The Next Lightweight Fighter

Not Your Grandfather's Combat Aircraft

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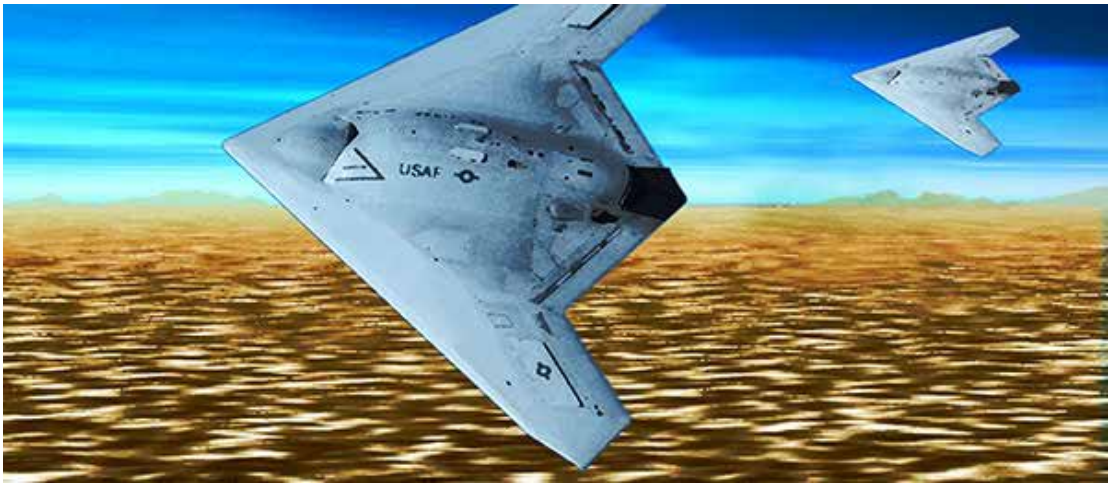
> *SEC. 220. UNMANNED ADVANCED CAPABILITY COMBAT AIRCRAFT AND GROUND COMBAT VEHICLES.*
>
> *(a) GOAL.—It shall be a goal of the Armed Forces to achieve the fielding of unmanned, remotely controlled technology such that—*
>
> *(1) by 2010, one-third of the aircraft in the operational deep strike force aircraft fleet are unmanned; and*
>
> *(2) by 2015, one-third of the operational ground combat vehicles are unmanned.*
>
> —Public Law 106-398, 30 October 2000
> National Defense Authorization Act, Fiscal Year 2001



A casual survey of unmanned combat aerial vehicles (UCAV) would show that various countries have pursued a dizzying variety of such possible weapons systems, starting in World War I and continuing today. Reconnaissance variants have a long and effective history, but no autonomous UCAV is close to becoming opera-

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
AUG 2013		**00-00-2013 to 00-00-2013**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
The Next Lightweight Fighter: Not Your Grandfather's Combat Aircraft	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Air Force Research Institute,Air & Space Power Journal,155 N. Twining St., Bldg. 693,Maxwell AFB,AL,36112**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Same as Report (SAR)**	**20**	

tional. The value of these aircraft remains a subject of much debate, and although UCAVs clearly are not ready to replace manned strike aircraft, the exact role they will fulfill is less clear.[1] Almost any discussion of the subject treats them as aircraft *that happen to have a combat role*. Although technically correct, this view misses the larger picture. UCAVs are nothing of the sort; rather, they are *combat aircraft that happen to fly without aircrews on board*. As such, UCAVs may represent a partial solution to the increasing expense and dwindling numbers of modern fighter aircraft in service of the United States.

In 1971 the Air Force started its last lightweight fighter program, which produced the F-16 Fighting Falcon and (eventually) the F-18. With the F-16 and F-15, the service settled on a "high/low" mix of aircraft to replace Vietnam-era fighters. It procured more than 1,000 F-15s and F-15Es and more than twice that number of F-16s. The Air Force wanted the F-22 Raptor and F-35 Joint Strike Fighter to follow a similar high/low strategy, but both programs have seen their total size shrink, and the Joint Strike Fighter may suffer from defense cuts. Given spiraling costs, the time is right to consider a new program. The next lightweight fighter should be small, maneuverable, and relatively inexpensive, having a combat radius similar to that of its heavier brethren—but it need not have a crew on board. The aircraft's different design constraints will distinguish it from a fighter, and it won't do everything we expect of the latter. Intelligently designed, a UCAV can become a force multiplier.

A Force Multiplier, Not a Replacement

The UCAV will not replace the manned fighter aircraft—we cannot build a control system to replicate the sensing and processing ability of trained aircrews. Nevertheless, UCAVs may play a valuable role as a supplementary system. Not remotely piloted aircraft, they will operate semiautonomously, serving as literal wingmen of limited capabilities. We can build the technology to fly an aircraft and execute preprogrammed routines. The "brains" of the operation will remain the

nearby human, who needs only to tell the UCAV what to do and (mostly) forget about it.

Design

For this purpose, the generic UCAV is designed in response to a set of requirements. Since it will not do the same thing as a manned fighter, it need not have identical capabilities. Gold-plating the system will raise the cost of the aircraft and likely destroy any reasonable argument for incorporating it into service. Thus, the Air Force must limit requirements to the following:

- Autonomous flight; navigation (including instrument approach and terrain following); identification, friend or foe; and communications.
- Small size.
- High maneuverability (up to 7 g's).
- F-16-like combat radius.
- High subsonic speed, service ceiling of at least 30,000 feet.
- Internal and external payload.
- Reduced radar and infrared signature (not necessarily "low observable").
- Modular avionics fit.
- Short takeoff and landing (STOL).
- Capability of interfacing with tactical networks.

The need to take off, fly, navigate, land, and communicate provides the backbone for an aircraft that can function without having to constantly tie up a human operator. If the airframe stays small, we can place a number of them in confined spaces, especially on board a variety of sea-basing options. Furthermore, smaller airframes lend themselves to relatively easy transport in significant numbers via airlift,

thereby shortening deployment time. Finally, adversaries will find such aircraft more difficult to detect and successfully engage. High maneuverability directly correlates to survivability against a variety of threats. If we assume that this UCAV will operate extensively (possibly primarily) with manned aircraft, then it must have range similar to the F-16's, possibly calling for an air-refueling capability. To keep up with strike aircraft, the UCAV must operate at high subsonic speed.[2]

We can partially attain signature reduction in a variety of spectra with small size, airframe shaping, and design. Since a number of UCAV missions will not demand stealth, most production airframes need not utilize expensive radar-absorbent coatings. Similarly, the aircraft must carry some payload internally to minimize drag and signature; it must also carry external ordnance and fuel.

The modular avionics fit is essential to maximize flexibility and control cost. Some UCAVs will carry advanced (and expensive) sensors and communications, but not all missions call for a full kit. In light of the historically high loss rates for remotely piloted platforms, the "basic" airframe design will permit the deletion or addition of capabilities, minimizing the cost of losing an airframe. For example, it might include space for a system (black box and antenna array) carried only as necessary.

STOL capability will assist operations from small airfields or the deck of a ship (not only carriers but perhaps also specially fitted amphibious ships) and allow recovery on damaged runways. Finally, since the UCAV primarily operates in conjunction with manned combat assets, it must "plug and play" into any tactical data links available.

Expanding further into conjecture, this article discusses what the UCAV might bring to the fight if the Air Force could launch the program in a short time frame. Accordingly, it incorporates a notional paper written at Air Command and Staff College in the year 2020:

Development and Employment of the F-40 Warhawk II: Looking Back from 2020

Given the need for a lightweight fighter, the Defense Advanced Research Projects Agency developed a prototype UCAV for use by both the Air Force and Navy, producing a small fighter aircraft available in three configurations. The F-40A, the basic airframe, does not utilize radar-absorbent materials (a cost-reduction measure), gaining its small signature by means of shaping and composite materials.[3] Many of the F-40A's design features were intended to support a flexible, modular configuration. The basic aircraft is equipped with antenna mounts and space for radar-warning gear, a self-protection system with expendables, satellite communications, optical communications, and a tactical data-link package. Internal payload is located in two internal bays, each sized to carry a GBU-32 (v) 1/B 1,000-pound Joint Direct Attack Munition (JDAM) or a four-pack of GBU-39/B.[4] There are two external, fuselage-mounted, removable hardpoints capable of holding AGM-84s, AGM-88s, or equivalent weapons or external fuel tanks.[5] Combat payload, exclusive of mounted sensors and internal fuel, weighs 3,400 pounds.

Identical in most respects to the A model, the F-40B does use radar-absorbent materials, further reducing its radar cross section. The B model has no external hardpoints. The F-40C—an F-40B with a more powerful engine—features higher performance, making it suitable for use with the F-22. The fact that the B and C models cannot carry external fuel limits their range, but all variants can permit air refueling via the boom on KC-135, KC-46, and KC-10 tankers; the A model also has a probe for probe-and-drogue refueling, the first aircraft since the F-100 equipped with both.[6]

The basic airframe allows the platform to function as a reusable cruise missile, weapon caddy, or reconnaissance package roughly equivalent to the early Model 147 Firebee drones employed over Vietnam (although enjoying much more precise navigation). Shorn of much equipment, it lacks even a camera to assist with recovering the

aircraft by remote control (although it can accommodate one); moreover, even though it has space for self-protection and radar-warning gear, none is permanently installed. As a result, the most expensive parts of the system are the engine and the navigation/control package, making the cost of a usable (although limited) aircraft as low as possible. Additional combat capabilities can be added to the airframe in modular fashion, including any or all of the following: a basic direction-only radar-warning receiver *or* an advanced radar-warning/electronic-support-measures package, chaff and flares, forward-looking day/night television for landing under manual control, a forward-looking-infrared camera, and advanced ground-mapping radar.[7]

The payload bays remain available for sensors, fuel, or weapons. The UCAV could carry additional weapons on external hardpoints, but external weapons compromise stealthiness and reduce the combat radius. Internal payloads include

- air-to-ground munitions, such as GBU-32s, GBU-39s/-40s, SUU-64/B canisters;[8]
- air-to-air munitions, currently AIM-120Ds;
- air-droppable sensors, including sonobuoys;
- a 1,600-pound fuel tank;
- decoys (ADM-160 miniature air-launched decoy [MALD]) or expendable jamming packages (MALD-J);
- standoff/escort jamming or other electronic warfare packages;
- special sensor packages, including a laser radar, radar, hyperspectral sensors, or photoreconnaissance;
- collection packages, including air-sampling tools;
- resupply pallets (aided by the Global Positioning System and parachute retarded);
- specialized signals-intelligence avionics;
- a communications relay package;

- advanced self-protection, including towed decoys and additional expendables (chaff/flares); and
- a directed-energy pallet (in development).

Some weapons are too large to fit inside, so the platform must carry them externally. It can accommodate both the AGM-88 high-speed anti-radiation missile and AGM-84L Harpoon II in pairs although the weight of the AGM-84L requires empty payload bays, at least at take-off.[9] The aircraft cannot carry especially heavy weapons.

Mixing payloads permits tailoring of the UCAVs for the mission in question. That is, a long-range mission might carry a single GBU-32 and fuel; a poststrike reconnaissance pass in a high-threat area might carry a photo pallet as well as an advanced self-protection package. Two identical bays offer more utility than one larger bay. A modular system design allows the services to minimize the expense of losing an airframe yet provide for multirole capability.

Lightweight Fighter Missions

Unlike the lightweight fighter of 1971, the F-40 has a very limited air-to-air role. No variant of the F-40 possesses an air-to-air radar. All variants can carry the AIM-120D advanced medium-range air-to-air missile, but they are simply missile caddies. Pairing a single F-40C with an F-22 increases the total missile loadout from eight to 12; the Raptor performs all target-detection and missile-guidance functions. This limitation is not as severe as it seems and may (in the future) provide a highly valued capability to other platforms. Block 20 aircraft will be able to interface with Aegis ships, as will follow-on blocks with E-2D aircraft, thus extending the outer boundary against air-breathing threats.[10]

The interchangeability of the F-40A proved quite valuable—particularly during the initial production run, which did not supply enough aircraft to go around. On several occasions, land-based F-40As launched, completed their mission, and recovered aboard a US aircraft carrier; thus, they could replace lost F-40s without "wasting" a sortie

on a ferry flight.[11] Ferry reconnaissance missions became commonplace during the Hamadan crisis, when aircraft that launched from eastern Turkey overflew Iran and recovered on board the carrier in the Persian Gulf (and the reverse).

The F-40 found its key niche in counterland or antisurface operations. As a combat aircraft, it acts either as an autonomous asset or as a force multiplier and is commonly assigned to manned aircraft, referred to as "consorts." Control methods vary with the complexity of the mission, but no control mode in the UCAV allows remote pilotage (except for takeoff and landing). All variants have three control modes.

Mode A (autonomous control). The simplest form of control for the F-40 is autonomous control, enhanced with an in-flight report and retasking ability, similar to that of a tactical Tomahawk. As in any mode—except for emergency landing—the vehicle itself handles basic flight operations, including terrain and threat avoidance. Useful for servicing fixed targets, this system can be retasked if the target moves. The Warhawk has two control loops—one for threat avoidance and one for fuel management. Autonomous operations have the advantage of very tight emissions control, immunity to communications interruption, and ease of planning, but their flexibility remains limited. Interdiction, critical resupply, and various reconnaissance missions use mode A; F-40s fly most of the high-speed tactical-reconnaissance missions on the air tasking order.

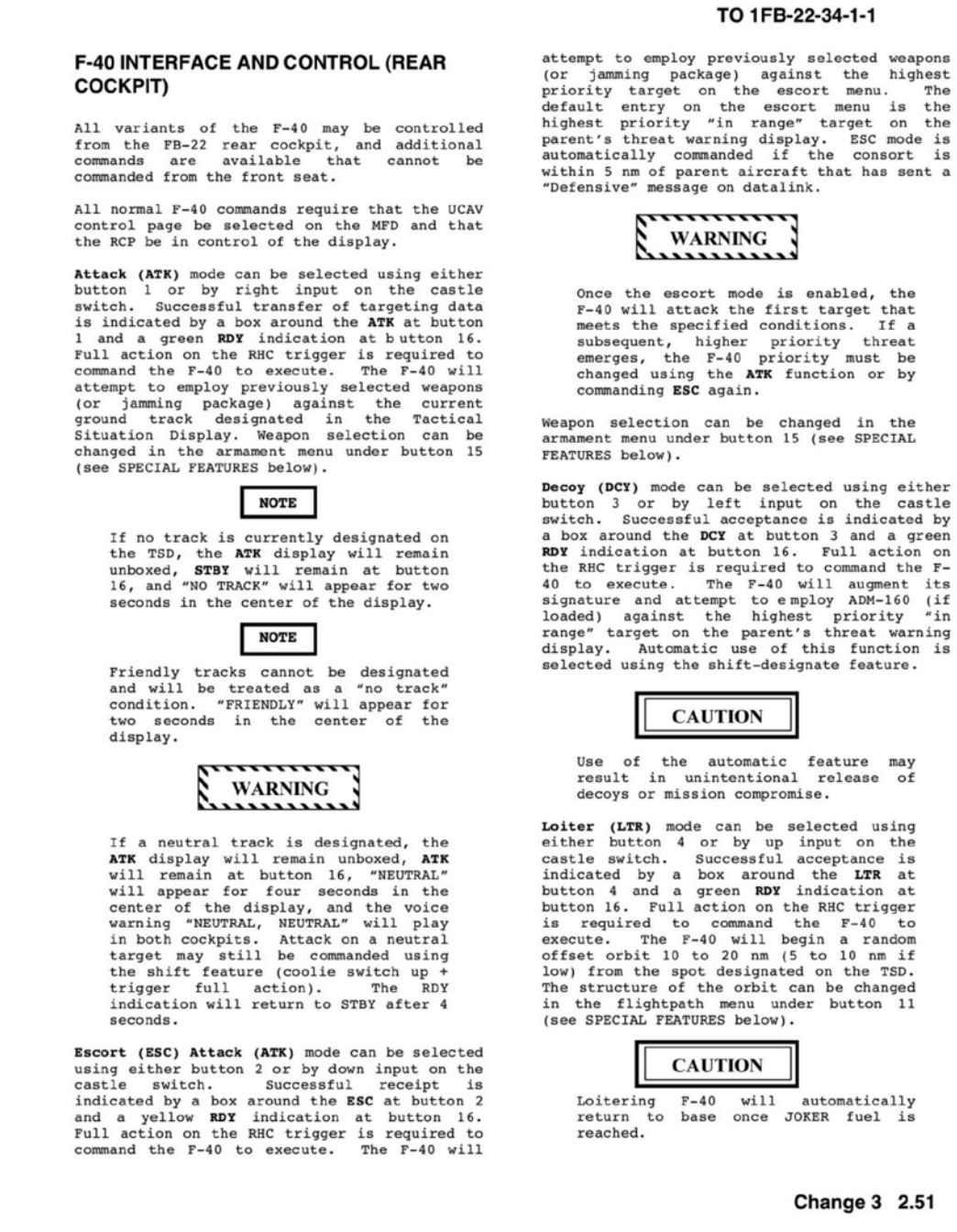
Mode B (cooperative). A simpler version of the semiautonomous operations mode (mode C), this mode allows the F-40 to perform simple cooperative operations whereby one of a number of UCAVs tied together via data link will react to conditions encountered by the others. One autonomous F-40 dropping bombs might be followed by another dropping unattended sensors. If the first UCAV becomes engaged, the second will replot the route to avoid the threat. If the first UCAV is destroyed, the second one may abort the mission, returning with key information about the loss. Cooperative mode also includes automatic collision avoidance—not a feature of autonomous mode.

Similarly, when paired with a manned aircraft, the F-40 can take action based on what its consorts or the other UCAVs are doing. In most cases, cooperative actions are merely the result of simple if/then statements: *if* threat radar illuminates the parent aircraft, *then* the F-40 will perform Y action (anything from launching decoys to attacking the radar directly). This simple scheme mimics the actions of intelligent machines but involves no direct human control, simply actions from a preplanned menu.

Mode C (semiautonomous control). The versatile semiautonomous control permits easier integration with the remainder of the joint force. Without it the Air Force might not have procured the aircraft. In semiautonomous mode (also referred to as the "wingman" mode), the F-40 is electronically tethered to a combat unit, which serves as the critical "man in the loop" for targeting and weapons employment—typically an aircraft, vessel, or ground unit. The manned unit supplies target identification, prioritization, assignment, and weapons allocation, thus clearing the "autonomous weapon" hurdle that has bedeviled weapons developers for decades.

The F-40 may receive updates and commands frequently or infrequently, and control can switch from one asset to another. No more than one unit may control any given UCAV although a single unit can control multiple F-40s. In short, under mode C the F-40 frequently acts as a literal wingman with no judgment, capable of following limited instructions.

Because the F-40 is not remotely piloted, mission commands are simple and easily integrated. It receives assignments of hostile air or surface "tracks" for attack, along with data on other UCAVs working in the same area. Other tasks may be assigned via simple commands, and the F-40 takes action based on its programming and the current "picture" provided via data link (see the figure below for primary commands used by the FB-22). Sensors on the F-40 usually integrate with those of the consort via data link



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F-40 INTERFACE AND CONTROL (REAR COCKPIT)

All variants of the F-40 may be controlled from the FB-22 rear cockpit, and additional commands are available that cannot be commanded from the front seat.

All normal F-40 commands require that the UCAV control page be selected on the MFD and that the RCP be in control of the display.

Attack (ATK) mode can be selected using either button 1 or by right input on the castle switch. Successful transfer of targeting data is indicated by a box around the **ATK** at button 1 and a green **RDY** indication at button 16. Full action on the RHC trigger is required to command the F-40 to execute. The F-40 will attempt to employ previously selected weapons (or jamming package) against the current ground track designated in the Tactical Situation Display. Weapon selection can be changed in the armament menu under button 15 (see SPECIAL FEATURES below).

NOTE

If no track is currently designated on the TSD, the **ATK** display will remain unboxed, **STBY** will remain at button 16, and "NO TRACK" will appear for two seconds in the center of the display.

NOTE

Friendly tracks cannot be designated and will be treated as a "no track" condition. "FRIENDLY" will appear for two seconds in the center of the display.

WARNING

If a neutral track is designated, the **ATK** display will remain unboxed, **ATK** will remain at button 16, "NEUTRAL" will appear for four seconds in the center of the display, and the voice warning "NEUTRAL, NEUTRAL" will play in both cockpits. Attack on a neutral target may still be commanded using the shift feature (coolie switch up + trigger full action). The RDY indication will return to STBY after 4 seconds.

Escort (ESC) Attack (ATK) mode can be selected using either button 2 or by down input on the castle switch. Successful receipt is indicated by a box around the **ESC** at button 2 and a yellow **RDY** indication at button 16. Full action on the RHC trigger is required to command the F-40 to execute. The F-40 will attempt to employ previously selected weapons (or jamming package) against the highest priority target on the escort menu. The default entry on the escort menu is the highest priority "in range" target on the parent's threat warning display. ESC mode is automatically commanded if the consort is within 5 nm of parent aircraft that has sent a "Defensive" message on datalink.

WARNING

Once the escort mode is enabled, the F-40 will attack the first target that meets the specified conditions. If a subsequent, higher priority threat emerges, the F-40 priority must be changed using the **ATK** function or by commanding **ESC** again.

Weapon selection can be changed in the armament menu under button 15 (see SPECIAL FEATURES below).

Decoy (DCY) mode can be selected using either button 3 or by left input on the castle switch. Successful acceptance is indicated by a box around the **DCY** at button 3 and a green **RDY** indication at button 16. Full action on the RHC trigger is required to command the F-40 to execute. The F-40 will augment its signature and attempt to employ ADM-160 (if loaded) against the highest priority "in range" target on the parent's threat warning display. Automatic use of this function is selected using the shift-designate feature.

CAUTION

Use of the automatic feature may result in unintentional release of decoys or mission compromise.

Loiter (LTR) mode can be selected using either button 4 or by up input on the castle switch. Successful acceptance is indicated by a box around the **LTR** at button 4 and a green **RDY** indication at button 16. Full action on the RHC trigger is required to command the F-40 to execute. The F-40 will begin a random offset orbit 10 to 20 nm (5 to 10 nm if low) from the spot designated on the TSD. The structure of the orbit can be changed in the flightpath menu under button 11 (see SPECIAL FEATURES below).

CAUTION

Loitering F-40 will automatically return to base once JOKER fuel is reached.

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Figure. Extract from notional Technical Order 1FB-22-34-1-1, *Weapons Employment Manual, FB-22 Aircraft*

Combat Employment: Close Air Support

The first combat employment of the X-45A occurred after the devastating Arabian quake in Somalia, which has almost no infrastructure and suffers from ongoing clan warfare. The United States deployed forces to assist in security and logistics support to United Nations relief efforts in that country, particularly around the regional capital of Bendir Kassim, which the quake had virtually leveled. A joint task force based in Djibouti stood up to direct the relief effort, exercising airborne command and control via E-8C aircraft.

The US Air Force lifted elements of an Army Stryker brigade combat team (SBCT) into Djibouti, from which they drove 300 miles along the coast road to what was left of the regional capital. Shorn of organic artillery so it could deploy rapidly, the SBCT relied instead on a squadron of 24 F-40As airlifted into Djibouti from war-reserve storage at the US air base at Incirlik, Turkey. Interference from warlords became routine, and the F-40s rotated to serve as on-orbit assets for responsive joint fires.

The initial use of UCAVs occurred on the second day after arrival of leading elements of the SBCT in Bendir Kassim. Uploaded with a mix of general-purpose (GBU-32 JDAMs) and antiarmor (CBU-97) munitions, the F-40s orbited in unthreatened airspace 10 miles off the coast. At 0900 hours, the brigade staff called the orbiting E-8 aircraft and requested retaskable close air support against a fortified building providing cover for militiamen firing on relief personnel.[12] The E-8 released a pair of F-40s to a close-air-support orbit. After they arrived over the city, a terminal attack controller established communications, designated the target, selected munitions, and keyed "attack" into the handset. Shortly thereafter two JDAMs hit the building, which collapsed in a cloud of powdered concrete and dust. The F-40s, still with half of their ordnance on board, then returned to their orbit.

Fifteen minutes later, the E-8C detected a column of vehicles heading towards the city from a suspect area. Using a Navy Fire Scout already in the area, the E-8C crew identified the vehicles as the ubiqui-

tous African "technicals"—light trucks armed with heavy weapons—and declared the convoy hostile in accordance with the rules of engagement. This time, the E-8C crew pulled all four F-40As out of orbit and tasked them to attack the column. The E-8 continuously updated the position of the individual vehicles, and the Warhawks executed a near-simultaneous attack against the entire length of the convoy. Despite a hail of small-arms fire, the UCAVs remained largely undamaged, each one dropping a single CBU-103 canister. Each of the canisters dispensed 40 independently targeted "skeets" that tracked the hot metal of the vehicle engines and fired explosively forged slugs. A scant 10 seconds later, the entire column consisted of immobile wrecks, some vehicles hit by as many as three slugs. Two empty UCAVs returned home automatically; the two with JDAMs returned to orbit for their remaining on-station time, which proved uneventful. This early demonstration of firepower limited the exposure of US troops to hostile fire and significantly augmented the firepower available to the brigade commander. Arrival of the USS *Abraham Lincoln* a week later added another squadron of F-40As to the stock of aircraft, along with F-18E/F aircraft and a number of helicopters. In this operation, multiple units employed the UCAVs—initially a tactical air control party, then a tactical command and control element, and much later an F-18 from the *Abraham Lincoln*. In most cases, these units provided only target identification, designation, and weapons selection—the F-40 handled course corrections, attack profile, and weapons employment.

"Small Wingmen"

In combat, F-40s have served primarily as "small wingmen." The drastic reduction in the size of both Air Force and Navy combat aviation drove development of the F-40 to "stretch" the capabilities of the more advanced fighters by "tethering" the UCAV to manned aircraft. Efforts to lighten Army brigades spurred additional momentum within the Department of Defense; specifically, the loss of organic artillery support drove an airborne solution to provide fires for light ground forces. The F-40's design made it compatible with a wide array of platforms

that give it instructions with a minimal increase in the crew's workload. F-40s employed in this manner retain the man in the loop for critical decisions.

Counterland and countersurface operations became the logical mission of choice for tethered F-40s. Typically, four to six F-40s accompany a flight of four manned fighters, the UCAVs offering extra weapons, an expanded sensor array, and capability to attack geographically distributed aiming points simultaneously. F-40s also supply both lethal and nonlethal suppression of enemy air defenses and are the weapon of choice for attacking located surface-to-air-missile batteries. Warhawks typically assume the dangerous poststrike reconnaissance mission.

Platforms other than fighter aircraft have made good use of the F-40. Realizing the potential of having a survivable, fast-moving jet under direction, users drastically increased in number. The Longbow Apache (AH-64E), originally built to designate targets for other aircraft using the Longbow radar, became the airborne forward air controller of choice for Army aviation brigades. The Apache/Warhawk combination offered unmatched capability for all-weather close air support. B-1 and B-52 bombers also use the F-40 as escort; however, because of the latter's limited range, the bombers join up with their Warhawks en route.

Some aircraft innovatively employ the F-40 as an airborne "scout." Terrain blockage and curvature of the earth prevent low-altitude or distant aircraft from looking into "the next valley" directly. Consequently, many a reconnaissance mission or package commander let the F-40 take a peek in advance. RC-135s effectively and regularly allow it to serve as an extension of their sensor arrays. EA-18G crews adopted this same concept by utilizing F-40s for lethal suppression of enemy air defenses but find them invaluable for providing "look-through" for their own jamming.[13] Strike aircraft operating at low altitude often direct an F-40 to "pop up" for a look around. Similarly, platforms flying over a weather deck have used this UCAV to investigate below the weather.

Surface combatants, particularly those operating close in the littorals, have turned to F-40s as surrogate sensors, allowing those vessels

to remain under strict emissions control and look beyond the horizon. Using the F-40 for weapons employment allows the location of the parent ship to remain uncompromised.

Air-to-air squadrons, though, did not readily accept the F-40. Despite the promise of extra missiles, the crews pointed out (correctly) that because Warhawks cannot fly either extremely high or supersonically, the advanced medium-range air-to-air missiles launched from those platforms lacked a running start and could not match the range of fighter-launched weapons. Defensive counterair missions partially alleviated this problem by placing the F-40 combat air patrol much closer to the threat although this tactic was of little use offensively. Any remaining objections vanished when a young F-22 weapons officer realized that the F-40's AIM-120, although shorter ranged for the typical nose-to-nose engagement, was longer ranged for any action in which the consort had to shoot off-boresight because of its defensive or neutral posture. The F-40 could afford to point at the enemy when its consort could not; AIM-120s shot from "hot" Warhawks wasted no energy making a turn to line up on target.

Black Operations

Granted, regular forces employed the UCAV in roles formerly filled by manned fighters, but the special operations community took to the F-40B like ducks to water. The F-40s gave this community two capabilities it had lacked entirely: a means of covert resupply and a pathfinder aircraft. Equipped with parachute-retarded supply pallets, Warhawks can resupply special operations forces yet minimize the chance of detection. A single UCAV can deliver 1,600 pounds of cargo in two pallets although long-range missions cut this figure in half because of the need to carry extra fuel.[14] Normally conducted with MC-130s and MV-22s, Pathfinder missions send F-40Bs along a planned flight route to survey the radar environment and help ingressing aircraft avoid detection.[15] UCAVs flying such a mission often carry a four-pack of

GBU-39 bombs for reactive suppression. Additionally, F-40s can pre-survey designated landing zones in advance.

The Department of Defense is not the sole user of the F-40B, but exact numbers and operators remain unconfirmed. Supposedly, the Central Intelligence Agency operates these aircraft, and both the Drug Enforcement Administration and Immigration and Customs Enforcement have been known to "borrow" Warhawks for surveillance. One of the rare payloads is a sampling pallet, used to take air samples along a specified route of flight. Unconfirmed rumor has it that such a payload has played a role in monitoring chemical weapons production and the Iranian nuclear-enrichment program.

Rapid Deployment and Sea Basing

The Air Force, Navy, and Marine Corps—the F-40's primary operators—can use the A and B models interchangeably although each service has its "own" appropriately marked jets.[16] Since all F-40s can fly from an aircraft carrier, it is not unusual to see a "USAF" aircraft doing so. Even F-40Cs have operated from flattops—a rare occurrence that involves a small Air Force maintenance detachment on board the carrier. Block 20 aircraft will be able to operate off *Wasp*-class amphibious carriers, effectively doubling the number of hulls that can accommodate UCAVs. Successful tests have taken place on the USS *Essex* (LHD-2) using a portable "ski ramp" for launch rather than the fleet carrier's catapults. Arrested landings remain the only means for recovery, utilizing a bolt-on three-wire arresting kit derived from the Air Force's mobile aircraft arresting systems. These systems permit smaller flattops to operate fast jets, but the launch and recovery of UCAVs interrupt normal helicopter and vertical and/or short takeoff landing and operations.

Current Navy and Marine Corps concepts call for a number of employment options since the Navy prefers to use tactical Tomahawk missiles rather than autonomous F-40s during high-intensity operations. Typically, F-40s fly a preplanned route to a pickup point where another aircraft (often from the same carrier), a nearby ship (includ-

ing submarines and littoral combat ships), or a forward air controller directs semiautonomous operations.[17] Operations from amphibious carriers allow the "delivery" of F-40s into holding orbits where they remain until called upon by Marine forces ashore.

The F-40A remains rapidly deployable: a single C-17 sortie can carry four crated UCAVs, and the C-5M can carry six. F-40s at lighter launch weights can take off from airfields as short as 3,000 feet. Clearly, short fields and sea basing significantly increase the basing opportunities. F-40s are stored in transportable configurations at a number of locations worldwide, more than half of the Air Force's UCAVs remaining in their crates, stored with support equipment and munitions stocks ashore and on maritime pre-positioning ships. Many of the overseas "cratehawks" reside at Air Force bases that also operate combat aircraft.

Training and Maintenance

Flight training for the F-40 occurs almost entirely by simulation—a first among major weapons systems. Since there is no pilot to train, the presence of the actual aircraft remains largely unnecessary. Most units have built-in software that allows them to train on simulated weapons that have the "look and feel" of Warhawk employment, obviating the need for the real platform.[18] Units capable of employing F-40s regularly practice with the simulations; some never conduct a tactical training mission without them. Normally, large numbers of the UCAVs appear only in large force exercises at Nellis AFB or Naval Air Station Fallon, Nevada.

Simulation allows most of the Air Force's F-40s to remain in storage (hence, the term "cratehawks").[19] When these aircraft first reached the field, everyone expected that all of them would stay in storage until needed—a notion that proved unsatisfactory for two reasons. First, because their maintenance crews received insufficient experience with real-world flight operations, the Warhawks' reliability rates were lower than expected. Second, joint terminal attack controllers felt uncomfortable with pure simulation because the F-40s never showed up in

training. Consequently, they rarely employed the UCAVs—even in simulation.

The Air Force corrected both problems rapidly and did so in a fashion that permitted it to kill two birds with one stone. At every base that has a squadron capable of employing F-40s, at least three fly daily operations.[20] Because these aircraft see heavy use when they exercise with ground forces, joint terminal attack controllers become accustomed to their air support. Most training still makes use of simulated weapons; thus, F-40s are often "reloaded" in flight, giving the appearance of a larger number than are actually flying.[21] These UCAVs routinely participate in live munitions drops at Nellis and Fallon, and both Combat Archer (an air-to-air weapons system evaluation program) at Tyndall AFB, Florida, and Combat Hammer (an air-to-ground weapons system evaluation program) at Hill AFB, Utah, routinely drop (or shoot) live weapons from F-40s under semiautonomous control.

By any standard, the F-40 program has been a resounding success, giving the United States a flexible, lightweight fighter at relatively low cost, and adding to the joint force a number of capabilities that did not exist prior to the Warhawk's initial operational capability. One can gauge the program's success by examining the proliferation of imitators: Russian, Chinese, and French manufacturers are all pursuing similar programs.[22]

The View in 2013

No one can realistically assume that UCAVs will replace manned combat aircraft anytime soon, public law notwithstanding. The flexibility inherent in having a pilot in the environment remains the single most important aspect of combat aviation writ large, and replacement of human aircrews is not in sight. Similarly, the remote-pilotage model used by the MQ-1 and MQ-9 is suitable only for uncontested airspace. Nevertheless, we could expand the capabilities of manned aircraft—even to the extent of replacing them on the air tasking order when ap-

propriate and reserving manned combat aircraft for those times when we need them. The United States has done so for more than 40 years, first with the Firebee drones in Vietnam and much later with Tomahawks and air-launched cruise missiles. Like the Firebee, the UCAV is designed to come back and do it again, and its assigned tasks are relatively simple—despite their importance. Given our fiscal challenges, the future threat environment, and the possibilities inherent in missionized UCAVs, they seem an obvious candidate for a major weapons program. ✪

Notes

1. Notably, arguments that favored purchasing the Predator and Reaper because they would reduce the risk to pilots have turned out to be nonsense because the aircraft can operate effectively only in environments without air defense.
2. This fact poses a design problem for operations with the F-22, which can "supercruise"—that is, cruise in excess of Mach 1 without using afterburners. Given the small size of the Raptor buy, most UCAVs will be employed with and by platforms that cannot (and need not) match the Raptor's performance.
3. The F-40 is an entirely notional system, discussed here solely to allow a usable reference point.
4. The weapons bay size (about 20 inches wide, 20 inches deep, and 150 inches long) also accommodates a number of other weapons, from the AIM-120D to the CBU-87/-89/-103. A four-pack of small-diameter bombs on a BRU-61 is 143 x 16 x 16 inches.
5. Because of the F-40's limited takeoff weight, the external hardpoints serve primarily to carry weapons too large to fit in the internal bay and, consequently, are rarely installed.
6. The tankers are equipped with a short-range communications link that provides flight-control data to the F-40 for refueling.
7. These packages count against the maximum gross takeoff weight but do not take up space in the payload bays. Thus, a "full-up" (but empty) UCAV would have all of the add-on combat capabilities.
8. The SUU-64/B canister allows for dispensing a variety of munitions—from leaflets to gator mines, sensor-fuzed weapons, or combined-effects submunitions.
9. The Navy has experimented with carrying two AGM-84s externally, with two empty fuel tanks in the payload bays. This configuration does not exceed the maximum takeoff weight and can then be refueled when airborne, effectively doubling the combat radius with a single refueling. Minor software adjustments allowed flight under very heavyweight conditions, which adversely affected handling characteristics. In the words of a flight-test engineer, the aircraft "flies like a drunken pig" when heavily loaded; therefore, naval air training and operating procedures as well as Air Force instructions prohibit operations below 500 feet.

10. The present F-40 series operates under the initial Block 10 production configuration. Block 20 aircraft will have an additional control module allowing interface with other air defense assets (the Patriot, Medium Extended Air Defense System, and Aegis especially). All Block 10 aircraft will be retrofitted.

11. The landing mode, ironically referred to as the "emergency landing mode" by the Air Force and the "trap mode" by the Navy, lets the carrier fly the UCAV on final approach, resulting in near-perfect recoveries in most weather conditions.

12. Retaskable close air support missions are issued as fragmentary orders in the air tasking order with no preplanned recipient and tasked as necessary on the fly, based on the need for joint fires.

13. Smart jamming platforms must be able to "look through" their own jamming to determine their effect on the victim signal—or determine if that signal exists at all. This often requires turning off the jammer for very short periods. EA-18G crews use a distant F-40 to determine the status of both the victim radar and the jamming technique as well as receive satellite communications data.

14. The cargo pallet itself weighs 100 pounds empty, including frame, parachute, and air bags. The maximum deliverable cargo weight amounts to 800 pounds on land and 1,000 pounds on water, all of which must fit within the fairly restricted canister dimensions.

15. B-2 Spirit bombers are also known to join up with F-40s launched in-theater, using them as both armed pathfinders and bomb caddies. The Air Force would have incorporated similar capability into the F-117 had the service not retired it.

16. Because of the different engine and the no-service requirement for supercruise, the Navy and Marine Corps did not purchase any F-40Cs although these aircraft remain capable of carrier operations.

17. Primarily, the E-2D and the two-seat F-18F and EA-18G serve as airborne controllers for multiple UCAVs (the P-3 and P-8 [multimission maritime aircraft] do so as well). F-18Es rarely control more than a single Warhawk.

18. For platforms (such as the RC-135) that did not have such software, Lyton Industries developed a retrofit kit to allow in-flight F-40 simulation.

19. This problem never manifested itself in the Navy and Marine Corps because all F-40s assigned to at-sea ships were fully assembled and ready to go.

20. Aircraft on flight status are rotated among the stock on hand so that all F-40 airframes fly for several periods each year and crews maintain proficiency in assembly, disassembly, and maintenance.

21. Because the Federal Aviation Administration remains skeptical about UCAV operations in controlled airspace, most F-40 activity outside the western test ranges occurs while they are tethered to a manned aircraft.

22. To be fair, the French Dassault "Gran Duc" program actually predates the F-40, having been a counterpart of the Defense Advanced Research Projects Agency's original UCAV program—the grandfather of the F-40.

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