WHY RAPTOR?

THE LOGIC OF BUYING THE WORLD'S BEST FIGHTER

Lexington Institute

EXECUTIVE SUMMARY

The U.S. Air Force has developed a replacement for its top-of-the-line F-15 fighter called the F/A-22 Raptor. Raptor flew for the first time in 1997 and is now entering high-rate production. This study explains the missions that Raptor will accomplish, the capabilities it will deliver, and the costs it will incur. The study was written by Dr. Loren B. Thompson of the Lexington Institute staff.

Missions — Raptor's most important mission is to assure U.S. global air dominance for the next 30 years. Air dominance enables every other facet of joint warfare. In addition, Raptor will be able to conduct precision strikes against ground targets, theater defense of coalition forces, electronic warfare, information warfare, and tactical reconnaissance.

Threats — Current U.S. fighters are losing their capacity to assure air dominance against foreign tactical aircraft and surface-to-air missiles. For example, U.S. fighters suffered severe losses in joint exercises with the air force of India during 2004. The Russian SA-20 is one of several mobile, integrated air-defense systems that provides developing countries with very effective protection against non-stealthy fighters at an affordable price.

Characteristics — Raptor provides U.S. forces with a highly maneuverable airframe that cannot be tracked by enemy radar, heat-seeking sensors or other means. Its powerful twin engines, combined with vectored thrust and supersonic speed at reduced rates of fuel consumption, further enhance aircraft survivability. The advanced weapons and sensors carried on Raptor far surpass the technology of likely adversaries, and can accomplish a range of information-age missions beyond the scope of Cold War fighters.

Capabilities — Raptor is designed to operate as part of Aerospace Expeditionary Forces in support of joint military campaigns. Its design features permit "first look, first shot, first kill" against fighters seeking to deny access to enemy airspace. They also have the capacity to quickly find, fix, track and attack mobile air defenses on the ground. Once Raptor has assured the access of friendly aircraft to hostile airspace, it then can shift to other missions such as destroying weapons that threaten coalition ground forces.

Costs — The cost of acquiring Raptor is currently estimated at $72 billion in 2004 dollars, most of which has been spent. That total may rise in order to increase the number of aircraft produced and enhance the baseline design for a wider array of missions. The recurring cost to build each Raptor currently stands at $110 million in 2004 dollars, which does not include $20 million for engines.

Numbers — The Air Force requires 381 Raptors in order to equip each of ten Aerospace Expeditionary Forces with a squadron of such aircraft. Providing each expeditionary force with an identical complement of fighters is necessary to sustain prolonged overseas deployments through a series of force rotations. Failure to purchase at least 381 Raptors would undercut Air Force plans to assure global air dominance into the fourth decade of the current century.

The unique shape of the F/A-22 enables it to be the stealthiest, most maneuverable tactical aircraft ever built.

WHY RAPTOR?

During the waning days of the Cold War, the United States Air Force began developing a next-generation fighter to replace its top-of-the-line F-15 Eagle. The new fighter came to be known as Raptor, and it flew for the first time in 1997.

Raptor was conceived to assure that the United States would have unfettered access to foreign airspace during the first three decades of the new millennium. Its role was to elude and destroy enemy fighters, surface-to-air missiles and other weapons posing a threat to coalition forces. Once Raptor had secured contested airspace, less survivable aircraft – bombers, transports, radar planes – could bring the full weight of American air power to bear against enemies.

Raptor was the latest in a long series of fighter programs aimed at sustaining America's global air dominance. U.S. "command of the air" was so complete in the postwar period that no U.S. soldier had been killed by hostile aircraft since the Korean War,

Aerial refueling can extend the combat range of a Raptor to thousands of miles.

and no U.S. plane had been shot down by a hostile aircraft since the Vietnam War.

But because Raptor was designed to counter the aircraft of the Soviet Union – the most capable enemy of the day – some questioned the need for a sophisticated new fighter once communism collapsed.

There is no question that threats have changed. However, the requirement for a highly survivable and lethal fighter remains. Air dominance enables every other facet of joint warfighting, and Raptor is uniquely capable of executing new missions that have emerged in the post-communist period.

This study concisely describes the missions that Raptor will accomplish, the capabilities it will carry, and the costs it will incur. The study also explains why failure to purchase an adequate force of Raptors could result in military defeat for U.S. forces in the early decades of the new millennium.

F/A-22 Raptor in flight maneuvers over the Sierra Nevada Mountains.

CORE MISSIONS

Since they first appeared in the skies over the Western Front in World War One, the main mission of fighters has been to combat other aircraft. They often are referred to as "tactical" aircraft because they are supposed to shape the setting in which friendly planes and surface forces can prevail, rather than delivering the strategic blow that wins a war.

At its inception, the primary mission of the Raptor was similar to that of previous fighters – to sweep the skies over future battlefields of enemy planes so that U.S. forces could operate without the danger of being attacked from the air. However, as threats and technologies have evolved, Raptor has gradually taken on additional missions – so much so that its military designation was changed in 2002 from F-22 to F/A-22 ("F" for fighter, "A" for attack), symbolizing that it was far more than simply a fighter.

Air dominance remains the Raptor's overriding mission, but a complete compendium of its future roles today includes six overlapping clusters of wartime activity:

Air dominance/air superiority – which means defeating enemy fighters and surface-to-air missiles so that U.S. forces can focus on taking the war to the foe rather than being pre-

Older aircraft such as these Russian Su-30's can defeat current U.S. fighters if new weapons and electronics are combined with superior numbers.

occupied with defending themselves against air attacks; air dominance is usually a prerequisite for effectively waging other forms of warfare.

Precision strike — which means exploiting stealth, speed, and agility to penetrate enemy defenses in search of high-value surface targets that can be destroyed with pinpoint accuracy using Raptor's precision munitions; some of the targets, like command bunkers, may be far behind enemy lines.

Theater defense — which means destroying missiles that can be launched from remote sites against friendly surface forces; in the case of ballistic missiles, Raptor would attack launch complexes before the missiles could be fired, whereas in the case of cruise missiles the attacks would occur mainly while the missiles are in flight.

Electronic warfare — which means the active suppression of enemy electronic sensors and communications; Raptor is equipped with an array of systems that can detect, interpret, jam and manipulate hostile electromagnetic emissions in support of the joint force without revealing its location.

Information warfare — which means penetrating enemy computer systems with the purpose of denying information critical to effective warfighting or spreading misinformation; Raptor's heavy on-board processing capability and capacity to operate near enemy information nodes gives it unique infowar potential.

Tactical reconnaissance — which means the ability to collect intelligence useful to forces in the field; Raptor carries a range of sensors for collecting signals intelligence that can provide the basis for immediate military action by the collecting plane or be transmitted to other locations for further assessment.

Despite continuous upgrades since it was designed in the 1960's, the U.S. F-15 no longer has an assured edge over foreign fighters.

EMERGING THREATS

In the decade that followed collapse of the Soviet Union, American air power enjoyed huge operational advantages over the forces of foreign nations. During that period, it became fashionable among military planners to speak of U.S. air dominance rather than mere air superiority.

However, even in the 1990's there were signs that the U.S. edge might be hard to maintain. During the 1999 Balkan air war, Serbian defenses downed a first-generation F-117 stealth fighter and greatly reduced the access of other NATO planes to Serbian airspace. In the early weeks of the war, the U.S. Air Force flew B-2 bombers on very long missions from Missouri to the Balkans because it was the only plane in the NATO arsenal that combined the survivability of second-generation

stealth technology with the satellite-guided munitions needed to hit targets precisely through cloud cover.

The U.S. advantage in the air has deteriorated steadily since then, due partly to the slow pace of military modernization in America and partly to technological advances overseas. Although the U.S. outspends the rest of the world on new military technology, it has only fielded a handful of modern fighters since the 1990's. The Air Force's top fighter, the F-15C Eagle, first flew in 1979. The Eagle has been upgraded since then, but it is essentially a thirty-year-old design that lacks many of the features now considered most desirable in fighters. It is also exhibiting signs of age, from metal fatigue to corrosion to parts obsolescence.

The most worrisome evidence of emerging challenges to U.S. air dominance is kept secret by intelligence agencies. In general though, emerging threats can be separated into three categories: (1) fighters that match or surpass the performance of U.S. tactical aircraft; (2) surface-to-air weapons capable of killing U.S. aircraft at considerable distance; and (3) long-range weapons such as cruise missiles that, while not directly threatening U.S. planes in flight, have the capacity to destroy bases of operation or forces depending on U.S. air cover for protection.

In terms of foreign fighters, several nations are now deploying and exporting tactical aircraft such as the Russian Su-35 Super Flanker that are the equal or superior of the F-15C in performance measures such as range, maneuverability and radar detection. In addition, many nations are modernizing older fighters with state-of-the-art sensors and weapons that minimize U.S. operational advantages. The latter trend became strikingly apparent in exercises held between the U.S. and Indian air forces in early 2004; U.S. F-15C's were repeatedly defeated by a combination of upgraded Cold War fighters, innovative tactics, and superior adversary numbers – precisely the circumstances that might arise in real conflicts.

In terms of surface-to-air missiles, many nations now possess heat-seeking and radar-guided weapons that can down non-stealthy aircraft at great distances. For example, the Russian SA-20 missile engages fast-moving airborne targets with reduced radar "signatures" at distances in excess of 200 miles. At a cost of about $110 million, purchasing countries can acquire two dozen SA-20 missiles, six mobile launchers, radars and command vehicles for an integrated air defense network. Other missiles being built for export by Russia, China and European states have less range, but greater probability of kill. It is unlikely that existing U.S. fighters – much less other military aircraft – could safely transit airspace defended by such weapons.

The F/A-22 will be the only aircraft in the U.S. fleet combining state-of-the-art stealth, vectored thrust and supercruise speed.

AIRCRAFT CHARACTERISTICS

Raptor was designed to outperform any fighter likely to be fielded by a foreign nation for the foreseeable future (roughly into the fourth decade of the present century). Its stealth and agility also will enable it to elude advanced surface-to-air weapons and directed-energy devices deployed by enemies during the same period. This section describes the design features facilitating Raptor's superior performance; the following section describes how those features translate into operational capabilities.

Airframe — Raptor's airframe is constructed mainly of titanium (39%) and composites (24%), both of which have better strength-to-weight characteristics than the aluminum (16%) traditionally used in fighters. The shape and composition of the airframe was selected to provide

maximum maneuverability while minimizing observability to radar, heat-seeking sensors and other methods of detection. In basic combat configuration, the airframe's radar cross-section is roughly that of an aluminum marble – a thousandth of a square meter, compared to several square meters for existing fighters. A radar that could detect current fighters at a distance of 120 miles would not see Raptor until it was 15 miles away (assuming no additional measures to mask the plane's location).

Propulsion – Raptor is equipped with two F-119 turbofan engines designed to sustain supersonic speeds without resorting to fuel-consuming afterburners. This feature, called supercruise, substantially increases the range and survivability of the plane. It also has a "thrust-vectoring" system that directs exhaust so that the plane can make tight turns at high speed. But Raptor is not designed to perform well just at extreme velocities: it can fly as slow as a single-engine Piper Cub, and outperforms existing fighters across the full range of operating regimes.

Weapons – Raptor is designed to carry all of its weapons internally rather than on wing stations where they would generate radar returns and aerodynamic drag. Although there are hardpoints on the wings to accommodate munitions, the normal configuration for fighting hostile aircraft would be to internally load six radar-guided and two heat-seeking air-to-air missiles. U.S. air-to-air missiles typically have better performance characteristics than foreign counterparts. For precision-strike missions, two 1,000-pound, satellite-guided glide bombs are substituted for four of the radar guided missiles. A smaller version of the satellite-guided bomb is being developed that would enable Raptor to destroy up to eight surface targets in a single flight. The glide bombs can be dropped fifteen miles from targets, and have an accuracy of about ten yards.

Sensors – The unprecedented computer capacity carried on Raptor enables the aircraft to assimilate timely information from a wide range of sensors, both on-board and off-board. The sensor usually described in open sources is the main radar – an electronically steered array that can simultaneously provide surveillance, fire control, jamming and other functions. However, Raptor also carries other sensors such as an infrared surveillance and tracking system that are seldom discussed. The sensors are integrated into Raptor's airframe in a way that preserves stealth but affords all-aspect awareness of any threat or target of opportunity. In effect, the entire aircraft is an antenna. The sophistication of the sensors is such that they can be used as offensive weapons in coping with certain types of electronic threats.

The outer skin of the F/A-22 contains embedded sensors that provide pilots with unparalleled situational awareness.

AIRCRAFT CAPABILITIES

The design features of the Raptor provide operational capabilities essential to the successful prosecution of future conflicts. In 1999, the Air Force reorganized its combat units into ten "Aerospace Expeditionary Forces" structured to support the rapid projection of global air power in support of joint military campaigns. The basic idea behind these forces was that they would integrate all the systems and competencies necessary to achieve a range of tactical objectives. Diverse aircraft and personnel would train together and go to war together, rather than being assembled on an *ad hoc* basis on the eve of conflict.

Although Aerospace Expeditionary Forces are typically tailored to the requirements of a particular campaign, in all operations other than humanitarian relief fighters are likely to play a central role. It is fighters that establish early air dominance so that other aircraft can function safely, and, at least during the early days

of conflict, it is often fighters that are best-suited to attacking the most heavily defended surface targets. Raptor is designed to assure that these roles can continue to be accomplished as the survivability of Cold War fighters gradually fades during the early decades of the new millennium.

With regard to asserting air dominance, Raptor's combination of a stealthy airframe, agile flight characteristics, advanced weapons and sophisticated sensors provides what the Air Force calls "first look, first shot, first kill." In other words, Raptor will see hostile aircraft before it is detected, fire weapons before it is targeted, and destroy enemies before it is endangered. In many cases, enemy pilots will be killed before they are even aware that they are under attack.

A similar fate awaits the ground crews operating air defense networks. The most capable surface-to-air weapons are usually netted together with their radars and command elements in what is called an "integrated air defense." The key components of such networks are almost always mobile and/or disguised. Raptor is designed to find, fix, track and attack these assets without revealing its own location. Sometimes the suppression of air defenses will be carried out with precision munitions and other times it will be accomplished electronically, but either way the result is that adversaries rapidly lose control of their airspace.

Once air dominance is accomplished, Raptor's role can shift to strikes against a wider range of enemy assets. Unlike other stealthy combat aircraft in the U.S. arsenal, Raptor offers supersonic speed, high maneuverability and low observability even in daylight hours. That means it can attack surface targets around the clock, often in circumstances where the adversary does not have enough time to react effectively to the threat Raptor poses. Raptor's unique capabilities will exert a powerful deterrent effect on many potential aggressors. If countries persist in pursuing aggression, though, the military costs they will incur in trying to cope with an aircraft like Raptor – denser defenses, dispersed command centers, and so on – will be quite imposing.

The targets most likely to be attacked by Raptor other than air defenses are weapons posing a threat to friendly surface forces or the American homeland. These weapons will probably be ballistic missiles that must be destroyed at their point of origin or cruise missiles more likely to be intercepted in flight. Raptor is the only tactical aircraft in the U.S. inventory likely to accomplish multiple shots against cruise missiles in an overseas environment where they might be attacking from any direction (paths of attack against the homeland are more predictable). Whatever the assets that Raptor attacks, its lethality will be bolstered by its multifaceted situational awareness and the digital datalinks that enable networked operations behind enemy lines.

The F/A-22's engines will provide superior performance across the full range of operating regimes while being easy to maintain.

FUTURE ENHANCEMENTS

When the idea of a stealthy replacement for the F-15C Eagle was first conceived in the early 1980's, Air Force planners envisioned an aircraft dedicated almost entirely to the task of defeating future Soviet fighters. By the time a winning design was selected in 1991, though, it was apparent that the Soviet Union was in terminal decline. The Air Force therefore began expanding the range of Raptor missions to include precision strike, electronic attack and information warfare. The process of rethinking Raptor's roles has continued ever since, in response to new threats, new technological opportunities, and new operating concepts.

Given the dynamic nature of national-security requirements in the post-Cold War period, the Air Force now anticipates nearly continuous modifications to the basic Raptor airframe and architecture over the course of

its service life. Other aircraft types such as radar planes and tankers will probably undergo a similar process, although on a less intensive basis. The first major modification of Raptor began in 2003, before the plane had even achieved operational status. Four additional "spirals" are expected over the next dozen years:

In 2007, the service will begin converting Raptor to a "global strike basic" configuration that improves air-to-air capabilities and permits release of glide bombs at higher speeds and greater distances from targets.

In 2011, a further conversion to "global strike enhanced" will occur involving integration of additional air-to-ground munitions and enhanced radar capabilities for attacking ground-based air defenses.

In 2013, the "global strike full" configuration will be funded that will bolster Raptor's capacity to suppress or destroy the full range of air defenses while also increasing the speed and precision of targeting.

In 2015, an "enhanced intelligence, surveillance and reconnaissance" capability will be added to broaden the array of targets that can be attacked and further enhance lethality.

Although each of these changes represents a relatively modest evolution of aircraft capabilities, they cumulatively transform Raptor into a radically different warfighting system from the fighter that first flew in 1997. One indication of how profound this transformation will be is that the final two spirals in 2013 and 2015 cannot occur until the aircraft's baseline computer architecture and avionics processors are replaced.

A final transformation that the Air Force is contemplating would go well beyond the usual definition of a modification to develop an "FB-22" variant of the Raptor airframe that could serve as a regional bomber. The variant would be considerably larger than the current plane and have a combat radius approaching 2,000 miles, but it would retain the low-observable characteristics and digital architecture of the baseline design. Air Force planners have been arguing the need for a survivable intermediate-range bomber ever since the FB-111 was retired in the 1990's.

The primary justification for the F/A-22's cost is that it will assure global air dominance into the fourth decade of the new century.

PROGRAM COSTS

The most persistent source of controversy surrounding the Raptor program has concerned costs. Critics contend that the price of each plane has risen far beyond what was originally planned, and that Raptors cost considerably more than the Cold War fighters they will replace. Both complaints are accurate. However, such criticisms seldom consider the cost of alternative approaches to preserving air dominance or the reasons why Raptor costs have risen. They also do not attempt to calculate the potential costs of losing global air dominance, a real possibility if Raptor is not acquired in adequate numbers.

Estimates of military program costs are often complicated by disagreement about which items should be included and what base year should be used in denominating dollars. The simplest

way to describe the cost of the Raptor program is to total all acquisition expenditures in current-year dollars. Using this approach, the total cost of the program is $72.3 billion in fiscal 2004 dollars, of which $31.3 billion (43%) is development, $40.4 billion (56%) is production, and the remainder military construction. These numbers include the cost of the first "spiral" enhancements to the airframe, funded in 2003, but do not include the cost of further enhancements described in the preceding section – which may or may not be funded.

At the end of fiscal 2004, 99% of development costs for the baseline program plus first spiral had been expended, as had 36% of production costs. The Government Accountability Office estimates that if all spiral enhancements currently planned beyond the baseline program are funded, then approximately half of total program acquisition costs had been expended through fiscal 2004. However, that estimate does not include the post-production costs of maintaining the fielded aircraft, nor does it cover the costs of any additional production funding above congressional cost caps. Although the Air Force has a stated requirement for 381 Raptors, production funding available within congressional cost caps would pay for less than 300 airframes.

The current "flyaway" cost for a Raptor is $110 million in 2004 dollars, which does not include an additional $20 million for its two engines (separately procured). This is about twice what an F-15C cost in constant dollars during the later stages of its production. The cost difference between the two planes is due partly to the greater complexity of the Raptor – computers, sensors, materials and so on – and partly to the relatively inefficient rate at which Raptor is produced. At 36 aircraft per year, the peak production rate for Raptor is less than half that of the F-15, which diminishes opportunities for economies of scale.

Flyaway cost is the least inclusive measure of aircraft acquisition costs, because it only covers the recurring cost of producing hardware and software. More expansive measures that include development costs would put the cost of a Raptor airframe somewhere in the vicinity of the latest Boeing 777 transport, which has a list price of $191 million. However, it is impossible to accurately assign an increment of development costs to each Raptor until the ultimate size of the production run is known. Moreover, development of Raptor is now a sunk cost that cannot be recovered, so the recurring cost of production is a more relevant measure of budgetary impacts for policymakers.

Cost growth has been a problem for the Raptor program. Most cost increases have been due to government decisions that changed requirements, delayed development, reduced production rates or cut the size of the planned fleet. Costs also have been increased by technological challenges that were not fully anticipated.

With development of the F/A-22 largely completed, the aircraft has entered high-rate production.

HOW MANY?

During the early stages of Raptor's development, debate centered on whether there was a valid requirement for a stealthy next-generation fighter and whether the program could achieve its performance objectives. With development now successfully completed and the aircraft entering high-rate production, debate has shifted to the issue of how many planes should be bought.

The original plan was to purchase 750 airframes for the Air Force and up to 550 carrier-based versions for the Navy. However, the Navy dropped out of the program and a series of high-level reviews reduced the Air Force buy to 648 in 1991, then 442 in 1993, and finally 339 in 1997. The 2001 Quadrennial Defense Review did not alter the goal of 339 aircraft for the Air Force, but changes in the schedule and scope of the program cut the number of airframes that could be afforded within congressional cost caps to well below 300.

Changes in program numbers have been driven by budgetary considera-

tions, and are not closely connected to military requirements. The Air Force's internal assessment of Raptor requirements is shaped by the need to equip each of ten Aerospace Expeditionary Forces with a squadron of 24 Raptors. In order to sustain a forward combat presence through multiple rotations – which is what protracted conflicts typically demand – the service must provide all ten expeditionary forces with the same number of fighters sharing the same characteristics and capabilities. Air Force planners do not believe their service can assure global air dominance against the full range of future threats, much less accomplish other missions, unless each expeditionary force has at least two dozen Raptors. That number is determined in part by an operating concept that envisions groups of four planes operating in networked fashion within enemy airspace.

Placing two dozen Raptors in each of ten Aerospace Expeditionary Forces implies a need for 240 airframes. However, for every increment of combat-coded fighters it buys, the Air Force must set aside additional planes to cover testing, training, attrition and downtime due to modifications. When the standard methodology for adding in those additional aircraft is applied, the actual number of Raptors needed to equip all of the expeditionary forces with a squadron is 381. So the Air Force's true operational requirement for Raptor is 381 aircraft. That is the minimum number that will support its strategy, force structure and concept of operations. Air Force leaders can easily envision other purposes for which Raptors might be used, but within the constraints imposed by scarce resources and competing missions, they do not realistically expect to obtain a number much higher than 381. Although the overall number of fighters in the active inventory is likely to decline significantly in the years ahead, the goal of 381 Raptors will remain a constant – in part because a reduction in numbers places a premium on the effectiveness of those planes that remain.

Raptor is the Air Force's highest modernization priority. Air Force leaders view it as indispensable to meeting their future responsibilities in waging joint and coalition warfare. Because that view has not wavered across five administrations, it is likely that Raptor will be deployed in large numbers around the world within the relatively near future. While there is little that can be said with certainty about what the future holds, deploying Raptor guarantees at least one thing: for the foreseeable future, America will have the best fighter in the world.

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Printed in the United States of America
July 2004

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