduction of core entities[1] or centers of gravity on an operating air base. Reducing the core entities has a direct impact on base defense. As fewer things become critical for sustained operations, defending them becomes easier. Further, there is a direct synergism in operability and defense. The same technologies that improve operability by making it easier to complete the mission or by reducing the cost of doing business also reduce the number of core entities, thereby reducing defense requirements.

On the air base of 1996, there are many core entities. Degrading or destroying any of the ascribed core entities could degrade mission accomplishment. For the aerospace base of 2025, very few things should be core. This paper identifies the concepts to use emerging technologies that have the potential to create a land base that may be considered an integrated system which provides a sanctuary; capable of sustaining operations regardless of threat, location, environmental condition, or type of mission.

First, the base can be harder to find and therefore target. This situation is accomplished by reducing the number of people, assets, buildings, spare parts, and so forth on the base. Reductions are possible for several reasons: an increase in the reliability and maintainability of everything on the base; the use of robotics for tasks not requiring human inputs; and a reduction of bomb dump size as munitions get smaller. Ambient temperature superconductivity could allow redundant, dispersed power generation, eliminating exposed power grids. The structures that remain could take advantage of material advances provided by nanotechnology and microelectromechanical systems (MEMS) to mask or reduce external infrared, radar, and visual signatures. These technologies could offer improved hardening to reduce damage should an adversary successfully prosecute an attack.

Second, the future base can be guarded by a ground-based multispectral sensor system integrated with and augmented by air and space sensors. Information from these sensors could be fed into an integrated command and control system which also controls or directs the base's response to an attack. Response could come from ground-based directed energy weapons, smart mines, "enhanced" human response teams with lethal and nonlethal capabilities, and armed unmanned aerial vehicles (UAV). The base could also be covered by a microwave energy shield able to translate the kinetic energy possessed by inbound weapons and use it to repel those weapons. The end result is a self-contained, self-protecting aerospace base.

If the base is actually damaged, the next concept envisions structures, runways, and taxiways able to determine the level of damage and initiate their own repairs. Chemical or biological contaminants could be detected and cleanup started using enzymes or catalysts resultant of advances in biotechnology.

It is assumed that the US may still need to deploy to forward bases.[2] The final concept draws upon advances in nanotechnology, MEMS, biotechnology, and methods of power generation which could allow the deployment, buildup, sustainment, and redeployment of an aerospace base including runways, buildings, and defenses with an order of magnitude less lift. In this vision of the future, runways could be created anywhere with air-dropped materials, while precision air-dropped structures self-erect or are organically grown onto a previously emplaced skeletal frame.

All of these concepts portend a revolutionary way of viewing aerospace base operability and defense. Today's air base is a necessary evil. It is expensive, large, and hard to defend. The aerospace base of 2025 will still be required; however, it should cost less, be much easier to operate, and be self-defending. The ability to position airpower assets anywhere in the world- based only on a set of coordinates instead of being tied to preexisting infrastructure- makes the aerospace base of 2025 a force enhancer rather than the mere force supporter of today's Air Force.

The conceptualization of (aerospace) basing as enhancing rather than merely supporting may foster a renaissance in thinking about the way the US applies military power. Today's forward operations are restricted by basing requirements, that is, water and runways. With the advances identified in this paper, air and ground power can go anywhere—together if desired. This, in turn, may offer unparalleled opportunities to improve the organization of joint operations or even the services themselves.

Notes

[1] Dr. Karl P. Magyar, "Conflicts in the Post-Containment Era," in Earl Weaver et al., eds., *War and Conflict Textbook*, vol. 1 (Maxwell AFB, Ala.: Air Command and Staff College, August 1995), 15. Dr. Magyar's Security Levels of Interest Model has been adopted by the team to represent the core, intermediate, and peripheral components or entities of an aerospace base to correspond to the respective components or entities functional importance to sustainment of the aerospace base mission. This concept is explained in detail in chapter 1.

[2] Jeffery R. Barnett, *Future War: An Assessment of Aerospace Campaigns in 2010* (Maxwell AFB, Ala.: Air University Press, 1996), xxv. The author directly infers that the United States will continue to use the military to respond to varying types of overseas contingencies. Peacekeeping, humanitarian, and disaster relief operations are examples which seem to be part of the United States' charitable ethic and will demand the maintenance of a capability to deploy forward.

Chapter 1

Introduction

> Petty geniuses attempt to hold everything; wise men hold fast to the key points. They parry great blows and scorn little accidents. There is an ancient apothegm: he who would preserve everything preserves nothing.
>
> — Frederick the Great
> Instructions for His Generals

In 2025, dominance in aerospace is possible, if and only if, the aerospace base is specifically designed to be a sanctuary for aerospace operations. Yet, with aerospace dominance enabled by networked, brilliant, multispectral sensors, no adversary can hide. Ill intent or aggressive action is met by near immediate response. Manned and unmanned air and space systems target and attack with unrelenting precision.

Thus, adversaries could target the key infrastructure that enables aerospace dominance. The United States (US) will potentially ". . . face threats from one or more sources: a successor state to the former Soviet Union armed with a large, diverse, and advanced long-range nuclear arsenal; a "second-rate" nuclear power with strategic forces resembling those now possessed by Britain, France, and China; or a developing state deploying a moderate number of ballistic missiles capable of hitting the United States."[1] A military peer or niche adversary could potentially attack the US with advanced weapon systems, including precision guided munitions or directed energy weapons based from airborne or space-based platforms.[2] The network of commercial, space-based, multispectral sensors, with the capacity to identify and pinpoint high-value assets and low-cost global positioning system guided missiles to attack them, could be available to anyone willing to pay the commercial fee.[3] Conversely, the US could remain vulnerable to low-technology attacks on aerospace bases in 2025 by an inferior adversary attempting to negate its overwhelming technological advantage.[4] Even today, post-Gulf War analysis by some third world countries has led to this conclusion. Indian brig Vijai K. Nair hypothesized that enemy special forces raids against United States Air Force forward bases and logistics concentrations, though sure to be costly, could produce disproportionately significant results.[5]

The relevant question is whether to even have forward operating bases in 2025 given the disproportionate effects of an attack by a determined adversary? While air and space force projection will predominately be continental United States (CONUS) based, the US could still require the use of forward airfields for reasons related to its position as a world power, its charitable ethic, conflict containment, and coalition force considerations.[6] These are factors which demand a physical presence, especially those related to peacekeeping, humanitarian, and disaster relief, and do not readily conform to operations based exclusively from CONUS.[7] Assuming that not all forward deployed operating areas will have suitable facilities,[8] the requirement to maintain a force deployment and beddown capability could be essential to air and space force projection. This requirement entails forward deployed aerospace bases to be fully automated and integrated facilities, similar to CONUS bases, with the added attribute of mobility.

Forward operating bases will not be able to rely on distance from the forward edge of the battle area, or its equivalent in 2025, as the principal means of protection from attack.[9] The base (including CONUS bases) will have to defend itself against a broad spectrum of threats. The nature of the challenges posed by the 2025 threat environment require a redefinition of operability and defense.

In 2025, operability and defense is the ability to mount and sustain aerospace operations regardless of the nature of threat, level of conflict, environmental conditions, and/or geographic location.[10] A key aspect of operability is the defense of those components or systems deemed critical to support of the aerospace base's mission. This analysis will demonstrate that by capitalizing on specific emerging technologies, the capability to enhance aerospace operability and defense is attainable by significantly reducing the number of aerospace base "core entities," and thereby increasing the base's survivability, if targeted and attacked.

Core is defined as the central, innermost part of anything, the most important part,[11] and *entity* is a thing that has definite, individual existence in reality or in the mind; anything real in itself,[12] hence the derivation of "core entity(ies)." Accordingly, and within the context of this thesis, a subordinate function will be to define those core entities which are most crucial to operability and potentially the most likely targets of an adversary. The analysis will also identify, but to a lesser degree, those elements of the aerospace base which are defined as intermediate and peripheral entities (i.e., nondecisive points or components). The end result of this identification process will illustrate the technological means to migrate those entities presently categorized as core entities outward into the intermediate and peripheral categories (see figure 1-1). Reducing the number and dispersing the key base functions, that if attacked, would halt operations, could reduce base vulnerability, and increase operational effectiveness. Said another way, by substantially reducing the number of core entities present on an aerospace base, the defense required to protect those remaining core entities is scaled proportionately. However, there is a resultant trade-off between defense and the number of core entities. It may be technically feasible to reduce the number of core entities but is economically infeasible. The converse is true, it may be expensive and difficult to reduce the number of core entities, but necessary because it may be even more difficult or more expensive to protect them.

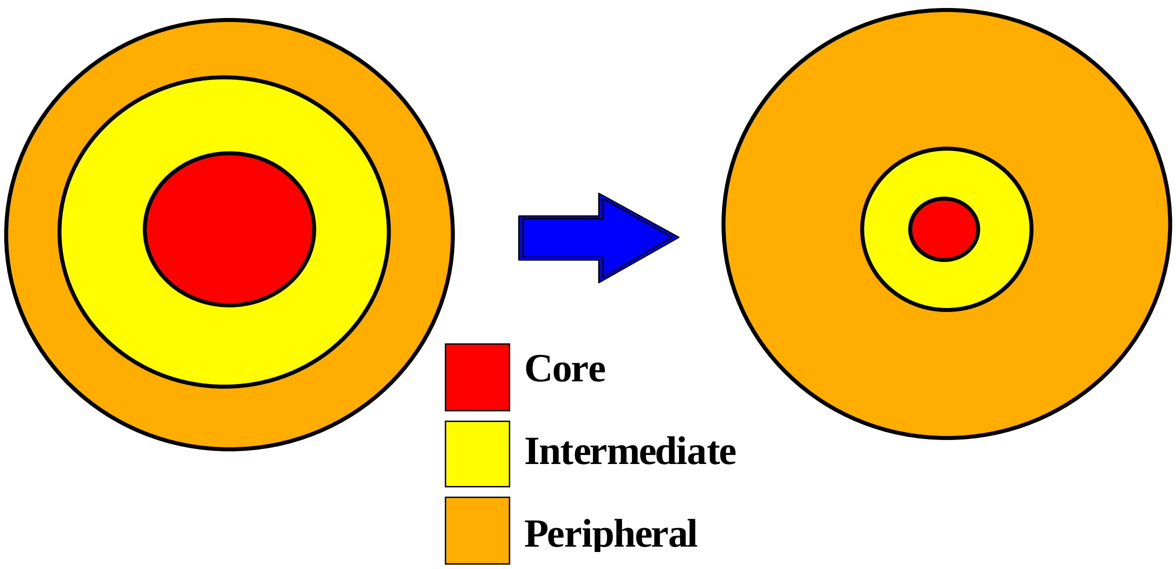


Figure 1-1. Migration of Core Entities

Today, operability and defense is considered a force support mission, similar to logistics and combat support.[13] The role of force support is to ". . . support and sustain the aerospace combat roles of aerospace control, force application, and force enhancement."[14] In 2025, improvements in the survivability, reliability, adaptability, defensibility, and mobility of an aerospace base could transform operability and defense into a force enhancement mission. As shown in figure 1-2,[15] this conversion elevates aerospace base operability and defense to the level of airlift, aerospace replenishment, special operations, and information operations—force enhancers—with the capability to ". . . increase the ability of aerospace and surface forces to perform their mission."[16]

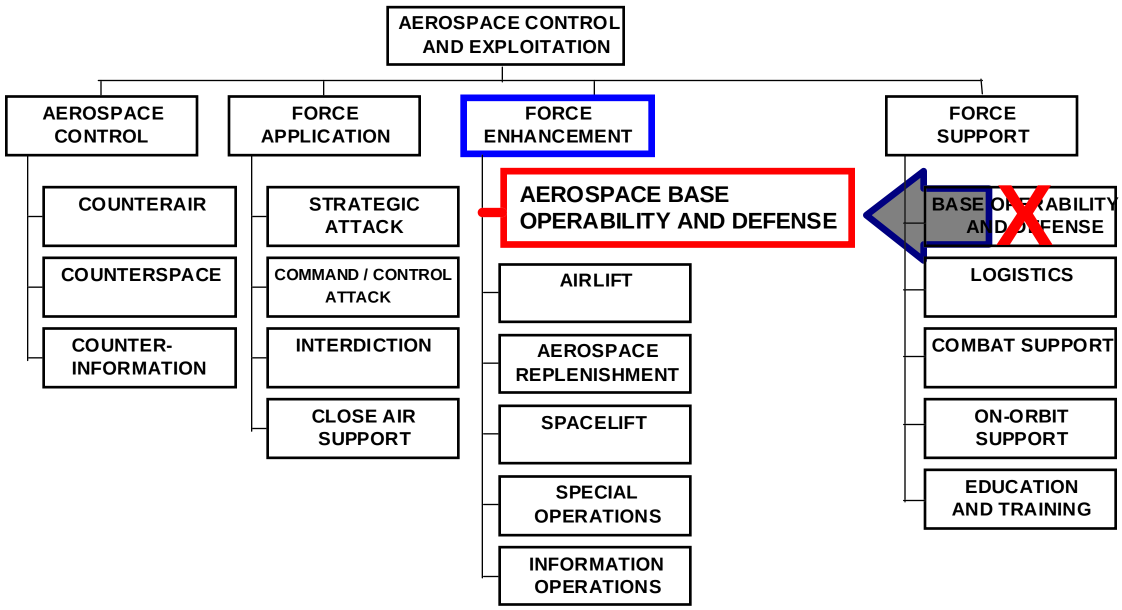


Figure 1-2. Roles and Missions Revision

Although the full ramifications of this concept are not completely clear, its fulfillment signifies a tremendous expansion in the capability of airpower force projection. Completion of the aerospace base metamorphosis will involve a counterbalancing trade-off between the migration (reduction) of core entities and increasing defensive capabilities. Whichever objective the cost/benefit analysis supports, the ability to operate and the necessity of defense are inseparable and leverage many of the same technologies anticipated to be available in 2025. The following chapter identifies the capabilities required to operate and defend an aerospace base of 2025.

Notes

[1] Institute for National Strategic Studies (INSS), *Project 2025* (Norfolk, Va.: National Defense University, 6 May 1992), 45.

[2] Jeffery R. Barnett, *Future Wars: An Assessment of Aerospace Campaigns in 2010* (Maxwell AFB, Ala.: Air University Press, January 1996), 27–28, 76–77.

[3] Ibid., 1.

[4] David A. Shlapak and Alan Vick, *Check Six Begins on the Ground, Responding to the Evolving Ground Threat to U.S. Air Force Bases*, RAND Report NR-606-AF (Santa Monica, Calif.: RAND, 1995), xv.

[5] Brig Vijai K. Nair, *War in the Gulf, Lessons for the Third World* (New Delhi: Lancer International, 1991), 225–28.

[6] INSS, 46-47.

[7] Ibid., 47.

[8] USAF Scientific Advisory Board, *New World Vistas: Air and Space Power for the 21st Century* (unpublished draft, the mobility volume, 15 December 1995), 37.

[9] Barnett, xxv.

[10] Team-derived definition of operability and defense for purpose of thesis development.

[11] *Webster's New World Dictionary of the American Language*, 2d ed. s.v. "cores"

[12] Ibid., "entity".

[13] AFM 1-1, *Basic Aerospace Doctrine of the United States Air Force*, vol. 1, March 1992, 7.

[14] Ibid., vol. 2, 285.

[15] Department of the Air Force, *Cornerstones of Information Warfare*, n.d., 11. This publication, signed by Gen Ronald R. Fogleman, Air Force chief of staff, and Secretary of the Air Force Sheila E. Widnall, updates the previously established AFM 1-1 Roles and Missions breakout to take into account changes brought on by the rising preeminence of information warfare. The "Cornerstone" model, shown in modified version, is being used as the baseline Roles and Missions model for the 2025 Project.

[16] AFM 1-1, vol. 1, 7.

Chapter 2

Required Capabilities

> The secret of success is to have a solid body so firm and impenetrable that wherever it is or wherever it may go, it shall bring the enemy to a stand like a mobile bastion, and shall be self-defensive.
>
> — Comte de Montecucculi
> *Principes de l'Art Militaire*

Overview

This chapter initially reviews operability and defense at today's air base, then enumerates the assumptions which bound the scope of this paper, and defines the worst-case operating considerations in 2025. Lastly, the requirements for a 2025 base will be defined and distributed under the categories of low-observable base, shielded base, self-healing base, and mobile base.

Today's Air Base

Currently, aerospace operations are conducted from three types of aerodromes. The first type is a main operations base (MOB).[1] MOBs are characterized by highly developed infrastructures and support architectures, mostly stateside. The MOB represents an extreme of operating environments and by far the most capable operating infrastructure. The second type of base is called a collocated operations base (COB).[2] A COB is typically owned and operated by an ally and characteristically varies in its state of accessibility and readiness. The final type of base is referred to as a forward operations base (FOB).[3] Most FOBs are extremely austere with little to no infrastructure. When an infrastructure does exist, it is usually poorly maintained or inadequate in some other regard. For the purposes of this paper, the discussion will be confined to the antipodes of operating bases: MOBs and FOBs. Both types of operating bases contain a large number of core entities, including aircraft, runways, aircrews, support personnel, and command post. Current air base defense operations are nested in the overall rear area defense and are the responsibility of the land component commander (LCC) in a theater of operations.[4] Locating air bases in the rear area enhances security as it uses geographical separation from the enemy to one's advantage. Traditionally, rear area defense is a low priority concern, as the LCC's attention is typically focused at the front and the enemy main. Rear units are then expected to provide their own security, and as a result, air base defense commanders are essentially on their own.[5] Consequently, this leads to an imbalance in the relationship between the number of entities needed to be protected and the level of protection available as represented by figure 2-1. The objective is to seek a more measured balance between the core entities of an aerospace base and its defensive capabilities. In order to achieve this objective, the aerospace base of 2025 must be defined with respect to the platforms it must support and sustain. But first, formulation of logical and reasonable assumptions regarding the dimensions of the requirement with respect to the most-demanding-to-support or worst-case scenario must accomplished.

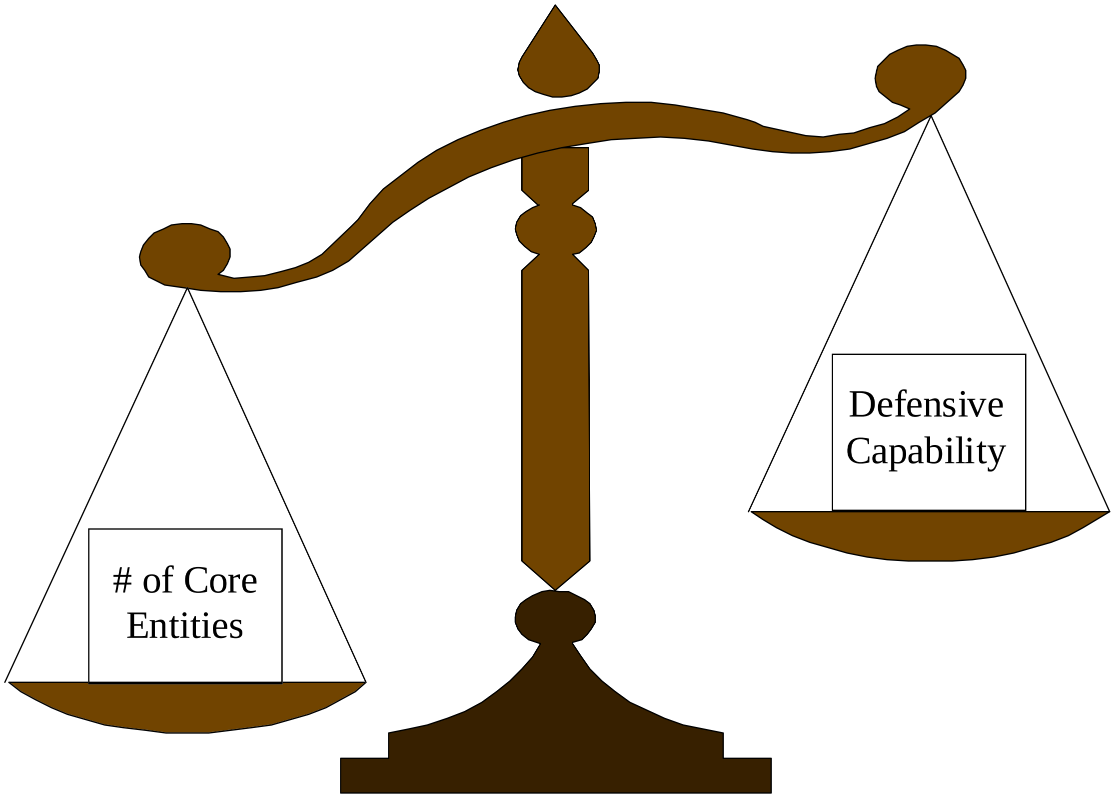


Figure 2-1. Defense/Core Entity Trade-off

Assumptions About Aerospace Bases in 2025

Aerospace bases in 2025 could assume many varying forms and sizes and support numerous differentiated types of forces. It is then with a focus on the worst-case scenario that the assumptions, in terms of operability and defense, are derived. Three considerations germane to operating and defending a base are size, location, and priorities of the resources on the base. The worst-case scenario is one which requires a runway of fixed-dimensions for horizontal takeoffs and landings and security of high-priority resources in a high-threat environment. This seems reasonable and plausible, since many of the airframes which may be on the ramp in 2025 are either on the ramp today or are in near-term production.[6] It is most likely that a greater number of manned and unmanned aerospace platforms in 2025 will have vertical takeoff and landing (VTOL) and short takeoff and vertical landing (STOVL) capabilities.[7] Presuming that the basing (launch and recovery) requirements for VTOL/STOVL platforms are substantially less than horizontal takeoff and landing platforms, hence easier to sustain and defend, they will not be addressed specifically because they do not meet the worst-case scenario criteria.

As introduced in the preceding chapter, a derived requirement of the 2025 aerospace base is to reduce the core entities required to support the mission. Given this requirement, several assumptions are critical to the analysis. Although not all bases will be the same, the worst-case and possibly the most likely case is that base infrastructure will still include the equivalent of a North Atlantic Treaty Organization (NATO) standard runway (7,500 feet × 125 feet), fuel, ordnance, operators, and maintainers. Supporting this primary force element will be personnel and equipment providing command and control, power generation, water and sewage handling, administration, billeting, medical/dental services, security, and other necessary infrastructure maintainers and systems. Although the number of people, types of systems, and the methods used may change, the necessity to perform these functions should still exist. On CONUS bases of 2025, it may be necessary to protect high-value assets at a near-zero attrition rate, while operating under the constraint of reduced operating budgets. Correspondingly, there may still exist the need to project airpower from FOBs with like capabilities of a CONUS base, using minimal assets for setup and sustainment. All aerospace bases present significant defense challenges in terms of retention of operability owing to the lethality and nonlinear attributes of the battlespace in 2025.[8]

Predictions concerning the future battlefield suggest that a theater of operations could well constitute and encompass the globe owing to space-based and intercontinental, surface-based strategic platforms (weapons and sensors). Thus, the "idea of a close engagement . . . will fade" and "disengaged conflict, a war fought from a distance that proceeds without massing of troops and weapons"[9] may be possible in the future. There may be no front line, it may be difficult to have secrets and bases in CONUS and abroad may be equally lucrative and vulnerable targets.

Successful targeting of an aerospace base can be pictured as a long chain of events (see figure 2-2).[10] Increasing the level of uncertainty or difficulty in completing the associated tasks of a given link in the chain correspondingly increases the probability of error and thereby decreases the potential for effective targeting. The potential adversaries of the US in 2025 could presumably still use this targeting methodology or a near-facsimile thereof but operate at a much faster tempo than currently possible. Essentially, anything that sits still longer than a few minutes in 2025 is a viable target,[11] but not necessarily one that is always targetable and destructible.

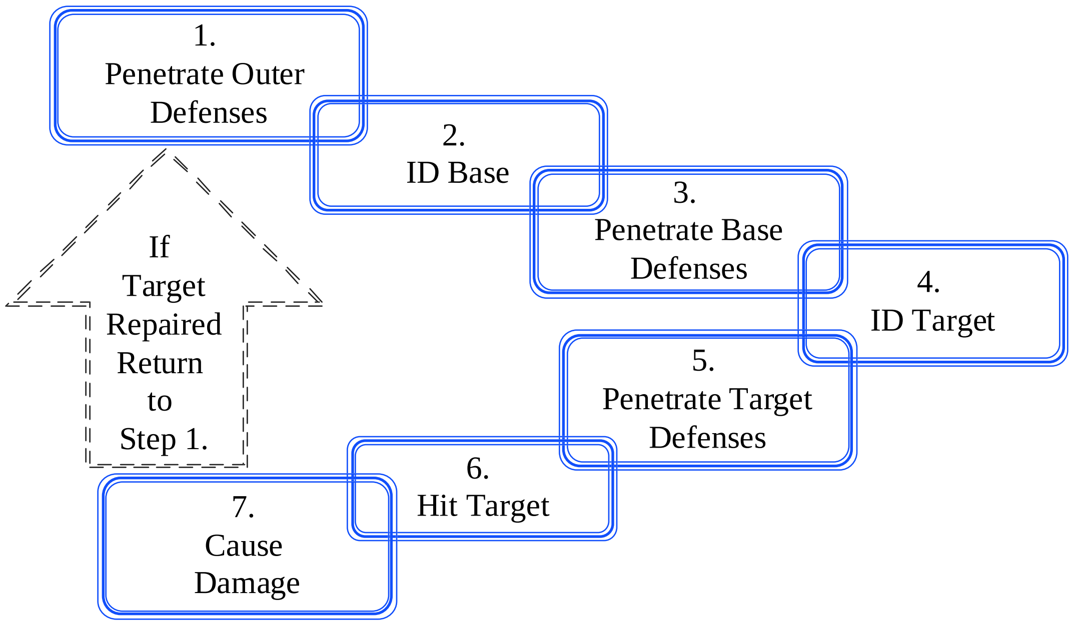


Figure 2-2. Targeting Chain of Events

Given the worst-case assumptions of a FOB in a high-threat environment with high- value resources, a runway of fixed-dimensions, and a high operational tempo, aerospace base requirements are distributed under the following four major categories: low observable base, shielded base, self-healing base, and mobile base. Irrespective of the category, the overarching concern is focused on reducing the number of core entities and protecting those that remain.

Low-Observable Base

Presently, bases are very large and easily identifiable. Base structures are fixed and typically laid out in symmetrical patterns organized around runways of at least 7,500 feet in length. Most MOB structures are categorized as "soft" targets with little or no attempt to conceal their physical identity. All air bases have visible control towers, runway and taxi lights, large fuel storage tanks, and flight line lighting. Adversaries can attack indirectly, using target coordinates, or directly, by target recognition, using any one of several spectral means. To survive and operate in 2025, aerospace base structures will have to be harder to discern and locate. Accomplishing this requires a combination of things to occur: (1) reduce the number of people and structures on-base, (2) increase the margin for error in threat system target acquisition, and (3) eliminate or "blend" all conspicuous aerospace base markings into the surrounding background. The concept is to stretch or completely break links two and four in the targeting chain of events previously denoted in figure 2-2.

Several technological advances need to be considered when developing this concept. Aircraft in 2025 could manifest dramatic improvements in reliability and maintainability when compared to their 1996 counterparts. It is feasible to expect a decreasing mean-time-between-failures rate.[12] Systems could be characterized by "graceful degradation"[13] with most hard failures requiring only the replacement of common circuit boards. Aircraft could be essentially self-contained for all normal operations and most maintenance operations.[14] The ramp population of aircraft ground equipment could be virtually nonexistent and what remains may only be used for abnormal equipment maintenance (engine removals). The explosive yield in conventional munitions could increase at least tenfold.[15] With added improvements in fusing and bomb case design, one or two bomb designs could conceivably replace today's myriad of cluster and conventional munitions, with a resultant smaller munitions storage area.[16] The improvements in systems reliability and munitions capabilities could reduce the number of people tied both directly and indirectly to the airfield. There may also be a resulting synergistic reduction in the number of storage buildings, houses, chow halls, and other facilities needed to be maintained in peacetime or protected in war, making the low- observable aerospace base less detectable.

Shielded Base

Should an attacker identify the location of an aerospace base, the next step in the successful attack chain is to prosecute an attack against the specific target(s). The adversary could threaten with a full range of attack methods—from sniping, to the use of precision guided munitions, to the use of a ballistic missile loaded with chemical or biological agents. Even directed energy attacks from space are plausible. The base commander will need a base that defends across the full attack spectrum if any modicum of operability is to be retained. The requirement then becomes to negate or interfere with the completion of steps three and five of the targeting chain of events denoted in figure 22. The aerospace base responds to the specific threat with a combination of autonomous and human-initiated self-protection mechanisms to defend itself.

A defense mechanism is any self-protective physiological reaction of an organism.[17] For an aerospace base, the self-protective reaction can be either to respond directly to defeat the threat or to mitigate the potential for damage. To actively respond to the threat, the base commander needs access to a nearly seamless defensive system with integrating intelligence and defense assets. The thrust is that no matter what the level of attack, the base commander will have a tiered defensive capability to prevent successful penetration of the aerospace base domain. Should the attacker penetrate the outer defensive tiers and successfully attack a structure or system, the aerospace base must be able to minimize the damage to the assets contained therein.

The aerospace base will also have to employ passive defensive techniques and technologies. This includes reducing the number of core entities, hardening the remaining structures, proliferating redundant key operating systems, and using advanced camouflage, concealment, and deception techniques. Power sources must be efficient and robust, allowing for uninterrupted operation for extended periods. Facilities must have an independent power supply with a reduced spectral signature to prevent adversarial targeting.

Operational control of defensive systems by the base commander could be accomplished through enhanced situational awareness. Enhanced SA, as defined for the purpose of this paper, is the enabler which permits the “human-in-the-loop” to correlate, decipher, and react appropriately to various simultaneous aural, visual, and electronic sensor inputs with greater rapidity and assuredness. This means the commander will need full and unfettered access to all levels of information. Lastly, and to facilitate joint and combined operations, sensory and communication capabilities must be survivable, redundant, and interoperable with allied nations and sister services.

Self-Healing Base

The final option in breaking the targeting chain of events is to recover quickly from a successful attack. The desired result is to place the enemy back at step one in the attack chain, as depicted in figure 2-2. In 2025, seconds may be a decisive factor in deterring, defeating, or withstanding an attack. The aerospace base will have to recover quickly from any disruptive attack with minimal, if any, external support. Quick recovery first requires being able to recognize the extent of damage. Recovery may then take the form of repairing or replacing the structure or system or just absorbing the damage and operating with a minimal loss of capability. Today's air base uses huge stockpiles of material for postattack recovery—the aerospace base of 2025 should not.

Mobile Base

The need for forward presence will not be eliminated in 2025; however, the manner in which forward presence is executed is expected to change. Therefore, at a minimum, a very definite requirement could exist to provide a versatile and mobile force packaging capability in order to accommodate forward presence requirements. As it stands now, the ability to select FOB sites is severely constrained by several limiting factors—the need for a NATO standard runway, water, fuel, ammunition, people, and supplies are among the most prominent. The FOB represents the most difficult operating environment. To meet the challenge of the operating environment of 2025, FOBs have to become smaller, reaching the point where each can be deployed, set up, and sustained entirely by air. The goal is to be able to select an aerospace base location using only a cursory map survey and selecting map coordinates for precision siting.

Core Entity Migration

Table 1 depicts, arguably, the most important entities relevant to today's operability requirements and their current status as either core, intermediate, or peripheral entities. Additionally, the table depicts those same requirements and their envisioned status (core, intermediate, or peripheral) in 2025 with regard to meeting the aforementioned operability requirements.

Table 1

Reducing Core Functions

Entity	Today		2025	
	MOB	**FOB**	**MOB**	**FOB**
Runway	Core	Core	Intermediate	Peripheral
Power	Core	Core	Intermediate	Peripheral
Fuel	Core	Core	Core	Core
Ordnance	Core	Core	Intermediate	Intermediate
Operators (Crews)	Core	Core	Core	Core
Maintainer/Aircraft	Core	Core	Intermediate	Intermediate
Airframes/manned	Core	Core	Core	Core
UAVs	Core	Core	Intermediate	Intermediate
Water	Core	Core	Core	Core
Civil Engineers	Intermediate	Core	Peripheral	Intermediate
Facilities	Intermediate	Intermediate	Intermediate	Peripheral
Security	Core	Core	Intermediate	Intermediate
Command, Control, Communications, Computer, and Intelligence (C^4I)	Core	Core	Peripheral	Peripheral

The denotation of core, intermediate, and peripheral does not necessarily correlate to importance but more appropriately to the entity's survivability or replaceability. For example, runways today are extremely difficult to construct and repair. Because severe cratering degrades sortie generation, runways are designated a core entity and require a high-level of protection. In 2025, the requirement for a runway will exist, but due to technological applications, it should be easier to construct and repair. Runways should require a much lower-level of protection and contribute to the reduced effectiveness of adversarial bombing due to their ease of repair. Conversely, aircrews of manned aircraft, a core entity today, could remain a core entity in 2025, largely due to the inability to quickly replace a trained aircrew.

As derived from table 1, the number of core entities in 2025 is significantly reduced from that of 1996. Core entities are reduced from 11 at a MOB and 12 at a FOB in 1996, to four for both the MOB and FOB in 2025. The accompanying net reduction in core entities provides a more equitable balance between the number of core entities and the defense required to protect them. Knowing the desired end-state, the task then devolves to defining those emerging technologies which could provide the means to achieve the desired balance between core entities and self-defense means of the mobile aerospace bastion.

Notes

[1] Department of Defense (DOD), Joint Publication 1-02, *Dictionary of Military and Associated Terms*, 23 March 1994, 224.

[2] Air Force Pamphlet (AFP) 93-12, *Contingency Response Procedures,* vol. 2, n.d., I-3.

[3] DOD, Joint Publication 1-02, 154.

[4] David A. Shlapak and Alan Vick, *Check Six Begins on the Ground: Responding to the Evolving Ground Threat to U.S. Air Force Bases*, RAND Report MR-606-AF (Santa Monica, Calif.: RAND, 1995), xv.

[5] Ibid.

[6] USAF Scientific Advisory Board, *New World Vistas: Air and Space Power for the 21st Century* (unpublished draft, the materials volume, 15 December 1995), 29.

[7] USAF Scientific Advisory Board, *New World Vistas: Air and Space Power for the 21st Century*, summary volume (Washington, D.C.: USAF Scientific Advisory Board, 15 December 1995), 32.

[8] Evaluation Division, *Warfighting Vision 2010: A Framework for Change* (Fort Monroe, Va.: Joint Warfighting Center, 1 August 1995), 3, 5.

[9] Gary Stix, "Fighting Future Wars," *Scientific American*, December 1995, 94.

[10] The targeting chain of events is a team-derived construct developed to visualize and discuss the general events associated with target acquisition and desired effects.

[11] Institute for National Strategic Studies, *Project 2025* (Norfolk, Va.: National Defense University, 6 May 1992), 37.

[12] Dr. Craig M. Brandt et al., "Logistics 2025, Changing Environments, Technologies, and Processes" (Wright-Patterson AFB, Ohio: Graduate School of Logistics and Acquisition Management, Air Force Institute of Technology, n.d.), 27–28.

[13] Adm William A. Owens, "A Report on the JROC and the Revolution in Military Affairs," *Marine Corps Gazette* 79, no. 8 (August 1995): 51.

[14] Brandt et al., 27.

[15] *New World Vistas*, summary volume, 9.

[16] Ibid., 37.

[17] *Webster's New World Dictionary of the American Language*, 2d ed., s.v. "defense mechanism."

Chapter 3

System Description

> The first stage is the formulation of a felt want by the fighting Service. Once this is clearly defined in terms of simple reality it is nearly always possible for the scientific experts to find a solution.
>
> — Winston Churchill

Integrated System

The aerospace base of 2025 is a dynamic and integrated system, providing warfighters with a seamless and robust base of operations. Gone are the stovepiped, manpower-intensive systems of 1996. They have been replaced with a ubiquitous architecture linking personnel, facilities, utilities, defense, and logistics into a seamless information net which is self-monitoring and accessible to all personnel, from headquarters to the lowest-ranking airman on the base.[1] The movement of core entities to the intermediate and peripheral categories (see table 2-1) through the application of technology has made them more survivable, more rapidly repairable, and so pervasive they are virtually indestructible. This then provides a survivable base to the warfighter, irrespective of the threat environment. Prolific ground sensor fields cover and surround the base providing complete situational awareness to command and defense personnel. Overhead, a fleet of unmanned aerial vehicle (UAVs) provide additional sensor capability, exchange information with satellites, as well as function collaterally as standoff weapon platforms for base defense.[2]

Enumerated below are selected technologies and applications that, if developed, could facilitate the movement of aerospace base core entities to the intermediate and peripheral categories, reduce defensive requirements, increase survivability, and ultimately achieve the reality of an aerospace sanctuary. They offer but one possible combination for the attainment of the concept of operations delineated in this paper. (A more complete picture of aerospace base operations in 2025 follows in chapter 4, Concept of Operations.)

Advanced Sensors

Aerospace base operational and defensive requirements necessitate continuous, near -real-time sensor coverage. Diverse sensor capabilities increase accuracy and identification probabilities and correspondingly lowers false alarms and error rates. Additionally, they are pervasive, aboard UAVs, on satellite constellations, and on the ground.[3] These staring and scanning sensors could produce multispectral and synthetic aperture radar images and light detection and ranging returns that could have a resolution of a few centimeters.[4] The UAVs "[could] deploy low-altitude or ground-based chemical sensors for accurate discrimination of chemical and biological agents."[5] These same sensors could be remotely interrogated, allowing them to have reduced size, weight, power, and vulnerability.[6] Fusing the sensor-derived information into the overall aerospace base communications architecture could give the commander a real-time view of the security status of the aerospace base and the surrounding area of interest. Approaching threats could be identified quickly and accurately. Integrating sensor information into a stand-off weapon system could permit accurate targeting at increased distances from the aerospace base, increasing security and in turn making adversarial targeting more difficult.[7]

Countermeasures. Presuming advanced sensor technology will be widespread, advances by the United States (US) may be negated unless the technology is more skillfully deployed and employed. Care should be taken to seriously consider nontraditional methods and means of deploying sensors in order to retain some level of superiority. Additionally and given a wide-spectrum of sensor capabilities, weather, electromagnetic pulse (EMP), or other interference may sufficiently degrade aspects of the capability and necessitate a return to visual observation means.

Robotics

Use of robotics can synergistically increase effectiveness by reducing manpower, infrastructure, and other support systems typically required for 24-hour operations on the flight line, in the bomb dump, and around the base. Today's robot is a mere infant compared to what may be available in 2025. The present advantages of implemented parallel processing in robots allow rudimentary cognitive skills.[8] When combined with the limited motor sensory skills available today, robotic structures are able to perform limited inspections on aircraft.[9] By 2025, robots could be designed as advanced "tools" with the capability to fully inspect, diagnose, and maintain aircraft, as well as most other base systems for day-to-day operations.[10] Robots could be expected to perform refueling operations, buildup, transport and loading of weapons, security functions, and even explosive ordnance disposal. The large computing capacity expected to be available in 2025 suggests that a single robot may be capable of alternating among the aforementioned tasks for every aircraft on the flight line, including those of our allies. Each robot could be engineered to be resistant to varying types of environmental extremes to retain its functionality; that is, ultraviolet rays, precipitation, cold and heat, EMP, and chemical/biological attacks.

Countermeasures. Although constructed to withstand EMP and other destructive measures, the possibility still exists for mechanical and/or software failure. Lack of on-scene personnel to effect repairs may well cause a significant drop in work productivity until restoration occurs, backup systems are activated or additional personnel arrive.

Nanotechnology

Nanotechnology is a process whereby matter can be constructed from the atomic level up. When fully deployed, nanotechnology may create a new "industrial revolution," for lack of a better descriptor. Current estimates project 20–30 years for this technology to mature.[11] Nanotechnology starts with atoms and uses molecular-sized machines to put them together in predetermined configurations. Maturation of this technology could mean thorough and inexpensive control of the structure of matter.[12] Nanotechnology infers materials and, thereby, structures can be manufactured to whatever specification is required—change colors, adapt to ambient temperatures, flex with stresses and strains, counter harmful vibrations or resonance, and even self-erect.

Nanotechnology also has important ramifications for aerospace defense in 2025. One of the earliest predicted applications of nanotechnology is in the area of sensors.[13] This technology could produce sensors which are extremely lightweight, energy efficient, and inexpensive to mass-produce. Efforts are under way to produce sensor capabilities that include chemical and virus detection.[14] Cheap, mass-produced, highly sensitive sensors could convey the capability to cover the base and perimeter area with very accurate sensing devices that require only small amounts of energy for functioning.[15] Adaptations of nanotechnology can reasonably be extended to provide multispectral sensing such as; heat, acoustic, optic, olfactory, and seismic capabilities that give a sensitized and near-real-time picture of the base and its surroundings. In the area of smell, sensors could be used to detect individual human pheromones for positive identification of personnel approaching the base. The sensor system could provide an accurate identification, friend, or foe (IFF) capability that could be deployed throughout the base proper, as well as outside the perimeter. The sensor system's multispectral capability may provide an all-weather, day/night operational capability, as well. Heat, acoustic, optic, and seismic inputs—fused with the other characteristics previously defined—may enable precise identification of what or who has penetrated the sensor area, thereby eliminating false alarms but, more importantly, enable the appropriately tailored security response.[16]

Microelectromechanical Systems (MEMS)

MEMS are the products of combining miniaturized mechanical and electronic components in sizes no larger than postage stamps.[17] MEMS could potentially afford increased capability, hence greater operability, while simultaneously reducing the volume required to deploy the specified capability.[18] For example, Westinghouse Science and Technology Center has reduced a 50-pound bench top spectrometer to the size of a calculator. Application of this type of technology could result in inexpensive nuclear, biological, and chemical contamination detection on the battlefield.[19] Small, mass-produced sensors may make biological and chemical detection affordable, easy to deploy, and difficult to counter.

Nanotechnology and MEMS could be merged for use in environmental cleanup, including cleanup after a biological or chemical attack.[20] Professors at the University of California at Berkeley are working on a chemical factory on a chip. When activated by an electrical charge, chemicals move down to a reaction chamber on the chip. Added heat assists the chemical reaction, and the resulting chemical is discharged.[21] The end product could very well be an antidote to a toxic substance propagated by adversaries or a lethal or nonlethal chemical designed to control crowds or halt intruders.

Researchers at the Massachusetts Institute of Technology (MIT) have invented robots, similar to ants, that exhibit certain limited aspects of intelligence and differentiated specialization such as avoiding shadows and staying away from each other. They are cheap and easy to reprogram.[22] "Thirty-five years from now, analogous small, lethal, sensing, emitting, flying, crawling, exploding and thinking objects may make the battlefield highly lethal."[23] Exploiting this capability by incorporating "intelligence" and IFF within our sensors could provide a "smart" minefield that extends as far from the installation as deemed necessary. This smart minefield could be programmed to automatically react/self-detonate to certain stimuli or be programmed to report findings and be command-detonated remotely by security forces.

Additionally, MEMS can make a material into a smart system. Researchers are making great strides in the area of intelligent materials. It is possible to animate otherwise inert substances through the application of a variety of devices: actuators and motors that behave like muscles; sensors that serve as nerves and memory; and communications and computational networks that represent the brain and spinal column.[24] Basically, intelligent materials allow structures to adapt to their environment, understand what is happening to them (cognizant of external forces or stimuli), and even record and report what they experience.[25] Such materials are currently in use.[26] Additionally, this technology could enable self-erecting buildings which are environmentally adaptive and self-aware.

Countermeasures. Overwhelming the sensor field with massive inputs, masking odors, or severe weather conditions may adversely affect sensor capabilities. The requirement for near-perfect accuracy may permit spoofing. In smart materials, complete destruction could obviously render the self-report and reconstruction capability nonfunctional.

Artificial Intelligence/Neural Nets

The principal technologies required to enable smart sensor networks to provide fused, intelligent information to the decision makers and enhance their situational awareness are artificial intelligence and neural net technologies. To enhance situational awareness it is necessary to fuse ". . . multivariate data from multiple sources which in turn can be retrieved and processed as a single entity."[27] Artificial intelligence and neural networks integrate sensor signals from various parts of the electromagnetic spectrum simultaneously and recognize more sophisticated patterns.[28] Efforts at the Machine Learning and Inference Center at George Mason University in Fairfax, Virginia, in working with pattern recognition, using large relational databases, are progressing remarkably well.[29] Advances in this research area may allow the development of applications which identify threats by using machine-learning algorithms to find patterns and associate the discerned threat with the learned pattern. Additionally, while exploiting artificial intelligence, smart nodes may be able to collect information from sensors and perform a variety of functions, including analysis and redistribution of the information.[30] Organizing the processing systems for these sensors into distributed systems should produce a robust and more survivable system, with no obvious targetable strategic core.[31] Hierarchical architecture, signal processing, and action occurring several levels away from the central processor are areas being looked at for intelligent materials and may be the answer for the sensor fields.[32]

Countermeasures. Artificial intelligence has proved more elusive than originally thought. Programming even commonly understood concepts is extremely difficult. Deception ploys by an adversary may be so unique, so completely unanticipated, and not contained within the software capability that the system can be spoofed.

Defensive Weapons

Nonlethal capabilities include but are not limited to the following: acoustical weapons, chemical disablers, low-frequency electromagnetic wave generators, and supercaustics.[33] The focus of these types of weapons is to preclude or mitigate the loss of human life. They are appropriate for peacekeeping operations or civil unrest scenarios. Given the wide-range of possible scenarios from operations-other-than-war[34] to full-scale war, flexibility in weaponry employment is deemed an enhancement to overall capability.

The Air Force Scientific Advisory Board in *New World Vistas, Air and Space Power for the 21st Century*: Summary Volume, states that "speed-of-light weapons with the full-spectrum capability to deny, disrupt, degrade, and/or destroy will leap past and could eventually replace many traditional explosive-driven weapons and self-protection countermeasure systems."[35] They identify five innovative technologies for "energy-frugal, practical directed energy weapons" and recommend the Air Force pursue them. These technologies are large, lightweight optics; high-power microwave antennas using thin membrane fabrication; high-power short-wavelength solid-state lasers; high average power phase conjugation; new approaches to adaptive optics and phased arrays of diode lasers. Application of these technologies to base defense weaponry could significantly increase options and improve capabilities to repel attacks in 2025.[36]

Additionally, use of a propagated microwave field could create a protective energy dome effect over the base. Functionally, this protective energy dome could detect incoming projectiles, convert their kinetic energy, and use the converted energy to repel the projectiles, including those as large as an aircraft or as small as a bullet. Counters to an adversary's use of microwave or laser weapons include the use of a pulsed plasma jet to ionize the air, which could effectively blunt the effectiveness of these types of offensive weapons.[37]

Countermeasures. Microwaves, lasers, and beam weapons, in general, require a robust power source. Unless significant advances are made in power generation and consumption, power remains a core entity, and if successfully damaged or destroyed, it could leave the base defenseless. Accordingly, defensive weapons must include a range of alternative power source derivatives to eliminate single-point failures.

Biotechnology

The threat of chemical and biological weapon usage has the decided potential to become increasingly widespread as more countries develop and acquire this capability.[38] Decontamination efforts will have to address reduced manpower, ease of handling/disposal, and cost considerations. Advances in biotechnology may permit the development of enzymes, (MEMS), or a synthesis of the two technologies which could either neutralize the contaminant or absorb it. Additionally, advances in Doexyribonucleic Acid (DNA) modification could result in the development of DNA-altering substances that neutralize contaminants.[39]

A new generation of materials, most probably composites, designed after principles of hierarchical structures in nature (biomimicking), manufactured at least in part by incorporation of biological self-assembly principles and processes (bioduplication), may result in materials having the behavioral properties of biological systems: durability, flexibility, responsive to change, reactive to internal injury (self-repairing), and/or damage tolerant.[40] It may be possible to genetically produce organically similar substances whose rate and consistency of growth could be used to grow materials and structures. The underlying concept adapted from these cited technologies is to be able to rapidly construct rudimentary structures, such as tents and paved surfaces, and expediently repair minimally damaged facilities.

Countermeasures. DNA advances could allow the development of new, possibly more lethal, compounds. Developing antidotes or DNA restructuring to neutralize new agents will be critical but time dependent. Introduced mutations or weed killer-like substances could alter normal growth patterns. Hardiness and resistance to nefarious attempts to alter original designs will need to be bioengineered in the early developmental stages.

Super Quantum Interference Devices (SQUID)

If a human must remain in the loop (and the presumption is that one must), the human also must be enhanced to avert "mental paralysis" due to information saturation. Enhancements to increase the cognitive capacity of future warriors would presumably improve information assimilation, information correlation, and decision-making processes; that is, situational awareness. One means by which improvement in these processes could be achieved is via bioelectronic enabling technologies. Envisioned is the placement of an embedded microprocessor in the brain, which is designed to increase the efficiency in the way information is received, stored, correlated, and retrieved.[41] A complementary feature of bioelectronic enhancement would be the ability to interface/communicate directly with an external computer system, thus mitigating or eliminating the necessity for physical or mechanical interfaces.[42] "Neurocompatible interface" efforts to date have affirmatively demonstrated the capability to produce an image directly in an individual's mind via surgically invasive methods. Alternatively, related research at the Media Laboratory of MIT is directed towards the development of a surgically non-invasive, "wearable computer" which maintains a continual communications interface with the human "host."[43] Irrespective of the method used to bioelectronically enhance a human, the resultant increase in mental agility and capacity—combined with the capability to interface directly with computers—could exponentially decrease the potential for confusion and disorientation in highly taxing and stressful situations.[44]

Countermeasures. Countermeasures are death or surgical removal of the embedded microprocessor or spoofing by insertion of disinformation. Implementation of this capability would require a change in US social values, as this form of human "adaptation" is not presently, nor universally acceptable.

Advanced Materials

A promising area of technology involves the development of advanced materials. Today's composites are substances made of fibers spun from carbon, glass, and other materials, which are then fused into a matrix of plastic, ceramic, or metal. Composites can provide the same structural strength as steel, but, at only one-fifth of the weight. Many believe costs may fall below that of steel as the demand increases over the next few years. Consequently, many future systems and structures could be constructed with composites because of the economical efficiencies gleaned from the weight versus performance ratios. The transportation, electronics, and medical industries are the major users of this technology today. The transportation industry uses composites in the manufacture of aircraft and automobiles. The electronics industry uses composites for the manufacture of components like resistors and insulators while the medical industry uses composites for prosthetics, including dental ware. The latter application is an area of particular interest and potential utility. Dentists apply an enamel-like substance that bonds with existing surfaces and becomes superhard when exposed to a certain wavelength of light. Expanding the application of this technology to wearing surfaces such as roads, building exteriors, and runways may be feasible, providing a capability to easily construct, resurface, or repair the particular worn surface. Should this technology become feasible, then the overarching requirement to defend these elements of the aerospace infrastructure at all costs against damage or destruction would be eliminated.[45]

Holography

Advances in holographic imaging, combined with infrared signature generators and radar reflectors, could give the base commander the ability to project false targets designed to deceive the adversary. This capability could allow the projection of false targets and signature modification of actual structures or could enable defenders to completely hide a structure. Holography is deception 2025 style, intended to prompt a potential adversary to question the effectiveness of his reconnaissance systems and ultimately designed to impede or negate his targeting ability.

Visualization of intelligence supporting three-dimensional analysis is a project aimed at assisting analysts in visualizing and manipulating complex, changing three-dimensional intelligence data.[46] Technicians use a cylinder approximately one meter in diameter and one-half meter high in which they project a three-dimensional, transparent spinning ball to recreate a three-dimensional tactical scenario. This image can be viewed from any side. Applied to aerospace base defense, a three-dimensional view of the battlespace could be generated encompassing the base proper and as far outside the perimeter as the sensor field extends. With near-real-time refresh capability, the commander can have an “unobstructed” view of the battlespace from a secure location. Projecting this picture to remote locations via the fused command, control, communications, computers, and intelligence (C^4I) base architecture could give base defenders a three-dimensional depiction of their assigned sector. Should technological advances allow the projection of images without the use of a cylinder container, false images could be projected at will to various locations to deceive adversaries.

Countermeasures. Unless the hologram is used in conjunction with other spectral deception means, adversaries probing with broad spectrum systems could uncover the ruse, rendering this capability only useful against unsophisticated target acquisition systems.

Power

The technological focus is to reduce cost to generate, transmit, distribute, operate, and maintain power generation systems. There is a great deal of potential for improvement over today's power generating systems. Currently, the power industry offers evolutionary improvements: high reliability components; smaller, high efficiency motors; automatic diagnostic and control systems; and multifuel generating equipment, to name a few. While alternative power sources, such as biomass, solar with photovoltaic receptors, geothermal, and wind all show promise, all suffer from the inherent problems of relatively low efficiency (conversion from source to useful distributed power) and lack of storage. Many of these systems require highly visible production systems. However, one truly revolutionary advance could change the entire concept of power generation—that technology is superconductivity.

Superconductivity is the ability to conduct electricity without resistance.[47] While application of this technology is not feasible outside of a carefully controlled laboratory environment, there has been recent progress achieving superconduction at higher temperatures.[48] Increased interest among the scientific community indicates that this capability has a reasonably good chance of coming to fruition. Assuming a breakthrough does take place, power generation equipment could be made considerably smaller; because it would no longer have to produce excessive amounts of energy to overcome the problem of line loss due to the heat associated with resistance encountered in existing conducting materials. The potential exists, with the advent of nanotechnology, to assist the process along by permitting a material that is superconductive to be built upward from the molecular level.

Achieving superefficient power usage could permit the use of marginalized power generation sources, such as solar or photovoltaic. This may then eliminate the requirement for certain electrical power grids. As such, each building could be equipped with its own combination of standard and independent power generation sources,[49] making power ubiquitous, easy to maintain, and pushing it from a core entity to a peripheral entity.

Table 2 summarizes the applicability of each technology to the aerospace base concepts postulated in this paper. There was no attempt to quantify the payoff for each technology, this is covered in chapter 5. This table identifies whether the technology was applicable to the concept. As shown, the two most versatile technologies are MEMS and advanced power generation. As the final column portrays, most technologies applicable to meet the first three concepts are leveraged to provide mobility. The application of each technology is discussed in the Concept of Operations (chap. 4).

Table 2

Applicability of Technologies to Concepts

Technology	**Application to Concept**			
	Low-Observable Base	**Shielded Base**	**Self-Healing Base**	**Mobile Base**
Advanced Sensors		Yes	Yes	Yes
Robotics	Yes		Yes	Yes
Nanotechnology		Yes		Yes
MEMS	Yes	Yes	Yes	Yes
AI/Neural Nets		Yes	Yes	Yes
Defensive Weapons		Yes		Yes
Biotechnology		Yes	Yes	Yes
SQUIDs		Yes		
Advanced Materials		Yes		Yes
Holography	Yes	Yes		
Power	Yes	Yes	Yes	Yes

Finding and exploiting new technologies is only one-half of the equation. Employing the technologies in innovative combinations to create a synergistic effect is at least as important, and one way of staying ahead of adversaries in a world of proliferating, inexpensive technology. The following chapter paints such a picture—a fully integrated, technologically enhanced, aerospace base in 2025. Thus, having formulated what is wanted and defined those wants in terms of simple reality for the experts to solve, the remaining step is to articulate the concept of operations for the aerospace base integrated system.

Notes

[1] Lt Col Gregory J. Miller et al., “Virtual Integrated Planning and Execution Resource System: The High Ground of 2025” (Unpublished white paper, Air Command and Staff College, n.d.).

[2] Lt Col Bruce W. Carmichael et al., “StrikeStar 2025” (Unpublished white paper, Air Command and Staff College, n.d.).

[3] USAF Scientific Advisory Board, *New World Vistas: Air and Space Power for the 21st Century,* summary volume (Washington, D.C.: USAF Scientific Advisory Board, 15 December 1995), 22.

[4] Ibid.

Notes

[5] Ibid.

[6] Ibid.

[7] Institute for National Strategic Studies (INSS), *Project 2025*, (Norfolk, Va.: National Defense University, 6 May 1992), 36-39.

[8] Roger Lewin, "Birth of a Human Robot," *New Scientist* 142, no. 1925 (14 May 1994): 26.

[9] Andrew Kupfer, "A Robot Inspector for Airplanes," *Fortune* 127, no. 9 (3 May 1993): 93.

[10] Dr. Craig M. Brandt et al., "Logistics 2025, Changing Environments, Technologies, and Processes" (Wright-Patterson AFB, Ohio: Graduate School of Logistics and Acquisition Management, Air Force Institute of Technology, n.d.), 27-28.

[11] Robert Langreth, "Molecular Marvels," *Popular Science*, May 1993, 110. However, Col (Ph.D.) Tamzy House, Air War College faculty member, believes this technology will not advance to this stage of capability until beyond the year 2025.

[12] John L. Petersen, *The Road to 2015* (Corte Madera, Calif.: Waite Group Press, 1994), 58.

[13] Robert Langreth, "Why Scientist Are Thinking Small," *Popular Science*, April 1993, 75.

[14] Langreth, "Molecular Marvels", 75.

[15] USAF Scientific Advisory Board, *New World Vistas: Air and Space Power for the 21st Century* (unpublished draft, the sensors volume, 15 December 1995), 146.

[16] Ibid., 150–151.

[17] Kaigham J. Gabriel, "Engineering Microscopic Machines," *Scientific American* 273, no. 3 (September 1995): 118.

[18] USAF Scientific Advisory Board, *New World Vistas: Air and Space Power for the 21st Century* (unpublished draft, the materials volume, 15 December 1995), 125.

[19] Ibid., 121.

[20] Barbara Starr, "Super Sensors Will Eye the New Proliferation Frontier," *Jane's Defense Weekly* 21, no. 22 (4 June 1994): 92.

[21] Gabriel, "Engineering Microscopic Machines," 121.

[22] INSS, 36.

[23] Ibid.

[24] Craig A. Rogers, "Intelligent Materials," *Scientific American* 273, no. 3 (September 1995): 122.

[25] Ibid., 123–125.

[26] "Smart Structures Dampen Motion, Increase Stability," *Signal* 8, no. 8 (April 1994): 20.

[27] Department of the Air Force, *SPACECAST 2020: Operational Analysis* (Maxwell AFB, Ala.: Air University Press, June 1994), 56.

[28] INSS, 37.

[29] Peter Wayner, "Machine Learning Grows Up," *Byte*, August 1995, 63.

[30] INSS, 39.

[31] Ibid., 39.

[32] Rogers, 125.

[33] **2025** Concept, No. 90026, "Commander's Universal Battle Display," **2025** Concepts Database (Maxwell AFB, Ala.: Air War College/**2025**, 1996).

[34] Department of Defense, Joint Publication 3-07, *Joint Doctrine for Military Operations Other Than War*, 16 June 1995, I-1.

Notes

[35] *New World Vistas,* summary volume, 60

[36] Ibid.

[37] Mark Lehr, Phillips Lab, Kirtland AFB, N. Mex., telephone interview, February 1996. AFIT technologists and 2025 assessors expressed skepticism regarding the invulnerability of the energy dome, as well as the associated energy consumption requirements.

[38] INSS, 45.

[39] Daniel E. Koshland, Jr., ed., "Molecule of the Year: DNA Repair Works Its Way to the Top," *Science* 266, no. 5193 (23 December 1994): 1926–27.

[40] USAF Scientific Advisory Board, *New World Vistas: Air and Space Power for the 21st Century* (unpublished draft, the human systems and biotechnology volume, 15 December 1995), M-11–13.

[41] **2025** Concept, No. 900523, "Chip in the Head," **2025** Concepts Database, (Maxwell AFB, Ala.: Air War College/**2025**, 1996).

[42] **2025** Concept, No. 900246, "The Borg," **2025** Concepts Database (Maxwell AFB, Ala.: Air War College/**2025**, 1996).

[43] Peter Thomas, "Thought Control," *New Scientist* 149, no. 2020 (9 March 1996): 41–42.

[44] **2025** Concept, No. 900702, "Implanted Tactical Information Display," **2025** Concepts Database (Maxwell AFB, Ala.: Air War College/**2025**, 1996).

[45] "Advanced Composites," *Scientific American* 273, no. 3 (September 1995): 126–127.

[46] Robert Ropelewski, "Making Sense of Sensor Data," *Interavia Aerospace World,* September 1993, 56.

[47] Paul C. W. Chu, "High-Temperature Superconductors," *Scientific American* 273, no. 3 (September 1995): 128.

[48] Ibid., 130.

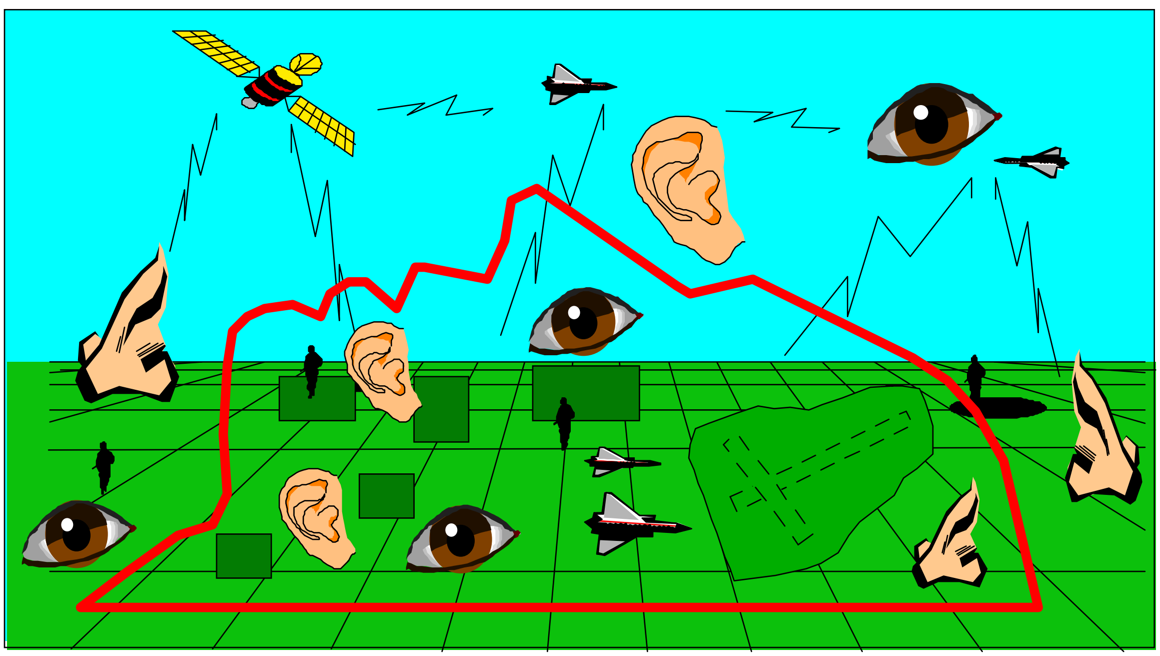
[49] Independent power generating sources may include any combination of following: solar collectors, photovoltaic collectors, high-power lithium batteries, and standard electric power generators. The particular combinations will be highly dependent upon the required use, as well as, the geographic location.

Chapter 4

Concept of Operations

It is a doctrine of war not to assume the enemy will not come, but rather to rely on one's readiness to meet him; not to presume that he will not attack, but rather to make one's self invincible.

— Sun Tzu
The Art of War



Source: Microsoft Clipart Gallery © 1995 with courtesy from Microsoft Corp.

Figure 4-1. Concept of Operations Pictorial—2025

Introduction

The pictorial on the preceding page is a symbolic representation of the aerospace base of 2025. The eyes, ears, and noses represent the pervasiveness of the "all-knowing" sensing attributes of the aerospace base, fused with and augmented by varying types of airborne sensor platforms. The nondescript depiction of the aerospace base (runways, buildings, and so forth) represents its inherent capacity to blend into its surroundings, thus making it nearly undetectable to an adversary. Lastly, the facial silhouette overlying the aerospace base symbolically represents the shield which surrounds the base with its complementary active and passive self-defense capabilities. The ensuing chapter paints a word picture that makes the graphic more meaningful and illustrates the plausibility of the concept.

This concept of operations (CONOPS) provides a multifaceted approach to operability and defense circa 2025. It includes five distinct capabilities which national decision makers can pursue based on international and domestic policies, military requirements, and economic capacity. The five capabilities are day-to-day operations, low-observable base, shielded base, self-healing base, and mobile base. Although the capabilities provide optimum operating conditions when employed together as an integrated system, any one or combination thereof will still improve operability and defense. Each of the following sections will present possible methods of applying the previously described emerging technologies to improve the ability to operate and defend bases in the future.

Day-to-Day Operations

Base operations in 2025 may occur in a manner radically changed from that of today. Overall base infrastructures may be smaller due to a reduction of services or functions currently provided at today's bases. The Department of Defense may no longer maintain base operating support (BOS) activities such as medical, financial, base maintenance, housing, and morale and welfare functions on federal installations. These services could migrate to the civilian sector and be subsumed by commercial interests in the adjacent civilian communities. However, many of the same functions required today to support aerospace activities may still be needed in 2025, the difference being the way they are accomplished. Technological advances in computers and information networks, robotics, highly reliable systems and components and vastly improved power sources may enable highly effective and efficient base operations.

The information available to all base personnel should be incredible. At the touch of a finger, future commanders could have immediate access to such information as aircraft and base status, mission scheduling, intelligence reports, and even the number of box lunches ready at the chow hall. In fact, anyone on base with a need to know could have that same information just as easily.

All of the systems on base, whether they be aircraft, environmental control, or sanitation, could be dramatically more reliable. This should permit a tremendous reduction in the size and scope of logistics and maintenance required to sustain base operations. Robots could be used extensively to replace humans in many of the repetitive, human-intensive functions on the flight line, at the munitions storage areas, and throughout the rest of the base.

In 2025, our main operations bases (MOBs) should, by necessity, function at the same operating level regardless of the threat condition. During normal operations, a MOB may be a veritable beehive of activity—but not to the naked eye with all base entities functioning as one integrated system. Operability would be a function of synergistically interconnected intelligent systems. The aerospace base would operate largely "hands off." Base systems would monitor and report on themselves through an interconnected artificial intelligence or neural net architecture. The routine health and status of the base would be monitored, controlled, and operated by this extensive computer system. The system would have multiple nodes, each more than capable of assuming overall direction, coordination, or control should any of the other nodes be incapacitated. Personnel would only be required to respond to complete outages, major malfunctions, and life/safety concerns such as accidents, fires, or other disasters. Facility and infrastructure maintenance personnel would rarely interface with base systems at all except for annual maintenance requirements owing to an expected and dramatic increase in systems reliability and improved building materials.

Base facilities, to include airfields, would be retrofitted with or constructed from stronger, more durable, and damage-resistant materials or composites. Most buildings, particularly the critical ones, would be capable of monitoring their own conditions. The placement of various types of sensors and intelligent materials would give new meaning to the term *building systems.* Routine facility condition inspections would be minimized to only those circumstances when the "facility" notifies the maintenance personnel of a condition warranting their attention.

Runways and other airfield pavements—all pavements for that matter—would be capped or constructed with extremely durable and minimal-to-no-maintenance type materials without any overt markings. The era of repainting, resurfacing, or replacing pavements every five to 10 years would be long gone.

Similarly, a combination of improved space-based global positioning capabilities that work with enhanced aircraft guidance systems would eliminate the need for ground-based visual approach and airfield lighting systems. In fact, control towers would be nothing more than distant memories of earlier aviation days.

The remaining airfield operations would be automated and fine tuned specifically to accommodate a combat turn type of ramp function. On approach, aircraft would automatically report their status to the base system through an unmanned control center. The control center would distribute the data throughout the base. The distributed information would include tasking specified support functions. For instance, fuels would know how much fuel is required. Munitions storage would know which armaments to select and transport to the aircraft for loading. Aircraft maintenance would know whether they need to respond to the aircraft to conduct system checkouts, repair, or replace components, and exactly what they need to bring with them. The base would be totally coordinated in supporting the aircraft's next mission. The aircraft would be directed to a specific location on the airfield where all support functions would automatically converge. The entire operation would be handled predominantly by robots. Delivery and loading of munitions, refueling, and final system checkout would all be automated. The only humans involved in the operation would be those necessary to perform high dexterity operations and to visually supervise the activities.

These "automatic" sortie generation and aircraft/base maintenance capabilities could improve efficiency and timeliness of support, as well as, reduce overall costs due to fewer required personnel. The key to the success of this type of operation is to limit the opportunities for outside interference or disruption from potential adversaries. One possible solution could come from technology, as it may provide the defensive capabilities to make the core entities less detectable.

Low-Observable Base

The threat posed to our bases is certain to include precision munitions and the use of space-based reconnaissance and surveillance systems by potential enemies. This threat capability may mandate the employment of enhanced defensive deception capabilities.

With the application of specific technologies, it could be considerably more difficult to identify the most critical base structures in 2025. All external structural surfaces ("skins") could be covered by a "cloaking" film or paint which would provide an active means of camouflaging buildings, runways, equipment, and so forth. These "skins" would be capable of "blending" into the surroundings in chameleon-like fashion.[1] This may include changing both color and temperature to negate electro-optical and infrared reconnaissance and targeting systems. At a minimum, any materials used to cover new facilities or recover existing facilities should be tinted to better match or blend in with the existing environs.

Projection of multispectral holograms could mimic real targets, confuse targeting systems, and foil attacks requiring visual target acquisition. Radar reflection enhancement devices could modify the electromagnetic picture. Commanders may also have the option of effecting the weather to further hide the base from several sensor detection spectrums.[2] Essentially, buildings, runways, vehicles, or even people would become virtually invisible.[3] Weapons acquisition systems would then be unable to accurately discern desired targets or aim points with any reliable degree of certainty. Furthermore, future structures could be fully independent and redundant. However, hiding a base may not be sufficient to thwart attacks.

Shielded Base

Defense of the base, regardless of whether a MOB or forward operations base (FOB), may vary in degrees, but not capability. The base system could coordinate and assimilate a multitude of active and passive defensive systems scattered throughout and beyond the base boundaries. This defensive system may consist of varying types of sensors and weapons systems, all interconnected to enhance the commander's situational awareness and reaction capability.

Encompassing and controlling all of the defensive sensors, countermeasures, and intelligence-gathering systems is a redundant, dispersed, situational awareness system. This neural net type C^4I system could integrate the incoming information from all data sources, positively identify the threat, and automatically coordinate a response. This ability to rapidly and precisely discern what the threat is, and then recommend an appropriate response would be a significant attribute of the system. If the object is human, the system would be able to identify who it is by cross-checking the human pheromone database.[4] Additionally, the neural net system could have the ability to produce a near-real-time, three-dimensional or holographic sand table image.[5] Any individual with a receiver device could be able to receive the entire picture modified to their particular requirements. For example, if a view of avenues of approach without the trees or the buildings is desired, they are "deselected," enabling an unobstructed view.

The base and its surroundings could be seeded with multispectral sensors to detect both air and ground threats accurately and consistently, far enough from the base to allow engagement without degrading the mission. Airborne and ground-based sensors could be widely dispersed, redundant with overlapping coverage, and extremely difficult to counter. Because of the sensor systems redundancy, elimination of one or more sensors would not eliminate the entire detection capability. The system should be designed to degrade gracefully and have enough power to operate for sustained periods without maintenance. Collectively, the sensors should provide a "brilliant" grid for threat detection and identification[6] throughout the entire spectral range.[7] The ability to detect and combine a wide range of signals from acoustics and pheromones, to motion and infrared, should allow highly accurate threat identification.[8]

Simultaneously, an overhead fleet of stealthy, extremely high-endurance, solar-powered UAVs could be positioned to orbit the base for months at a time. This fleet could have the ability to detect both airborne and ground threats and relay their location to remotely controlled fire control units.[9] Deployed in great numbers, the UAVs could also have the capability of providing standoff weapon support to security forces and serve collaterally as communication relays. The UAVs could be capable of receiving and relaying information from other sensor platforms, such as satellites and Airborne Warning and Control System.

The holographic projection of security personnel to challenge unidentified intruders may permit resolution of a potential situation without an actual physical response. For instance, should an intruder not respond to the holographic warning, the standoff weapons capability of the UAVs could be brought to bear without jeopardizing the safety of security personnel. If a physical response is required, security force personnel could respond in small, environmentally controlled, self-contained hovercraft equipped with a variety of nonlethal and lethal weapons.

Another advantage of the sensor field would be its capacity to detect nuclear, biological and chemical agents and respond autonomously.[10] Positive detection could automatically launch a decontamination missile programmed to detonate at a required altitude or signal selected UAVs to respond with neutralizing systems. Such systems could employ cleanup bugs or bioengineered enzymes. Application of the neutralizers could be accomplished via aerosol dispersal in quantities sufficient enough to form a suppression "cloud or fog" over the affected area. As the suppression cloud falls, the bugs remove and/or the enzymes react with the contaminants in the air and on the ground, rendering the area clean without any harmful residue.[11] Structures, aircraft, vehicles, and the like could be treated with a catalytic/enzymatic decontaminating coating to neutralize contaminants not affected by the aerosol dispersed enzymes.[12]

Improved sensor capabilities could also benefit buildings, no longer remaining dormant targets for adversaries. The most critical buildings could be outfitted with a combination of sensor-activated, reactive armor systems and advanced lightweight hardening materials that would make them less vulnerable to many types of munitions.

A final measure of passive protection is to be an energy field, covering the base like a dome. The energy field could detect airborne threats attempting to penetrate it. As the airborne object "collides" with the energy field, the kinetic energy produced by the collision could be transmitted down to the energy field's source ground station. If the object is determined not to be friendly, the ground station could retransmit that energy, multiplied, back to the front of the object, effectively stopping or deflecting it, much like a force field.

Other active capabilities to defeat or deter a threat to the base could incorporate lethal and nonlethal systems. Beginning with the lethal variety, directed energy weapons (DEW) are requisites for base defense. The ability to neutralize or destroy fast-moving or hardened threat platforms mandates the need for a highly accurate and reliable weapons platform(s) with superior lethality—these systems should provide that capability. DEWs could be mounted on ground-based platforms; long-endurance, high-orbit UAVs; space-based killer satellites; or a combination thereof. Point target lasers with a rapid recycling rate to allow multiple missile engagement, coupled with directed energy weapons could comprise the principle means for close-in defense.[13] UAVs loaded with scatterable "intelligent" mines would be on-call for dispersal against ground attacks should the need arise.[14] Lastly, robotic "insects" could be released to swarm and defeat preprogrammed targets.[15]

While this interconnected and layered passive and active defensive system may provide as close to an impenetrable fortress as possible, there always remain the possibility of an opponent discovering a way to penetrate or defeat the systems. Therefore, a capability to recover after an attack must be considered.

Self-Healing Base

The ability to sustain damage and recover while continuing to operate could be crucial to base operations, particularly during war. In 2025, postattack damage recovery could be nearly automatic with the level of human involvement much reduced from what it is today. Postattack actions include airfield and facility bomb damage assessment (BDA), explosive ordnance reconnaissance (EOR) and disposal (EOD), rapid runway repair, decontamination (DECON), and bomb damage repair (BDR). The difference between today and 2025 may be the nature of response and timeliness of recovery operations. There may no longer be the need to dispatch the hundreds of vulnerable civil engineering troops to recover the base.

Recovery typically begins with EOR and BDA. These tasks could be conducted in a number of ways, depending on the nature and extent of damage. Robotic sniffers and MEMS, working in concert with existing sensor systems, could locate and identify unexploded ordnance (UXO) and damage. UAVs equipped with very high resolution multispectral imaging devices could assist with BDA while combat engineering personnel oversee the entire process. Once initial reconnaissance is accomplished, recovery teams could begin preparations to conduct RRR and BDR activities. However, the risk to personnel and equipment from any UXOs must first be minimized. This EOD phase of recovery could be accomplished using MEMS to seek and destroy, robots to disarm and remove, and/or portable tower-mounted directed energy weapons to blast away individual UXOs or more densely covered areas, like bomblet or mine fields, that pose extreme hazards.

While chemical or biological agents may be neutralized as previously discussed, some personnel may still be required to operate temporarily in chemical/biological environments. When that is the case, personnel could don new chemical-resistant battle dress uniforms (BDUs)[16] and vastly improved gas masks with improved filtration, comfort, and visibility. The commander may have the option of enhancing the local weather to minimize or negate the effectiveness of many chemical and biological agents. Once the level of risk to recovery teams is deemed acceptable, full-scale recovery and repair operations could commence.

RRR could be accomplished by small teams of personnel and robotics equipment. Equipment could be compact and versatile, very much like the "bobcat" tractors used around today's construction sites, only these may be remotely controlled or programmable. The teams could push eject (pavements and substrate material displaced due to bomb penetration and explosion) back into craters. Next, they could apply chemical compounds or bioengineer catalysts that would penetrate and harden the material pushed back into the crater. The third step would involve the placement of expanding and self-leveling foam which would harden sufficiently to preclude the need for crater hole compassion. Finally, the teams resurface the crater holes with a remotely controlled machine, not unlike the systems currently used to resurface ice skating rinks. The machine could place materials which can either harden rapidly on their own or use a chemical or light-induced hardener. Use of this type of machine could ensure rapid repairs within the required roughness criteria for the pavements effected. This capability may enable crater repairs to be conducted by one person with a couple of pieces of equipment—a significant improvement over the 25–30 men per crater and multiple pieces of large construction equipment required today.

At the same time, facility BDR could be under way. Small teams of personnel and equipment would perform necessary repairs. Critical facilities and systems would sense and report the extent of their damage. Based on the reported information, certain capabilities or functions could automatically transfer to other facilities or systems until repairs are completed. Repair teams could be automatically tasked by the base system to respond to damaged facilities and systems in accordance with preestablished priorities. However, in some cases, depending on the type and scope of the damage, some facilities would be able to repair themselves. Facilities and systems could self-repair using MEMS or other specially embedded capsules. Repair teams would respond to effect more involved repairs. Robots could be capable of applying expanding and self-hardening foams to cracks, crevices, and holes in walls and roofs. Additionally, teams could employ organic materials that would grow rapidly once a catalyst is applied, or sheets of composite materials which could be cast in place on-site. Regardless of the damage (not withstanding complete and utter destruction), each structure, runway, taxiway, or system is easily and rapidly repaired or replaced with minimal, if any, significant effect on base operations.

Mobile Base

FOBs may be required to support operations throughout the contingency continuum which may include everything from peace operations and humanitarian/disaster relief to major regional contingencies. Unfortunately, there may not always be access to suitable base facilities in the most desirable or optimal locations. What follows is a CONOPS, nicknamed “Harvest Geronimo,” for rapid power projection in 2025—a capability to rapidly deploy necessary forces along with the ability to establish and easily sustain forward bases virtually anywhere we want them. In essence, it describes a mobile base system that is “light on its feet.”

The nickname is a hold over from the 1980s line of United States Air Force transportable bare base support systems in the vein of Harvest Bare, Eagle, and Falcon. It recalls the nomadic tendencies of early Indian tribes that set-up camps wherever it was most suitable to their needs. It also draws reference to the traditional cry of paratroopers, who yelled “Geronimo” upon aircraft exit during paradrop operations. Harvest Geronimo is a self-contained, completely airmobile, air-droppable, self-erecting base support system with relatively small mass to the resulting volume of utility and employment.

The employment of the mobile base would always involve the following four phases: deployment, force beddown, sustainment (which includes preattack preparations and postattack recovery operations), and redeployment.

Phase I—Deployment

It all starts with mobility. A significantly improved fleet of long-range, heavy-lift aircraft could enable this CONOPS. Potential locations could be derived from varying intelligence means with the selection of the most suitable land area determined from a more advanced version of photogrammetry—essentially, virtual surveying. Should airfield facilities (runways, taxiways, and parking aprons) be required, commanders would have the option of improving substandard airfields or creating new ones. For the purpose of illustrating potential capabilities, establishment of a new airfield on a barren piece of land will be described.

First, the selected location could be secured by a rapid deploying force of one or more unmanned combat UAVs or "StrikeStars"[17] and an air base defense team. Cargo UAVs precision air-drop or disperse the weapons and sensor systems previously discussed in the section entitled "shielded base." The air base defense team facilitate system setup and checkout. Once the desired location is secure, an airborne base establishment team proceeds to the site to create the required airfield.

The next step of the operation is accomplished largely via airborne platforms. A specially equipped aircraft begin operations by making a few overhead passes to spray a polymeric soil cement-type substance that penetrates and hardens the soil to bearing capacity strengths commensurate with 1,000 pounds per square inch concrete. The application does not have to follow an exact geometric pattern, although application must be relatively consistent. Subsequent passes involve the aircraft spraying self-leveling foam-like compounds to fill in grade inconsistencies. This achieves desired flatness criteria without earth-moving, "cut and fill" operations. The foam would harden rapidly into an expansive crystalline type composite with adequate structural capacity. The final step would be to surface the airfield. Here, the aircraft sprays a self-leveling, polymeric composite material which reacts with certain light wavelengths to bond and harden, using an airborne laser system (ABL). The ABL scans the prepared surfaces at the desired wavelength and dwell time to complete the job. The landing surface is then ready for use, with one notable exception—it looks more like a "puddle" than a runway. Incidentally, parking aprons and taxiways are simply extensions to the puddle, constructed in the same fashion.

An alternative approach to airfield establishment may be the use of organically similar materials which apply the concepts of bioduplication or biomimicking to essentially grow airfield surfaces. The airfield surface structural sub-bases would be established in much the same way as with the preceding method. In this case, materials would be placed in desired areas and treated with catalysts or reagents that would spur rapid growth and hardness. Once again, the airfield would not take the standard geometric shapes of today. An added advantage of organic airfields, from a camouflage, couccalment, and deception (CCD) standpoint, would be their similarity to the surrounding environment.

Phase II—Force Beddown

This phase begins with precision guided airdrops, thereby avoiding the need for large-scale, cargo-handling operations on the ground. Facilities, equipment, and personnel would be precision air-dropped into the cantonment area or "point-of-use."[18] Upon contact with the ground, troops depart their air-dropped personnel carriers and facilitate base setup and system checkout. The air-dropped facilities then self-erect. Deployed personnel create a 2025 version of tent city, albeit far smaller than what is currently required. To accomplish this task, personnel would use rapid biological growth kits which involve the erection of lightweight skeletal structures to serve as growth frameworks. Troops would then simply apply, most likely by spraying, organic materials, and catalysts to "grow" the facilities. The resulting facility would take the requisite shape by following the previously erected structure and provide a shelter no less stable (perhaps more so) than the tents used today. Other facilities self-erect by mechanical processes or inflation. Such facilities could be used to shelter the more critical functions and systems.

The power infrastructure would consist of extremely efficient sources that will be simple to set up and maintain. Advances in superconduction to enable near-zero resistance at ambient temperatures may enable the installation of small distributed and networked power generation systems requiring less fuel as a result of their ability to transmit electricity without having to overcome excess requirements due to line losses. Some of the smaller sized units may use an alternative fuel, such as nitrogen (an extremely prevalent and inexpensive fuel source) for power conversion. Even batteries could have far greater life spans and approach the capability of miniature power plants.

All ground-based command, control, communications, computers, and intelligence (C^4I) will be small, extremely powerful systems that take advantage of the same superconductive materials and computer advances discussed in previous sections. Some C^4I systems may be in the form of manpacks, used by security and other operations personnel, differing only in the quality and quantity of information available to the users. The entire system would be fused to ensure complete and near-real-time situational awareness.

Phase III—Sustainment

The sustainment phase of operations would be essentially the same as at a main operations base (MOB) and perhaps even less manpower intensive. It would involve standard base operations as well as preattack and postattack activities.

Standard base operations would be a function of logistics. Logistical systems would be minimal and most likely just-in-time. Resupply could be accomplished via airdrop. High reliability and low maintenance systems lead to very few support personnel and a reduced logistics tail. Further, the probability of extending the mean-time-between-maintenance for up to 60 days will make logistics simple and manageable. Munitions and fuel could remain as the only continuing logistical concern. However, efficiency of delivery and loading operations on the ground could be enhanced greatly by all-terrain versions of the robotic systems employed at MOBs.

Preparation for attack would actually be coincidental to the initial turn-on of base functions. As much as possible, hardening, CCD techniques, and systems would be designed into the self-erecting structures and deployed systems. Many aspects, like false signal emitters, would simply be unleashed. Much like the concept of the "low observable base," the FOB would become an extremely difficult target to acquire and damage.

Since there are no guarantees against successful attacks, forces must be prepared and capable of recovering damaged facilities and airfields. The same systems employed at the MOB would be suitable for FOBs. However, repair may actually be more a function of replacement due to existing expedient construction techniques and airlift improvements. Operations would continue to follow these general processes until the mission is complete.

Phase IV—Redeployment

The final aspect of mobility operations is redeployment. Only the high-tech, smart facilities (self-erecting) would be repackaged for shipment back home. Many, if not most of these items, could be aerially extracted via a fleet of UAVs. Depending on the location of the FOB, the UAVs could either deliver the items to a staging base or directly back to the point of origin. The organic facilities, including the airfield surfaces, could be disposed of in-place. They could be sprayed with biodegradable enzymes or other corrosive substances to effectively disintegrate right where they were initially emplaced. This capability could negate the use of such facilities and/or locations by potential adversaries. Redeployment would be as efficient and expedient as deployment, and all systems immediately available for reuse at another location, should it be required.

Conclusion

These capabilities could enhance the ability to project power, regardless of location, by essentially creating a sanctuary from which the US, and her allies, may pursue national objectives. The real challenge is in determining investment paths and priorities. Acquisition of these capabilities may not be cheap, but the derived benefits most certainly outweigh the associated costs.

Notes

[1] **2025** Concept, No. 900605, "Active Cloaking Film/Paint," **2025** Concepts Database (Maxwell AFB, Ala.: Air War College/**2025**, 1996).

[2] Lt Col Brad Shields et al. "Weather as a Force Multiplier: Owning the Weather in 2025," (Unpublished White Paper, Air Command and Staff College, n.d.)

[3] **2025** Concept, No. 900573, "Dielectric Materials for Stealth," **2025** Concepts Database (Maxwell AFB, Ala.: Air War College/**2025**, 1996). (PROPRIETARY)

[4] **2025** Concept, No. 900567, "If I Can Smell You . . . ," **2025** Concepts Database (Maxwell AFB, Ala.: Air War College/**2025**, 1996).

[5] **2025** Concept, No. 900206, "Commander's Universal [Order of] Battle Display," **2025** Concepts Database (Maxwell AFB, Ala.: Air War College/**2025**, 1996).

[6] **2025** Concept, No. 900368, "Land Identification, Friend or Foe," **2025** Concepts Database (Maxwell AFB, Ala.: Air War College/**2025**, 1996).

[7] **2025** Concept, No. 900508, "Magnetic Detection of Aircraft," **2025** Concepts Database (Maxwell AFB, Ala.: Air War College/**2025**, 1996).

[8] **2025** Concept, No. 900518, "Electronic Grid Throwaway Sensors," **2025** Concepts Database (Maxwell AFB, Ala.: Air War College/**2025**, 1996).

[9] **2025** Concept, No. 900953, "Multi-Sensor, High Altitude, Long Endurance UAV," **2025** Concepts Database (Maxwell AFB, Ala.: Air War College/**2025**, 1996).

[10] Chemical and biological agents will be candidates for cleanup by advanced enzymes or catalysts; but, radiation hazards will still require time to decompose in accordance with their respective half-life.

[11] **2025** Concept, No. 900388, "Smart Bugs," **2025** Concepts Database (Maxwell AFB, Ala.: Air War College/**2025**, 1996).

[12] Larry M. Sturdivan et al., "Chemical and Biological Defense for the New Century," *Army Research Development and Acquisition*, July-August 1995, 28.

Notes

[13] **2025** Concept, No. 200009, "Pyrotechnic Electromagnetic Pulse," **2025** Concepts Database (Maxwell AFB, Ala.: Air War College/**2025**, 1996).

[14] **2025** Concept, No. 900350, "Aerial Mines," **2025** Concepts Database (Maxwell AFB, Ala.: Air War College/**2025**, 1996).

[15] **2025** Concept, No. 900612, "Bumble Bee Bombs," **2025** Concepts Database, (Maxwell AFB, Ala.: Air War College/**2025**, 1996).

[16] Sturdivan et al., 27–28.

[17] Lt Col Bruce W. Carmichael et al., "StrikeStar 2025" (Unpublished White Paper, Air Command and Staff College, n.d.).

[18] USAF Scientific Advisory Board, *New World Vistas: Air and Space Power for the 21st Century*, summary volume (Washington, D.C.: USAF Scientific Advisory Board, 15 December 1995), 31–32.

Chapter 5

Investigation Recommendations

> We should base our security upon military formations which make maximum use of science and technology in order to minimize numbers of men.
>
> — Dwight D. Eisenhower

No single technology or system will bring the operability and defense concepts to fruition. In and of itself, the 2025 aerospace base is an integrated system dependent upon advances in a number of fields and disciplines. A subjective rating system was developed in an attempt to rank the technologies introduced in chapter 3. This limited evaluation provided a single-weighted score for use in comparing all of the technologies against each other based on a set of qualities defined by the research team.[1] Each team member ranked the qualities from one to eight (eight most important) to derive an average quality weighting factor. Table 3 shows final average ranking for the qualities used to rate the technologies. The top three are *enhance operability*, *enhance survivability*, and *cost-effectiveness*.

Table 3

Average Quality Ranking Matrix

	Enhance Operability	Enhance Mobility	Enhance Survival	Enhance Recovery	Cost-Effective	Feasible	Commercial Application	Other Military Applications
Total Ranking Scores	36	19	31	14	26	18	18	17
Average Quality Ranking	7	4	6	3	5	4	4	3
Maximum Possible Ranking = 8								

Each member then rated individual technologies against the quality criteria as defined below. The scores were summed up and multiplied by the weighting factor to arrive at a final weighted score. The qualities used to score the technologies follows.

Enhance Operability

Will the technology enhance aerospace base operability as defined in chapter 1? Sample attributes to consider include technology effects on sortie generation rate, base systems reliability, manning levels, and sustainment needs. Scale is from one to five (5 = revolutionary enhancement; 3 = significant enhancement; 1 = modest enhancement).

Enhance Mobility

Will the technology enhance aerospace base mobility? Factors include enhancements to airlift deployment requirements, ease of setup for forward deployed bases, and redeployability. Scale is from one to five (5 = revolutionary enhancement; 3 = significant enhancement; 1 = modest enhancement).

Enhance Survivability

Will the technology enhance aerospace base survivability from all levels of attack? Attributes to consider include ability to prevent or minimize damage from the full spectrum of attacks, ability to degrade gracefully, and ability to improve base self-defense effectiveness. Scale is from one to five (5 = revolutionary enhancement; 3 = significant enhancement; 1 = modest enhancement).

Enhance Recoverability

Will the technology enhance aerospace base recoverability after an attack? Attributes include minimizing downtime after attack, ability to reopen runways, and ability to clean up unexploded ordnance and residual contaminants. Scale is from one to five (5 = revolutionary enhancement; 3 = significant enhancement; 1 = modest enhancement).

Cost-Effectiveness

To what extent does the technology improve aerospace base operability and defense compared to the cost of implementation by the military? This is the most subjective of the quality measurements. A high score implies a high benefit to cost ratio. This can be the case either because the military absorbs the full cost and gets a tremendous return, or the commercial sector pays for the development and the military only pays for conversion. Scale is from one to seven (7 = significantly cost-effective; 5 = moderately cost-effective; 3 = neutrally cost-effective; 1 = not cost-effective).

Feasibility

What is the probability that technology will advance enough in key areas to provide the capability described in the concept by 2025? Scale is from one to five (5 = very high feasibility, 3 = moderate feasibility; 1 = low feasibility).

Commercial Applications

To what extent does the concept have technology spin-offs which have application within the commercial sector? A high score implies that there could be significant cost savings in the development or production costs due to commercial interest. Scale is from one to five (5 = extensive commercial applications; 3 = moderate commercial applications; 1 = minimal applications).

Military Applications

To what extent does the technology have other military applications? A high score implies that development costs will be leveraged across numerous military development programs. Scale is one to five (5 = significant number of other military applications; 3 = moderate amount of other military applications; 1 = minimal amount of other military applications).

Results

Table 4 shows the average ratings for each of the technologies. The maximum possible total score for any technology is 25. The last column shows the total score for each technology as a percentage of the maximum possible score. These percentages are also shown graphically on figure 5-1.

Table 4

Average Technology Ratings Matrix

	Enhance Operability	Enhance Mobility	Enhance Survival	Enhance Recovery	Cost-Effective	Feasible	Commercial Application	Other Military Applications	Total Weighted Score	% of Maximum Score
Super conductivity	4.8	4.4	3.4	2.6	3.9	3.0	5.0	4.8	19.1	76%
MEMS	4.2	4.0	4.2	4.0	3.1	4.0	4.6	4.0	18.8	75%
Alternate Power Sources	4.2	4.2	4.2	3.0	2.6	3.6	4.8	4.2	18.0	72%
AI/Neural Nets	4.2	2.4	4.0	3.0	3.3	4.0	4.6	4.2	17.7	71%
Advanced Materials	3.8	4.4	3.8	3.0	2.6	4.2	4.2	4.4	17.5	70%
Nano technology	3.8	4.0	4.0	3.6	2.7	3.0	4.4	4.0	17.2	69%
Robotics	3.8	2.8	2.8	3.6	2.9	4.4	4.4	4.2	16.5	66%
Biotechnology	3.4	3.2	3.8	4.2	2.9	3.4	3.6	3.6	16.3	65%
Advanced Sensor Fields	3.2	2.0	4.4	2.6	3.3	4.0	3.2	4.0	16.1	64%
Defensive Weapons	2.6	2.0	4.4	2.4	3.1	4.2	1.4	4.6	14.9	60%
Holography	2.6	2.0	4.0	1.8	1.9	3.8	3.2	3.4	13.3	53%
SQUIDs	3.2	1.6	2.8	2.0	2.0	2.0	1.4	4.0	11.6	46%
								Maximum Possible Score = 25		

As the data shows, most of the technologies are grouped within a 12 percent band. Only three technologies, SQUID, holography, and directed energy weapons seem to drop out of contention. The top two technologies, superconductivity, and MEMS, standout from the rest of the group while alternate power sources and artificial intelligence/neural nets round out the top four.

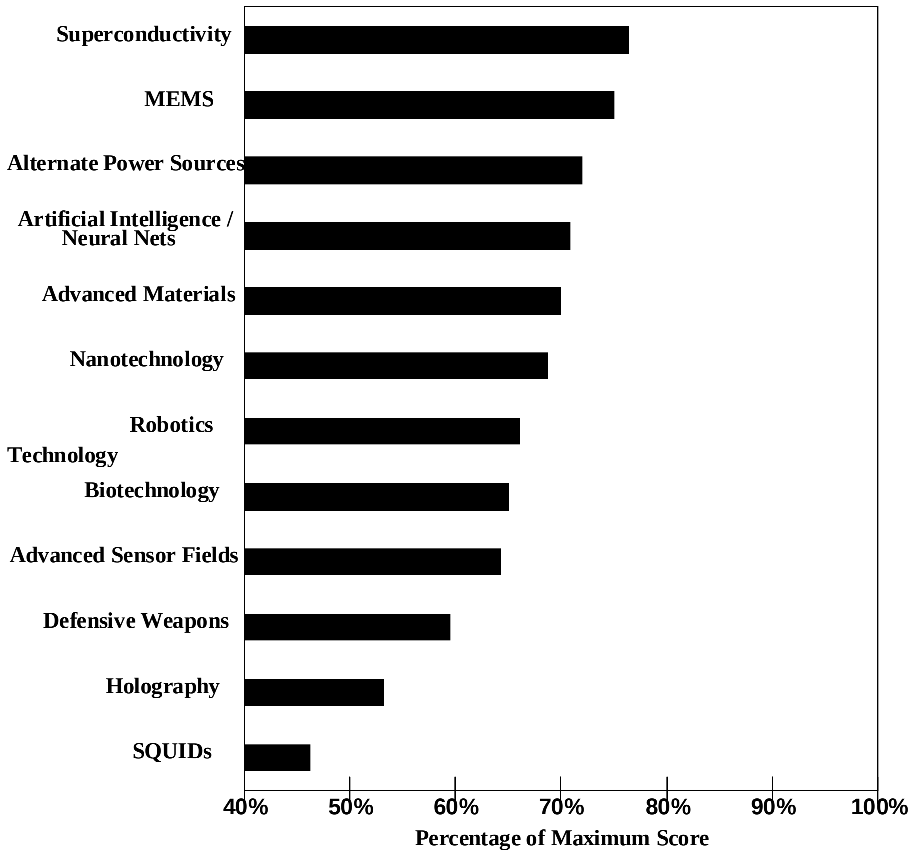


Figure 5-1. Average Technology Rating—Graphic Depiction

Although the results are limited by their subjective derivation, they indicate a distinct predilection for technologies that directly improve operability and indirectly improve base defense and correspondingly reduce the core entity ring. Two of the top four technologies are related to revolutionizing the way base systems generate power, taking power generation from a key core entity to the intermediate or peripheral entity category—these are synergistic technologies. As ambient temperature superconductivity becomes possible, the use of alternate power generation methods becomes more cost- and performance effective. The broad applications of MEMS for use in low-observable facilities, battle damage repair, and self-erecting structures have the potential to also move several additional entities out of the core entity category. Finally, artificial intelligence offers the potential to provide the synergism needed at the base level to integrate and operate all of these capabilities. The low scores for directed energy weapons, holography, and SQUIDs are a reflection of their applicability to only the defense side of operability and defense.

The capabilities envisioned for the aerospace base of 2025 could become available incrementally with a combination of commercial and government investment in diverse technologies. For many of these technologies the driving factor will be the development costs. Figure 5-2 shows an estimate of the relative development cost sharing for each technology area discussed above.[2]

On a positive note, the top technologies recommended by the research team have significant commercial applications and investment potential which may be readily leveraged by the military. Some of the cited technologies are further from reality than others; however, the facilities they would effect are being built today. Consideration on how to effect the transition which will enable the application and use of these new capabilities is strongly recommended. As an example, we spend a great deal of money and effort improving the human factors of base systems and aircraft maintenance. Consideration should begin with regard to making systems suitable for robots—robonomic.[3] New construction and facilities modifications should, at a minimum, consider the need for future low-observable retrofits and modifications for hardening or use of reactive armor. Ongoing environmental cleanup and the increasing threat of biological and chemical contamination strongly suggests a continuing need to consider the means to take advantage of biotechnology for contaminant cleanup.

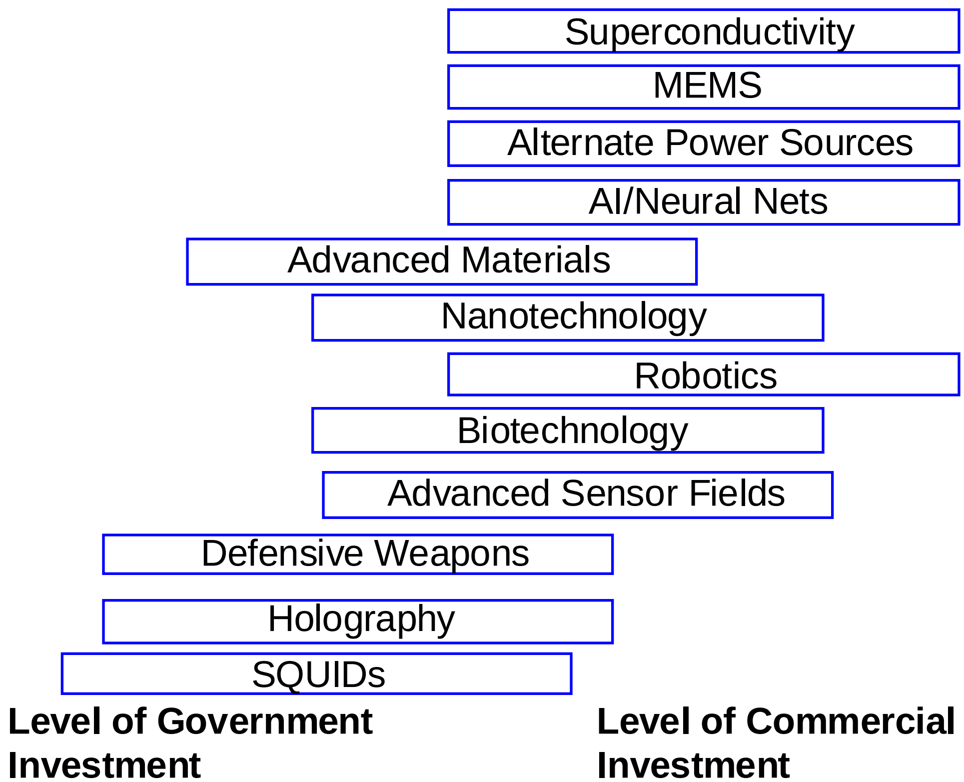


Figure 5-2. Development Cost Sharing

None of the technologies and concepts discussed above is singularly important to operability and defense. Together though, they provide a quantum synergism that can greatly increase the effectiveness and survivability of the 2025 aerospace base. In the year 2025, operability and defense will not and cannot be mutually exclusive. Day-to-day operations will have to consider the potential for instantaneous transitions to combat footing. This applies to CONUS-based MOBs and FOBs. Reducing the number of core entities provides an obvious improvement in base defense since the number of entities that have to be protected "at all costs" goes down. There is a corresponding, though less obvious, improvement in day-to-day base operability. The steps taken to reduce core entities include improvements in base systems reliability, decreases in base manning levels, and use of reliable, low-cost power generation, among other things. All are steps which combine to simplify day-to-day operations and even reduce the operating costs. The upshot is that most of the technologies identified in this research paper have civilian applications or military applications in other areas. The downside is that today's base infrastructure is typically tomorrow's infrastructure, so implementation of these concepts will need to start today.

Summation

The issue of operability and defense in the year 2025, and as presented in this paper, is not one based exclusively on arguments for the development or advancement of a specific technology or technologies. Nor is the issue of operability and defense focused narrowly on developing a singular system which will permit the aerospace base of 2025 to function and sustain aerospace power projection, despite actual or attempted disruptions. The integrated system inherent to the aerospace base of 2025 denotes a major revolution in operability and defense because of its force enhancement qualities of adaptability, defensibility, mobility, reliability, and survivability. Within this construct, vulnerabilities of the integrated system resident at an aerospace base have not been discounted but considered in terms of their elimination. Successful attacks on the whole or parts of the system, by a determined adversary, have not been discounted either but addressed in terms of building in robustness and redundancy, allowing for graceful degradation.[4] Reduction of the number of core entities, so vital to the functioning of the aerospace base, has been presented as a viable means to preserve the functionality of the base to support its designated mission.

So it is, that the five force enhancement qualities of adaptability, flexibility, mobility, reliability, and survivability are integrated throughout the aerospace base infrastructure. In the end, the overarching vision for the integrated aerospace base of 2025 is not derived from the objective of developing an impregnable fortress. The vision articulated in this paper is focused on providing a sanctuary for aerospace dominance through the creation of a low-observable, shielded, self-healing, and mobile aerospace base. This vision includes reducing and dispersing core functions, thereby reducing the consequences of attack. Finally, by using new technologies to accomplish this, and by creating a sanctuary, the aerospace base becomes a source of energy and replenishment that enhances aerospace power.

Notes

[1] The evaluation qualities can be viewed as two categories; functional qualities related to how well the technology enhances aerospace base operability and defense, and implementation qualities which provide insight into the likelihood of the technology being affordable or doable. However, all eight qualities were ranked as one group since any future development program will have to trade off cost, performance, and schedule qualities as necessary to decide which technologies to pursue.

[2] This is a subjective assessment derived from each team member's impressions of each of the technologies researched. As such, the assessment only provides a very rough idea of the split between government and commercial funding for development. Thus, subsequent investigation should refine and validate these findings.

[3] Term contrived by the team to denote ergonomic considerations for robots.

[4] Adm William A. Owens, "A Report on the JROC and the Revolution in Military Affairs," *Marine Corps Gazette* 79, no. 8 (August 1995): 51.

Bibliography

"Advanced Composites." *Scientific American* 273, no. 3 (September 1995): 48, 126–27.

AFM 1-1. *Basic Aerospace Doctrine of the United States Air Force*, 2 vols., March 1992.

AFP 93-12. *Contingency Response Procedures,* vol. 2, n.d.

Barnett, Jeffery R. *Future Wars: An Assessment of Aerospace Campaigns in 2010.* Maxwell AFB, Ala.: Air University Press, January 1996.

Brandt, Dr. Craig M., et al. "Logistics 2025: Changing Environments, Technologies, and Processes," Air Force Institute of Technology, n.d., 27–28.

Carmichael, Lt Col Bruce W., et al. "StrikeStar 2025." Unpublished white paper, Air Command and Staff College, n.d.

Chu, Paul C. W. "High-Temperature Superconductors." *Scientific American* 273, no. 3 (September 1995): 128–30.

Department of the Air Force. *Cornerstones of Information Warfare,* n.d.

———. Department of the Air Force. *Spacecast 2020: Operational Analysis.* Maxwell AFB, Ala.: Air University Press, June 1994.

Department of Defense, Joint Publication 1-02. *Dictionary of Military and Associated Terms*, 23 March 1994.

——— . Joint Publication 3-07. *Joint Doctrine for Military Operations Other Than War*, 16 June 1995.

Gabriel, Kaigham J. "Engineering Microscopic Machines." *Scientific American* 273, no. 3 (September 1995): 118, 121.

Heinl, Robert Debs, Jr. *Dictionary of Military and Naval Quotations.* Annapolis: United States Naval Institute, 1966.

Institute for National Strategic Studies. *Project 2015.* Norfolk, Va.: National Defense University, April 1995.

———. *Project 2025.* Norfolk, Va.: National Defense University, 6 May 1992.

Kleiner, Kurt. "Marine Enzyme Launches Attack on Nerve Poisons." *New Scientist,* 13 January 1996, 22.

Kupfer, Andrew. "A Robot Inspector for Airplanes." *Fortune* 127, no. 9 (3 May 1993): 93.

Langreth, Robert. "Molecular Marvels." *Popular Science,* May 1993, 110.

———. "Why Scientists Are Thinking Small." *Popular Science*, April 1993, 75.

Lewin, Roger. "Birth of a Human Robot." *New Scientist* 142, no. 1925 (14 May 1994): 26.

Machiavelli, Niccolo. *The Prince.* Translated by Luigi Ricci. New York: Random House, Inc., 1950.

Military Air Power: The CADRE Digest of Air Power Opinions and Thoughts. Edited by Lt Col Charles M. Westenhoff. Maxwell AFB, Ala.: Air University Press, October 1990.

Miller, Lt Col Gregory J., et al. "Virtual Integrated Planning and Execution Resource System: The High Ground of 2025." Unpublished white paper, Air Command and Staff College, n.d.

Nair, Brig Vijai K. *War in the Gulf, Lessons for the Third World.* New Delhi: Lancer International, 1991.

Owens, Adm William A. “A Report on the JROC and the Revolution in Military Affairs.” *Marine Corps Gazette* 79, no. 8 (August 1995): 51.

Peterson, John L. *The Road to 2015.* Corte Madera, Calif.: Waite Group Press, 1994.

Rogers, Craig A. “Intelligent Materials.” *Scientific American* 273, no. 3 (September 1995): 122-125.

Ropelewski, Robert. “Making Sense of Sensor Data.” *Interavia Aerospace World,* September 1993, 56.

Shields, Lt Col Brad. et al. “Weather as a Force Multiplier: Owning the Weather in 2025.” Unpublished white paper, Air Command and Staff College, n.d.

Shlapak, David A., and Alan Vick. *Check Six Begins on the Ground, Responding to the Evolving Ground Threat to U.S. Air Force Bases,* Rand Report NR-606-AF (Santa Monica, Calif.: RAND Corporation, 1995), xv.

“Smart Structures Dampen Motion, Increase Stability.” *Signal* 8, no. 8 (April 1994): 20.

Starr, Barbara. “Super Sensors Will Eye the New Proliferation Frontier.” *Jane’s Defense Weekly* 21, no. 22 (4 June 1994): 92.

Stix, Gary. “Fighting Future Wars” *Scientific American*, December 1995; 94

Sturdivan, Larry M., et al. “Chemical and Biological Defense for the New Century.” *Army Research Development and Acquisition* (July-August 1995): 28.

Thomas, Peter. “Thought Control.” *New Scientist* 149, no. 2020 (9 March 1996): 41–42.

2025 Concepts Database. Maxwell AFB, Ala., Air War College/**2025**, 1996.

USAF Scientific Advisory Board. *New World Vistas: Air and Space Power for the 21st Century,* Summary Volume. Washington, D.C.: USAF Scientific Advisory Board, 15 December 1995.

USAF Scientific Advisory Board. *New World Vistas: Air and Space Power for the 21st Century.* Unpublished drafts, the Human Systems and Biotechnology Volume, the Materials Volume, and the Sensors Volume. 15 December 1995.

Wayner, Peter. “Machine Learning Grows Up.” *Byte,* August 1995, 63.

Webster’s New World Dictionary of the American Language. 2d ed. New York: Simon and Schuster, 1984.