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The Air Superiority Fighter and Defense Transformation

Why DOD Requirements Demand the F/A-22 Raptor

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Foreword

In this paper, Lt Col Devin L. Cate tackles the question of whether an air superiority fighter is relevant to warfare in the twenty-first century. Critics of the F/A-22, the US Air Force's next generation air superiority fighter, have identified it as a cold war relic—unjustifiably expensive and out of step with the Department of Defense (DOD) transformation. Colonel Cate argues that the six operational goals of the DOD transformation, as defined in the *Quadrennial Defense Review Report* (QDR) of 2001, actually demand a highly capable air superiority fighter. He shows how achieving these transformational operational goals requires performance of the four offensive counterair functions of surface attack, fighter sweep, escort, and suppression of enemy air defenses (SEAD), as well as defensive counterair. He demonstrates that only an air superiority fighter can efficiently and effectively satisfy all these functions.

Colonel Cate then identifies the operational requirements for an air superiority fighter to adequately contribute to the operational goals of the transformation. These requirements are superlative air-to-air and air-to-ground performance, survivability against modern air defense systems, and a capable sensor suite that allows the fighter to be a sensor-shooter and participate in the joint data network. Finally, Colonel Cate assesses the leading candidates for a twenty-first century fighter—the F-15C/E, F/A-22, F-35A, uninhabited combat aerial vehicle (UCAV), and the common aerospace vehicle (CAV)—against these requirements. The proliferation of advanced air defense capabilities during the next few years will seriously challenge the suitability of the aging F-15C/E as an air superiority fighter. He notes that while the UCAV holds long-term promise an air superiority platform, we still have much to do in developing its capability and the doctrine, tactics, and training to employ the UCAV in the air-to-air mission, especially against manned air-to-air threats in close engagements. Consequently, Colonel Cate concludes the F/A-22 is the only fighter that will meet all the requirements for a transformational air superiority fighter by 2007.

This paper provides rich material for discussion not only about the role of the air superiority fighter in the twenty-first century but also concerning the nature of defense transformation itself. As with all Maxwell Papers, we encourage discussion and debate of Colonel Cate's important paper.

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About the Author

Lt Col Devin L. Cate is a student at the Air War College located at Maxwell Air Force Base, Alabama. He has served tours as a physicist, flight test engineer, and staff officer on the Air Force Secretariat and the Office of the Secretary of Defense (OSD) staffs. He has participated in a diverse number of research, development, test, and engineering efforts, including the ground-based laser space segment of the Strategic Defense Initiative (SDI) and the F-117A Nighthawk. Colonel Cate led the Air Force's Red Teams for counter-precision-guided munitions and directed-energy programs, including the airborne laser. At OSD, he served as the program director for the national low-observable (LO) and counter low-observable (CLO) programs, authoring Department of Defense policy for management of the LO and CLO programs, including export policy. Colonel Cate's awards include the R. L. Jones Award for being the top engineer graduate of the US Air Force Test Pilot School. He is a distinguished graduate of the Squadron Officer School and Air Command and Staff College. Colonel Cate holds a bachelor of science degree in physics from the US Air Force Academy and, as a recipient of the Boeing Fellowship, he also earned a master of science degree in aeronautics and astronautics from the University of Washington. Additionally, Colonel Cate has published papers on laser optics, adaptive control, and prototyping.

The Air Superiority Fighter and Defense Transformation

Why DOD Requirements Demand the F/A-22 Raptor

The end of the cold war and the beginnings of a transformation of this country's national defense forces have led some to question the need for a new air superiority fighter, specifically challenging the continuation of the F/A-22 program.[1] The requirement for air superiority has been an accepted tenet of US doctrine since the War Department published Field Manual (FM) 100-20, *Command and Employment of Air Power*, in 1943.[2] Given the recent changes to the strategic environment that underpin the current transformation of Department of Defense (DOD), is there still a need for the traditional air superiority fighter? A careful reading of the operational goals of the transformation of DOD as codified in *Quadrennial Defense Review* (QDR)-01 demonstrates that this transformation cannot be accomplished without a new air superiority fighter. This new fighter must exhibit dominance in air-to-air engagements, have significant air-to-ground capability, survive against a sophisticated surface-to-air missile (SAM) threat, and serve as sensor and shooter in the joint data network (JDN). The options for fielding a new air superiority fighter include an upgraded F-15C/E, the F/A-22, the F-35A, the uninhabited combat aerial vehicle (UCAV), and the common aerospace vehicle (CAV). Only the F/A-22 can meet the emerging needs of the air superiority task in the coming decades. In the longer term, other options hold some promise.

Air Superiority Defined

Air superiority and its enabling complement, counterair operations, are defined in joint doctrine. Joint Publication (JP) 1-02, *Department of Defense Dictionary of Military and Associated Terms*, defines *air superiority* as "that degree of dominance in the air battle of one force over another which permits the conduct of operations by the former and its related land, sea, and air forces at a given time and place without prohibitive interference by the opposing force."[3] Counterair "integrates offensive and defensive operations to attain and maintain a desired degree of air superiority. Counterair missions are designed to destroy or negate enemy aircraft and missiles, both before and after launch."[4] Air superiority, then, is the degree to which a force has attained freedom to conduct joint operations by dominating the air. Counterair operations are the means of achieving air superiority.

Air Force Doctrine Document (AFDD) 2-1.1, *Counterair Operations*, describes air superiority as a core competency of the United States Air Force (USAF) and asserts that it "is normally the first priority of US forces whenever the enemy possesses air and missile assets capable of threatening friendly forces or inhibiting their ability to use the air and space medium to apply force."[5] According to AFDD 2-1.1, "any action taken to achieve the effect of dominance above the Earth's surface yet within the atmosphere fits into counterair operations."[6] AFDD 2-1.1 maintains that counterair operations not only include air attack but also information attack, surface attack, or space-based attack—as long as the effect is air superiority.[7]

There are two types of counterair operations: offensive and defensive. Offensive counterair (OCA) operations destroy, disrupt, or degrade enemy air and missile threats, with the goal of defeating these threats at their origin. OCA reduces the enemy air threat and frees friendly forces to use airspace for their own purposes, including other air operations.[8] Defensive counterair (DCA) is defense of friendly forces from enemy air and missile attacks. The spectrum of DCA ranges from active air defense designed to destroy incoming air and missile threats to passive measures intended to reduce the effectiveness of these threats.[9] Because the focus here is the air superiority fighter, the discussion that follows concentrates on its roles in OCA and DCA. The primary reference is to AFDD 2-1.1 for OCA and DCA discussions since it is more detailed and recent than JP 3-01, *Joint Doctrine for Countering Air and Missile Threats*.[10]

Offensive Counterair

Offensive counter has four elements: surface attack, fighter sweep, escort, and suppression of enemy air defenses

(SEAD).[11] Surface attack (called "Offensive Counterair Attack Operations" in JP 3-01) destroys, disrupts, or degrades enemy air and missile threats and their associated support infrastructure.[12] The goal of surface attack is to prevent employment of enemy air and missile weapons by attacking them before they are launched.[13] Fighter sweeps search for and destroy enemy aircraft, airborne missile launch platforms, and other airborne targets of opportunity.[14] Escorts protect friendly aircraft from enemy air-to-air and surface-to-air threats while over enemy territory. The escort mission supports other air missions such as interdiction, reconnaissance, airlift, search and rescue, aerial refueling, airborne command and control, and electronic warfare.[15] Suppression of enemy air defenses neutralizes, destroys, or temporarily degrades enemy surface-based air defenses by disruption or destruction.[16]

Defensive Counterair

According to AFDD 2-1.1, "DCA missions for fighters include high value airborne asset (HVAA) protection, point defense, and area defense."[17] Protecting HVAA encompasses the defense of "critical airborne theater assets such as Airborne Warning and Control System (AWACS), RIVET JOINT, and Joint Surveillance Target Attack Radar System (JSTARS)."[18] Point defense protects a limited area—typically vital elements of forces and installations.[19] Area defense protects a broad area and is usually conducted in coordination with a combination of weapons systems.[20] Having established the definitions and missions relevant to the air superiority fighter, as found in joint and USAF doctrine, it is now appropriate to discuss the operational goals of DOD transformation.

Air Superiority and the Operational Goals of DOD Transformation

QDR-01 identifies six operational goals that define the focus of DOD transformation efforts:

1. Protecting critical bases of operations and defeating chemical, biological, radiological, nuclear high-yield

explosive (CBRNE) weapons and their means of delivery
2. Assuring information systems in the face of attack and conducting effective information operations
3. Projecting and sustaining US forces in distant anti-access or area-denial environments and defeating anti-access and area denial threats
4. Denying enemies sanctuary by providing persistent surveillance, tracking, and rapid engagement with high-volume precision strike
5. Enhancing the capability and survivability of space systems and supporting infrastructure
6. Leveraging information technology and innovative concepts to develop an interoperable, joint command, control, communications, computers, intelligence, surveillance, and reconnaissance (C^4ISR) architecture and capability that includes a tailorable joint operational picture.[21]

The air superiority fighter, as envisaged, will fulfill each of these goals to varying degrees. These goals also provide insight into the capabilities that will be required of an air superiority fighter by DOD transformation. Appendix A summarizes how air superiority missions contribute to the operational goals of transformation.

The protection of critical bases of operation offers challenges that can be addressed in part by an air superiority fighter, especially those related to defense against CBRNE delivery systems. Base protection against CBRNE delivery systems is a task of DCA. The air superiority fighter must be part of a layered defense against airborne threats such as aircraft and cruise missiles. To be effective, this fighter requires advanced sensor systems with sufficient capabilities to meet low-observable cruise missile threats, such as the Apache and Storm Shadow/Scalp EG.[22] It must have significant air-to-air advantages over enemy airborne threats. It also requires the ability to communicate with ground-based air defense systems such as the Patriot; other airborne air defense systems such as the joint land attack missile elevated netted sensor system; and command and control (C^2) systems, such as AWACS. OCA also plays a role in base protection. Surface attack destroys enemy CBRNE delivery systems and their support infrastructure on the ground. Sweep, escort, and SEAD support joint force attacks on CBRNE assets. To perform these missions, the air superiority fighter must defeat threats as closely as possible to their origins. For this, it will need survivability. A new, highly capable air superiority fighter could make significant contributions to the joint effort in meeting the demands of the first operational goal of transformation—base defense.

The air superiority fighter will contribute to the conduct of information operations (IO). The four OCA missions—surface attack, sweep, escort, and SEAD—can ensure the air superiority required to conduct C^4ISR operations and airborne electronic attack and network attack over enemy airspace. In its DCA role, the air superiority fighter protects HVAA employed in IO and supports base protection, which indirectly contributes to offensive and defensive IO.

The air superiority fighter's most critical contribution is to the third operational goal of DOD transformation—projecting and sustaining US forces in distant, anti-access or area-denial environments and defeating anti-access and area-denial threats. This goal requires highly survivable platforms that not only can penetrate modern air defense systems but also can conduct all four OCA missions. Surface attack directly defeats anti-access threats from the enemy's air assets and surface-based air defenses at their origin. Sweep and escort allow friendly forces to move freely about enemy airspace to conduct other types of operations. Power projection is impossible without such freedom of movement. SEAD directly suppresses air defense systems such as antiaircraft artillery and SAMs. The presence of modern SAMs in future enemy anti-access schemes will require the air superiority fighter to possess significant survivability, including stealth capability, as well as advanced electronic attack and electronic protection measures. Projecting and sustaining US forces require a capable and survivable OCA air superiority fighter.

The US Air Force is developing a new concept of operations (CONOPS) that addresses power projection and sustainment in the modern anti-access environment. It is the global strike task force (GSTF) CONOPS. The *US Air Force Transformation Flight Plan* explains that the purpose of the

GSTF is to overcome enemy anti-access systems to gain and maintain access for follow-on joint forces.[23] "At the start of a conflict, it will 'kick down the door' into denied battlespace by rapidly degrading, and then defeating, the adversary's C^{4}ISR, anti-access weapons, CBRNE delivery systems, and threats to ground and naval forces, thus clearing the way for joint persistent follow-on operations."[24] The GSTF draft CONOPS describes the attack operations of the GSTF, highlighting the fundamental requirements for an air superiority fighter to participate in the GSTF.

> GSTF assets must have the capability to operate within anti-access environments and to . . . find, fix, track, target, engage, and assess (F2T2EA) the full spectrum of an adversary's anti-access capabilities to include: long-range air and missile defenses [and] mobile ballistic and cruise missiles. . . . The GSTF CONOPS requires the capability to independently locate, destroy, or suppress enemy interceptors and fixed or mobile air defenses using a mix of on or off-board sensors and weapons. . . . The GSTF CONOPS requires the capability to accomplish Time Sensitive Targeting involving anti-access threats despite operating in conditions where there may be extended distances between sensor, command/control, and shooter constellations.[25]

Clearly, this CONOPS calls for, among other things, an air superiority fighter to conduct the OCA surface attack, sweep, escort, and SEAD missions against enemy anti-access systems (SAMs, ballistic and cruise missiles, and airborne interceptors). This air superiority fighter must survive in the anti-access environment and be capable of engaging targets with or without the aid of off-board C^2 assets. GSTF envisions the air superiority fighter enabling the B-2 to operate freely, even in daylight conditions, creating a new "24-hour stealth" capability.[26]

Additionally, the *US Air Force Transformation Flight Plan* enumerates specific performance requirements for GSTF assets, of which the following are relevant to an air superiority fighter.

1. First look, first shot, first kill: Ability to detect, identify, shoot, and kill adversary air threats before they have a similar opportunity.
2. Low observability for penetrating strike assets versus radar, IR [infrared], acoustic and, to some extent, visual electro-optic sensors.

3. Survivability and countermeasures versus the air defense threat.
4. Onboard launch warning for enemy weapons employment.
5. Location and targeting of active air defense systems.
6. Precision striker sensors to accomplish solo F2T2EA and combat identification.
7. Precision attack against the GSTF target array.[27]

The requirements above may be summarized in three fundamental characteristics. The air superiority fighter for the GSTF must have superlative air superiority performance (in both air-to-air and precision surface attack), survivability, and sensors. The role of the sensor suite in fulfilling the air superiority fighter's role in the GSTF is critical. The GSTF CONOPS demands its strike assets have a highly capable, interoperable, and robust sensor suite.

GSTF CONOPS assets will employ a wide range of standoff and penetrating asset-based sensors and flexible command systems to provide accurate, timely, target-quality data to decision makers and cockpits. Using advanced data links, the GSTF CONOPS will leverage the sensors already mounted on strike assets to feed data into the theater picture. This use of GSTF CONOPS assets as sensors will also enable these assets survivability and rapid attack upon fleeting or time sensitive targets [*sic*].[28]

The GSTF CONOPS requires the air superiority fighter to be a sensor for the joint force theater picture. GSTF—the Air Force's CONOPS to meet the third operational goal of DOD transformation—requires an air superiority fighter with the capacity to strike heavily defended targets effectively and with the sensor and data link capabilities that allow it to function both autonomously and in conjunction with other systems.

In addition to OCA, the air superiority fighter has a DCA role in sustaining US forces in anti-access and area denial environments. Protection of HVAA assets like Rivet Joint, AWACS, and JSTARS will require an air superiority fighter that can defeat air-to-air threats and suppress or destroy surface-to-air threats before they can threaten our HVAA assets. SAMs with extended range (greater than 250 miles) missiles can threaten HVAAs in friendly airspace. [29] This threat makes survivability and the capability to detect and engage advanced SAMs key requirements for this air superiority fighter, even when originally tasked for the DCA role.

A new air superiority fighter is clearly demanded by the DOD transformation operational goal of projecting and sustaining US forces in distant anti-access or area-denial environments. GSTF is the USAF CONOPS created to meet this goal. As conceived by the Air Force, GSTF calls for an air superiority fighter to conduct air superiority operations with leading-edge, air-to-air and air-to-ground performance; survivability in the presence of sophisticated air defense systems; and a sensor suite that enables it to search for mobile targets, conduct electronic attack and protection, and operate either autonomously or in cooperation with other GSTF assets. This fighter also bears a corresponding DCA role in supporting this transformational goal.

The fourth operational goal of DOD transformation is to deny enemies sanctuary by providing persistent surveillance, tracking, and rapid engagement with all-weather precision strike against fixed and mobile targets. An air superiority fighter contributes to this goal through all four OCA missions. Surface attack provides highly survivable, rapid engagement of enemy air and missile assets, especially when coupled with a capable sensor suite. Sweep and escort allow airborne intelligence, surveillance, and reconnaissance (ISR) assets and other strike assets to move into enemy airspace and find critical targets. SEAD protects these assets from SAM threats. DCA protects HVAA intelligence, surveillance, and reconnaissance sensors operating in friendly airspace. To satisfy this operational goal, the air superiority fighter must have the air-to-air and air-to-ground performance, survivability, and sensor suite capacity discussed above.

Enhancing the capability and survivability of space systems and supporting infrastructure is the next goal of DOD transformation. The contributions of an air superiority fighter to this goal are somewhat limited. The air superiority fighter can be used for surface attack or air-to-air engagements to defend joint tactical ground stations or other deployed ground stations supporting friendly space assets. Again, there would be no unique performance requirement for defending space assets, as the requirements would be a function of the threat environment as in the previous discussions.

Leveraging information technology to develop a joint C^4ISR capability, including a tailorable joint operational picture, is an essential requirement for the transformational air superiority fighter. This air superiority fighter must be capable of autonomous and supported operations. The air superiority fighter acts as a shooter-turned-sensor, sharing data with the rest of the joint force. Because such a fighter will be fielded in far greater numbers than high-demand, low-density (HDLD) airborne sensors such as AWACS and JSTARS, it has the potential of adding to the joint air picture via sensor netting—a volume and quality of data unattainable today. Moreover, a new air superiority fighter with a capable sensor suite is highly valuable since it can survive in close proximity to targets of interest.

The Transformational Air Superiority Fighter

To this point, the operating assumption has been that only a fighter aircraft can satisfy OCA tasks (surface attack, escort, sweep, and SEAD). Other weapons systems are often mentioned as alternatives to a dedicated air superiority fighter such as the F/A-22.

Alternative Solutions

To determine whether an air superiority fighter is essential to the transformation of DOD, we must examine the alternatives—ground-based, sea-based, and other airborne alternatives such as cruise missiles, the airborne laser (ABL), and airborne high-power microwave. Space-based systems are a candidate for a future air superiority weapon, but discussion of them is deferred until later.

Ground-based systems such as artillery, the Army tactical missile system (ATACMS), and SAMs have the capability to conduct some OCA and DCA missions, but with limitations. Artillery systems and ATACMS can conduct surface attack and SEAD missions. However, they can only be used if friendly forces occupy ground within range of the targets. Likewise, SAMs, such as Patriots, can conduct

DCA missions but again only if the enemy threat is within the range of the system. Ground-based systems cannot feasibly conduct sweep or escort missions. Sweep and escort missions require the ability to engage throughout the entire theater airspace and respond to highly mobile threats. Ground-based assets can only do this in cases where enemy airspace is extremely limited, and the placement of ground-based assets is unusually advantageous. Refuelable airborne systems overcome these limitations by virtue of their ability to move freely and operate over a theater-wide area. Special operations forces (SOF)—another type of ground-based asset—can perform surface attack and SEAD missions, but, once inserted, they are limited in mobility and responsiveness to time-critical targeting contingencies.

Sea-based systems, such as AEGIS cruisers and destroyers and the Tomahawk cruise missile, have a degree of flexibility to perform some air superiority missions but are limited to operations within the range of their seaborne launch platforms. While the abilities of AEGIS systems to engage air threats and the Tomahawk to conduct surface attack across the littoral make them a critical element of the joint force, they cannot perform the full spectrum of air superiority missions throughout the entire theater.

Other airborne alternatives to an air superiority fighter include cruise missiles such as the joint air-to-surface standoff missile (JASSM), ABL, and airborne high power microwave. Cruise missiles such as JASSM are useful for surface attack and SEAD against fixed sites. Because they are bomb-on-coordinate weapons, cruise missiles are not appropriate for moving targets such as airborne threats and, therefore, cannot carry out sweep and escort missions. ABL presents an interesting alternative for the air superiority fighter. Designed for the tactical ballistic missile (TBM) threat, the ABL can bring lethal energy to bear over long distances at the speed of light. However, the ABL is a large aircraft and an HVAA. It is unlikely to be used over enemy airspace. Therefore, the ABL is subject to range limitations due to its lack of survivability. The fact that it is an HDLD asset limits its flexibility to address multiple air superiority demands. Ultimately, ABL technology should progress to the point of being hosted on smaller, numerous, flexible platforms—like the air superiority fighter.

Airborne high-power microwave, like airborne laser, holds promise for satisfying each air superiority mission. Like the ABL, this technology likely will be advanced to the state where it can be hosted, not on an HDLD platform, but on a flexible, survivable air superiority fighter.

Although alternatives to the air superiority fighter may be capable of executing the missions of surface attack, sweep, escort, and SEAD under certain conditions, no single class of weapon system currently has the capability and freedom of movement to conduct all these operations effectively throughout the theater, except for the air superiority fighter. Therefore, the remainder of this paper focuses on an airborne fighter solution to the air superiority requirement.

Requirements for the Air Superiority Fighter

Having laid the foundation of what an air superiority fighter does and how it can contribute to the operational goals of the DOD transformation, it is now appropriate to identify requirements such a fighter must meet to be relevant in the twenty-first century. These requirements are the capability to defeat advanced air-to-air and surface-to-air threats; to survive in an anti-access environment imposed by a modern IADS; and to participate fully as sensor and shooter within a modern warfare network.

Ability to Defeat Air-to-Air and Surface-to-Air Threats. The air superiority fighter must be able to defeat air-to-air and surface-to-air threats as well as TBMs and cruise missiles. In a 2001 *Aerospace Power Journal* article, Air Force chief of staff Gen John P. Jumper identified the Sukhoi Su-35 and Su-37 as air-to-air threats superior to the F-15C, the current US air superiority fighter.[30] More alarming are the highly capable SA-10 and SA-12 surface-to-air missile systems.[31] QDR-01 identifies cruise missiles as a major concern, as these long-range systems—some of which enjoy the benefits of low-observable technology[32]—may be used by the enemy to delay or deny US forces seeking access to overseas bases, airfields, and ports.[33] Defeating these threats requires several capabilities. To engage fighters beyond visual range requires, as seen in the GSTF requirement set, a first look, first shot, and first kill capability. Additionally, to engage advanced air-to-air fighters within visual range requires superior maneuverability. First look, first shot, and first kill require not only low observability but also superior radar range performance, speed, altitude capability, and air-to-air missile performance. Low observability works against the enemy's capability to achieve the first detection. Radar range performance works in concert with low observability to yield a first look. Speed and altitude extend the kinematic range of air-to-air missiles. Superior air-to-air missile performance works in conjunction with low observability, radar range performance, speed, and altitude to allow a first shot. Superior air-to-air missile performance is a function of aircraft speed and altitude at launch and missile aeronautical performance, onboard processing, and seeker and fusing performance. It ensures the first look and first shot result in a first kill.

To defeat modern SAMs, the fighter must first be survivable, meaning it must feature all-aspect low observability and have advanced electronic countermeasures (ECM). All-aspect low observability allows access in dense air defense environments, where it is not always possible to keep threats on the nose. Advanced ECM adds a margin of survivability. To defeat modern SAMs, the air superiority fighter must also have significant surface attack and SEAD capability. This means it must be capable of carrying munitions (while maintaining its low signature) and have the sensor suite required to find threats and carry out attacks on them.

Cruise missile threats drive many of the same requirements as air-to-air threats. To address cruise missiles, the air superiority fighter must have radar performance capable of detecting the incoming missile, which may be low-observable and operating at low altitudes, where ground clutter and terrain can degrade conventional radar performance. Additionally, the fighter's weapon suite must have the avionics and missile performance to support defeat of the cruise missile in flight. In summary, to fulfill its role of defeating air-to-air, surface-to-air, and cruise missile threats, the air superiority fighter requires superior aeronautical performance, surface attack capability, all-aspect low observability, electronic countermeasures, and advanced air-to-air missile avionics support and performance.

Survivability. Survivability in the presence of modern air defense systems is a major issue for the air superiority fighter in the twenty-first century. Requirements for survivability for the near future will be driven by the capabilities of the SA-10, SA-12, and SA-20 SAMs. The SA-10C (the North Atlantic Treaty Organization [NATO] designation for the Russian S-300PMU-1) is a highly capable surface-to-air system with a missile, the 48N6, which has a range of roughly 90 miles.[34] The S-300PMU-1 has been exported to China and Cyprus.[35] Russia is marketing an upgraded version, the S-300PMU-2, with the 125-mile range 48N62 missile, which is designed for TBM threats.[36] Russian design engineers are working on a further improvement to the S-300 series, the S-400 (NATO designation SA-20), with a missile range of 250 miles.[37] One Russian designer claims this newest generation of technology includes the capability to detect even stealth designs at 60 miles.[38] Countries that have S-300 series SAMs include Bulgaria, India, Iran, and most of the former Soviet republics.[39] Intelligence sources reportedly claim Syria, Iraq, and Libya are among the possible customers for these systems, which cost more than $100 million.[40]

Sensor-Shooter Capability. A transformational air superiority fighter must function as sensor and shooter within a modern warfare network. The airborne fighter must operate effectively with other members of the joint force within the JDN. It must communicate with other air defense assets in the air, on the ground, and at sea to defend our bases effectively against enemy aircraft and cruise missiles. It must receive data that will allow it to respond to mobile or emergent threats or targets of opportunity. Likewise, it must quickly pass threat data to other members of the joint force that are in a better position to address the threat. Finally, it must have the capacity to support and contribute to IO by acting as a capable and survivable sensor-shooter. Beyond being compatible with the JDN, the air superiority fighter must also have an exceptional onboard sensor capability.

The next generation air-to-air fighter must have a capable active-electronically-scanned-array (AESA) radar. AESA radar offers the air superiority fighter revolutionary performance, flexibility, autonomy, enhancements to survivability, and the ability to act as a network sensor. AESA radars are already being exported on US fighters, and foreign interests are now independently developing AESA radars.

AESA radar is a revolution in radar technology. It physically manifests the doctrinal tenet of centralized control and decentralized execution in that it distributes the function of the radar to hundreds or thousands of small independent but centrally controlled radars. This leap in capacity makes its host platform a capable autonomous sensor for the networked joint force. AESA radar is built from hundreds or thousands of low-power individual transmitter/receiver elements known as T/R modules.[41] These T/R modules are small, lightweight, and highly reliable. Each module combines highly miniaturized antenna and electronics assemblies. Advanced processors manage data from the hundreds to thousands of T/R modules to present an integrated picture to the pilot.[42]

AESA radar is a technological leap beyond conventional, mechanically scanned array (MSA) radar, which is comprised of a single high-power dish that acts as its transmitter and receiver. AESA radar yields greater detection range performance than MSA radar. Open source literature estimates the range of the AESA radar on the F/A-22 against a target with a one-square-meter radar cross section to be an astounding 125 nautical miles.[43] AESA radar is far more flexible than MSA radar since it can perform a wide variety of functions nearly simultaneously. This flexibility results from the fact that the beam is electronically scanned through independently controlled transmission modules rather than mechanically scanned by a single dish. That means the revisit rate—how quickly the radar can scan a particular part of the airspace scan volume—is not mechanically limited by a large gimbaled dish, but by the processing speed of the controller. Because AESA radar can scan and process data quickly, it can interleave several different waveforms with the result that it can perform dissimilar functions nearly simultaneously. These functions include the traditional air-to-air radar functions of scanning and tracking targets and guiding missiles inflight, along with more diverse tasks such as jamming, threat warning, surface attack,[44] and ground mapping.[45]

With its ability to support so many combat functions simultaneously, AESA radar gives the air-to-air fighter the ability to act without support of off-board electronic support (e.g., jamming) or off-board C^2. This capability to act autonomously in the opening engagements of an air campaign is an essential element of GSTF. AESA radar also enhances the fighter's survivability by controlling side-lobes and beam width as well as by transmitting radar pulses that are agile in frequency and exhibit different waveforms from pulse to pulse.[46] This manipulation reduces the ability of enemy observers to detect the aircraft from its radar emissions.[47] Finally, AESA radar gives the air superiority fighter an important contribution to the joint force by acting as a network sensor. The air superiority fighter will use its AESA radar to collect and process electronic data to provide threat location, target tracking, bomb damage assessment, and other critical reconnaissance data to the joint force.[48]

Because AESA radars are configured on several export aircraft and because foreign interests are developing their own AESA radars, the air superiority fighter must have an AESA radar to establish air superiority in an environment where this technology is proliferating. AESA radars are featured on several US exported vehicles. These aircraft include the F-16 Block 60 (which is being exported to the United Arab Emirates[49] and is one of the aircraft being considered by Singapore in its future fighter competition[50]); the F-15K (which is being exported to South Korea,[51] and a version of which is also competing for the Singapore fighter[52]); and the F/A-18E/F (which has wide approval for export and is a candidate in the Singapore competition[53]). Additionally, a European consortium (comprised of EADS, Thales, and BAE Systems) is developing its own AESA radar.[54] Since US-built fighters with AESA radars will be exported within the next 10 years, and with the development of a competing European system, AESA radars will become standard configuration items for air superiority fighters worldwide. Given the extraordinary capabilities of AESA radar, the US air superiority fighter must have an AESA radar that is not only survivable but also dominant in its air superiority mission.

The Air Superiority Role: A Comparison of the Competitors

There are several candidates to achieve the air superiority requirements driven by DOD transformation. The alternatives examined here are the F-15C/E, F/A-22, F-35A, UCAV, and an advanced space-based system called the common aerospace vehicle. The requirements are superior air-to-air and air-to-ground performance, survivability against modern air defense threats, and a sensor suite that allows the fighter to act autonomously or as an active part of the JDN. Appendix B summarizes how each candidate measures against these requirements.

F-15C/E

The F-15C/E does not satisfy all the requirements for a transformational air superiority fighter. It does not exhibit the aeronautical performance required for air-to-air dominance against threats like the MiG-29, Su-27, and Su-35/37. The F-15C does not carry out surface attack OCA missions. The F-15E is able to conduct surface attack missions, as well as other air superiority missions, but its increased weight over the F-15C reduces its aeronautical performance. The F-15C/E does not have the low observability required to make it survivable in the modern air defense environment. However, it does have the capability of hosting an advanced sensor suite compatible with the JDN. Still, the newest F-15Cs will be 20 years old in 2007 and nearing the end of their current service life (8,000 hours), which is twice the original specification.[55] On balance, the F-15 cannot continue to serve as America's frontline air superiority fighter after 2007.

The US Air Force and some defense observers judge that the F-15C will not be able to compete against next-generation fighters. In a 1998 interview with *Aviation Week and Space Technology*, Gen Richard Hawley, commander of Air Combat Command, said, "the F-15 will not be able to operate effectively against upcoming threats such as four-and-a-half- and fifth-generation fighters like the Eurofighter and Rafale and upgraded versions of the Sukhoi Su-27."[56] According to the Federation of American Scientists, "simulations conducted by British Aerospace and the British Defense Research Agency compared the effectiveness of the F-15C, Rafale, EF-2000, and F-22 against the Russian Su-35. The Rafale achieved a 1:1 kill ratio. . . . The EF-2000 kill ratio was 4.5:1 while the F-22 achieved a ratio of 10:1. In stark contrast was the F-15C, losing 1.3 Eagles for each Su-35 destroyed."[57] Some argue these deficiencies can be addressed through radar and avionics upgrades. However, improvements in aeronautical performance (acceleration, maneuverability, engine thrust, and rate of climb) and radar cross-section are more difficult to make without significantly changing the airframe. The inefficiency of making these kinds of upgrades to a platform that has been operational since 1979—and was last built in 1986[58]—makes fielding an entirely new and more capable fighter a more viable option. The F-15E performs air-to-ground missions like surface attack OCA and other air superiority missions. However, its increased weight over the F-15C compromises its performance against other air-to-air fighters.[59] Its survivability and sensor suite characteristics are similar enough to the F-15C to merit no further separate discussion of the F-15E.

The Air Force does not believe the F-15 will be survivable against modern air defense threats like the SA-10, SA-12, and SA-20. In the same interview cited above, General Hawley noted F-15Cs will not be capable of handling SA-10 or SA-12 threats.[60] General Jumper, in a 1999 interview conducted when he was commander, US Air Forces Europe, affirmed that the introduction of SA-10s and SA-12s into Kosovo would have "changed the landscape of [Operation ALLIED FORCE] significantly,"[61] dramatically increasing the threat to conventional platforms like the F-15C. Although actual radar signature data and threat system performance are classified, its fielding predated the operational fielding of stealthy platforms like the F117. Although conventional aircraft can be modified to achieve some degree of stealth, they cannot achieve the same low-observable signature performance of an aircraft designed for stealth from the outset, like the F-117. Once the basic physical configuration of the airframe is determined, design trade-offs required for signature reduction—such as platform alignment; materials selection; and design of leading edges, nozzles, intakes, access panels, and myriad other critical details—are no longer feasible.[62] Thus, not only is the F-15C not survivable against modern air defense threats but low observability treatments to it are unlikely to give it the signature performance available to a new air superiority fighter designed for stealth from the outset.

The F-15C can be upgraded to have the sensor performance required to be a transformational air superiority fighter. The Air Force has already upgraded 18 F-15Cs in the 3d Fighter Wing at Elmendorf Air Force Base, Alaska, with the APG-63(V)2 AESA radar.[63] Additionally, it is considering a fleetwide upgrade to the APG-63(V)3 AESA radar.[64] Some critics of the F/A-22 assert that these radar upgrades are sufficient to provide the air superiority needs of the future.[65] However, this judgment ignores the fact that more than radar detection performance is required to attain first look, first shot, and first kill capability against enemy fighters. Without a stealthy signature, improvements to the F-15 radar are not enough to make it a survivable and dominant air superiority fighter. Given the age of the F-15C airframes, the existence of non-US air superiority fighters with better performance than the F-15C and the proliferation of modern SAMs, the F-15C/E cannot meet the requirements to be the US air superiority fighter after 2007.

F/A-22

The F/A-22 not only meets all the operational requirements for a transformational fighter, but its initial operating capability (IOC) date of 2005 makes it the best near-term solution for a twenty-first century fighter.[66] Its outstanding aeronautical performance, stealthy signature performance, and advanced avionics, including an AESA radar, make it extremely capable in its role as an air superiority fighter.

The *US Air Force Transformation Flight Plan* summarizes how the F/A-22 (called the F-22 at time of its publication) meets Air Force transformational goals and the requirements outlined in this paper to meet operational goals of the DOD.

> The F-22 Raptor combines into one platform multiple capabilities—such as air dominance, negation of enemy air defenses, precision attack, supercruise, advanced all-aspect stealth, and information integration—that previously required many separate aircraft. . . . In addition, when modified with an air-to-ground radar and armed with the Small Diameter Bomb, the F-22 can . . . take out critical, highly defended targets at the outset of conflict, especially enemy air defenses armed with advanced SAMs. . . . Its ability to "supercruise" without afterburner above Mach 1.5 makes it the ideal air-to-ground platform to dramatically shorten the time between finding a rapidly moving target and destroying it . . . This capability will also dramatically improve the ability to shoot down cruise missiles over a large area of airspace, contributing immensely to effective theater missile defense . . . The F-22, with its stealth, extreme lethality, first-look/first-kill capability, high mission capable rates, and low logistical requirements, will be critical to achieving air superiority into the foreseeable future.[67]

The F/A-22 would also meet transformational requirements for sensor contributions to the JDN. With the APG-77 AESA radar, the F/A-22 will make an exceptional impact on joint force capabilities, especially with its capability against elusive cruise missiles.[68] The F/A-22 meets all operational requirements for a transformational air superiority fighter.

F-35A

The F-35A, the Air Force version of the joint strike fighter, is not an acceptable candidate for an air superiority fighter.[69] The F-35A is highly capable of fulfilling surface attack and SEAD missions, but it is not designed to fulfill the air-to-air sweep or escort missions. Additionally, its IOC date of 2011 creates a gap in air superiority performance as the F-15C exceeds its service life and becomes less capable of filling the air superiority role.[70]

The USAF does not consider the F-35A an air superiority fighter. Within the construct of the GSTF, the F-35A is part of the joint follow-on forces that are brought into the fight only after the first wave of highly survivable GSTF strike assets are brought to bear.[71] The F-35A—designed for a range of missions such as close air support—cannot achieve the F/A-22's level of stealth and air-to-air performance.[72] Although it can function in surface attack and SEAD missions, it is not currently expected to fulfill sweep or escort missions.

Nevertheless, with regard to its ability to function as a sensor in the JDN, the F-35A, with its next-generation AESA radar, will likely exceed the capability of the F/A-22 for some while.[73] The following excerpt from the *US Air Force Transformation Flight Plan* describes the F-35A's capability.

> The F-35A incorporates an advanced "Multi-Function Array," which employs a number of multi-spectral sensors and transmitters to provide high-resolution detection, recognition, and jamming of air and ground targets . . . The F-35A will provide persistent battlefield stealth, day and night, in adverse weather conditions, to attack and destroy a broad range of mobile and heavily defended targets and offer vastly increased close-air-support capability to ground forces. The F-35A will have a SEAD/Destruction of Enemy Air Defenses (DEAD) role in the 2015 timeframe. The combination of stealth, internal weapons carriage, and sensor array, including airborne electronic attack, will give it a robust capability in this role.[74]

Coupled with the fact that thousands of F-35As will be fielded,[75] this sensor suite will make the F-35A a vast and highly capable sensor array for the JDN. Even though the F-35A will have superior air-to-ground capability, significant level of low observability, and exceptional sensor suite, it is not designed for OCA sweep and escort missions. As a result, it cannot be considered a transformational air superiority fighter.

Uninhabited Combat Aerial Vehicle

The uninhabited combat aerial vehicle (UCAV), like the F-35A, has limited suitability as an air superiority fighter because it is not designed for an air-to-air role. The UCAV is a developmental program to field airborne strike capability on a stealthy unmanned aerial vehicle. It is programmed for an IOC of 2008.[76] The *US Air Force Transformation Flight Plan* describes the purpose and benefits of the UCAV program.

> The Air Force UCAV program is intended to field a highly survivable light attack aircraft. . . . Current Air Force plans emphasize application for SEAD. . . . UCAVs will increasingly take over the combat missions of manned vehicles today, especially those involving high risk, high-priority targets that are critical to defeating an adversary's anti-access strategy. The advantages of UCAVs are obvious. They would put no aircrews in harm's way, especially during very dangerous missions. They are not restricted by human physical limitations. . . . They can loiter far longer over the battlefield and operate at greatly increased ranges enabling time-critical targeting of moving targets. Finally, more platforms with increased capability can be built with less money.[77]

The UCAV will satisfy many of the requirements for the transformational air superiority fighter. It will have the capability to conduct surface attack and SEAD missions. It will be survivable. It should make a significant contribution to the joint force as a sensor-shooter—it has greater potential than manned aircraft because greater numbers of them may be fielded. In addition, the UCAV is envisioned for electronic attack, with some speculation that it could ultimately host a high-power microwave weapon.[78] However, currently there is no plan to make the UCAV an air superiority fighter, capable not only of strike and SEAD but also sweep and escort. Consequently, the UCAV, as currently envisioned, is not a candidate for the transformational air superiority fighter.

However, it is conceivable that a next-generation UCAV (2025, assuming a 15-year procurement cycle starting in 2010) could be developed with air-to-air capability that would satisfy all air superiority missions, including sweep and escort. This would be a major transformation for UCAV operators. The addition of air-to-air missions would significantly complicate training. For beyond visual range engagements, the additional mission would be difficult enough, but for close engagements requiring maneuvering tactics, the training required to produce the skill and incentive to win against an enemy with more inherent incentive to survive (a manned vehicle) will be truly challenging. In summary, UCAV, as envisioned for IOC in 2008, does not meet requirements for a transformational air superiority fighter. With changes to the weapon system concept and the requisite change to operator training, UCAV holds promise in the far term (2025) to provide a capable and prolific air superiority fighter.

Space-Based Systems

Space-based systems hold promise for some air superiority tasks but are unlikely to fulfill the requirements of sweep and escort missions. Today's space-based systems are focused on the mission areas of space control, force enhancement, and space support—none of which address directly attacking terrestrial-based targets, a mission area called space force application. According to Joint Publication 3-14, *Joint Doctrine for Space Operations*, "currently there are no space force application assets operating in space."[79] However, the Air Force has proposed a future system called the common aerospace vehicle in its *Transformation Flight Plan*.

> The Common Aerospace Vehicle is an advanced space delivery vehicle capable of delivering and dispensing conventional payloads worldwide from and through space. The [CAV] is deployed as a prompt response, precision accuracy weapon system to engage the enemy anytime and anyplace without advanced deployment. Prompt response permits action in the initial phases of conflict to strike high-value, time-critical, or heavily defended targets in advance of or complementing expeditionary forces. . . . The [CAV]'s speed and maneuverability combine to make defense extremely difficult. Planned payloads include the small diameter bomb, unmanned aerial vehicles, wide area search autonomous attack miniature munition, and a unitary penetrator. . . . The common aerospace vehicle can also support area surveillance, SEAD, and anti-personnel missions with appropriate payloads.[80]

Clearly, the CAV is designed for surface attack and SEAD, but does not lend itself to air-to-air missions of sweep or escort. However, CAVs could be used as a platform to dispense a UCAV to perform these missions. Nevertheless, it is unlikely that the common aerospace vehicle would be used directly in air-to-air engagements. Finally, one can conceive of a space platform to do all air superiority missions. This could be a space-based weapon that uses directed energy or kinetic kill devices against air and surface targets. Many technological and legal hurdles stand in the way of making this a reality.

Although future space-based systems may be able to conduct surface attack and SEAD missions, they do not lend themselves to the OCA missions of sweep and escort. The proposed common aerospace vehicle will be able to conduct strike missions and may be able to carry UCAVs to perform other air superiority missions. Nevertheless, space systems are unlikely to fulfill the need for an air superiority fighter.

Conclusions

The United States cannot meet its operational goals for DOD transformation without a new air superiority fighter. This fighter must have the capability to defeat advanced air-to-air and surface-to-air threats, survive in an anti-access environment imposed by a modern IADS, and function as sensor and shooter within a modern JDN. The only weapon system able to meet all these requirements by 2007 is the F/A-22 Raptor. The UCAV holds promise as the future generation air superiority fighter (2025)—given some major changes to the weapon system concept and training. Even in this age of transformation, air superiority is still required for bringing forces to bear successfully in theaters of conflict. The operational goals of DOD transformation demand a highly capable air superiority fighter with wide-ranging capabilities. The only system capable of fulfilling these demands within the next five years is the F/A-22 Raptor.

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Appendix A

Air Superiority Missions versus Transformational Goals

Air superiority missions	Protect Critical Bases	Assure Information Systems	Project and Sustain US Forces	Deny Enemies Sanctuary	Protect Space Systems	Develop Joint Operational Picture
OCA						
Surface attack	Defeats airborne threats to bases at source	Destroys ground-based threats to ISR assets	Defeats airborne threats at source	Direct strike capability on enemy forces	Destroys ground-based threats to space systems	Sensor-shooter part of joint data network
Fighter sweep and Escort	Defeats airborne threats to bases at source and supports joint attack on these threats	Defeats airborne threats to ISR assets	Protects friendly airborne assets operating in enemy airspace	Defeats enemy ISR assets and airborne threats to friendly ISR assets	Defeats airborne threats to space systems and supports joint attack on these threats	Same as surface attack
SEAD	Defeats SAM threats to forces attacking threats to bases	Defeats SAM threats to ISR assets	Defeats SAM threats to airborne assets	Defeats SAM threats to airborne assets	Defeats SAM threats to forces attacking enemy threats to space systems	Same as surface attack
DCA	Defeats inbound airborne threats to bases	Protects HVAA ISR assets in friendly airspace	Defeats inbound airborne threats to forces	Protects HVAA assets in friendly airspace	Protects ground-based support for space assets	Same as surface attack

Appendix B

Comparative Capabilities of Air Superiority Fighter Candidates

Candidates	Air-to-Air	Air-to-Ground	Survivability	Sensor Suite	IOC
F-15C	Insufficient	None	Insufficient	Insufficient but can be upgraded	Current
F-15E	Insufficient less than F-15C	Excellent	Insufficient	Insufficient but can be upgraded	Current
F/A-22	Superb	Superb	Superb	Superb	Current
F-35A	Insufficient	Excellent	Excellent but less than F/A-22	Superb-better than F/A-22	2011
UCAV	None; can be upgraded to give beyond-visual-range capability; Unlikely to yield maneuvering air-to-air capability	Adequate	Excellent	Adequate	2008
Common Aerospace Vehicle	None; can conceivably release UCAVs with air-to-air capability	Adequate	Adequate	Adequate	Unknown