The *New* Old Threat:

Fighter Upgrades and What They Mean for the USAF

by Jim Cunningham

There was a time, not too long ago, when the development of the "next air superiority threat" was speculated upon with enthusiasm by thousands in the military, political, commercial, and even amateur arenas of the aviation field. The threat originated from the Soviet Union, and everyone tried desperately to figure out what their next generation fighters would be like. What materials would be used in their construction? How reliable would they be? What technologies had been developed or acquired (through whatever means) from the west and incorporated into the new designs? Would the Soviets be able to replicate western fighter developments? And how was doctrine being changed to accommodate all this? Less reliance on ground control intercepts? More pilot initiative?

Speculation on the answers to these and other questions ran rampant, and various articles were written in publications such as *Air Force* magazine about what the future threat would be like. There was no doubt about the origin of the threat, nor about where the threat would be encountered. The answer was always "the Soviets" and "in Europe."

The world of those not-so-long-ago days no longer exists. In its place there is a vastly different one with more complexities and fewer certainties. The "threat" facing American fighter pilots today is much murkier. It has become all but impossible to predict what country may have to be engaged in armed conflict during the next few years (though some nations stand out as being more likely than others.) As the list of potential adversaries has grown, so has the number of types of aircraft that could be met in a hostile sky. The Russians, in a bid to obtain urgently-needed foreign currency, will sell their equipment to almost anyone able to buy. In addition, the shifting sands of the new world disorder mean that we may no longer be fighting former Soviet aircraft— indeed this has already happened in the Persian Gulf War where the Coalition engaged French-built Mirage fighters of the Iraqi Air Force.

The global economic slowdown has also affected the potential for war. Conditions for small post-Cold War brushfire conflicts between states may be more favorable, but in most instances economic decline has meant that many interested parties have not been able to modernize their armed forces as they would like to. The compromise often made is to upgrade existing equipment, including fighter aircraft. Numerous hungry aerospace companies world-wide are competing for modernization business, and as a

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result a number of upgrade packages have been made available which substantially enhance fighter capabilities for very reasonable costs. The resulting aircraft are vastly superior to their original configurations, and pose a new kind of threat.

The global economic slowdown has also made military procurement more difficult for the United States. In the past new threats were met with brand-new, cutting-edge-technology fighter designs, but we can no longer afford this as a solution in all instances. The F-22, a revolutionary fighter with capabilities much ahead of our current generation fighters and upgraded models of older ones, will be acquired later and in fewer quantities than originally had been planned, and is even under review for possible cancellation. This means that for the immediate future, and perhaps the mid-range future as well, we will not be able to apply the usual solution of developing a new fighter.

Fighter Upgrades Detailed

In order to fully appreciate the upgraded fighter, or new old threat, we need to review the characteristics of the older aircraft being modernized, analyze the technologies that have been developed since the aircraft were originally designed, and determine the suitability for retrofitting these technologies. Finally, the characteristics and capabilities of the upgraded aircraft will be compared to the original and current fighters in the American inventory.

The aircraft that are prime targets for upgrading are what noted aviation author Dr. Richard Hallion categorizes 4th generation and 5th generation post-1939 period fighter aircraft. Their characteristics are:

Fourth Generation: Supersonic (limited purpose) (1955-70): F-104, early model MiG-21, EE (BAC) Lightning, early model Mirage III. Supersonic aerodynamics, area ruling; fourth generation turbojets; radar for search and fire control. Overreliance on air-to-air missiles based on unrealistic expectations thereof. Mach 2.0.[1]

Fifth Generation: Supersonic (multirole) (1958-80): F-105, F-4, late-model-MiG-21, late-model Mirage III, F-5, F-111, Mirage V, Su-24, MiG-23/27, Jaguar, Mirage F1, Kfir. Refined supersonic aerodynamic design, including canards and variable geometry wings; fourth- and fifth-generation engines; stability augmentation, mixed-gun air-to-air missile (AAM) armament; terrain-following radar for low-level high-speed flight; radar search and fire control; infrared sensors, heads up displays (HUD); laser ranging and targeting; wide range of air-to-surface missiles, bombs, and rockets, including precision-guided munitions. Mach 1.4-2.5.[2]

Now we will review the advances in the most significant technologies made between those two generations and the current, or sixth fighter generation. These technologies are armament, propulsion, avionics, stealth, and cockpit design.

Armament: As was noted in the description of the fourth fighter generation, reliance on the air-to-air missiles of their time was hopelessly unrealistic; missiles were very limited in capability. Infrared guided missiles

such as the early Sidewinder versions were only useful in a tail-chase situation— their sensors would only detect the heat plume of a jet engine's exhaust. The early radar-guided Sparrow missiles did not live up to expectations, either. Prior to the Vietnam War estimates indicated that missiles would have a 90 percent reliability, but in reality they achieved only a 42 percent rating for Sidewinder, and an incredibly low 15 percent for Sparrow.[3]

Newer missiles are much improved, being more reliable and having greater capability. The Sidewinder version "L" and onward, for example, are all-aspect, meaning that they can detect an aircraft from any angle— not just from behind. This adds a tremendous combat capability. Current versions of the Sparrow are much more accurate and reliable, and these missiles are being superceded by the even more capable AMRAAM. AMRAAM uses active radar guidance, meaning that it does not require the firing aircraft to point its radar— and nose— at the target until the missile hits. The launching aircraft is free to maneuver.

These newer missiles can be fitted to older aircraft with little difficulty or aircraft modification for a modest price (though the missiles themselves must be purchased). The result is an aircraft that has state-of-the art armament no different from that used by current generation fighters.

Propulsion . Considerable strides have also taken place in the field of propulsion. The turbojet which powered the fourth and fifth generation fighters has been replaced with the turbofan. The turbofan engine provides significantly more thrust for its weight than its turbojet predecessors did. Comparing the J79 turbojet (powerplant of a variety of fighters such as the F-4 Phantom) to the F100 turbofan (which powers such aircraft as the F-15 Eagle and F-16 Fighting Falcon) illustrates the advance vividly: The F100 weighs 12 pounds less than the J79, provides 5,000 pounds more thrust, and requires less than half the number of maintenance hours.[4] Cutting-edge developments include vectored thrust, which greatly enhances maneuverability, and supersonic cruise, which enables a fighter to travel at speeds greater than Mach 1 without using fuel-gulping afterburners. Among the advantages of the latter include being able to outrun an enemy— the other aircraft will not be able to sustain the supersonic speeds nearly as long. The F-22 will be the first production fighter to have supersonic cruise, and will be the only one for the foreseeable future (pending the development and production of the Russian I-42 prototype which has yet to be displayed).

Refitting engines is more difficult than are most other systems. Engines will vary in weight, affecting an aircraft's balance, and are often different in size, requiring (expensive) structural and possibly aerodynamic modifications. Some engine refitting is taking place nevertheless.

Avionics . This is perhaps the greatest area of advancement in aircraft systems, and has the greatest attraction and combat enhancement capability. The radar systems of fourth generation fighters are remarkably primitive by current standards. The original radar set for the Mig-21, NATO designation Spin Scan, had a range of approximately

Table 1

Technology for Fighter Refits				
	Retrofitability	Added Capability	Cost	Comments
Armament	Simple	High	Moderate	Newer missile designs give older fighters greater firing range, are capableof hitting targets from more diverst angles than older missiles, and are moreaccurate.
Propulsion	Practical/ Difficult	Moderate	Considerable	Engine refits generally give improved fuel consumption (and therefore flyingrange), require less maintenance, and give slightly higher speeds.
Radar	Practical	High	Moderate	Improved radar gives greater detection range, tracks mor targets, detects and tracks targets under the fighter, and is more reliable.
Avionics	Simple	Moderate	Moderate	Improved avionics (including flight data computers) reduce pilot workload, provide the pilot with more accurate information, require less maintenance, and are more reliable.
Stealth	Difficult/ Impossible	Considerable	High	This technology is not generally exported due to its sensitivity and classified nature.
Cockpit	Practical	High	Moderate	Glass cockpits include displays which provide pilots with more information organized more efficiently, simplify pilot workload, and require less “head in the cockpit” time via HOTAS and HUD.

Notes:
Scales for retrofitability are: Simple, Practical, Difficult, Impossible depending on how easily the technology can be incorporated into older fighter designs. Scales for all others are: High, Considerable, Moderate, and Low.

13 miles.[5] The data were presented to the pilot in an unrefined form, requiring considerable skill for accurate interpretation. Avionics were improved for the following generation of fighters such as the Mig-21bis and F-5, which incorporated considerable improvements in the areas of lighter components, increased range, and superior reliability. Revolutionary improvements, however, came about in the late fifth and especially sixth generation fighters. These developments introduced the capability to look down and discriminate between low-flying aircraft and ground clutter and vastly improved range. More important than that was the greatly enhanced computing power allowing radar control to be automated and the data refined before being presented to the pilot. Further advances also made possible improved maintenance time, and more reductions in size and weight. Additional strides within the generations of aircraft have also been made, mostly due to the dramatic increase of computer power at reduced cost. The F-15A, for example, utilizes 60,000 lines of code for its systems, while the F-15E, a variant of the original F-15 design, uses some 2.4 million lines of code.[6]

This tremendous improvement in capability means that avionics replacement gives the most "bang for the buck" in upgrading older fighters. Cost, while not insignificant, is often held down by incorporating avionics systems from current fighter aircraft into the older designs. This is accomplished with a minimum of effort in most cases, thus saving the cost of designing a new system or extensively modification of an existing one. The result is a modified fighter with avionics capability very similar to existing current designs such as the F-15 or F-18.

Stealth . Stealth, or low-observable technology, is the greatest development in air combat technology in the past few decades. The ability to make an aircraft difficult to detect greatly negates some of the advantages made in other areas, most notably in the field of avionics. Making existing aircraft stealthy, even specially-designed variants of current designs, is difficult and unlikely to be implemented in the refitting of older aircraft, for several reasons.

First, stealth depends heavily on an aircraft's configuration. The design of the airframe must be such that features are shaped very specifically and precisely, and the vast majority of older aircraft designs are not stealthy shapes. Making them fully stealthy is prohibitive in that the aircraft would have to be virtually redesigned and rebuilt on a level similar to that of a newly-manufactured aircraft, which negates the cost savings of a refit.

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Some aircraft designs lend themselves more to stealth modifications than others. Those with large, slab-type shapes with joints of wing and fuselage at 90 degree angles have a high radar cross section and are all but impossible to modify. Other designs which feature a blending of surfaces are easier to modify by the application of various Radar Absorbent Materials (RAM) in various forms such as panels or special paint. An example of just how well this can work is the B-1B bomber. The original B-1A design was well-suited for stealth, featuring blended surfaces rather than boxy components like those on the B-52. Stealth modifications to the B-1A design included the application of internal and external RAM, as well as modification of some external features. The result: the Radar Cross Section (RCS) of the original B-1A was 10 square meters, and the RCS of the B-1B a mere one square meter— an impressive reduction, but short of the one-tenth of a square meter RCS of the B-2.[7]

Prospects for stealth modification of older aircraft appear dim for several reasons. First, as has been noted, there are the matters of expense and shape suitability. Older fighters tend to have boxy shapes and highly-angled joints which give them a high RCS. Studies conducted on F-15 and F-16 designs to derive a low-cost alternative to the F-22 program failed to produce adequate RCS reductions due to airframe design limitations and external weapon carrying configurations.[8] Perhaps more important than these factors is the sensitivity of stealth technology and efforts made to keep it secret. Only the United States has shown to have highly-stealthy aircraft, though there is evidence that other first-world nations have tinkered in the field, mostly with applications to existing designs. So far no nations with stealth technology seem to be willing to export it to anyone but their closest friends. For now, at least, this combat multiplier seems to be the exclusive domain of developed nations.

Cockpit design. Improvements of cockpit design are a combination of technological advances and ergonomic improvements based on years of practical experience. The first of these is Hands On Throttle And Stick (HOTAS), which centralizes most controls required for flight, thus minimizing the required hand movement and optimizing coordination and response time in situations where every second counts. This is partially based on experience and partially based on technological advancement. Automation of various aircraft systems, such as radar, means that fewer controls are required to operate them than were necessary in earlier fighter designs.

Just as an aircraft's important controls have been centralized, so has the display function. The major advancement comes in the form of the Head Up Display (HUD). The HUD enables data, such as information about the pilot's aircraft including speed, heading, and weapon status, along with some target aircraft data, to be projected on a piece of glass looking out over the aircraft's nose. This keeps the pilot's attention where it is most needed— out of the cockpit and in the sky. This, like the HOTAS concept, adds precious seconds of response time to air combat engagements. Newer systems also project imagery, most notably enhanced views of the ground at night, onto the HUD as well. HUDs are used in most or all combat

aircraft today, and are also beginning to appear on transport aircraft.

Vast improvements have been made to cockpit displays as well. Fourth and even fifth generation fighters featured display systems which could not easily be read in bright sunlight, thus requiring the presence of a hood that a pilot had to crane his neck to see into— a difficult thing to do in the high-G environment of a dogfight. Current display technology allows for screens that can be read in daylight conditions and which show precise, computer-generated graphics— maps, aircraft system status, radar data, and other critical information. Again, such systems save precious time for the pilot. Helmet-mounted sighting systems are also beginning to appear. These systems give pilots all the advantages of a HUD over a much wider viewing angle, adding considerable flexibility. It is also interesting to note that this particular system is only a suggested future enhancement on the U.S. F-22, but is being offered as an immediately-available feature for at least one F-5E upgrade program.[9]

Specific Upgrade Programs Available

Anyone who frequents military aviation journals has undoubtedly come across several articles on fighter upgrade programs over the past few years, as well as advertisements for them. The May/June 1994 issue of *Jane's Defence Systems Modernisation* featured three advertisements for fighter upgrade programs alone, with two of those being for the F-5 series. Such programs were also mentioned in several articles throughout the issue as well. Upgrade programs are available for a range of fighters and from a number of countries, some of them seemingly unthinkable only a few years ago. Contractors in Israel, for example, will upgrade Mig-21s and F-5s alike.

Chilean F-5Es and F-5Fs are being upgraded by Israel Aircraft Industries (IAI). Refitted components include new avionics which are derived from the cancelled state-of-the-art Lavi fighter program.[10] Some modifications were necessary, such as reducing the size of the radar's antenna in order to get the unit to fit inside the F-5's smaller nose.[11] Much of the research and development cost for these systems has already been paid for as part of the cancelled Lavi program, thus helping to keep costs down on the F-5 upgrades. Cockpit modifications include full HOTAS capability, as well as computer-generated displays which greatly enhance the organization and display of information. The IAI display modification, in fact, improves even on those in contemporary F-15 and F-16 fighters by providing the pilot with the majority of information on a single better-organized display instead of two. This shortens response time even further, giving a greater advantage.[12] Weaponry enhancements include the usual upgraded all-aspect missiles, including the respected Israeli Python 3 missile. Precision Guided Munitions (PGMs) are preferred for the air-to-ground role, since they have greater accuracy than would a heavier load of "dumb" bombs.[13] Other options are available for F-5 owners, including such features as a helmet-mounted sighting system and reconnaissance capability.[14]

How much capability does this upgrade add? Tests with an F-5 with the upgraded radar yielded results slightly better than an F-16 with APG-

The F-5 is one of the most popular candidates for fighter upgrade programs.

66 radar. In addition, the F-5's small size helped to make the aircraft more difficult to detect in engagements against an F-16, both in the visual and radar modes.[15]

Bristol Aerospace Limited of Canada is also performing F-5 upgrades. This originally began as a late Cold War effort to provide both a lead-in trainer for CF-118s (F-18) and also to enhance the aircraft's ability to perform Close Air Support (CAS). With the Cold War over and defense budgets declining, Canada has decided to sell off its CF-5s, but this decision was made only after the upgrade program was well along (24 of the 35 programmed aircraft completed thus far). In an unusual arrangement, Bristol Aerospace, rather than the Canadian government, will handle the sale of the aircraft. This will enhance the company's position in the F-5 upgrade market.[16] Modifications include improved avionics, HUD, HOTAS, and other features which make the modified aircraft similar to an F-18.[17] Bristol Aerospace's advertisements for the "F-5 2000" state that they are "the World Leader in F-5 Aircraft Modernization."

Not to be outdone, the original manufacturer of the F-5 series, Northrop, is beginning to realize the potentially lucrative upgrade market for the aircraft. Northrop also has the unique advantage of having developed the follow-on improved F-5, the F-5G/F-20 Tigershark. Based on the original F-5 design, the F-20 incorporated many new technologies, including state-of-the art avionics and radar, an improved single engine, and minor structural/fuselage modifications. The F-20, alas, was never put into production. Segments of the F-20 project, however, are now making their way into the F-5 upgrade program being put forth by Northrop, though with the goal of making the F-5 more like an F-16 than an F-20.[18]

A variety of modification packages are available, price varying with the extensiveness of the upgrade. The complete upgrade, with the APG-66 radar of F-16 fame, HOTAS, glass cockpit with Multi-Function Displays (MFDs), HUD, and new avionics, costs between four and five million dollars. Other upgrade packages from Northrop featuring only some of the above features are also available at correspondingly lower prices.[19] Tests carried out with an APG-66-equipped F-5E yielded an impressive range of 30 miles, a considerable improvement over the original APQ-153 radar's maximum 20 mile range in search mode.[20] Other possible radar upgrades for the F-5 series with similar performance capability to the APG-66 include the APG-67 (originally intended for the F-20) and the APG-69 from Emerson, the manufacturer of the APQ-153 radar which originally equipped the F-5E series.[21]

The other popular upgrade fighter contender is the classic Soviet

Mig-21. This fighter has been built in greater quantities and in more versions than any other fighter since World War II.[22] In spite of the draw-down in armed forces worldwide and the retiring of Mig-21s for reasons of cost or replacement, the Mig 21 endures, remaining in service in no less than 27 different countries.[23] Israel Aircraft Industries (IAI), a key Mig-21 upgrade provider, estimated that some 5,000 of the type remain in service.[24]

Upgrade proposals are nothing new for this aircraft. Proposals began appearing in the late 1980s from both eastern and western sources, marking some of the first direct competition for this type of business. Like the F-5 upgrades, the Mig-21 updates focus primarily on electronics, which provides the greatest combat enhancement for cost. Chinese F-7M (Mig-21) copies were refitted with a GEC radar, HUD, and other electronics, while Egyptian Mig-21s were modified with equipment to enable the use of Sidewinder missiles, western HUDs, and other avionics systems.[25] Proposals from American companies included adapting the APG-66 radar and General Electric F404 engine (which powers the F-18 and F-117A) for use in Mig-21s, but these were never realized.[26]

Two of the major Mig-21 upgrades available today are from IAI and Mikoyan, the latter a relative newcomer in spite of being the aircraft's manufacturer. This unique advantage may help them make up for time lost to western companies.

The IAI Mig-21 upgrade features an EL/M 2032 radar (essentially the same unit offered in the F-5 Tiger III program described earlier, which has look down/shoot down capability), HUD, MFDs in the cockpit, and an improved one-piece canopy to improve pilot visibility. Like the F-5 modernization program the company offers, this upgrade can also include Python 3 to improve firepower and accuracy over the older and far-less-capable original Soviet missiles. The possibility also exists of adding other

Table 2

F-5E Upgrade Comparisons			
	Armament	Radar	Cockpit
Original F-5E	AIM-9J (limited aspect)	APQ-153 (Range: 20 miles; no look/shoot down)	Optical flight
IAI Tiger III	AIM-9P (all aspect) Python 3 (all aspect, hard kill)	EL/M-2032 (Range: 30+ miles; full look/shoot down)	HUD HOTAS Multi-function display
Northrop upgrade package	AIM-9P (all aspect)	APG-66 (Range:30 miles; full look/shoot down)	HUD HOTAS Multi-function displays

Table 3

Mig-21 Upgrade Comparisons				
	Armament	Radar	Cockpit	Comments
Early Mig-21 upgrade	AA-2 Atoll (tail aspect)	Spin Scan (Range: 12 miles; no look/shoot down)	Gunsight	Early model Mig-21s are poor condidates due to aging air-frames and inferior engines.
Late Mig-21	AA-8 Aphid (some versions all-aspect)	Jay Bird	Gunsight	Late model Mig-21s are excellent candidates for upgrades with their lower airframe times and improved engines.
IAI Mig-21 upgrade	Python 3 (all aspect, hard kill)	EL/M-2032 (Range: 30+ miles; full look/shoot down)	HUD, Multi-function displays, one-piece canopy	
Mikoyan Mig-21I and Mig-21-93	AA-11 Archer (all aspect), various air-to-ground missiles proposed	Kopyo (Range: 28 miles; full look/shoot down), TV and laser guidance (Mig-21-93)	HUD, Multi-function displays, one-piece canopy, helmet-mounted sight (optional)	Proposed for additional Mig-21-93 upgrade with new RD-33 turbofan as in Mig-29.

features such as a helmet-mounted sight, beyond-visual-range missiles, PGMs.[27] Like the F-5 program, the IAI-modified Mig-21 has performance specifications similar to those of current generation fighters.

The Russian modification program utilizes research and equipment developed for other Russian fighter designs, most notably the Mig-29. Improvements include a derivative of the Mig-29M's radar system, called Kopyo, which has a range of some 28 miles, compared with the range 11 mile range of the original set. The improved aircraft also includes flare dispensers as well as Electronic Counter Measure (ECM) capability in the form of French-built units slated for the Indian Air Force Mig-21 upgrade program.[28] In the cockpit, an MFD takes the place of the old hooded radar display.[29] There is also a helmet-mounted sight—something not even seen on current western fighters.[30] Other modifications include a new one-piece canopy for much-needed improved pilot visibility (though this is still lacking), and of course state-of-the-art missile armament. For BVR medium-range combat the uprated Mig-21 can use one of two missiles. The first is the new

R-77, with capabilities similar to the AMRAAM, including active homing capability.[31] The other choice for medium range engagements is the older but still effective R-27, also known by its NATO designation AA-10 Alamo.[32] This missile comes in either infrared or semi-active radar-homing varieties, both with ranges well-suited for the range of the improved radar set mentioned earlier.[33]

For shorter-ranged air combat, the newer R-73 (NATO designation AA-11 Archer) and older R-60M (NATO designation AA-8 Aphid) are available. The R-73 (A-11) is reported to be the best missile in its class world-wide, chiefly due to the west having delayed or cancelled short-range missile programs such as ASRAAM or the AIM-9X improved Sidewinder.[34] The R-73 features all-aspect capability, high off-boresight capability, and thrust vectoring control. No other missile has all these characteristics today.[35]

The R-60M (AA-8) version referred to is a later model of that missile type, and incorporates all-aspect capability, a feature lacking in earlier variants.[36] These missiles were developed to replace the original AA-2 Atoll missiles which were copies of early Sidewinders and had very limited capability. Even the R-60M represents a significant combat enhancement over the original AA-2 Atoll capability initially associated with the Mig-21.

The F-5 and Mig-21 are the two most popular candidates for fighter upgrade programs, but do not represent a monopoly. Plans for upgrading other older fighters have been proposed for some time; some being realized while others remain paper airplanes.

The New Zealand Royal Air Force was in an economic dilemma when faced with the need for a fighter replacement in the early 1980s. Options considered included the purchase of F-16s, F-18s, or F-20s, but all were considered too costly. Instead, the decision was made to upgrade the existing A-4 Skyhawk aircraft, evolving these into multi-role aircraft instead of using them as strictly the ground-attack platforms that they were originally designed to be.[37] Modifications include the installation of the AN/APG-66NZ radar, which is a variant of the APG-66. The New Zealand version has a slightly smaller antenna to fit it in the A-4's nose (a common modification for fighter radar refits) and a different surface search mode.[38] All other avionics were also replaced with state-of-the-art equipment. The refurbished A-4s are capable of carrying a diverse range of weaponry, including AIM-9L all-aspect Sidewinders, Maverick air-to-ground missiles, PGMs, and the less-precise unguided bombs and rockets carried originally.[39] Cockpit upgrades, including HOTAS and the installation of a HUD, allow the weapons to be delivered accurately and effectively. All aircraft were also re-winged. The final resulting A-4Ks is said to have 80-90% of the F-16's capability in low-level combat for one-sixth the cost of F-16 replacements.[40]

A number of upgrade programs have been suggested, and a few actually undertaken, for the venerable F-4 Phantom. This remarkable fighter, though about to finally leave USAF service, is still operational in considerable numbers around the world. The two major upgrade programs for this aircraft, somewhat modest by upgrading project standards, are from Germany and Israel.

Germany upgraded its F-4F fleet with new radar and related avionics in the Improve Combat Efficiency (ICE)

program. The original radar set is replaced with the APG-65 system (as used on the F-18 Hornet) and improved navigation, fire control, and MFD systems. These improvements give the F-4F look-down/shoot-down capability.[41] Perhaps more importantly, these modifications give the aircraft the capability of launching the AMRAAM missile, which provides a considerable combat enhancement in that it is a fire-and-forget active homing radar missile.[42]

Israeli modifications to the F-4 series are more radical, at least at the proposal level. The original plan called for replacement of the aircraft's avionics, radar, and engines. This program, known as Super Phantom, featured a wide-angle HUD, HOTAS, structural modifications, state-of-the-art radar, MFDs, and Pratt & Whitney PW1120 turbofan engines to replace the fuel-gulping J-79 turbojets.[43] The new engines provided 15% more power while weighing 25% less than their predecessors.[44] Ultimately this upgrade proved too expensive, even for the Israelis, who opted for the more austere Phantom 2000 upgrade, which featured the above modifications short of the engine refit.[45] This may not be the final word in Israeli F-4 upgrades however: Plans are developing for an Israeli program to upgrade Turkey's considerable F-4E fleet.[46]

The Boeing aircraft company also proposed a similar F-4E upgrade program. Like the IAI proposal, this variant featured the same PW1120 engines, additional fuel, countermeasures gear, updated avionics, and an APG-65 radar system.[47] Also like the advanced IAI program, this proposal never generated interest, most likely because of the expense required.

Implications and Solutions

The implications of the above upgrade programs are considerable. For a fraction of the price of a new fighter, a nation can purchase an upgrade which will put its fighters much closer in performance to current generation fighters than has been possible before. While the performance of upgraded fighters will still not be equal to current-generation machines, the United States will no longer enjoy the qualitative aircraft advantages as it has in the past. A recent Government Accounting Office (GAO) report claimed that the F-15 will be adequate against

Technologies and systems developed for aircraft such as the F-22 can be at least partially incorporated into existing designs to enhance their capabilities.

any threat through 2010.[48] "Adequate" is a relative term, however. While it is difficult to imagine a potential enemy of the near future gaining any level of air superiority over American air forces, the lack of definitive superiority as it previously existed invites higher American casualties. This is something that the American public will no longer tolerate, as demonstrated in the Vietnamese and Persian Gulf Wars. A

clear, overwhelming superiority in the air is necessary both to make conflicts acceptable to the American public and also to deter potential aggressors. An aggressor who deems his military capabilities close to equal to or better than those of his adversary is more likely to commence hostilities.

The technological equity problem is compounded by the new world order in two ways. First, the USAF no longer has the relative luxury of knowing likely areas of conflict well in advance as was the case with the Soviet Union. During the Cold War, American pilots could deploy to their designated wartime bases and experience the skies over the potential battlefields firsthand. Even in the Persian Gulf War units were deployed to a region where some had at least trained before. Equally important was the five months spent in-theater to prepare themselves (except the first units deployed in early August of 1990 when it was feared that Iraqi forces would cross into Saudi Arabia). Such conditions may well not be available in the next conflict.

Compounding this particular problem is the possibility of deploying rapidly to areas where few or no facilities for fighters exist. Lack of access to adequate maintenance facilities would seriously impact readiness rates and degrade fighter performance. Against an enemy air force flying out of home fields with full maintenance capability, the American "adequate" margin could become rather slim.

Another very significant variable in the equation is the potential for unknown enemy strengths. Enemy aircraft types may well be known, but their upgraded capabilities may not be. Indeed, the details of upgrade work are not disclosed in many instances.[49] Is that Mig-21 out there armed with all-aspect missiles or not? Fire and forget missiles? How good are the enemy's avionics? The answer to these questions could be vital... and unavailable. A wider margin of USAF superiority is highly desirable in these instances.

Lest all of the above sound too alarming, understand that it represents worst-case scenarios in many instances, and furthermore that quality fighters alone do not an air force make. The Iraqi Air Force was armed with some very fine fighters, among them the Mirage F1 and Mig-29, yet only one Coalition aircraft was shot down in an air-to-air engagement in the entire Persian Gulf War. Nevertheless, fighters refitted with current technology make fighting in the air much easier than using older fighters with outdated systems against an enemy with more modern equipment.

Intelligence agencies that monitored the former Soviet Union and Warsaw Pact air forces must now widen their nets. Air forces of potential aggressors must be studied in considerable detail and carefully observed. Upgrades must be studied—detailed information on which upgrades are performed and with what resulting capabilities, must be secured in order to optimize the use of our own air assets.

Sales of advanced upgrade technologies and equipment should not only be monitored, but also controlled where necessary. In some instances this has in fact already been done, though often as not for commercial rather than political/military purposes. It will be difficult, however, to control what other countries are willing to export. Nations such as Russia, desperate for business from any customer willing to pay, are

probably more than willing to sell to nations that the United States would prefer not possess technologically advanced fighter aircraft.

The USAF should also undertake its own measures to minimize the impact of upgraded older fighters that might be faced in a hostile sky. These measures are also sound guidance in most challenges the USAF is likely to face, and include:

- Maintain a well-rounded force. In times of tight budgets it is tempting to cut back on or do away with specialized missions and/or aircraft, such as ECM, Airborne Early Warning (AEW), and reconnaissance. The most glaring examples of this today are the phasing out of the EF-111 and F-4G platforms, which are to be replaced with other, less-capable aircraft in their missions. The Persian Gulf War demonstrated both the advantages of having such fully-capable assets and the devastating effect of their absence. The Coalition, which had all of these specialized assets, was able to utilize fighters much more effectively than the Iraqis did. AEW aircraft kept the area of hostilities under constant watch and vectored in fighters when Iraqi aircraft left the ground. ECM interfered with Iraqi communications and radar. Reconnaissance platforms (aircraft and others) kept track of the locations and dispositions of Iraqi fighters, allowing the Coalition to allocate its own fighters optimally and conform to the military principle of economy of force.

The Iraqis, on the other hand, while possessing state-of-the art fighters such as the Mig-29, did not have a well-rounded force. They had few reconnaissance aircraft, no significant AEW (and a centralized, vulnerable ground-based Early Warning system), and no ECM aircraft. Their fighters, in spite of being some of the best available, had no intelligence assets to work with, and therefore were at a serious disadvantage. The USAF must maintain superiority in the previously-listed areas to help compensate for the narrowing fighter technological advantage.

- Readiness is crucial. This, too, was a chief advantage enjoyed by the Coalition in the Persian Gulf War. A fighter with the latest technology will do an air force little or no good sitting on the ramp in need of maintenance, or flying with some of its avionics non-operational. The level of complexity of high-technology refits on fighters (or any other weapon system for that matter), while of higher reliability for the most part than older systems, requires specialized maintenance and therefore highly-trained specialists and ample supplies of spares. The American military went through a difficult period in the late 1970s and early 1980s where both were lacking, and suffered accordingly. Readiness rates were a disaster. In 1980, for example, the 1st TFW miserably failed an unannounced deployment exercise, having only 23 F-15s deployable out of a total of 66 aircraft. This was due both to a lack of spares (some aircraft were cannibalized for parts to keep others functioning) and under-trained maintenance personnel.[50] This trend was overcome, as the high readiness rates during the Persian Gulf War demonstrated, but recent budget cuts have been blamed for the slightly-declining readiness rates reported since then. This downward spiral cannot be allowed to continue. The

readiness gap between the USAF and a potential adversary could be a key factor in winning the war in the air. A fighter force must be ready to fight if it is going to win.

• Maintain pilot quality. The painful lesson of Vietnam should not be forgotten: train as much as possible and do it in as realistic a manner as possible. This will be more difficult in these times of leaner budgets and uncertain adversaries. Lower funding means fewer flight hours, and uncertainty over adversaries means that specially-crafted training to simulate a particular adversary (such as the specialized aggressor squadrons which simulated Soviet tactics) will no longer be possible, but care must be taken not to let training and pilot quality slip too far.

Poor pilot quality has proven to be disastrous in every major war of the jet age, from the Korean War to the Persian Gulf War. General Charles Horner, Coalition Air Forces Commander in the Persian Gulf War, stated that there was concern over Iraqi pilot quality before hostilities commenced. Horner spoke of one Iraqi Mirage F1 pilot that the U.S. Navy had rescued after he was shot down during the Iran-Iraq War. From the debriefing the USN did on this man, they concluded that he had excellent combat skills.[51] This skill, however, was obviously not universal in the Iraqi Air Force. At one point during the Persian Gulf War, Coalition pilots were amazed when one Mig-29 in a flight of two turned in front of his wingman, who promptly fired a missile at him and shot him down. This amazing feat was compounded by the reaction of the shooter, who was apparently so shaken by what he had done that he flew into the ground moments later.[52] Again, pilot quality is needed to utilize technologically-advanced aircraft to the fullest of their capabilities and can help overcome the narrowing of the technology gap. Pilot quality must be maintained by the USAF.

• Counter the narrowing gap by widening it again— build and deploy the F-22. The deployment of this aircraft will restore the high technological advances enjoyed by the USAF in the past. The F-22 incorporates advances seen in few, if any, other combat aircraft on the edge of deployment anywhere in the world. Among these are stealth, supercruise, and next-generation avionics and radar.

Stealth, of course, is in use on aircraft such as the F-117 and B-2, and has been used to reduce the RCS of several other aircraft. The F-22, however, is the first true fighter design (the F-117 is not a fighter in the true definition of the word) to use stealth as a design priority. Stealth will negate or diminish many of the technological advancements gained by refitting older fighters, most notably radar upgrades and advanced radar-guided missiles. The F-22 will be able to detect and destroy (or evade if necessary) an adversary before the adversary can detect, let alone destroy, the F-22.

Supercruise also gives key advantages back to the USAF. With supercruise, pilots may use high supersonic speeds more freely, for when doing so they will no longer use afterburners with their enormous fuel consumption. In worst case scenarios,

F-22 pilots may accelerate and sustain supersonic speeds for durations greater than an adversary without supercruise can maintain.

Radar and avionic advantages enjoyed by the F-22 are also key in defeating an enemy with current systems. The F-22 radar will incorporate Ultra-Reliable Radar (URR) technology, resulting in smaller unit size and, more importantly, fewer maintenance personnel and less maintenance time. As stated earlier, these variables are critical in view of the uncertainty over deployment areas and existing maintenance facilities (if any) that will be there. The radar system will incorporate other advances as well, many of which are classified. Sure to be among these are functions such as Electronic Counter-Counter Measures (ECCM), emission management to avoid broadcasting the fighter's presence where practical, and improved target identification capability.[53]

The design and development of the F-22 hail from the larger defense budgets of a few years ago, and the aircraft has been subjected to numerous procurement stretchouts and proposed design changes in the past few years as the defense budget has been dramatically reduced. There has even been a movement to cancel the F-22, until now a jewel which has survived any plans in capability reduction, at all. While the the shift of political climate has made the cancellation less likely, it is certain that the F-22 will not be produced in the quantities that were originally envisioned.

The stretchouts and other reductions must be halted if this aircraft is to be fielded in a timely and cost-efficient manner. If the F-22 is not procured, the technological gap between the USAF and potential adversaries will continue to narrow, and our forces will be increasingly challenged to maintain superiority by the other means discussed above.

If the F-22 is finally cancelled, other means will be necessary to at least preserve our ability to field technologically advanced fighters in the future. In short, the Research and Development infrastructure must be retained and kept alive. There have been proposals in recent years to do exactly this-- continue R&D work, perhaps even to the prototype stages, of new weapon systems so that the industrial base foundation is preserved and to eliminate R&D time in the event that the military must be enlarged to face some new threat. This would retain at least the potential to keep the fighter technology gap between the USAF and its adversaries, whoever they may turn out to be, wide enough for comfort.

Upgrade existing fighters. Technologies and systems developed for aircraft such as the F-22 can be at least partially incorporated into existing designs to enhance their capabilities. The avionic systems for the F-22,for example, could be retrofitted with a minimum amount of difficulty. Such modifications would not be inexpensive, but would enhance the current fighters' capability and reduce maintenance time and personnel.[54] Other advantages in avionics upgrades include data link with reconnaissance platforms for real-time intelligence and navigational data, and an enhanced passive detection system which would analyze, identify, and locate hostile radar systems, including those of enemy fighters. Such systems,

being passive, would have the distinct advantage of not broadcasting the fighters' location as does using its own onboard radar and other active sensors.[54]

Conclusion

The old world order of a known enemy and predictable arena of battle, with an existing support structure and facilities, is gone. Gone also are adequate defense budgets and automatic advances in weapon systems to assure the fielding of cutting-edge technologies. Potential adversaries in the new world order are many and unpredictable, and the research and development efforts of both the former eastern and fwestern superpowers are being used to upgrade the air forces of nations around the world, friend and foe alike. The result of all these events is a new kind of challenge that must be met with creative solutions in order to assure continued USAF air superiority in any future conflict.

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