Counterair:
The Cutting Edge

A Research Paper
Presented To

Air Force ***2025***

by

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August 1996

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Preface

The counterair mission has been the core of every air operation since the days of the first dogfights of World War I. The successful prosecution of every battle, every campaign since that time has relied on the ability of friendly forces to dominate the skies. A question that has arisen numerous times since the start of *2025* has been: will the counterair mission still be relevant 30 years from now? The answer is a resounding *yes*. Regardless of the state of the art, the nature of the enemy, or the battlefield task at hand, the ability to use the skies with impunity, while denying the same capability to an enemy, is a *prerequisite* for every other war-fighting element of any future campaign. Without it, we lose the advantages gained by the inherent speed, range, and flexibility of airpower. We also risk putting ourselves on the defensive while ceding these same advantages to our adversaries. As the precision and lethality of our weapons increases, air superiority must be gained to allow us to observe the enemy, track his activity, and react in a prompt and decisive manner, whether or not he uses (or can use) airpower in support of his own objectives, or even whether or not we choose to use (or can use) airpower in support of our objectives. For this reason alone we are driven to examine not whether the counterair mission will still be performed in 2025, but how we will achieve it in the most effective, efficient manner. This study examines what the counterair mission of 2025 will entail and how we will accomplish it.

Executive Summary

This white paper examines the counterair mission in 2025—what it is, what the threats are, and how we counter them. In the broadest sense, the counterair mission will not change in the next 30 years. The basic premise of air superiority—neutralizing or destroying an adversary's ability to control the skies—will remain intact. This paper examines the counterair mission by first performing an analysis of three different trajectories. The first is an evolutionary trajectory based on projections of current and programmed capability. The second and third trajectories represent extremes—"anything but" approaches for conducting the counterair mission. The second trajectory is "anything but" inhabited aircraft, and the third is "anything but" aircraft at all—performing the counterair mission solely with surface and space-based systems. The results of this analysis will provide a basis of comparison for each.

Common themes emerge from all three trajectories. The primary theme is a requirement for near-real-time collection, processing, and distribution of information, or in some cases knowledge, to support the commander's assessment and reaction to a given situation. A comprehensive holographic display system is required to present the information to the commander. There also is a need for robust command, control, and communications networks distributed over commercial and military networks to pass this information. Finally, a synthesis of the three approaches will yield a system of systems—a counterair triad. The triad will be geared to handle a multiplicity of threats, from Cessna aircraft threatening the White House to uninhabited aerial vehicles attempting to monitor our operations, from Chinese-built stealth fighters in the Pacific to cruise missiles from Iran, or from terrorists with hand-held antiaircraft weapons to North Korean theater ballistic missiles. Inhabited vehicles provide flexibility where the fidelity of information available is limited or cut off, particularly in sensitive situations requiring definitive action as well as accountability. Uninhabited vehicles will provide a capability for rapid response using hypersonic, highly maneuverable lethal and nonlethal application of force against an adversary's air forces. Space and surface-based counterair forces can provide immediate, precision strike against cruise missiles, intercontinental and theater ballistic missiles, as well as instant lethal and nonlethal force against forward air threats out of reach of

available friendly air forces. A synthesis of the results of all three trajectories into a counterair triad will allow the strengths of each area to fill in the weaknesses of the other two, permitting a full range of nonlethal to lethal application of force against any adversary.

Chapter 1

Introduction

The major thesis held by Trenchard and Mitchell, as well as Seversky, was that command of the air is of first priority to any military success in war.

— Maj Gen Dale O. Smith

Airpower is the cutting edge of the sword of the Republic, and upon that sword the Republic will stand or fall. This statement was true in 1980 and it will still be true in 2025. The direction of this effort is to describe the counterair operational world of 2025. The world of 2025 will be different from the world of 1995. This is a given; the question is: how different? Part of the approach of 2025 is the requirement there be no surprises. The approach taken here is to first perform an analysis of how the counterair mission could be accomplished using the "anything but" construct. This analysis looks at the counterair problem from several different perspectives. The first perspective is a projection looking out from 1996 to 2025 based on what we know today. The second and third perspectives are extremes, used to facilitate analysis of the problem. The second perspective examines counterair using anything but inhabited aircraft. The third perspective includes anything but air-breathing aircraft.

The next part of the analysis requires a recognition of where technology is headed and where the Air Force leadership is placing its emphasis. A review of *New World Vistas* demonstrates an emphasis on reduction in USAF spending on specialized systems for common needs (such as communications), a view towards uninhabited air vehicles (UAV), and increased reliance on command, control, communications, computers, and intelligence (C4I) and space.[1] As commercial enterprises outstrip the ability of the military to fund advanced research and technology initiatives, it behooves the US armed forces to take advantage of their efforts rather than fund separate "stove-pipe" military systems.

Air Force Executive Guidance, December 95 Update, focuses on "effective planning for future alternatives."[2] It provides a thumbnail sketch of the environment and threat, as well as specific planning guidance and describes offensive airborne vehicles and weapons of mass destruction (WMD) as the most direct threat to US security. The key assumptions drawn from it are an increasing air-breathing threat, including cruise and theater ballistic missiles; an increasing requirement for nontraditional defense systems, such as high-power microwave and lasers against attacking aircraft; and a continuing requirement to suppress enemy air defenses as a prerequisite for air superiority. The guidance that falls from these assumptions is consistent; there is a need to detect, locate, identify, engage, and destroy targets on the surface (both fixed and mobile) and in the air, as well as ensuring onboard threat warning and self-protection systems for aircraft of all air forces.

Finally, a review of the threat environment puts proposed capabilities into proper context. A briefing given by the special assistant to the chief of staff for long-range planning (HQ USAF/LR) to the Defense Science Board in March 1996 describes three types of future adversaries. The first type is a regional adversary, those who will challenge the US in their geographic areas (such as Iraq or North Korea). The second type is peer competitors, which are viewed as likely to emerge in the long term. A peer competitor could be a nation or group of nations with broad-based military power projection capability, able to threaten US or allied interests in more than one region of the world, and could include a resurgent Russia or emergent China. The third possibility is a niche competitor, including nonnation/nonstate actors capable of acting against US interests (i.e., terrorists or drug cartels).[3]

Combining these views results in three different trajectories, each with a different outcome for how the counterair mission could be conducted in 2025. The first is the evolutionary trajectory. An extrapolation from today in terms of development and modernization programs, this trajectory assumes a world of continuing technological advancement, relatively constant US defense spending, and world players in the same relative positions of strength. Air superiority and the counterair mission will be dominated by existing airframes and those already budgeted or in development. UAVs and space assets will augment these to accommodate smaller air forces relying on power projection from the continental United States (CONUS), aircraft carriers, and a select few major overseas bases.

The second is the "penurial robophile"—cheap robot-lover—trajectory. This assumes a significant reduction of defense spending, coupled with significant advances in technology and its application. An American world view focused internally but still concerned about external threats drives the air superiority mission towards a reliance on awareness and a reactive stand-off capability, representing air forces in being—the strength of the force is in its capabilities, not its size. This cut in spending, reliance on technology, and reluctance to expose US armed forces personnel to risk leads to a primarily UAV counterair capability.

In this trio of possible paths the counterair mission might follow, the last is the virtual trajectory. This trajectory assumes a globally minded United States with a surplus of technology and a budget to back it up. It represents the ultimate in virtual presence, virtual power. It is a ubiquitous space-based capability that includes not only force enhancement capabilities but force application, complemented by surface-based assets for those hard-to-reach, hard-to-kill targets or those evading the space-based assets. This capability allows all the functions listed in the *Executive Guidance* (detect, locate, identify, engage, and destroy targets) to be performed almost instantly.

This white paper reviews each approach with a critical eye towards the goal of no surprises. The triclinic of these trajectories will result in a synthesis of capabilities designed to provide assured air superiority in 2025.

This paper assesses the future counterair mission using the following organization: (1) to define the counterair mission and the focus of this white paper; (2) to develop the assumptions, required capabilities, systems, enabling technologies, and concepts of operations in each of the three trajectories; and (3) to recommend a counterair capability based on a review these results in the context of ensuring no surprises and assured air superiority and develop a concept of operations for employment by 2025.

Counterair Defined

If we lose the war in the air, we lose the war and lose it quickly.

—Field Marshal Bernard L. Montgomery

Counterair is a mission that currently falls under the role of aerospace control. The focus of this white paper is limited to counterair (not counterspace) operations; however, the future is bringing with it a fusion of air and space capabilities that will increasingly blur the distinctions between counterair and counterspace operations. Aerospace control permits aerospace and surface forces to operate freely while denying access to the aerospace by the enemy. Counterair is the enabler that makes this possible. This is true today and it will be true in 2025. The counterair world of 2025 will be a smaller world where the Atlantic and Pacific Oceans will not provide the obstacles to offensive/defensive air operations they do today. The definitions for counterair and the counterair missions follow.

Counterair is a term for operations conducted to attain and maintain a desired degree of air superiority by the destruction or neutralization of enemy air forces. Both air offensive and air defensive actions are involved. The former range throughout enemy territory and are generally conducted at the initiative of the friendly forces. The latter are conducted near to or over friendly territory and are generally reactive to the initiative of the enemy air forces. For example, an F-22 launching an antisatellite missile at a space-based laser attacking friendly air forces would be a counterspace sortie. On the other hand, an F-22 taking defensive measures against a space-based platform is included in the counterair arena. As a guideline, action taken against space assets by air assets in a defensive response is included in the counterair mission area, while preplanned missions against space assets are counterspace missions. Additionally, in 2025, countering the cruise missile and theater ballistic missile (TBM) threat will be a part of both the offensive and defensive counterair mission.

Offensive counterair operations are operations mounted to destroy, disrupt, or limit airpower as close to its source as possible. While suppression of enemy air defenses (SEAD) is clearly in this category, the tactics and weapons to destroy, disrupt, or disable the enemy air defenses fall under the categories of tactical/strategic attack. *Defensive counterair operations* provide the protection of assets from air attack through both direct defense and destruction of the enemy's air attack capacity from the air.

Why Counterair?

It is our principal responsibility to provide the umbrella under which US and multinational forces may operate. Our success in military operations in the future, wherever or whenever they might be, will depend on how successful we are in this area.

—Secretary of the Air Force Dr Sheila J. Widnall

A common question, asked since the birth of airpower, is: Why is air superiority important? The answer lies in examining the purpose for the use of air forces. When the enemy is engaged in insurgency, without an organized air force, friendly air forces seek to minimize the fog of war through the use of reconnaissance and surveillance assets, limit the insurgent's freedom of action through interdiction, or reduce the enemy's ability to mount sustained operations through strategic attack. Successful prosecution of the counterair mission reduces the risk to friendly air and surface forces while increasing the risk to enemy operations. Suppression of enemy air defenses (even as simple as the shoulder-launched weapons that today are available to even the most rudimentary terrorist organization) becomes a deciding factor in the application of airpower.

Against a heavier, more conventional foe, enemy air forces (inhabited and uninhabited) become a threat to friendly forces—air, ground, and naval. In this instance, the more familiar notions of air superiority take over. The cycle comes full circle against a foe who can, but chooses not to use airpower, and instead employs cruise missiles, directed energy weapons, or more crude but equally effective measures such as radio frequency (RF) jammers or highly accurate antiaircraft artillery (AAA). In every instance, air superiority is essential.

While it may be true that it in each case the success of the counterair mission may not be the sole deciding factor, it will at a minimum be the enabler that allows the success of the other elements of US military power to come to the fore. This alone is sufficient reason to examine the counterair mission in 2025.

Notes

[1] *New World Vistas* distinguishes between uninhabited reconnaissance aerial vehicles (URAV) and uninhabited combat aerial vehicles (UCAV) for combat and noncombat UAVs. See 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), 8, 11.

Notes

[2] *Air Force Executive Guidance*, December 1995 update, 4.

[3] Briefing, HQ USAF/LR to the Defense Science Board, subject: "Air and Space Power Framework for Strategy Development," 19 March 1996.

Chapter 2

The Evolutionary Trajectory
The Fighter Pilot—Here to Stay?

> *The most important thing to have is a flexible approach .... The truth is no one knows exactly what air fighting will be in the future. We can't say anything will stay as it is, but we also can't be sure the future will conform to particular theories, which so often, between the wars, have proved wrong*.
>
> —Brig Gen Robin Olds

The first trajectory evaluated is the *evolutionary trajectory*, an extrapolation of where the US is today. Assuming a world of continuing technological advancement, relatively constant US defense spending, and world players in the same relative positions of strength, air superiority and the counterair mission will be dominated by existing airframes and those already budgeted or in development. UAVs and space assets will augment these to accommodate smaller air forces relying on power projection from CONUS, aircraft carriers, and a select few major overseas bases.

> *If a man's trust is in a robot that will go around the earth of its own volition and utterly destroy even the largest cities on impact, he is still pitiably vulnerable to the enemy who appears on his doorstep, equipped and willing to cut his throat with a penknife, or beat him to death with a cobblestone. It is well to remember two things: no weapon is absolute, and the second of even greater import—no weapon, whose potential is once recognized as of any degree of value, ever becomes obsolete.*
>
> —J. M. Cameron

While uninhabited aerial vehicles will be widespread in 2025, the inhabited vehicle will be the backbone of air forces around the world. Space assets will have active and passive antiaircraft capabilities. Likewise, aircraft will have antisatellite active/passive capabilities. Multiple detection technologies will abound, with radar remaining as the primary active detection medium. Air-to-air/space-to-air/air-to-space combat operations will be increasingly lethal. While the current generation of air-to-air missiles like the AIM 9, Python 4, and the advanced medium range air-to-air missile (AMRAAM) have demonstrated high probability of kill (P_K), in 2025 missiles will be even better—smaller, faster, and more accurate. The surface-to-air missiles (SAM) and space-based weapons (SBW) can also be expected to exhibit similar increases in lethality.

In spite of technological advances, dogfights likely will still occur in 2025. Fighters in 2025 will still have a "gun." The lessons learned from development of the F-4 will still apply. In the 1950s the development of air-to-air missile technology negated the gun requirement for the F-4. By 1965 lessons learned in Vietnam necessitated a gun retrofit for the F-4C/D; the F-4E was designed with an internal gun. Every multirole fighter built or designed since, including the F-22, has included a gun. The counterair mission will require a variety of weapons to use against the entire spectrum of threats and available countermeasures. The gun will remain a lethal weapon when everything is electronically jammed or laser blinded.[1] This advanced gun may have the capability to fire solid projectiles and/or directed energy beams. Also, if history is any indicator, the multi-staged improvement (MSIP) F-22 will still be operational, and possibly upgraded versions of the F-15 as well.

Counterair Requirements

> *We're not in the business of being defensive when we engage. We want to take the fight to the other guy and we are going to dominate his airspace. We will operate in it, and he will not.*
>
> —Gen Ronald R. Fogleman

The aircraft force mix of 2025 will evolve from the current developmental programs, including the F-22 and derivatives, the joint strike fighter (JSF), and a number of UAVs, to both support inhabited vehicles and to operate independently. The F-22 derivatives may include a Wild Weasel platform that will be able to target both radio frequency(RF)-guided surface-to-air missiles (SAM) and directed energy antiaircraft weapons. UAVs will be used predominately to engage high-threat antiaircraft weapons and to provide active sensors for inhabited vehicles that will rely on passive sensors for the majority of their situational awareness.

Sensors and the data they provide will be widely distributed to provide maximum situational awareness. Fighter-mounted sensors should supply information to companion aircraft as often as they provide information to their bearer. Detection and identification probabilities will increase rapidly with sensor diversity and the false-alarm probability and error rates will decrease correspondingly. Uninhabited combat aerial vehicles (UCAV) should provide active sensors that work cooperatively with passive sensors on low observable (LO)-inhabited aircraft. Technologies such as high bandwidth, secure communication for satellite, and aircraft cross and downlink must be developed.

System Descriptions

The F-22 will be the only new fighter available to the US in the next decade. The joint strike fighter should appear after that to replace most current US fighter aircraft. By the time the F-22 and JSF appear, new technologies will be available to enhance their performance, but both aircraft are being designed using extant technologies. These aircraft will not produce a revolutionary change in the way air combat is waged. They represent an evolutionary change in the capabilities of aircraft. As 2025 comes to pass, the US will still have the requirement to control the air over enemy territory. This capability will come from the planned aircraft for the first part of the twenty-first century such as the F-22 and JSF, but also a whole new breed of uninhabited vehicles.

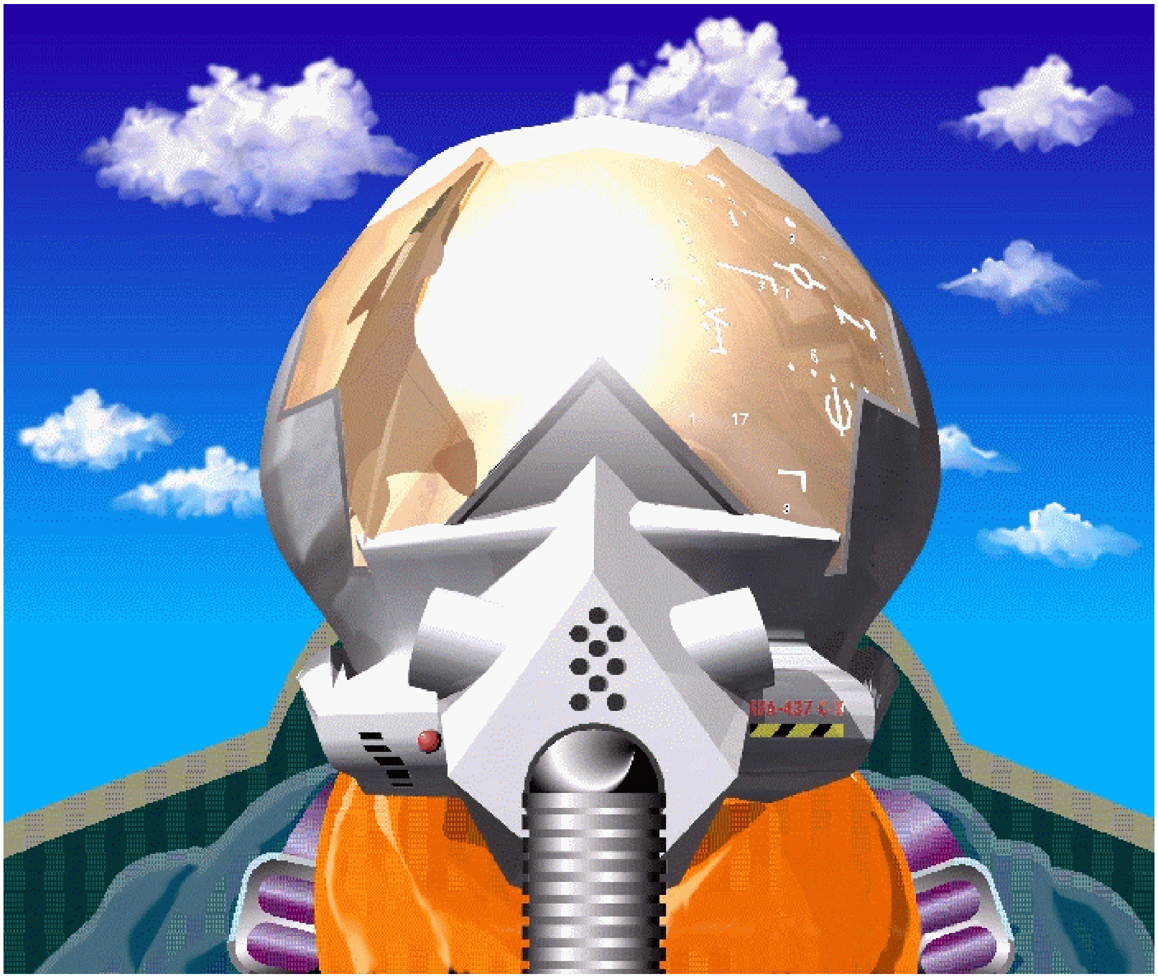
The twenty-first century, and the threats that accompany it, will require the capability to project airpower over a wide area of responsibility relative to today. This trajectory employs a mix of inhabited and uninhabited vehicles to accomplish the counterair mission. The inhabited vehicles will be a mix of upgraded F-22s and JSF aircraft. The uninhabited vehicles will be a whole new family of combat aircraft that will both support the inhabited vehicles and carry out some missions autonomously. If technologies develop as some believe, the concept of a "FotoFighter" as discussed in *New World Vistas* could be a reality in small numbers, or as a prototype. These aircraft would use large arrays of diode lasers to communicate, designate, and execute thermal kills of targets.[2]

Both inhabited and uninhabited vehicles will have a requirement to detect, identify, and target all types of airborne targets. This will require a combination of improved situational awareness, sensor capability, and lethal weapons. Significant effort will be required to expand beyond the current sensor suites forecast to allow the pilot to correctly identify threats, even if they are stealthy and their sensors are not actively emitting. This capability will increase survivability when outnumbered in future air battles.

Situational Awareness

The cockpit in 2025 should be linked to virtually every available source with high- bandwidth communications to ensure the highest degree of situational awareness.[3] Satellite surveillance networks, sea-based and land-based sites, and mobile platforms in the air and on the battlefield will play vital roles in providing the uplink and downlink of targeting information, individual engagement status, and battle space management directly to the operator.[4]

Onboard computers will correlate all information and display it to the aircrew in a helmet-mounted display (HMD) (fig. 2-1).[5] Visual presentations will also be displayed using long-range reconnaissance platforms and missile status uplinks. Cockpits will be fully compatible with night and all-weather operations. Fighter-mounted sensors will provide updates to companion aircraft (and vice versa) as often as they provide updates to their bearer.[6]



Source: http://www.thomson.com:9966/janes/jpictl.html, Geoff Fowler Media Graphics © 1995.

Figure 2-1. 360-Degree Helmet-Mounted Display

Detection and Acquisition

Airborne detection of adversary aircraft will be increasingly easy in 2025. Cutting edge technology in 1996 will be commonly available and widely dispersed. Effective airpower hinges on early detection and employment of weapons. Detection techniques will incorporate high-confidence, real-time situational awareness (SA) with highly diversified, multisensor detection capabilities and very lethal air-to-air weapons to ensure first launch, first kill and survivability of the launching platform.[7]

It is imperative that target detection and acquisition (hereafter jointly referred to as targeting) occur at the longest possible ranges. Identification of the detected vehicles at the earliest possible time will be critical to survival of the launching platform. Precision targeting will be possible using linked information from both surveillance and reconnaissance satellites and early warning aircraft correlated to that from onboard sensors.[8] Laser detection and ranging (LADAR), coupled with advanced Global Positioning System (GPS) inputs, will provide the longest range detection probability in clear air mass.[9] Radar of one form or another will still provide the longest range detection in adverse weather. Artificial intelligence will aid the aircrew by filtering through and sorting a plethora of linked information on possible targets.[10]

Weapons

To take advantage of complete SA, as well as first detection and acquisition, airborne weapons must be flexible, long-range, smart, and extremely lethal in all quadrants. Only a single type of air-to-air missile, possessing the capabilities necessary to ensure destruction of adversary aircraft, is necessary. The missile must be common to all US armed forces, with ordnance personnel from any service able to perform necessary maintenance. The endearing feature of this missile will be its ability, once launched, to perform the entire intercept independent of the launching platform.

Prelaunch information will be input to the missile, either from the aircraft or from external sensors, at increased speeds, proportional to an increased onboard computability. Postlaunch updates, if necessary, will be a combination of inputs from the launch platform and/or the same targeting sensors linked to the aircraft via secure low probability of intercept (LPI) datalink. Conversely, missile status will be linked from the weapon to targeting sensors and the launching platform throughout the engagement, including endgame battle damage assessment (BDA) to enhance SA.[11]

At launch input, the weapon will compute an intercept trajectory and fall from the aircraft. Using reactive jets, the missile will turn to the correct heading and then begin the boost phase of flight. Active detection capability inherent in the missile will compare data to all available outside sources to ensure precision intercept to the correct target. Autonomous target acquisition will occur and advanced guidance laws, coupled with guidance integrated fuzing, will assure intercept and kill. Postlaunch missile-to-cockpit status will allow the aircrew to determine subsequent courses of action regarding the target in question.[12]

Dependent upon the range to target at launch, the missile will move from the boosted phase flight to a sustained flight stage. Optimum altitude and speed for the missile will be computed based on target data.[13] This will give the missile the greatest potential flexibility during midcourse and terminal phases.

Precision GPS-derived location will be a primary guidance source during the weapon's entire time of flight. During the terminal phase of the intercept, the missile will incorporate the GPS guidance with precision onboard targeting technology to effect missile-target intercept. Terminal tracking and guidance may employ a combination of LADAR, infrared (IR), magnetic anomaly detection (MAD), jet engine modulation (JEM), photographic, and acoustic sensors, dependent upon weather and atmospheric conditions.[14] It is important to note that we expect that multimode seekers will be required based on expected countermeasure proliferation. Multiple warhead missiles will be possible with guidance to each warhead in the terminal phase.[15]

Countermeasures and Countercountermeasures

Survival in a hostile integrated air defense system will be essential. Survival will depend on avoiding detection to accentuate the advantage of surprise in a tactical environment. Enemy detection capabilities will have increased to the point where both active and passive stealth techniques will be necessary. Other countermeasures should include both expendable and nonexpendables, as well as redundancy and reconfigurability of the air vehicle. Expendable countermeasures will include micro-UAVs that actively engage inbound threats to the vehicle it is protecting. If the vehicle is detected, it will have to recognize that detection and then be able to precisely locate and identify what has detected it so that that sensor can be deceived, jammed, or targeted.[16]

Enabling Technologies

Active radio frequency and passive infrared stealth capabilities will be the highest payoff technology development for the evolutionary trajectory.[17] Active stealth capability should allow the US to develop techniques that will provide survivability and lethality to more platforms. The expense of developing passive stealth beyond current capabilities will increase exponentially but will not provide backwards compatibility to older platforms that active techniques might provide. Some of the active stealth concepts developed might include active cloaking film using nanotechnology-based film of micro-robots that vary their color and reflectivity to make an object "invisible" and "paint" with electro-optic materials that adopt a range of colors depending on the voltage applied.[18] These materials could be used to effectively provide active stealth in a particular bandwidth. No single system is envisioned which could provide a cloaking capability across the electromagnetic spectrum.

The fusion of multispectral sensors from different platforms will provide the next leap of capability in 2025 (fig. 2-2). Air vehicles will require the exploitation of offboard information using a high-bandwidth, secure datalink to increase SA and allow real-time targeting. Sharing of the offboard information will be enhanced by artificial intelligence based cooperation and distribution of mission responsibilities between platforms.[19] A distributed satellite system for surveillance and datalink to aircraft will allow the information to be shared throughout the theater of operations, providing real-time command and control.[20]

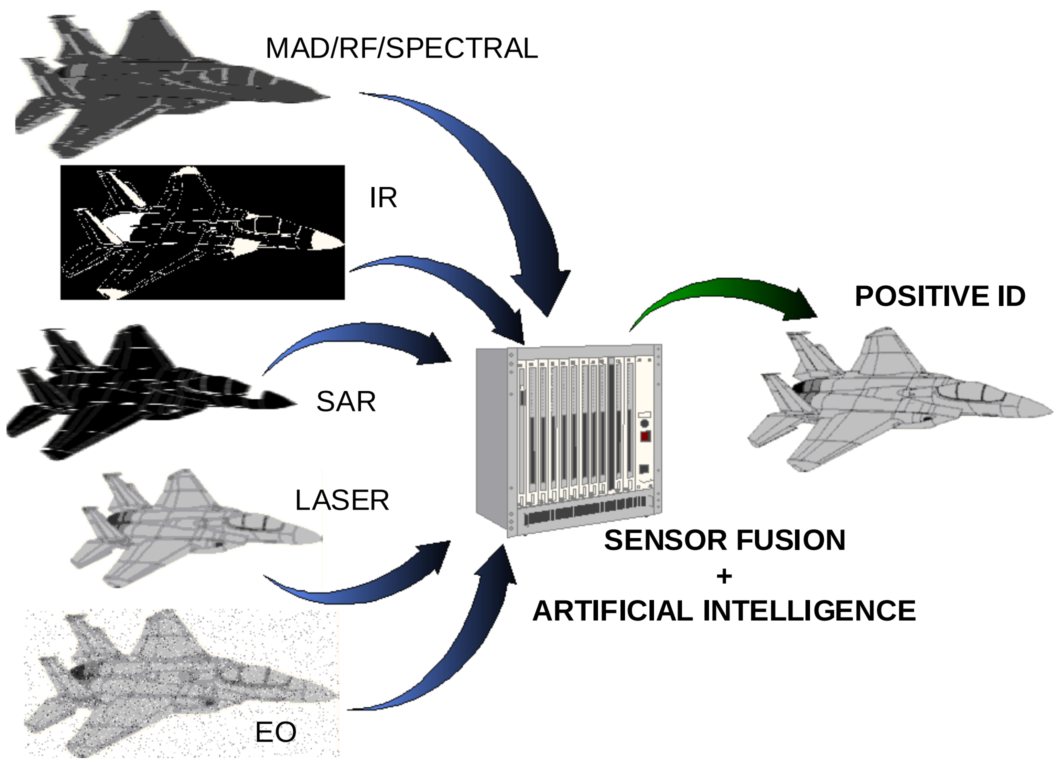


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Figure 2-2. Sensor Fusion and Target ID

It is essential that the sensor technology continue to be developed to provide capability against a growing countermeasure proliferation. These technologies include integrated sensors and conformal apertures with open system architectures, cooperative and distributed electronically scanned arrays, and multispectral, multimode seeker heads.[21]

Advanced identification friend or foe (IFF) capability will need to be developed to allow adversary platforms to be targeted with confidence at long range for survivability of the launch platform. Problems exist in current IFF systems that prevent long-range launch of long- and medium-range weapons at optimum ranges. These must be overcome to both negate the possibilities for fratricide and allow effective use of longer range weapons. One option could include the use of LADAR IFF. LADAR would provide 3-D mapping of the target to perform identification (ID).[22] The use of sensor fusion across platforms will also help in this endeavor.

After adversary platforms have been detected and identified, the platforms have to be neutralized as a threat. It is imperative that weapons technologies remain lethal in an environment of increasingly sophisticated countermeasures. Advanced munitions and missiles with multispectral and multimode seeker heads will be a necessity. Warhead development that includes nonlethal high-power microwaves will provide the capability to destroy or neutralize the electronics of targeted aircraft or systems.

Concept of Operations

Air superiority fighters will operate in conjunction with UAVs using active sensors and/or weapons appropriate to the mission and will communicate through a worldwide communications data network. A worldwide joint tactical information display system (JTIDS) will provide high-resolution data to both the commanders and the aircraft actually in combat. Space systems will provide the surveillance picture to the network. The artificial intelligence (AI) capability in the aircraft and drones will use both onboard and offboard inputs to give recommendations for tasks such as targeting, a-pole, and ordnance selection.[23] This worldwide data network will result in a flattened hierarchy for command and control. The potential threats and the mission to be accomplished will determine the mix of inhabited and UAVs in a force package.

Once the inhabited fighters and UCAVs have established their defensive combat air patrol (CAP) or offensive sweep, they will use a combination of onboard active and passive sensors and the available data linked information to search their area of responsibility. The AI software in the avionics will fuse the data from multiple sensors, both on and offboard the vehicle, to detect and identify air vehicles (bombers, fighters, cruise missiles, etc.) and develop situational awareness displays for the pilots of the fighters or UCAVs. The decision to engage or avoid the threats will be made and communicated directly to the entire chain of command via the JTIDS link.

If the decision to engage is made, the fighter (or UCAV) will attempt to employ weapons at maximum range to increase survivability. The weapon employed will depend on the current weather conditions and countermeasures employed by the adversary. Ideally, a directed-energy weapon from a FotoFighter could be employed against numerous threats in a very small time period. Since the F-22 and JSF fighters will still be limited to missiles previously discussed in this chapter, the engagement may occur at closer ranges due to late identification of the threat or because longer range weapons may be defeated by countermeasures. Very strict rules of engagement (ROE) could also lead to close-in visual engagements. In either case, the requirement for a close-range weapon appears inescapable. The weapons employed at close range could vary from high power microwave (HPM) to “bullets” from an advanced gun.

Once the engagement is finished, the fighters will return to their assigned area of responsibility or refuel to continue the mission. If the mission objective has been achieved, or if fuel and weapons are not sufficient to continue, the fighters and the UCAVs will return to base. The results of the engagements and significant intelligence information will be passed through data link to update the command and control system. This type scenario will be played again with multiple flights of air vehicles, both inhabited and uninhabited, throughout the area of responsibility for the particular joint force aerospace component commander (JFACC). The force mix and tactics involved will be determined by the mission objective and the perceived threat.

Summary

The capability described above is based on the assumptions that technological advancement between now and 2025 will be evolutionary, and that inhabited vehicles are the dominant means of maintaining air superiority. Since the advent of the counterair mission, we have seen under what circumstances conventional air forces will prevail—typically when the adversary presents a similar capability, such as World War II, Korea, or the Gulf War. There have also been situations, such as in Rwanda or Somalia, where counterair capabilities have played a lesser role. From this it can be concluded that evolutionary counterair capabilities are best suited to a peer or regional competitor, vice a niche competitor during an insurgency or guerrilla war. This is primarily because conventional counterair forces, as we know them today, have limited nonlethal capabilities. An additional limitation is the fragility of inhabited aircraft systems. The high cost of individual airframes, the cost of training pilots, and the requirement for forward basing in a potential threat area may make the American public too risk-averse to the employment of airpower under even the most compelling circumstances.

However, these are more than counterbalanced by the feasibility of these systems; and survivability of these systems will increase as more complex countermeasures are employed. The passive stealth features of the F-22 and JSF will be a significant improvement over the F-117. The next generation of active countermeasures need not be tied to the airframe technology. Indeed, as nanovehicles become the norm, they will find increasing use providing countermeasures in a hostile air-to-air environment. UAVs could also provide an active countermeasures screen to allow inhabited vehicles with passive countermeasures to penetrate enemy air defenses and engage enemy air forces directly. Upgrades to the present airborne laser program will support the targeting of smaller, more advanced counterair threats such as ballistic and cruise missiles.

Finally, one of the most important reasons for maintaining inhabited air forces will be accountability. In 2025, many of the competitors the US is likely to face will be regional competitors, whose inventories will be little different from what they have today.[24] In circumstances where the nature, or more likely the intent, of enemy air forces is not known, a higher level of fidelity—that provided by the pilot—will be necessary to discern the true air threat to the US or its allies. The situational response to many of the circumstances involving a regional or niche adversary in 2025 requires the hands-on accountability that is only possible with inhabited aircraft. In addition, most high-technology weapons such as lasers or HPM, are not recallable; once engaged, the target is permanently affected to the degree the engagement has progressed before it is terminated. There will also be situations where strict ROE demands a pilot on-scene to make a real-time determination of the actual threat presented. The international political and practical ramifications of an accidental shootdown by uninhabited US systems of either nonbelligerents, or enemy forces whose intent was in question would be significant; it would probably dwarf the response of the international community to situations such as the shootdown of civilian aircraft by the Cuban air force in February 1996. The bottom line is that warfare is still an engagement between two reactive entities, and the instincts and finesse of the pilot will be required to gauge the situation, either to defend the US or prevent an international incident.

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Chapter 3

The Penurial Robophile Trajectory
Pilots—the Rarest Breed

Why can't they buy just one airplane and take turns flying it?

—Calvin Coolidge

No system exists which can provide continuous all-weather coverage of worldwide targets .... To meet the above requirements, the Joint Staff has identified an urgent need for the capability of an Endurance Unmanned Aerial Vehicle (UAV) System.

—Dr John M. Deutch,
Under Secretary of Defense
(Acquisition and Technology)
July 1993

The road to 2025 may be sown with domestic strife and the propensity for the US to look inwards at its own problems. If so, US interest in world issues and debates would be greatly reduced, while concern for threats to US security from foreign countries or groups would be only as real as the threat. The same domestic problems driving this inward emphasis would drive consistently low defense budgets and interest. Technology would continue its near exponential rate of climb, but with an emphasis on domestic uses. The successful use of UAVs in the Gulf War in 1991 and in Bosnia in 1995–96 might motivate the US to accelerate the development of more advanced, multipurpose UAVs.[1] This technology offers more potential for weapon system performance at apparently lower costs. At the same time, UAVs "serendipitously accommodate the probable inexorable trend of American society who are more and more expecting no losses during US military operations." [2]

Although defense budgets and interest by the average citizen may be low, technologies applied to commercial communications and other areas such as electronics and materials would migrate to military applications as a leverage against lower budgets. Sensors and propulsion systems would continue to improve at similar rates. A more advanced and jam resistant Global Positioning System (GPS) constellation might replace the stage 2R satellites deployed between 2000–2010.[3] The level and sophistication of enemy air defenses might grow with technological advances to the point where inhabited systems must accept much higher risks for missions over enemy territory. At the same time, the cost of survivable inhabited systems would grow exponentially, making the development and fielding of these systems economically impossible.[4] In such a world, the joint service Defense Airborne Reconnaissance Office (DARO), formed in 1993 to manage the UAV program, not only survives early budget challenges and interservice rivalries, but grows in scope and responsibility.[5] By the year 2010, DARO might be responsible for the development of all UAV systems regardless of mission. In an effort to maximize smaller defense budgets and maintain consistency with the unsupportable expense of inhabited weapon systems and the sophistication of air defenses, civilian and enlisted pilots are recruited to "fly" the uninhabited air forces of 2025.[6] A fleet of multipurpose UAVs would then replace the aging fleet of F-15s. The F-22, joint strike fighter, and other proposed inhabited fighter and attack aircraft programs would all be canceled due to escalating development costs and the public perception of no real threat. Support and airlift aircraft, maintaining orbits far from potential air defenses, are available for the launch, retrieval, and rearming of UAVs. In the world of 2025, the fighter pilot of old is indeed rare.

Counterair Requirements

As mentioned previously, enemy air defenses have grown more sophisticated with technology. This requires the ability to detect, locate, identify, engage, and destroy fixed and mobile surface and air targets anywhere in the world on short notice. A limited overseas presence and a complex political environment demand power projection with greater precision, less risk, and more effectiveness.[7] Therefore, the uninhabited counterair force of 2025 must have the ability to deploy from CONUS, strike a target anywhere in the world, and return to a friendly base in CONUS, in the air, or at sea. These operations require a mix of autonomous and controlled flight missions. Finally, nontraditional defenses against aircraft, like high-powered microwaves, and an increased air-breathing threat, especially cruise missiles, will put a premium on a counterair force mix capable of meeting both the offensive and defensive counterair requirements of 2025.

System Descriptions

The UAV force mix of 2025 evolves from development efforts in the late 1980s and early 1990s, and draws on the combat experience of Bosnia in 1995–96. Stealthy, high- flying, very long-range systems use modular sensor and weapon bays and air or surface launch and recovery for optimal mission flexibility. The Tier 2 Predator, Tier 2 Plus, and Tier 3 DarkStar UAVs fielded in the 1990s were the first systems to demonstrate high- altitude, long-range, and stealth capabilities, respectively, using commercial off-the-shelf (COTS) and government off-the-shelf (GOTS) technology.[8] The counterair system of 2025 combines the attributes of each of these systems into a single, stealthy system capable of unrefueled global range and the ability to operate from low, terrain-following altitudes to altitudes over 100,000 feet. The multipurpose UAV of 2025 has an advanced turbofan engine, is structured almost entirely of composites, and has a minimum payload of 2,000 pounds.[9] If technology development permits, a UAV capable of transitioning from air-breathing propulsion to hypersonic capability and back again provides even longer range, higher altitude, more rapid reaction, double digit mach speed, and the enhanced survivability derived from these advancements.[10] Advances in materials and sensors provide for embedded sensors (smart skins) for 360-degree awareness and communications.[11] Reconfigurable control surfaces (smart structures) optimize range and performance while minimizing radar cross section.[12]

In addition, active stealth systems will eliminate other detection vulnerabilities.[13] Increasing maneuverability beyond human tolerance, plus or minus 12 Gs or more, enhances survivability; increasing to plus 20 to 40 Gs greatly enhances missile avoidance in the end game.[14] In addition, advanced defensive avionics use active and passive systems, including mini-UAV decoys and other expendables.[15] Modular sensor suites and weapon bays provide snap-in and snap-out mission customization, keeping unit fly- away cost for the basic air vehicle to the equivalent of today’s cost of $10 million.[16]

Applications

In the year 2025, intelligent signal and data processing and secure, redundant data links for control and intervehicle information sharing are standard.[17] The multipurpose UAV will employ the latest synthetic aperture radar (SAR), bistatic radar, infrared (IR) and electro-optical (EO) target tracking capability, target illuminators, and jam resistant, low probability of intercept (LPI) communications and data links to perform any of the envisioned counterair missions.[18]

The air tasking order (ATO) of 2025 will be automatically deconflicted by using surface, air, and space-based sensors to provide a synergistic effect for netted systems. Advances in artificial intelligence, computing speed, and secure communications links will make real-time ATO deconfliction and tasking a reality.[19] The joint forces commander of 2025 will display situational awareness and battle management information in the holographic war room with the assistance of UAVs while directing other UAVs to fight the counterair battle.

Weapons

The multipurpose UAV will employ the latest in advanced weapons for air-to-air and air-to-ground attack. The advent of very small, very smart bombs and missiles will optimize payload capacity.[20] Explosives with 10 times the destructive force for the same weight will make these sorties 10 times more effective than today.[21] Advanced GPS receivers embedded in individual powered or unpowered weapons provide fire-and-forget capability without the need for laser illumination from other platforms or sources.[22] Smart fuses will enhance hard target kill, while the launch UAV or another UAV in the mission package provides real-time BDA via satellite uplink.[23] Advanced air-to-air weapons will use vectored thrust for optimal turn performance. Distributed satellites and advanced GPS provide worldwide, jam-resistant, low probability of intercept command, control, communications, navigation, and pinpoint weapons delivery and target acquisition.[24]

Continuing developments of microelectromechanical systems (MEMS) and potential developments in nanotechnology could provide an entirely new family of microminiature, intelligent weapons. Swarms of microminiature weapons could disable or destroy air or surface targets in support of the counterair mission.

Intelligent materials systems, built at the atomic level by precisely placing each atom and molecule, could be powered by light for near limitless range and undetectable size. Inertial guidance systems, sensors and associated actuators, and their control by neural networked microprocessors could all be microsized through the application of MEMS and nanotechnology. Microminiature weapons could be aided by swarms of similarly sized intelligence, surveillance, and reconnaissance (ISR) systems. Swarms of microminiature weapons and sensor platforms could be launched by very small UAVs if the MEMS and nanotechnology development continues at its present rate.[25] The multipurpose UAV weapon system can perform a totally autonomous air-to-air or air-to-ground mission and, through advanced GPS guidance and preprogrammed mission parameters, can act in intelligent coordination with other UAVs or be remotely controlled from air, land, or sea bases by the ground pilot of 2025 (fig 3-1).[26]

Source: http://www.afit.af.mil/Schools/PA/gall3.htm, courtesy of Gene Lehman, AFIT/LSEC.

Figure 3-1. Representation of UAV Ground Cockpit

The increasing threat to air vehicles will also be countered by the introduction of the FotoFighter into the inventory. The FotoFighter will use low observable technology coupled with conformal arrays of phased high-power solid-state diode lasers to provide simultaneous surveillance, tracking, designation, and thermal kill of targets, as well as communications.[27] The FotoFighter could form the backbone of the air strike capability, since it would be designed to be capable of high speed and maneuverability (hypersonic speeds and $\pm$20 G capability) increasing its survivability; removal of the pilot would also increase opportunities for signature suppression.[28]

Countermeasures and Countercountermeasures

Wideband radars and multispectral detection systems will challenge the capability of the multipurpose UAV force to survive in hostile airspace. Active and passive stealth capabilities, low and high-altitude operation, and low subsonic to hypersonic speeds will complicate detection by even the most advanced radars or other systems.

These capabilities provide survivability against surface and airborne threats. The camouflage, concealment, and deception of surface targets will complicate the surface attack portion of the offensive counterair mission. These factors will be offset by using wideband SAR systems, advanced IR detection from other UAVs and space assets, and the overall sensor synergism from surface, air, and space assets.

Enabling Technologies

Target detection and identification will require advanced GPS and distributed satellites, along with artificial intelligence-based cooperation and distribution of mission responsibilities between platforms.[29] Cooperative and distributed electronically scanned arrays will support interaction between strike platforms and optimize targeting.[30]

The key to successful implementation of UAV technology will be in active radio frequency and passive infrared (IR) stealth.[31] The aircraft itself must be constructed of high strength, lightweight, and reconfigurable materials.[32] To maintain on-orbit times and increase endurance, UAVs will use advanced fuels for lower specific fuel consumption and better all-altitude performance.[33] Hypersonic propulsion systems are needed to cope with the dense threat to air vehicles due to state-of-the-art air-to-air and surface-to-air missiles.[34] Part of the job will be to track friendlies, requiring advances in identification friend or foe (IFF) capability.[35] Detecting and tracking enemy aircraft means improvements are required in modular integrated avionics, including a downsized and wideband SAR.[36] Finally, the high speeds and maneuverability of these systems will dictate advanced munitions and air-to-air missiles.[37] MEMS and nanotechnology could provide an exponential leap in microminiaturization for both weapons and platforms. To support the counterair mission in the high-speed, short-time-horizon battle space of 2025, mission planning and execution will require dynamic planning and execution control a la *New World Vistas*.[38]

Concept of Operations

Multipurpose UAVs armed with sensors and/or weapons appropriate to the mission act in conjunction with surface, airborne, and space-based assets. The modular sensor and weapon bays discussed above provide mission planners the ability to mix and match components for optimal performance against the threat and targets. Potential threats and the mission to be accomplished determine the number and configuration of UAVs in a given mission package—threat detection, threat negation, active and passive decoys, sensor or communications relay, or armed for the defensive or offensive counterair mission. The FotoFighter would provide a unique quick strike capability against counterair targets of opportunity presented by short dwell targets such as missiles, missile launchers, or other hypersonic threat aircraft (fig. 3-2).

The UAV mission package is then launched from CONUS bases or airborne or sea-based platforms described above. This force package will use such air- and space-based assets as GPS and satellite communication links for autonomous operation over long distances and for terminal remote control if desired. Regardless of the mission, offensive or defensive counterair, armed UAVs will suppress enemy air defenses as necessary, destroy enemy aircraft and other systems in the air or on the surface, and return to CONUS bases or other platforms for refueling, rearming, and retasking.[39] At the same time, other UAVs operating independently or as part of the overall mission package identify and illuminate targets or threats for the strike UAVs, act as communications or data links, and provide real-time BDA.

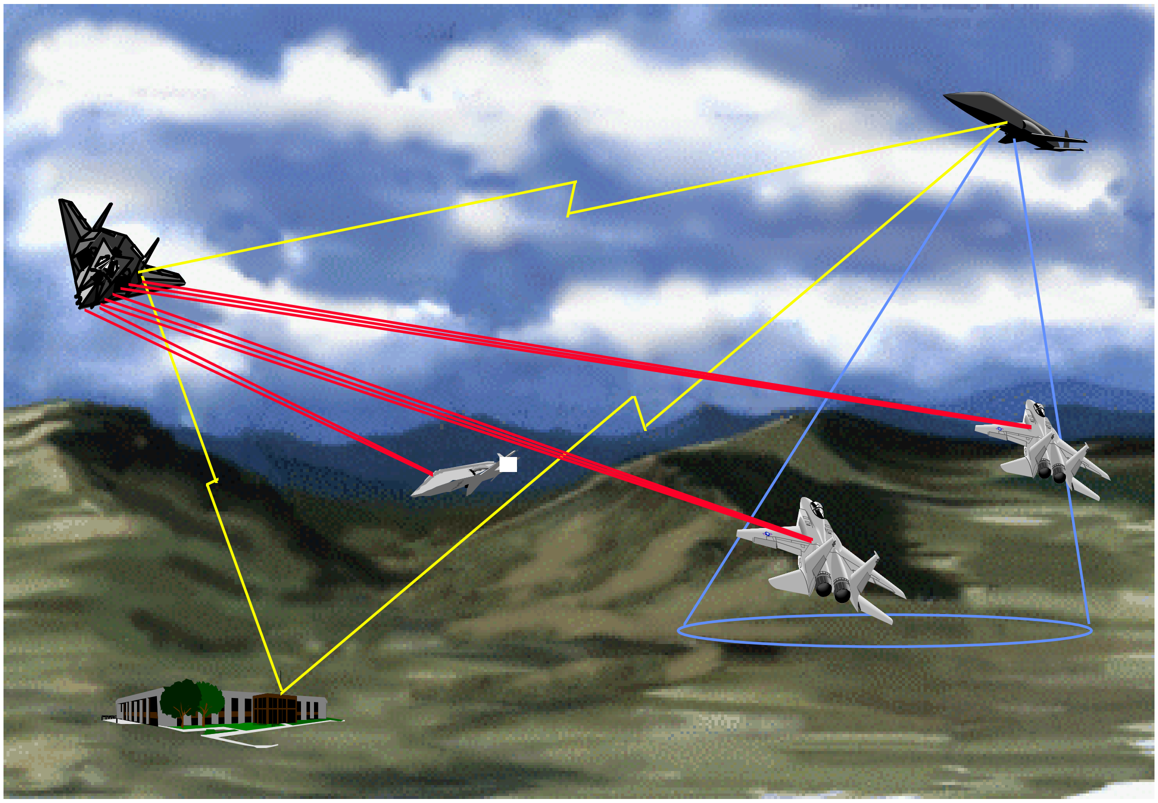

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Figure 3-2. UCAV Strike Fighter (FotoFighter)

The systems, technologies, and concept of operations described here provide the joint forces commander of 2025 with a multipurpose, long-range, lethal, and hard-to-detect and hard-to-kill autonomous weapon system or force package. Multipurpose UAVs accomplish the counterair mission of 2025 more efficiently and effectively, without risking the lives of pilots.

Summary

As the US continues to attempt to do more with less, it becomes more and more likely the US will turn to UAVs to perform many of the missions requiring inhabited aircraft today. The counterair mission will be no exception. As described in this chapter, there is an opportunity to perform the entire counterair mission using UAVs. The current characteristics of UAVs—range, adaptability, and loiter time—when coupled with advances that will yield hypersonic strike capabilities, will allow the employment of UAVs in any environment against any type of adversary, from low-tech adversaries to peer competitors using stealthy cruise missiles or F-22 equivalents.

UAVs are even now coming of age, and decreased development, production, training, and replacement costs make them an attractive alternative to inhabited aircraft. In addition, the modular nature of much of our UAV fleet will allow tailoring of vehicles for specific missions, including air-to-ground counter-C2, SEAD, and conventional air-to-air against low-tech second wave air forces, as well as advanced fighter capabilities of peer adversaries. The FotoFighter, in particular, presents a significant leap in capability likely to be available in 2025. The addition of directed-energy weapons of variable lethality will be a considerable advance over the selectivity of current armaments for close-in and medium range-engagements. The flexibility and increased speed of hypersonic uninhabited strike aircraft will also allow these vehicles to avoid surface-to-air threats as simple as small arms and stinger missiles. This decreases the fragility of our counterair capability while enhancing survivability. Whether based in CONUS or on carriers, these assets can respond on demand, arriving on station in any AOR within hours, ready to conduct the mission without crew rest or prebriefing—the ground pilots having completed these activities while the UAV is en route to target. Once on station, trained ground pilots will assume control of the aircraft, allowing a level of fidelity near that achievable with pilots on-scene, increasing the flexibility of response.

The most difficult challenge will be to develop the technology required to support the strike UAV—the FotoFighter or its equivalent. In addition, to achieve the fidelity required to match a pilot on-scene, allowing the ground pilot to feel as if they are flying the mission will require significant advances. CONUS basing may also pose some challenges to situations that require a more immediate response; deployed UAV carriers would enhance responsiveness in crisis scenarios. Recovery and replenishment will require special attention, but some armament limitations may be overcome by the use of rechargeable DE weapons or nanoweapons. Even as the first of many UAV squadrons becomes operational, it is clear the enhanced capability and flexibility UAVs provide at lower overall risk and cost will drive the US towards an increased use of UAVs in the conducting the counterair mission.

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Chapter 4

The Virtual Trajectory
Air Superiority without an "Air" Force?

New conditions require, for solution—and new weapons require, for maximum application—new and imaginative methods. Wars are never won in the past

—General of the Army Douglas MacArthur

As described earlier, the virtual trajectory assumes a globally-minded US with plenty of technology and money to support military technological advancement. Its motto is Virtual Presence, Virtual Power. The premise: the US is a global power with an attitude, has a strong economy and leverages an exponential growth in technology, but is reluctant to put its blood and treasure on the line routinely for questionable causes or outcomes. This, coupled with an increasing ability to locate, identify, and track both fixed and moving targets with high precision; a space-based force application ability (lasers, high power radio frequency (HPRF), high power microwave (HPM), etc.); and possession of surface-based weapons of a similar nature, leads to a reduction in the need for air superiority aircraft.

The America of 2025 is a global superpower in every respect, defined by a strong economy, political decisiveness, a resurgence in moral strength, worldwide recognition as an honest broker, and a position at the cutting edge of the technology of the day. However, there are some that wish to discredit or challenge the US's place in the world view. The US's penchant for conflicts of minimal violence, with few casualties and little collateral damage, has placed renewed emphasis on precision in lethal application of force and a new stress on nonlethal force for subduing enemies. The result is a need for a space- and surface-based counterair capability for subduing any challenger using standoff weaponry.

The author made some basic assumptions to frame our approach and demonstrate the need for a surface- and space-based counterair capability. The first assumption is that there would be a limited personnel and airframe base. Defense drawdowns would have reduced the availability of highly skilled pilots. As recently as the Gulf War, it was emphasized repeatedly that "no target is worth an airplane," and the American predisposition towards risking as few lives as possible is well known.[1] As such, inhabited airframes will be used only for key targets that cannot be hit from the surface or space without risking mission failure or collateral damage; the most likely use is in strategic attack or special operations roles. It was also observed during the Gulf War that the Iraqi population understood the US was targeting Iraqi military capability, and not the general population, because of the precision with which their military assets were targeted.[2]

The second assumption is the availability of adequate communications bandwidth to support the command, control, communication, computers and intelligence (C4I) infrastructure required for coordinated real-time target acquisition, tracking, and battle management.

The third assumption is that the US will reap the benefits of huge leaps in technology that allow US armed forces to develop and deploy advanced space- and surface-based weapons. This assumption does not eliminate the possibility that a regional competitor, such as Iraq, could not possess capabilities that would pose a threat to most of our forward deployed forces, or even continental United States (CONUS)-based assets.

A related issue is the impact of having an adversary as technologically capable as the US investing primarily in a virtual capability. In this case, the counterair mission as we know it would disappear, its requirements would likely be assumed by strategic attack and interdiction forces.

Counterair Requirements

The requirements for this space- and surface-based counterair system can be broken down into three major areas: information collection and processing; situation awareness/command, control, and communications (SA/C3); and force application systems. Target tracking and identification must allow identification of all friendly and threat aircraft in the area of responsibility (AOR) including airframe type, location, and heading, using both military, COTS systems, and commercial inputs. COTS processing capability will give the required computing power, and commercial multispectral and other inputs will provide additional data points to the threat identification process. When possible, the weapons load of enemy aircraft should be determined to allow the US to estimate the nature of the threat. Once an adversary is targeted, the weapon will require the capability to acquire a specific airframe to an accuracy that will allow submeter precision (particularly for lasers, to allow targeting specific control surfaces or weapons on the aircraft). This will be required since the most vulnerable parts of airframes are the pilot and the wing root.[3] Target acquisition and tracking systems will require a high degree of accuracy. Laser weaponry, in particular, will require accuracies to the centimeter for the more lethal effects. This is one area in which military research and development (R&D) will likely be required.

SA/C3 systems are the linchpin of the effort. They will be required to ensure mission critical communications are being passed between target tracking systems, to the regional commander in chief's (CINC) battle management operations center (BMOC) and then to a target engagement node. Secure, jam-resistant communications must be available to support all phases of operations. The BMOC must be able to coordinate and direct all counterair assets and evaluate attack results. Battle damage assessment (BDA) can be accomplished by the same systems used for tracking and engagement in much the same way as the virtual presence capabilities described in *New World Vistas* where virtual presence allows for laser systems to provide attack, high-resolution imagery, high bandwidth point-to-point communications, optical IFF, and active remote sensing.[4] The biggest challenge will be sustainment of space-based systems. Once on orbit, space-based systems must either be maintained in-place (using a transatmospheric vehicle (TAV) or other technology) or replenished as required.

System Descriptions

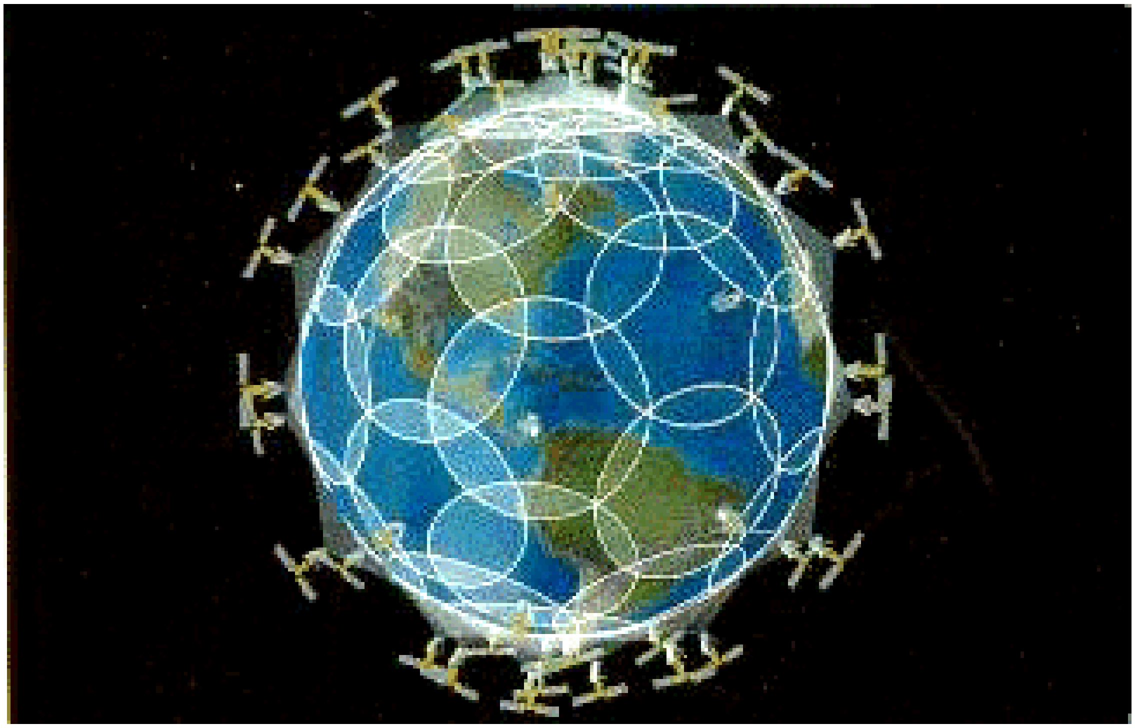
> *Minimizing collateral damage is a requirement that will dominate all future contingencies and combat operations.*
>
> —Col Richard Szafranski
> *GEO, LEO and the Future*

A virtual counterair capability will provide near-instantaneous precision strike with minimum collateral damage. To conduct the counterair mission, the virtual air forces rely on three key components: information collection and processing capability, SA/C3 capability, and force application systems.

Information Collection and Processing

The information collection system is based on the premise of performing wide area (global) surveillance at a low level of resolution, but looking for cues that require detailed monitoring. These cues will trigger a switch to a reconnaissance mode providing multispectral, high-resolution information on activities in a given region or area of interest. A mix of phenomenologies will accomplish this. Using multiple phenomenologies is critical to seeing through enemy camouflage, concealment, and deception efforts to ensure we see what we think we are seeing. In 2025, distributed satellite constellations will be our eyes and ears, providing the global view described in *SPACECAST 2020*.[5] Distributed systems of small single-function satellites, working in planes much as GPS does today, will allow continuous coverage of the battle space in multiple frequency bands. A constellation of cooperative space-based radar satellites will be capable of providing a moving target indicator (MTI) capability and synthetic aperture radar (SAR) images similar to Joint Surveillance Target Attack Radar System (JSTARS) (fig 4-1). A complementary set of satellite receiver platforms can be used to perform geolocation of electronic emitters or bistatic imaging and tracking of noncooperative targets.[6]

Similar potential exists for EO and IR detection and tracking of targets. Multispectral EO and IR images can be merged with SAR images by superprocessors capable of correlating data from multiple sources and providing a high-resolution image of targets in near-real-time. Finally, a phased-array, space-based laser system will also be able to take high-resolution (submeter) imagery, further improving our capability. This will be accomplished by the use of a super-GPS time and position standard, allowing multiple laser images to be correlated with other sources of information to further refine target knowledge.



Source: http://leonardo.jpl.nasa.gov/msl/Quicklooks/Pictures/iridconst.gif, courtesy of Mike's Spacecraft Library.

Figure 4-1. Distributed Satellite Constellation

The space-based assets will be complemented by a series of fixed and mobile surface-based assets. Their capabilities will mirror those of their space-based counterparts; time-coded signals from individual satellites can be used for SAR image processing, MTI, and bistatic processing. A network of surface-based EO and IR sensors, as well as laser sites, will cover those targets obscured by high-level clouds, further adding to the information base on targets in any given AOR. Those areas covered by frequent low- to mid-level clouds will rely more heavily on the RF-based systems.

The focus of these collection systems is a multimode polyocular processing (M2P2) system that will correlate information using powerful, knowledge-based, image processing capabilities, providing detailed three-dimensional (3D) target images on demand. The combination of EO, IR, and RF phenomenologies, combined with processing designed to detect and identify enemy systems, will allow the US to see through almost any conceivable deception effort. The pseudoimage will be matched against IFF and threat data from space-based airborne warning and control system (AWACS) platforms and against standard target profiles, allowing determination of the weapons load as well as specific modifications made to the target that present special vulnerabilities we can exploit. Thus, a nominal resolution of 1-10 meters from any individual EO, laser, or IR sensor, combined with bistatic or other SAR images of up to one meter resolution, will result in submeter imagery to support target detection, identification, and tracking capabilities for force application worldwide. Communications redundancy, using a combination of laser-crosslinks for space-to-space weapons platforms communications, and heavy reliance on redundant commercial communications encrypted for military use (particularly using wireless, cellular communications) will ensure worldwide connectivity for the entire system. The result is a system that lets US forces see in near-real-time what is happening in any region of the world at any time. The bottom line of our information collection and processing capability is our ability to continuously monitor the battle space.

Situational Awareness/Command, Control, and Communications

The heart of any operation is its operations center. The air operations center of 2025 has evolved into part of the CINC's battle management operations center. The god's-eye view afforded the CINC and the JFACC, fed by the information collection and processing system previously described, gives the JFACC the ability to display the battle space in its entirety, or zoom down to a particular aircraft or engagement. This is accomplished using a holographic war room, much like the holodeck from "Star Trek," where 3D visualization of the battle space is possible from the synoptic (broad area overview) perspective, to allow monitoring and engagement throughout the AOR, down to a particular target, with the JFACC actively interacting with the holographic depiction, controlling engagement activity and monitoring the progress of the battle in near-real-time (fig. 4-2).[7]

The BMOC fulfills multiple functions. The war room allows not only real-time centralized control, but also, using very high-speed computers (up to 1,000,000 times faster than today's computers), airspace deconfliction, battle simulations, expected outcomes in accelerated time modes, and BDA assessments. The speed-of-light nature of many of the laser and high-powered microwave weapons allows deconfliction of most engagements within minutes (or even seconds) of tasking.[8] Accelerated simulations allow the commander to evaluate courses of action in near-real-time. The computer will simulate the progress of an engagement based on the capabilities and doctrine of enemy forces using knowledge-based artificial intelligence software. As the BMOC learns more about how the enemy fights, this information will be applied to the engagement simulations, helping the JFACC select the best mix of weapons and weapon effects.[9]

Source: http://www.afit.af.mil/Schools/PA/gall3.htm, courtesy of Gene Lehman, AFIT/LSEC

Figure 4-2. Holographic War Room

The fast-forward outcomes can also be stored for comparison with the actual engagement, so the system can give the commander an empirical estimate of the outcome once a history of engagement activity is built. The results of both the simulations and the actual engagements will be stored as part of lessons learned for postconflict debrief and tactics modification. An assumed outcome to this will be a change from decentralized execution to distributed engagement. Distributed engagement is a result of the use of multiple small weapons to achieve a larger weapons effect, lack of time lapse between decision to engage and actual weapons on target, and a centralized command structure. A benefit of distributed engagements is a graceful degradation and increased survivability. A downside is the increased reliance on a single command center and its potentially vulnerable communications.

Part of the speed with which this activity is performed comes from the ability of the commander to use voice commands to establish ROE, pick targets, and finally specify weapons effects, from nonlethal to lethal. The commands can be as specific as "destroy the four F-16s crossing the Kuwaiti border" (centralized control--centralized execution) to "disable all enemy aircraft entering friendly airspace" (mission-type orders). The BMOC will recommend a series of options, which can be played out in the war room, allowing the commander to see the expected results, then select from one of the courses of action (COA) displayed. At that point, the commander will direct frag orders be sent to the individual weapon systems for execution. Based on inputs from the weapons sensors themselves, as well as our surveillance and reconnaissance systems, the actual battle can be displayed with insignificant time lag; the commander can observe the engagement as it is conducted, obtaining near-real-time feedback on the status of the mission. The closed-loop nature of engagement and feedback will allow rapid retargeting to ensure the CINC's and JFACC's objectives are met effectively and when required. The fog and uncertainty of war are significantly reduced, and adjustments to any engagement parameter (target, weapon, effect) can be made as required during the battle.

Force Applications Systems

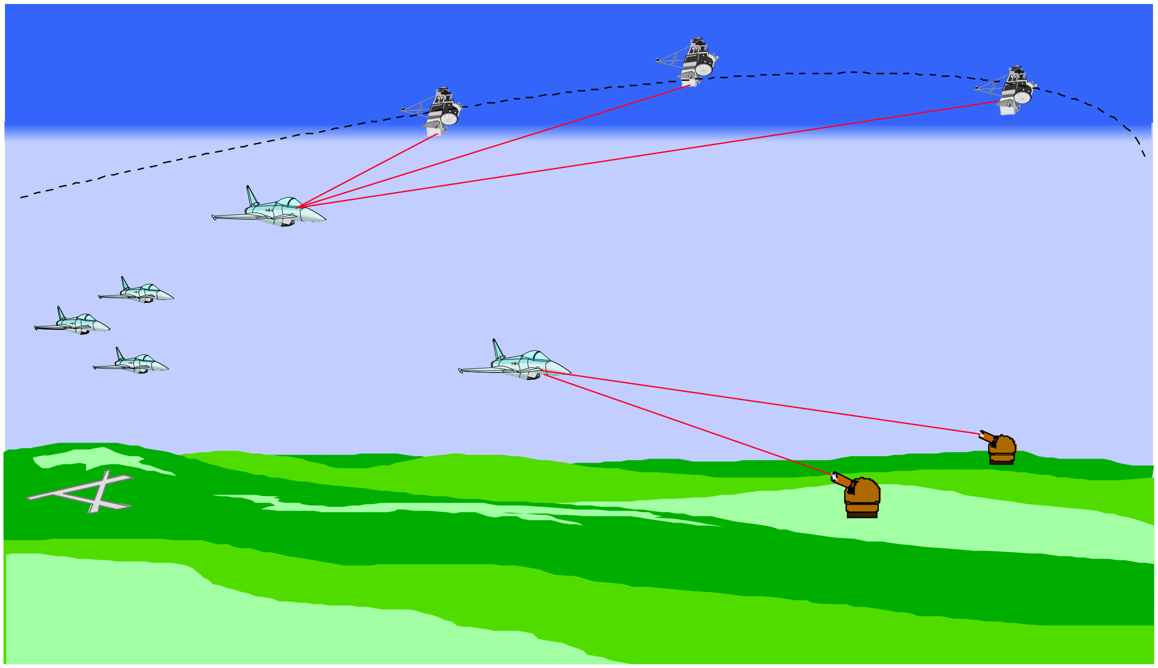
High energy lasers (HEL) and high power microwave devices have been noted to be complementary.[10] Lasers are noted for their potential for destructive power; however, they require accurate targeting and a relatively benign environment (no clouds or overcast, smoke, or smog).

HPM weapons, on the other hand, are typically capable of less overt destructive power, but are capable of operating in virtually any environment and constitute an all-weather capability. They represent two sides of the same coin which can be leveraged in 2025.

High Energy Lasers

HEL weapons will constitute a part of both the space- and surface-based systems. Space-based lasers will come of age by 2025. A number of advances will make this possible. The first is a super-GPS capability that will provide a level of time accuracy to the nanosecond and position accurate to the millimeter.[11] This capability will be tied into our constellation of distributed phased array laser satellites (PAL-sats). These PAL-sats will not have to be the monster satellites envisioned in the Strategic Defense Initiative (SDI) era; they will be small, medium-power satellites, numerous, and easily replaced. By definition, space-based lasers are long-range weapons. Their power is derived from the ability to use a phased array approach to putting energy on target. The phased array is managed by a central control satellite, using a low power illuminator (also capable of imaging targets) to provide a phase reference for the deployed elements of the laser array (fig. 4-3). The phasing signal could also be used to communicate between elements of the system, passing targeting data, etceteras. Additionally, if the capability is developed, communication between phased array laser elements could be accomplished using quantum communications methods, so phasing between elements could be communicated simultaneously.[12] Using the phase information in the phasing signal, each PAL-sat will use deformable mirrors made of microelectromechanical devices and phase compensation measures such as phase conjugation to compensate for atmospheric and other effects. If coordination of these elements became too difficult or thermal heating of individual array PAL-sats became a problem, time-division-multiplexed lasing could be employed, with each PAL-sat firing in sequence against a particular point on the target, effectively providing a continuous laser from multiple-pulsed lasers.

The constellation approach simplifies each satellite, making it more affordable. The effect of the constellation is a graceful degradation of the weapon's capability if any one of the satellites is removed from operations due to weather, malfunction, or attack. It also allows for multiple weapons effects, which will be described below. Energy for such a system can come from multiple sources; the primary advantage in 2025 will be the development of composite materials that can change their characteristics on command. This is done using microelectromechanical systems (MEMS) deposited in the composite body of the satellite. When in one mode, the device can be rotated to minimize its signature, providing a measure of stealth. If the MEMS are rotated, like the highway billboards you see today, the devices soak up energy—either from the sun or a beam provided from the surface to recharge the weapon.



Clipart elements from Federal ClipArt © 1995 with courtesy from One Mile Up, Inc., and Microsoft Clipart Gallery © 1995 with courtesy from Microsoft Corp.

Figure 4-3. Friendly Phased Array Lasers Targeting Enemy Aircraft

Surface-based systems are based on the same principles as the space-based systems. The phased-array approach allows surface-based assets to be used against the same target as the space-based system, and also allows targeting of medium-range targets. Hard kill of airframes becomes a greater possibility, permitting a larger range of weapons effects. It also helps defeat the mitigating effects of weather.

One of the greatest advantages of energy weapons is the variability with which they can be applied. Effects can range from nonlethal to lethal. Nonlethal effects can range from cloaking—using lasers to provide holographic camouflage in the visible portion of the electromagnetic (EM) spectrum—to hide assets from visual identification, to generating holo-threats that would appear to move in out of nowhere, confusing the adversary who must engage a virtual enemy or run for home.[13] To more fully deceive or confuse enemy onboard systems, HEL systems may require an adjunct whose only purpose is to provide a return for the enemy's radar—physical chaff launched by conventional means or rail gun, or RF deception of their radar systems. Granted, this assumes an unsophisticated enemy, but sometimes this may be enough psychologically. The combination of surface- and space-based systems is well suited for this type of deception.

A slightly higher level of lethality comes from a higher application of power. Effects such as canopy glazing, blinding, thermal effects (cooking off fuel or lubricants), or weakening structures is possible by varying the strength and width of the beam.[14] Lethal effects can be achieved by burning through control structures, fuel lines, or electronics, or causing foreign object damage (FOD) to the aircraft engine.

Finally, and probably one of the greatest reasons for fielding this capability, is the ability to target and destroy cruise missiles, intercontinental ballistic missiles (ICBM), and theater ballistic missiles (TBM). Whether the threat is against an ally overseas or to the continental US, a PAL-sat constellation provides a precision strike capability against even a multiple missile threat.

Countermeasures and Countercountermeasures. The downside to laser weaponry is its vulnerability to atmospheric effects. Although this vulnerability can be partially overcome by adaptive optics and wavelength adjustment, smog, fog, clouds, smoke, and dust can prevent successful operation. Local weather control may be possible to support operations in limited areas.

A prolific PAL-sat constellation and surface complement is also one way to defeat certain local conditions. Hardening against low-power laser radiation is also fairly simple; reflective surfaces go a long way in this direction, but the trade off is increased visibility. Laser-seeking devices could also be a threat to the weapons platforms themselves; in effect, when in operation, laser weapons designate themselves, a factor that needs to be considered. Defender satellites or space sentries in place to counter an antisatellite threat is a possible solution.[15] Visual or IR chaff are also options.

RF and High Power Microwave/Electromagnetic Pulse Devices

Space- and surface-based RF, HPM, and EMP devices will complement the laser capability of 2025 by providing an all-weather, day/night, variable lethality weapon. In addition to an all-weather capability, the greatest advantage of HPM/EMP over laser is that it does not require the same level of precision for targeting; the target may try to evade, but the beamwidth of the HPM device will usually cover an area equal to or larger than the airframe, and, as long as tracking is to that order of magnitude, evasive tactics will prove useless. Collateral damage can still be minimized by proper beam formation and effects limited to the target(s). EMP is even less discriminating in its tracking and targeting requirements. However, it is a oneshot weapon, and the target has to be in the proximity of the device to be strongly affected, particularly for low-yield, high-explosive warheads.

HPM can be implemented in much the same way as lasers, using a phased-array approach, with both a distributed satellite constellation and surface-based elements. Beam shaping can be accomplished by using various combinations of the constellation and surface-based elements. HPM will be medium- (surface) to long-range (space) weapons. EMP will be implemented as a warhead weapon, being delivered either by railgun or cruise missile, providing everything from close-in to long-range targeting, depending on the required speed of the response or extent of desired effects. Railgun delivery from in-theater assets will be almost as timely as speed-of-light weapons and just as flexible. Surface-launched cruise missiles from CONUS or carriers provide a long- range, stand-off capability that can also serve as a deterrent.

RF weapons are a special case, because they represent a capability for a surgical strike. At any range, an RF weapon could be used to do anything from disrupt aircraft control to take over an aircraft (a.k.a. tractor beam).

Weapons Effects. HPM weapons are particularly effective due to the varied impact they can have on an adversary. As with lasers, HPM weapons can have nonlethal as well as lethal effects. The application of nonlethal HPM can result in thermal effects, such as weakening the structure of airframes, missiles, or command and control (C2) facilities.[16] Continued application of microwaves against human targets (intentional or unintentional) can cause disorientation, discomfort, or long-term damage. At moderate power levels, the composite materials used in modern aircraft tend to absorb microwave radiation rather than reflect it, rapidly aging aircraft materials and destroying its stealth properties. Higher power levels of HPM can cause disruption of electrical circuits, particularly in sensitive integrated circuits or magnetic media. EMP can be used in a SEAD role by using shaped EMP charges to burn out receiver front ends in aircraft, C2 facilities, or SAM sites. Another side effect of EMP bursts to targets on the surface and in the air is cable coupling, causing serious electrical system and structural damage.[17] RF weapons are capable of the simplest effect: basic ECM. This includes using space-based (or, where applicable, surface-based) systems to simply jam the front ends of enemy receivers, to generate false radar images to confuse the enemy's picture of the air war, to insert false imagery into his data stream.

Lethal effects can vary from igniting fuel vapors and the consequent loss of the aircraft, to torching avionics and electronics with directed HPM or wide-area effect EMP bursts, causing loss of control. EMP bursts of sufficiently high power and/or proximity can cause aperture coupling, where the airframe itself couples the energy of the burst, thus causing destruction of all electrical components and damage to control surfaces, as well as possible destruction or damage to any human occupants.[18] In the RF realm, the most lethal effects will be the use of the tractor beam, where MEMS could be placed on an airframe, either by special operations forces, or by having them burrow into the avionics and electronics systems of an aircraft after it flew through a cloud of MEMS designed to penetrate the fuselage and implant themselves. Once implanted, a computer on our side could analyze the aircraft's control systems, and an operator on the surface could establish a link and take control of the enemy aircraft to force it down, or merely land it at a friendly airfield for analysis and pilot debriefing.

Countermeasures and Countercountermeasures. The most significant countermeasure to HPM and EMP is stealth and structural design. If the aircraft is sufficiently stealthy, it will be difficult to track and apply the energy levels required to damage or destroy the aircraft. However, in 2025 few adversaries, if any, will have the capability to make their airframes invisible to all the forms of energy (EO, IR, microwave, laser, radar) used to detect, identify, and track their forces. Structural design can be used to mitigate the effects of aperture and cable coupling. A stealth paint can be applied to surfaces to further reduce visibility in selected portions of the EM spectrum.[19] Possible countermeasures are spectroscopic detection of the paint, exhaust tracking, or magnetic detection of aircraft.[20] These capabilities will make the ISR systems described under the Information Collection and Processing section above even more robust. The best countercountermeasure (CCM) for US satellite-based capability would be the embedded MEMS in the composite structures described earlier that would allow the satellite to change its visibility based on the type of sensor attempting to track it, or a shell that deploys to protect the satellite, or the defender satellites mentioned above.

The RF/MEMS link is particularly hard to defend against. If a quantity of these MEMS is suspended in a slowly falling cloud above an air base, they would either fall onto enemy aircraft as they sit on the ramp, force adversary aircraft to fly through them to get airborne, or cause those aircraft to retreat to storage. In each case, the adversary's air capability is effectively grounded.

Kinetic Energy Weapons/Ground Launched Cruise Missiles

Kinetic energy weapons (KEW) and an improved ground launched cruise missile (GLCM-X) capable of intercontinental ranges will provide an enhanced capability against hardened targets and targets of opportunity. The GLCM will replace the ICBM, mostly to enhance survivability. ICBMs are too easily tracked, and deviating from ballistic trajectories for ICBMs is tantamount to GLCM use in any case. Space-based KEWs are possible, but orbitology and time of flight will limit their application. Rapid progress in railgun technology was seen during the 1980s, and kinetic energy weapons have been demonstrated using railgun technology to propel warheads of up to 1000 kilograms (kg) and in excess of six kilometers per second (km/sec).[21] By 2025, advances in technology for these devices will yield vehicle-mounted weapons that could be located in the AOR and will give a response time that complements our energy weapons. Super-GPS combined with near-real-time target updates will allow medium-to-long-range attacks on hardened airfields, aircraft revetments, airbase C2 facilities, runways, or even aircraft in flight with both types of delivery systems.

Weapons Effects. The advantage of KEW and GLCM weapons is their capability against hardened targets and those targets requiring a tailored warhead. The ability to carry a sizable warhead allows the US to develop sophisticated nonlethal effects that can be delivered to submeter accuracy. Nonlethal effects include HPM/EMP warheads capable of producing effects similar to the space- and surface-based systems, less the phased-array aspect. However, proximity to the target and shaped warheads will compensate for this. The warheads can be delivered by either railgun or GLCM, depending on the state of our forces in theater and the type of response the national command authority (NCA) desires—overt action in theater or covert delivery from CONUS. Other nonlethal warheads include FOD bombs examples include webbing or netting over aircraft on the ground, suppression clouds, oxygen suckers, or highly tensile “silly string” to freeze control surfaces, thereby keeping aircraft grounded.[22]

Lethal effects can be achieved by MEMS that can damage or take an aircraft apart in flight, drop submunitions on a runway, or deposit acid or other destructive liquids on airframe surfaces or airbase facilities.[23] An alternative antiaircraft artillery (AAA) method is to use railgun warheads to eject a suspended net of high-tensile-strength steel that would shred aircraft control surfaces as the aircraft passes through it. This same method could be used for theater missile defense, disabling or destroying missiles and/or warheads in flight. The most direct approach is obviously to take a high explosive (HE) warhead right to the target–a GLCM warhead can take out a hardened facility, revetment, or C2 facility. With a multiple reentry vehicle warhead and MEMS-controlled submunitions, it could take out an entire air wing on the ground. The railgun would serve as a twenty-first century AAA, putting submunitions right through airframes at hypervelocities capable of ripping the airframe apart. In addition, the surface-based railgun will provide another layer in the cruise and ballistic missile defense umbrella, complementing the capabilities provided by surface- and space-based lasers.

Countermeasures and Countercountermeasures. There are few countermeasures except extremely expensive hardening against HPM/EMP or stealth (antitracking) measures. The high speed of railgun projectiles would negate evasion maneuvers.

A sufficiently small projectile, made of composites and moving at hypervelocity, would be hard to detect, much less counter. The GLCM-X would be designed to go against hard, fixed targets or produce wide-area effects requiring large payloads/warheads; given this, the only effective counter is successful camouflage.

Enabling Technologies

The enabling technologies allowing the successful implementation of the counterair mission using space- and surface-based assets can be grouped into the same categories as the areas requiring development: information collection and processing, situational awareness/C3, and force application. The key technologies supporting information collection and processing include advanced space-based radars capable of SAR, MTI, and bistatic detection; high-speed computing and real-time linking to support space- and surface-based phased array laser and HPM capability; timely, cost-effective launch of tailored, distributed satellite constellations; and distributed processing of multimodal information for real-time tracking of targets.

The requirements for SA/C3 technologies include allowing real-time displays of order of battle, enemy and friendly COA generation, and wargaming of outcomes. This includes artificial intelligence/knowledge processing systems capable of correlating multispectral, multimodal information. Fused, correlated information would be used to generate enemy and friendly COAs and three-dimensional holographic presentation and real-time simulation of enemy and own force activities in fast forward modes. Combined with the distributed processing of target information, this could also provide near-real-time BDA.

Weapons application technologies are centered around advanced GPS, capable of nanosecond accuracy and millimeter precision, and high-resolution optics, beam directors, and deformable mirrors for laser applications. The phased array lasers and HPM also require the development of phased array timing/phase synchronization signals (such as time-coded reference signals or quantum nodal communications) to allow timely communications between physically separated array elements. Composite materials, with imbedded MEMS capable of changing states to accommodate stealth (energy absorption), power accumulation (energy conversion), or active transmission are needed to support the stealth aspects of our platforms. High power RF and HPM technologies must be developed to make spaceborne platforms viable. Mobile, moderate payload (up to 1000 kg), hypervelocity railgun delivery systems are needed to support the rapid response of surface-based EMP and HPM weaponry.

Concept of Operations

The BMOC is the heart of counterair operations. Using all-source information generated by space- and surface-based sensors, the holographic war room will give the CINC and JFACC the ability to monitor friendly and enemy forces in near-real-time. The JFACC, using voice commands, will be able to ask the war room to "show enemy air forces," followed by "show enemy IADS." After reviewing the enemy order of battle, he can ask the system to "show probable enemy actions and targets." Once requested, the system will examine the enemy ordnance load and fuel capacity (gathered by space and surface-based SAR, EO, and laser imagery), and project their tracks to and from targets. The JFACC will then ask the system to "show own forces," and all offensive and defensive systems and their effectiveness envelopes will come up. At that point, the commander's intent will have to be specified in terms of the mission: deter, disrupt, or destroy enemy assets. Depending on the enemy, the target, and the CINC's objectives, the JFACC will request COAs appropriate to the mission. After reviewing the COAs in fastforward mode, one will be selected and targets identified and designated in the war room. One fallout of the responsiveness of energy weapons to tasking is the requirement for centralized control and centralized execution of these systems. The immediacy of the impact of weapons use and requirements for real-time deconfliction with other air and surface forces requires control from the war room. This need is reflected in the way space and surface counterair forces are tasked. The degree of damage or destruction of each target will be specified before engagement, and target parameters passed directly to the weapon systems.

Most adversaries will be deterred by the recognition that, as a global superpower with worldwide virtual presence, the US is capable of quickly identifying enemy actions and responding before they pose a threat. Because of this, most operations will likely be deterrent missions, demonstrating capability and resolve to the enemy. Simple methods such as holographic projection of an air threat against the adversary would be attempted first to scare him off. As the adversary increases the aggressiveness of his posture, the US could respond in kind by increasing the threat to enemy air forces, using the MEMS cloud or GLCM to keep enemy aircraft grounded. If deterrence fails altogether, a destruction COA will become more likely. The weapon of choice could be selective lasing of vulnerable airframe surfaces, disabling HPM bursts, or airspace control devices such as the silly string or steel nets. Active high-power lasing, RF or HPM bursts will disable, destroy, or ground large segments of the enemy air capability. Near-real-time BDA will allow for rapid retargeting of assets; one of the advantages of space-based weapons is that they are always forward deployed. In this instance, if high energy lasing of a penetrating aircraft was required, real-time reporting from the laser platforms would be combined with EO, IR, and SAR imagery to determine if the target was "heating up," had exploded, or gone down in near-real-time. The tractor beam capability will be reserved for high-value air assets and reconnaissance vehicles. This will allow the US to determine the type of enemy systems and capabilities and to build countermeasures or deception programs around this system. This will also increase US stature in the world community by reducing the death and destruction of airframes and pilots, and give the US another source of human intelligence (HUMINT) from pilot debriefings.

Cruise missile and ballistic missile defense (BMD) will be a primary function of space- and surface-based counterair forces. Part of the driver for the global surveillance and focused reconnaissance capabilities of the BMOC will be to accommodate the requirement for constant vigilance of the cruise and ballistic missile threat. The combination of laser, HPM, and railgun payloads will provide a multitiered, all-weather defense against ballistic missiles (fig. 4-4). The M2P2 processing capability described above will allow the determination of location, velocity, and probable launch and impact points. The war room will provide detail on the nature of and confidence level of the threat, but the crews on watch in the BMOC will be the human in the loop to ensure the threat is identified quickly—within 60 seconds—but verified before destruction. Although 60 seconds is not a significant improvement over detection and warning times today, the problems of detecting stealth missiles will complicate the problem, and the ability to begin neutralizing the threat within seconds of identification provides significant leverage that does not currently exist.

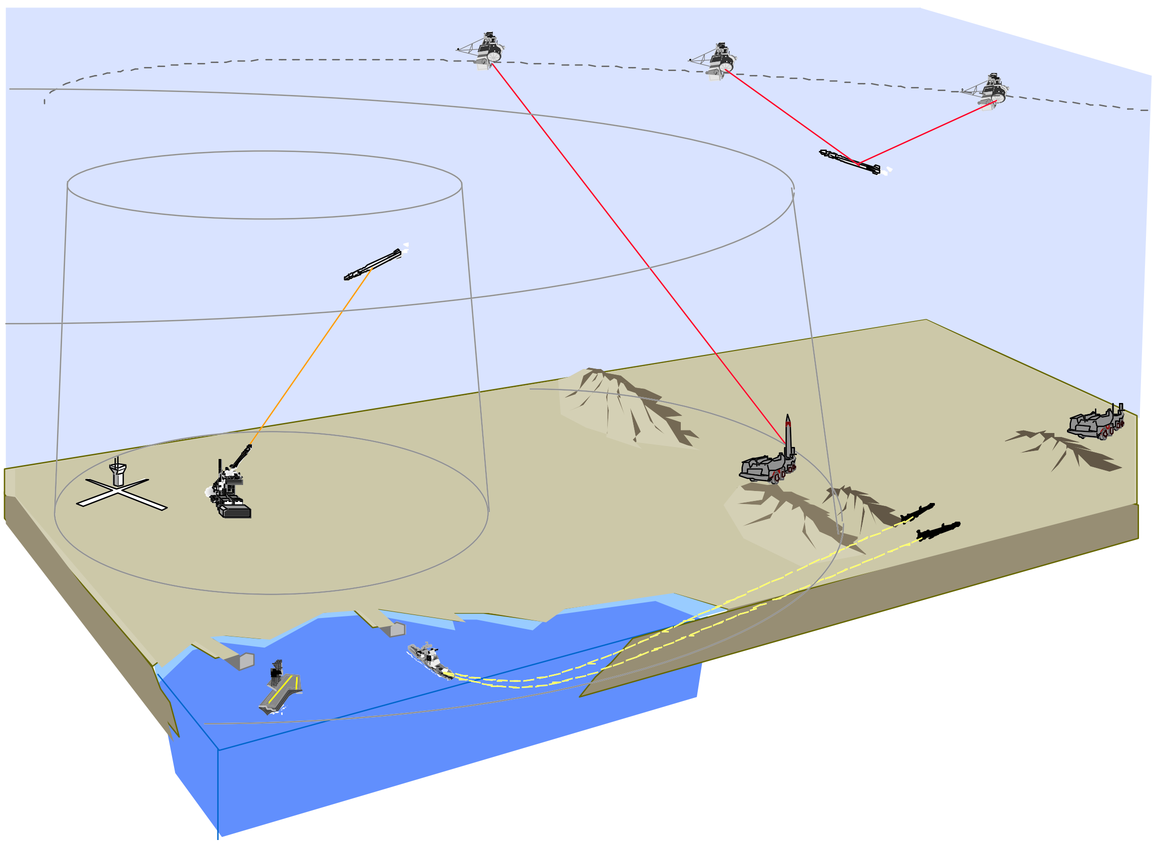


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Figure 4-4. Multitiered (Laser, GLCM, Railgun) Missile Defense Capability

Summary

The key to the success of the systems described above is matching the capability to possible threats. This paper described the range of threats. The applicability of directed energy weapons, cruise missiles, and nonlethal munitions payloads varies across the spectrum. The strength of the systems described above is in their versatility and responsiveness. Directed energy weapons have their strength in their ability to engage at everything from very low to very high power levels, increasing from nonlethal disruptive effects to lethal destruction at the flick of a switch. Cruise missiles will be highly accurate, delivering any payload at high precision at any given time for measured effect. Railguns give the added versatility of being able to put "steel (or plastic) on target" in a short period of time, also with the possibility of multiple payloads.

The weakness of DEW is the flipside of its strength—once engaged, the mission can be halted, but whatever damage is done, is done. Cruise missiles can be destructively aborted; railgun payloads lie somewhere between the two, depending on distance to target and the nature of the payload. None of these systems carry much finesse once a mission has started; a human in the loop is not the same as a human on the scene, and the fidelity of feedback is much more limited.

Even a fused picture of the battle space will not yield the same insights as a pilot in the cockpit engaged in a flyby of possible hostiles. For this reason, UAVs or inhabited aircraft are much better suited to low tech or second wave adversaries engaged in such cat-and-mouse tactics as airspace infringement or insurgency. The significant advantage of these systems is, as previously described, their ability to instantly engage a target. Distributed space-based systems, in particular, provide a method of reaching targets worldwide on a moment's notice. This is crucial when considering the theater ballistic missile, ICBM, and cruise missile threat of 2025.

The surface- and space-based systems described in this trajectory also enjoy the advantages of low fragility; they appear less vulnerable as a system because of their distributed nature. The distributed engagement concept also allows for a multiple simultaneous target scenario over a large (basically global) engagement area—a direct result of the forward deployed aspect of space assets. This in turn supports the ability to train as you fight, which is inherent in these systems since, to the operator, any simulation seen during training will appear identical to what would be seen in an actual engagement.

The most daunting aspects of fielding these systems are the technological and financial requirements. The technological improvements required to implement a space-based phased array laser or HPM capability are an order of magnitude or more increase from state of the art in 1996. The associated cost for research and development and deployment are significant for all the elements of the system—information collection and processing, SA/C3, and force application systems.

In the final analysis, the ability to immediately reach out and touch a target with both lethal and nonlethal consequences will provide a significant deterrent as a key component of US overall counterair capability.

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Chapter 5

Synthesis

The bedrock of what we do is air superiority ... we want to dominate the other guy's airspace.

—Gen Ronald R. Fogleman
Air War College address

The world of 2025 is a world of varied threats. The air threat can be as simple as a terrorist with stinger missiles or Cessnas flying from Latin America or Cuba. On the other end of the scale, the threat could be long-range cruise missiles from Iran, a Chinese stealth capability much the same as the F-117, a Russian air-based laser, or a North Korean theater ballistic missile.

From the previous discussion several conditions can be derived that must be met for the successful execution of the counterair mission. The first condition is that the US must be able to counter the full range of threats, from the surface to the edge of space. These threats encompass the full range from small arms to lasers. What is common to the airborne threats is that they cease to become threats once they are no longer airborne.

This leads to the second condition, one based on the definition of counterair operations—that mission success is based on the neutralization of the enemy's air forces. This can be accomplished by keeping them on the surface or, if airborne, to remove them from the protected/defended airspace and hence remove the threat they pose.

The third condition that must be met for successful execution of the counterair mission is to establish the freedom to operate in any airspace with impunity—the crux of air superiority. The threat the US must deal with is the antiair capability of today and tomorrow—something as simple as a shoulder-launched antiaircraft missile to a space- or surface-based laser similar in capability to the type described in our virtual trajectory.

Over time, we have recognized a fourth condition—there will be an increasing need to perform the counterair mission in both a lethal and nonlethal manner. A priority is reducing the exposure of air assets and their operators to enemy fire.

The fifth condition is derived from the increasing ability to project great power over great distances in a short period of time. This mission must be performed both at short range and at increasingly long ranges—and not only protect US airspace at home, but also be able to project power from CONUS to halfway around the world at a moment's notice.

Analysis

A critical assumption is derived from the previous analysis and the conditions described above: the need for a mix of inhabited and uninhabited aircraft as well as surface- and space-based systems. The need for inhabited aircraft is driven by the convergence of two forces—the nature of a second wave airpower threat and the fact that in our democracy we will always consider leaders, at all levels, responsible for their actions. The inescapable conclusion is that some threats require not just a human in the loop, but a human on the scene. At no point in the previous discussion has the assertion been made that any of these systems is foolproof; in a given situation, one may present a better solution than another. The dominant battle space awareness provided by the ISR and situational awareness systems of 2025 will never provide perfect knowledge of enemy capabilities or intentions.[1]

Examples are the probing missions conducted by the USSR near US airspace in Alaska during the cold war and the shootdown of private aircraft near Cuba in February of 1996. In the future, US airpower will encounter aircraft in international airspace with questionable or unknown intentions. Even with the near-real-time relay of information, these circumstances will spawn situations where nothing can replace the intuition, or gut instinct, of a pilot flying combat air patrol (CAP), making the determination based on information from offboard, onboard, and experience.

The positive control implied by a pilot on-scene is a powerful deterrent as well; an adversary may be much less likely to attempt to down an inhabited aircraft in a nonprovocative situation for fear of an adverse US or international response. It is also likely that as countermeasures improve, there may be situations where inhabited as well as uninhabited vehicles will be cut off, losing their eyes and ears. The advantage of inhabited aircraft is that the pilot will be much more capable of recovering from the situation, and possibly taking advantage of it, whereas if the UAV is cut off, it will require a fail safe that will, at best, allow it to return to base.

On the other hand, in the case of a general war scenario, uninhabited vehicles, commanded from a remote operations center for preprogrammed missions or via a real-time data link may be the weapon of choice. In this case, the FotoFighter described in *New World Vistas* may be the right vehicle for taking out enemy targets; combined with uninhabited reconnaissance, command and control, and relay aircraft, the FotoFighter may be the best all-around choice for close-in and medium-range targets.

The disadvantages of the inhabited aircraft have been enumerated many times: high training costs, limited number of platforms, limited number of pilots, and limited number of target engagements per platform. An increasingly hostile threat environment, including hypervelocity missiles with multimode seeker heads, makes conventional aircraft increasingly unattractive in terms of the cost of a single failed engagement. This must be balanced with the projected relative ease and timeliness of the application of high-energy weapons, whose maintenance costs may be high and where depth of magazine, particularly in the space-based situation, may be limited.

The downside of aircraft is reaction time. The best equipped strike fighter is useless if it shows up after the battle is lost—and reaction time will be at a premium against our more sophisticated foes in 2025. Adversaries will increasingly have access to weapons that today seem exotic, such as stealthy cruise missiles.[2] This is where US space- and surface-based capabilities come to the fore. The ability to detect, acquire, identify, then destroy the enemy's counterair capability within seconds will be the driver behind this capability. It will also provide a more robust deterrent capability, since mobile surface and particularly space-based assets are always forward deployed, basing is not a problem, and there are no assets to move to a forward area under the global grid interconnectivity envisioned for 2025.

The forward deployment of space-based weaponry and the ability to instantly apply firepower is particularly important against the cruise and ballistic missile threat. Once the threat is identified, time is crucial. Delays in detection and identification due to active and passive stealth measures will mean the leverage found in the immediacy of figuratively putting steel on target make DE weapons a key element of our counterair capability. The complementary nature of high energy lasers, HPM, and railgun kinetic energy weaponry will provide an all-weather, multitiered defense against the ballistic and cruise missile threat of 2025.

The result of the analysis is the identification of a need for a combination of capabilities, a synthesis of the three trajectories. The identification of the strengths and weaknesses demonstrate how the capabilities described in each trajectory complement each other. The combination yields a counterair triad that matches capabilities against threats, and best succeeds at meeting the conditions for successful mission execution described above.

Comparison

Four approaches were developed for conducting the counterair mission based on the evolutionary, penurial robophile, and virtual trajectories, plus a fourth approach defined by the system of systems combination of all three: the counterair triad. Table 1 compares each of the four approaches and maps it against a set of criteria describing the capabilities required in 2025. A four-level gray scale was developed for comparison of each approach against those criteria. On this scale, white means the criteria were not well covered or the capability is limited, with gradations up to black, meaning the criteria is well covered or the capability is robust. These criteria allow a side-by-side comparison of all four approaches to better visualize what each brings to bear in the conduct of the counterair mission.

1. *Applicability to Multiple Scenarios*. There are three types of scenarios at a high level—a regional competitor (a medium-tech, second wave adversary such as Iraq or North Korea); a peer competitor (the old USSR or a future China); and a niche competitor (terrorist/insurgency, etc.). Measure of merit: white = covers none; light gray = one of the three; dark gray = covers two of the three; black = covers all.

2. *Capability Leap*. Measures whether the capability is an evolutionary change or tends to revolutionary improvement in capability. Measure of merit: white = current capability; light gray = minor improvement in capability; dark gray = significant improvement in capability; black = order of magnitude improvement (revolutionary).

3. *Range*. Applicability to close-in (less than 150 miles), medium-range (150-1000 miles), and long-range (1000+ mile) engagements. Measure of merit: white = none; light gray = engages at one range set; dark gray = engages at two range sets; black = at all ranges.

4. *Selectivity*. Describes the range of options provided by the approach, from lethal to nonlethal. Measure of merit: white = no capability; light gray = nonlethal; dark gray = lethal; black = selective lethality (nonlethal to lethal).

5. *Response Time*. Indicates the time between the decision to employ force until action against the threat. Measure of merit: white = days; light gray = hours; dark gray = minutes; black = seconds.

6. *Flexibility*. Reflects the ability to provide a flexible response in the mission profile prior to weapons employment. Measure of merit: white = none; light gray = some; dark gray = routine; black = selective.

7. *Fragility*. Indicates the perceived cost of the loss a of single asset—aircraft, spacecraft, cruise missile, and so forth. and/or loss of life. Measure of merit: white = very high; light gray = high; dark gray = medium; black = low.

8. *Targeting*. Describes the number of potential target engagements per sortie. Measure of merit: white = single; light gray = few; dark gray = many; black = lots.

9. *Weapons Engagement Area*. Indicates the effective area the system can engage in at one time. Measure of merit: white = visual range; light gray = sensor range; dark gray = regional (beyond platform sensor range); black = global.

10. *Basing Limitations*. Describes the type of basing required for each approach. Measure of merit: white = in the area of operations; light gray = in the CINC's AOR; dark gray = CONUS; black = flexible.

11. *Cost*. Reflects the relative cost of deployment/employment of the approach in each approach. Measure of merit: white = very high; light gray = high; dark gray = moderately high; black = baseline.

From this comparison it is clear that each approach has certain strengths and weaknesses. The evolutionary approach is more achievable given today's state of the art and can accommodate more sensitive situations through direct contact of the pilot on-scene, but is more fragile and less responsive than the other two to immediate threats. The penurial robophile approach has more overall strength, but lacks some fidelity, even with ground pilots and, like the evolutionary trajectory, suffers from an inability to respond to immediate threats. The virtual trajectory is best suited for situations requiring an immediate response (overseas threats or cruise missiles), but requires the greatest leaps in technology, most significant cost, and the most trust in the system—not necessarily a given when such significant responsibility and accountability is demanded of our people. The fourth approach—the triad—covers the approaching threat and required capabilities of 2025 best. A balance of response time, lethality, fidelity, and cost, the counterair triad allows us to respond with the right amount of force at the right time in the right place.

Table 1

Comparison of Counterair Approaches

Criteria / **Approach**	Evolutionary	Penurial Robophile	Virtual	Triad
Applicability				
Capability Leap				
Range				
Selectivity				
Response Time				
Flexibility				
Fragility				
Targeting				
Weapons Engagement Area				
Basing				
Cost				

The analysis of the three trajectories allows us to put in perspective a more comprehensive approach to the accomplishment of the counterair mission. Each trajectory had its own approach to the counterair problem based on a particular set of assumptions. The convergence of these trajectories leads to a solution set all its own—where the triclinic of these trajectories meets to address a wide range of threats in a variety of environments. The result of this synthesis are found in the next chapter.

Notes

[1] Col Jeffery R. Barnett, *Future War: An Assessment of Aerospace Campaigns in 2010* (Maxwell AFB, Ala.: Air University Press, January 1996), 83.

[2] Ibid., 111.

Chapter 6

Recommendation

You should not have a favorite weapon. To become over-familiar with one weapon is as much a fault as not knowing it sufficiently well. You should not copy others, but use weapons which you can handle properly. It is bad for commanders and troopers to have likes and dislikes. These are the things you must learn thoroughly.

—Miyamoto Musashi
A Book of Five Rings

The overall requirements for the counterair mission are based on the conditions for successful mission execution described in the previous chapter. The trajectories presented reflect the need to examine the extreme ends of the scale on which counterair missions may be conducted, using an "anything but" criteria. The first trajectory examined "what if technology does not advance much, or the money is not there to implement many changes." The second trajectory looked at how counterair would be conducted if we used anything but inhabited vehicles. The final trajectory examined how the counterair mission would be conducted using anything but aircraft. Having reviewed these potential outcomes, we realize that in 2025 the counterair mission would and must actually use a mixture of systems from each of the three. There are some common themes running through all of the trajectories, and these will be a part of the counterair mission in 2025—the need for enhanced, real-time intelligence, surveillance, and reconnaissance (ISR), using multiple modes of detection—RF, IR, EO, SAR, spectrographic analysis, laser imaging, magnetic anomaly detection, passive and active intelligence collection, and so forth. Each trajectory also clearly recognized the human propensity for visualization, and identified the need for an operations center based on a near-real-time, three-dimensional presentation of the battle space—a holographic war room. The war room will use advanced knowledge processing to synthesize a visual view of the threat based on multimode polyocular processing, using the inputs from the many multispectral eyes available to generate a detailed image and depiction of threat capability for course-of-action generation, simulation, selection, and mission execution. The glue that holds these elements together is communications—a robust mix of dedicated military and civilian communications. The combination of information processing to allow situation awareness at a level of detail that can be tailored to the user or operation, combined with real-time simulation and observation of the friendly and enemy actions, and connected by a global grid of intermeshed communications nodes, allows prompt and sustained action in support of air operations.

The varied threat will require a mix of response capabilities—from low-threat, low- speed, nonlethal responses to high-threat, high-speed, lethal response. In each of the three trajectories, there are cases where the capability described is wholly appropriate for the situation. The high-probability second wave threat makes conventional aircraft attractive; the need for stealthy, low-cost, less personnel-intensive, AOR-specific reach and force application make uninhabited vehicles an approach whose time has come; and the need to counter high-speed, high-lethality threats such as TBMs, ICBMs, or cruise missiles, or the need to react on a moment's notice with power projection to a deployed force or ally halfway around the world makes surface- and space-based weapons an excellent choice. This drives the need for inhabited and uninhabited aircraft, as well as surface- and space-based capabilities for the world of 2025.

Concept of Operations for 2025

The counterair forces of 2025 will use the information collection, processing, distribution, and presentation methods described in each of the three trajectories. Distributed satellites, using hyperspectral collection methods, will be processed in real-time to provide everything from wide-area, synoptic views down to details on specific targets. The commander-in-chief or the joint force aerospace component commander (JFACC) of 2025 will be able to use a holographic war room to visualize the battle space, ask the battle management operations center processor to show suspected enemy courses of action, suggest friendly courses of action, and project outcomes. The friendly courses of action will be based on the nature of the threat and the CINC's intent. Simulations can be run for various combinations of friendly versus enemy COAs, and using elements of Chaos theory, projections made on the utility and chance of success of the responses. From these, the CINC or JFACC can make the appropriate choice and implement it in near-real-time.

The key to determining which assets are required to perform the counterair mission of 2025 is a function of the threat, the required level of deterrence, disruption, or destruction of enemy air forces, and the timeliness of the required response. Minimal threats require minimal, nonlethal response, but politically sensitive operations may require feedback that is only possible with inhabited aircraft. More substantive threats, such as F-22 type aircraft or uninhabited strike aircraft such as an enemy FotoFighter, may require lethal to nonlethal responses that can range from short to long range, and varied amount of time to react, making either inhabited, UAV, or surface- or space-based response appropriate. Antiair railguns, with projectiles moving at hypersonic speeds, will provide a lethal air defense capability against enemy UAVs. At the extreme end of the spectrum, the threat may consist of hypersonic stealthy cruise missiles, theater ballistic missiles, or ICBMs where a long-range, immediate response is required, making surface- and/or space-based assets the only appropriate response (fig. 6-1). The end result is a triad approach based on threat, intended effect, and immediacy of response. The options available to the JFACC will be composed of the systems described by our three trajectories. The JFACC will apply the portion of airpower that best suits the mission objective, threat, and desired weapons effect, and his instructions will be passed via his holographic war room. The JFACC will watch his instructions being carried out and get BDA in near-real-time. The common link that will drive this capability will be communications capability. The importance of this capability cannot be over-emphasized as we look forward to 2025.

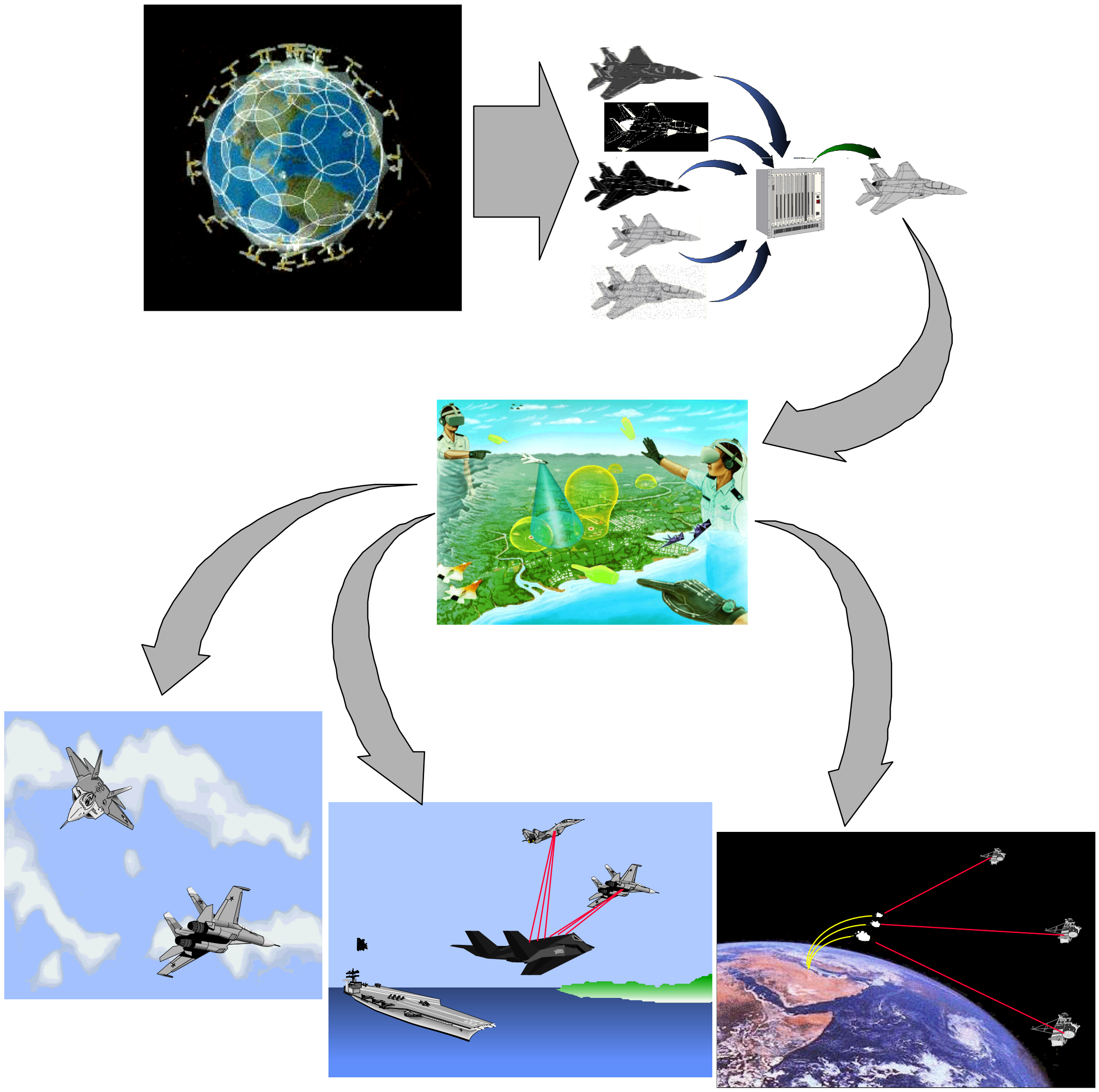

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Figure 6-1. Counterair Triad Concept of Operations

The result is a concept of operations based on systems from all three trajectories. As a singular superpower in a multipolar world, the complexities of the counterair threat posed to the US will only increase. The capabilities-based response made possible by the counterair triad described above ensures the US air superiority against each of the threat environments posed above, whereas any one alone will not. The overlapping synergy of the counterair system of systems—the counterair triad—will ensure air superiority for the US in *2025* and beyond.

Conclusion

> *When offensive weapons make a sudden advance in efficiency, the reaction of the side which has none is to disperse, to thin out, to fall back on medieval guerrilla tactics which would appear childish if they did not rapidly prove to have excellent results.*
>
> —Gen G. J. M. Chassin

> *In war the chief incalculable is the human will.*
>
> —B. H. Liddell Hart

The three trajectories presented in this paper are the culmination of a comprehensive analysis of what the counterair mission might entail in the year 2025. Each was developed with an eye toward continuing and sometimes exponential technological progress and innovation. Yet, while there should be little doubt that the far-reaching advances envisioned in these approaches will play a critical role in tomorrow's military, it would not only be wrong to expect technology to be solely responsible for shaping those forces, it would be dangerous to do so. Hence, our triad—a system of systems derived from a combination of the evolutionary, penurial robophile, and virtual trajectories described in this paper. Many of the concepts depicted in this paper are common to all three trajectories, and they are easily assimilated into the triad. Other concepts can be found in only one of the postulated futures, and those that complement each other to best address the capabilities required in 2025 have been included in the recommendations.

The ability to collect and process information will be as central to the decision- making process in 2025 as it is today, and our triad relies on significant advances in this area. As previously described, stealth and weapons technology are also expected to make significant leaps in the next 30 years. The most profound changes, though, will come with better human-machine interfaces for the commanders, planners, and pilots of 2025 which will, without doubt, improve the efficiency and effectiveness of each sortie flown. But, even with an exponential technological growth, the human in the loop and on the scene will still be a requirement. Machines can be programmed to learn; machines can be programmed to react in given scenarios; machines can make decisions. However, machines cannot be programmed with the gut feel that has always been, and always will be, an integral aspect of how we fight. As long as commonsense reasoning remains the holy grail of artificial intelligence research, the best computer available will continue to be the one between the ears. The bottom line: the counterair triad will be the right capability for performing the counterair mission in

2025, while the human in the loop or on the scene, and their instincts and intuition concerning everything from gauging enemy intentions to the decision to fire weapons, will continue to be the last word on how we conduct the counterair mission.

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