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A 21st-century Concept of Air and Military Operations

by Robbin F. Laird

Overview

The evolution of 21st-century air operations is unfolding under the impact of a new generation of fighter aircraft and a significant shift in the role of air operations in support of ground and maritime forces. So-called fifth-generation aircraft often are mistakenly viewed as simply the next iteration of airframes: fast, stealthy replacements of obsolescent legacy platforms. In fact, the capabilities of fifth-generation aircraft, and their integration into a network-centric joint force, will change the roles of manned fighter aircraft in air, ground, and maritime operations. These changes are so far-reaching that the Services face the challenge of crafting a new concept of 21st-century air operations, indeed, of all combat operations.

Historically, fighter aircraft have operated mainly within the classic domain of air operations in the distinct roles of air superiority, air dominance, air defense, strike, and support. Numerous models and modifications of the first three generations of fighters were assigned separable tasks to be performed in sequence. (See box on the next page for a discussion of the five generations.) As the capabilities of fighters increased, the old distinctions blurred, particularly with the introduction of fourth-generation, multirole fighters. Fifth-generation aircraft coming online now will transform the roles of all air elements, including legacy aircraft, and lead to a new concept of operations. Designed (or redesigned) and built in the information age, these aircraft take full advantage of and contribute to the networking of U.S. Armed Forces. The result is a fully capable distributed approach to air operations that enables the United States and its allies to support the full gamut of military missions. Multimission aircraft enable global multimission operations for U.S. joint forces.

Toward a New Concept

Air operations are a significant component of 21st-century U.S. and allied joint and coalition operations. As fifth-generation aircraft enter service in larger numbers, they will generate not only greater firepower, but also significantly greater integrated capability for the nonkinetic use of aircraft[1] and an expanded use of connectivity, intelligence, surveillance, and reconnaissance (ISR), communications, and computational capabilities built around a man-machine interface that will, in turn, shape the robotics and precision revolutions already under way. The capability of air assets to connect air, ground, and maritime forces throughout the battlespace can support the decisionmaking of ground and maritime command elements. Indeed, the command, control, communications, computers (C^4) and ISR envisaged in networked operations is becoming reshaped into C^4 and ISRD, whereby decisionmaking (D) is shared across the battlespace. Distributed information and decisionmaking will be enhanced as air operations become much more capable of providing information in support of the deployed decisionmaker, and kinetic and nonkinetic support elements can be cued in support of air, ground, and maritime combat requirements.

A RAND Corporation brief on air combat issued in August 2008 generated debate about U.S. air capabilities in difficult future combat scenarios.[2] In particular, the F–35 came under scrutiny in much of the political and analytical coverage. The RAND brief and the reactions to it are a good starting point for discussion of the changing nature of air operations induced by the introduction of the new manned aircraft.

The RAND analysts focused on a core challenge facing the Air Force in the 21st century, namely, the evolving capabilities of competitors' air systems and counterair capabilities. In particular, the RAND study focused on a 2020 scenario over the Taiwan Strait in which Chinese forces sought to deny air superiority to the United

Defining Fifth-generation Aircraft

Jet fighters can be classified in five generations. The first consisted of subsonic aircraft developed early in World War II through the Korean War (German ME–262 Schwalbe, American F–86 Sabre). The second generation incorporated lessons from air combat and ground support during the Korean War and exploited technological advances, especially in materials and electronics (F–8 Crusader, F–104 Starfighter) and was capable of supersonic flight. Third-generation fighters were largely shaped by Cold War competition with the Soviet Union and combat experience in the Vietnam War; these included increasing use of air-to-air missiles and defense against surface-to-air missiles, both of which put a premium on advanced avionics (F–4 Phantom, F–111).

The first three generations of jet fighters lasted about a decade each. The fourth generation began around 1970 and continues to constitute most fighters in service, although recent versions of some fighters are so improved that they sometimes are called generation 4.5 (F–15 Eagle, F–16 Falcon). Fifth-generation fighters are air superiority and multimission aircraft that achieve increased performance through numerous advances in airframe and propulsion and increasingly sophisticated avionics, including flight control systems.

Fifth-generation fighters are distinguished from generations 4 and 4.5 mainly by their inherent stealth and compatibility with a network-centric or distributed concept of operations, although they are much more capable in many respects. Computing capacity, sensors, and communications systems enable them to gather, exploit, and disseminate information to an extent that can multiply the effectiveness of military forces throughout a theater of operations. To date, only the Air Force F–22 and F–35 qualify as fifth-generation fighters, although several nations are developing comparable fighters.

Non-experts tend to think the shift from legacy aircraft to fifth-generation aircraft is largely about the airframe or stealthiness. Stealth is important, but it is the conjunction of stealth and other capabilities that creates a different capability for a flying force:

- Stealth allows the aircraft to operate over enemy positions, and onboard sensors enable it to target mobile as well as fixed weapons systems. Indeed, the increasing capability of mobile air defenses is a major threat to air superiority in the 21st century. Legacy aircraft rely on target data from other platforms to launch strikes and may not be able to identify and target mobile systems. Incorporation of stealth and sensors in one aircraft puts mobile targets within the scope of effective strike actions.
- Command, control, communications, computers, and intelligence, surveillance, and reconnaissance capabilities are built into the aircraft itself. Integration allows the aircraft to process data and to make informed decisions much more rapidly than fourth-generation aircraft, which need Airborne Warning and Control Systems, electronic attack aircraft, and a variety of accompanying specialized assets to operate effectively in a 21st-century threat environment.
- An easily upgradeable, distributed computer system provides processing power that facilitates a greatly improved man-machine relationship. The aircraft can process data and assist pilot decisionmaking. Indeed, many decisions can be made without intervention by the pilot, which makes the aircraft particularly useful in 21st-century air operations. The man-machine relationship of fifth-generation aircraft enables integration of airborne robotic systems in 21st-century air operations as well. Indeed, as the new aircraft are deployed, a new generation of unmanned systems will develop as well.

States. The study addressed three key elements of U.S. air superiority—the use of nearby bases or seas, exploitation of stealth advantages, and employment of beyond-visual-range (BVR) missiles—applied against Chinese forces. The study argued that all three U.S. advantages could be countered by a Chinese strategy that combined a significant numerical advantage, antiaccess denial strategies, counterstealth innovations, and countermeasures and operations to defeat BVR missiles. In the RAND scenario, the Chinese innovated, but the United States did not.

The study underscored reasonable concerns. Numbers do matter, antiaccess technologies and strategies are evolving rapidly, and defensive measures against stealth and BVR missiles are improving—and Chinese defenses are proliferating. Simply building a small number of highly capable platforms will not enable the Air Force or the U.S. military to prevail in combat.

That is the bad news. The good news is that by leveraging the capabilities of new systems, crafting a 21st-century approach to air operations, more effectively integrating legacy and new air and naval forces, and evolving combined and allied operations, the United States can counter the evolution of a competitor like China. The proliferation of capabilities being developed by China and Russia globally to U.S. and allied competitors is enhancing the need for a rapidly evolving concept of operations (CONOPS) for U.S. and allied forces shaped by the forcing function[3] of fifth-generation aircraft and associated air and naval systems.

Before returning to the analysis of the RAND brief, I want to develop an understanding of 21st-century air operations and the role of fifth-generation aircraft and unmanned systems within the CONOPS. I will then apply the 21st-century CONOPS to the RAND analysis and suggest how the outcome might look quite different.

Connectivity and Battle Management

Air operations in the 21st century are characterized by an increasing ability to connect air, ground, and maritime forces, whereby air assets can support the decisionmaking of ground and maritime command elements. In 20th-century CONOPS, air assets are a largely self-contained force that needs to bring its own assets—notably Airborne Warning and Control System (AWACS) and electronic warfare aircraft—to support air operations. In the new CONOPS driven by fifth-generation aircraft, the combat and strike power of a single aircraft within the operation will not be defined by what it carries, but by its ability to direct and rely on deployed network partners.

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Fifth-generation aircraft will be able to direct strikes by any assets within range of an identified target, whether the weapons are carried by air, ground, or maritime platforms.

In traditional CONOPS, credit for combat power could only be given for internally stored weapons. For the fifth-generation aircraft, a core ability to direct strikes from outside is a core competence for the aircraft and a key element enabling 21st-century air operations. Air battle management becomes networked as well, and not reliant on AWACS, which presents a large profile for air-to-air missiles and thus will be attacked early in an air battle. The Air Force considers the combined air operations center (CAOC) a weapons system in and of itself. To date, CAOCs have been physically located on the ground or dependent on AWACS. With the deployment of fifth-generation aircraft, first the F–22 and then the much more numerous and allied anchored F–35, the CAOC will be enabled by additional flying ISR and command and control (C^2) systems. The combination of sensors and stealth enables the new aircraft to operate at altitudes (in the case of the F–22) or over adversary air space (in the case of both aircraft) to serve as nodes in a dispersed or distributed air battle management system. In this role, they become extensions of the CAOC.

The primary forcing function of fifth-generation Air Force aircraft is to enable distributed air operations across the air, maritime, and ground platforms within which unmanned assets and networked information and strike assets become central to the overall capability of the Service. The F–22 is evolving into a battle management system able to fly at a substantially higher altitude than the F–35. After performing its air dominance missions, the F–22 can transition into a battle management and strike management aircraft.

connecting manned and unmanned systems is a central aspect in the evolution of distributed air CONOPS

A key dimension of shaping distributed air concepts of operations is shaping the "connectivity workspace" within which the fifth-generation aircraft are linked and the evolution of capabilities to link the new aircraft with other air, ground, and maritime military assets.

With regard to connecting stealth assets, a vital aspect is to communicate without detection within "denied" air space or, as the Air Force refers to it, enabling "antiaccess denial" strike forces. Here, the concern is to connect the F–22 with the F–35 with the B–2 and with new unmanned stealth assets. Connectivity for this effort was the focus of a Joint Requirements Oversight Council decision in July 2008, which approved the F–35 data link as the new standard for integrating airborne assets. Specifically, the Multifunction Advanced Data Link (MADL) is to be used by both the F–22 and F–35 as the centerpiece for data transfer in the antiaccess denial strike mission.

But linking these assets with legacy aircraft, ground forces, maritime forces, and the evolving robotic fleet is a dynamic task. The current data standard Link-16 is considered not robust enough by many analysts to provide for full connectivity for the evolution of U.S. military capability. A new approach such as the new Tactical Targeting Network Technology (TTNT) being developed by the Defense Advanced Research Projects Agency and Rockwell Collins could provide for such a possibility.[4]

Connecting manned and unmanned systems is a central aspect in the evolution of distributed air CONOPS.[5] Currently, unmanned aircraft systems (UAS) are built with little regard to connectivity with manned systems. The computer systems of the F–35 will manage new robotic systems that will become part of the airborne air battle management system.[6] In turn, a 21st-century CONOPS enables the operating characteristics of the fifth-generation aircraft to be optimized.

The RAND authors assumed the fifth-generation aircraft were going to operate as if they were combat aircraft in a 1991 air CONOPS. They concluded that the Chinese air capability circa 2020 would prevail, in part, because of superior numbers of aircraft and weapons. As Douglas Barrie of *Aviation Week & Space Technology* observed, "in the Rand study's combat scenario, while the exchange ratio is hugely in favor of the F–22, weight of numbers (of a capable combat platform) coupled with weapons load-out still mean key 'Blue' assets—tankers, airborne warning and control, maritime patrol, and surveillance unmanned aerial vehicles—would be lost."[7]

The RAND study evaluated F–22s and F–35s only in their stealth mode; only missiles contained in internal bays were counted when calculating exchange ratios. But fifth-generation aircraft will not operate only in stealth mode. Indeed, their advantage is that they can be loaded heavily with external stores, operate outside the "stealth operational" range, and launch missiles that are then guided by other fifth-generation aircraft or stealthy unmanned systems (such as the proposed Naval Unmanned Combat Air System) operating within the stealth operational range. After firing external weapons or dropping fuel tanks, the fifth-generation aircraft can refuel and return to the fight and, operating in stealth mode, enter the combat zone and function as forward air controllers, ISR, or C^2 assets—with the internal bay still loaded with missiles.

Working through enhanced collaboration is an evolving effort as fifth-generation aircraft are introduced and a "collaborative workspace" is shaped with other aircraft and between air and surface elements. The potential is significant because of the core capabilities of the new aircraft. Fully realizing the potential will require shaping collaborative tools and CONOPS that leverage the elements of a national or allied force structure. Military platforms and systems are significant, but working through effective concepts of operations for using them is central. This is why one should speak of the "forcing function of fifth-generation aircraft," rather than assuming that simply introducing these aircraft into the inventory is a "silver bullet."

The F–22

The first Air Force fifth-generation aircraft (the F–22)[8] has evolved over nearly 30 years. Originally conceived of as the replacement for the F–15 to maintain air dominance against Soviet aircraft, the focus was largely on shaping F–22 capabilities to generate multiple kills of enemy aircraft. While air dominance remains the sine qua non of successful air operations and power projection into denied territory, the still-evolving F–22 can contribute much more to a joint force. Some of the key lessons learned from years of F–22 deployments are being transferred to the F–35 fleet. More importantly, the air dominance capabilities of the F–22 relieve the F–35 from being designed for this mission set and allow it to focus on its synergistic role working with air, ground, and maritime platforms.

The primary task of the F–22 is air-to-air dominance, followed by core competence in counterair defense missions. The latter task is increasingly difficult, given the evolution of mobile air defense systems. The trend line in adversary air defenses is toward rapid mobility. For example, SA–10s and SA–20s can be dismantled and moved and be ready for action in a short period of time. Mobile air defenses mean that strike aircraft must be able to do target identification, target acquisition, and strike missions virtually simultaneously. A key aspect of the fifth-generation fighter is its onboard processing capability, which allows the pilot to perform operations simultaneously that historically required several platforms operating sequentially.

But the most significant evolution of the F–22 is in its ISR and C^2 capabilities, both associated with its unique Active Electronically Scanned Array radars.[9] The F–22 is evolving into a battle management system able to fly at substantially higher altitude than the F–35. After performing its air dominance missions, the F–22 can transition into a battle management and strike management aircraft, a role further enhanced by the deployment of the to-be-much-more-numerous F–35.[10]

F–22 and F–35 Dynamics

The limited numbers of the F–22 will ensure that the F–35 will be the dominant fifth-generation aircraft in terms of both numbers and availability in a coalition environment.[11] From the standpoint of thinking through 21st-century air operations, the ability of the F–22 and F–35 to work together and lead a strike force will be central to U.S. core capabilities for projecting power. And it is to be remembered that the F–35 is coming off Air Force airfields, allied airfields, Navy carriers, and, in the case of the F–35B (the vertical lift version of the F–35), virtually anywhere close to the action.

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The F–22 and F–35 will work together in supporting air dominance, kicking in the door, and supporting insertion of a joint power projection force. Here, the F–22 largely provides the initial strike and guides the initial air dominance operations; the F–35 and fourth-generation aircraft support the effort. The F–35, because of its stealth and sensor capabilities, will be able to operate in a distributed network to provide strike, ISR, and air defense suppression, as well attack shore defenses against maritime projection forces.

The F–35 is more than a fifth-generation fighter; it is a first-generation flying combat system.[12] The effects that the F–35 can deliver within the battlespace are flexible, synergistic, and multidimensional (air, ground, maritime).[13] The F–35's open architecture allows this flying combat system to become the focal point of three core activities: air-to-air, air-to-ground, and air-to-maritime roles and missions. The F–35 will be defined by how its open architecture is customized by national militaries in meeting their perceived priority needs and mix of air, ground, and maritime mission sets. Its combat capabilities will be defined in part by "CONOPS customization."

One example of an opportunity for CONOPS customization derives from the F–35's multimodal/multimission capability, which includes the ability to deliver nonkinetic as well as kinetic effects, offering decisionmakers many options. The F–35 is central to operationalizing the networked battle management environment. It can provide services (communications, intelligence, and electronic support) to others in the battlespace in ways that are transparent to its pilot. Large platforms that used to provide battle management will be supplanted by a force mix of the F–35 and unmanned vehicles, shaping a 21st-century approach to air operations.

CONOPS customization is the reason that the F–35B is of special interest to the Marine Corps, Royal Air Force, Italian navy, and other forces. The F–35B's short takeoff and vertical landing (STOVL) capability will make possible a different approach to ground-air integration and CONOPS than with that of the F–35 conventional takeoff version. Almost certainly, weaponization and ISR requirements will be modified to work with the STOVL-enabled CONOPS.

An additional aspect in developing joint or coalition CONOPS for the F–35 will revolve around its interaction with other manned and unmanned assets. With regard to manned assets, a key challenge will be to work an effective connectivity battlespace with other manned aircraft, such as the Eurofighter Typhoon and legacy U.S. aircraft. Here, the advantages of each platform in contributing to the air battle and to the type of flexible military force packages that 21st-century air capabilities provide will be the focus of a joint concept of operations.

In addition to the core dynamic of working with a variety of manned aircraft across the joint and coalition battlespace, the F–35 will be highly interactive with the evolution of robotic elements. UAS are not well designed for self-defense. For early entry UAS to stay alive, they need to be part of a wolf pack built around the protective functions of the manned aircraft. As air dominance and air superiority operations succeed, their significance can recede during an operation, allowing the role of unmanned aircraft to increase significantly and, over the course of the operation, supplant manned aircraft in ISR and C^2 roles.

The man-machine attributes and computational capabilities of the F–35 provide a significant opportunity to evolve the robotic elements within airspace to provide for data storage, transmission, collection, weapon emplacement, and loitering strike elements, all of which can be directed by the manned aircraft as the centerpiece of a manned-robotic strike or situational awareness wolf pack. Rather than focusing on robotic vehicles as self-contained units with proprietary interfaces and ground stations, the F–35 can be useful in generating common linkages and solutions to combine into a core wolf pack capability.

Overlaying Concepts

Unlike the authors of the RAND study, I am assuming that the United States is innovating, too, and applying a 21st-century approach to a CONOPS that will complicate Chinese planning and effectiveness. The Chinese will attack U.S. airpower with counterair assets, including fighters in number and in force, and with significant missile strike assets. Like the RAND authors, the Chinese will assume that the Air Force will fight alone, following 20th-century air battle management and attack CONOPS. This assumption will be an important contribution to the Chinese defeat.

First, the Air Force and Navy can operate as an integrated strike and defense force. Fifth-generation aircraft will be used as forward air assets to support coordinated strike and defense operations. As the Chinese reach out to strike U.S. air assets, the distributed operations of the Air Force and Navy will use UAS, fifth-generation fighters, legacy aircraft, integration with Aegis systems, and reliance on Navy strike missiles to provide a comprehensive offensive and defensive capability. Allies will contribute land-, sea-, and air-based systems to the fight. Fifth-generation aircraft functioning as forward air controllers will provide a complicated set of vectors of attack and defense, and Chinese strike assets will be exposed to counterstrikes as they seek to reach out to assets they think they can see in the forward area.

Second, the fifth-generation fighters will draw on lethal assets outside the forward area to attack approaching Chinese forces. Distributed over the battlespace, and operating as nodes in the strike determination network, fifth-generation aircraft will guide strikes and determine core targets for a counteroffensive.

acquiring fifth-generation aircraft in sufficient numbers to enable 21st-century air operations is crucial

Third, the STOVL capability of the F–35B[14] will allow its distribution throughout the battlespace on dispersed launch points to contribute to the diversity of vectors of attack and defense against the Chinese. The ability of the F–35B to penetrate the battlespace in a stealth mode, land in a remote area, and then wait to deploy against a primary target is an additional capability, which this fifth-generation aircraft contributes to the new CONOPS.

Fourth, allies will be available to contribute ISR and other nodes in the attack and defense network, which can contribute to a further enhancement of the distributed network. Australian F–35s can participate in the fight or their Wedgetail and Global Hawk assets deployed to provide further battle management capabilities.[15]

Fifth, the introduction of the Navy's new unmanned combat air systems (UCAS) and other unmanned aerial vehicles can provide important strike assets that can be directed by the F–22s and F–35s functioning as forward air controllers.

Sixth, the movement away from AWACS to the use of the fifth-generation fighters as air battle management assets will significantly reduce the ability of the Chinese to shut down the force multiplier aspects of air battle management. Indeed, the RAND study provides an important warning for why the United States needs fifth-generation aircraft. AWACS is an increasingly easy target for a force such as China.

Seventh, the tanker vulnerability identified in the study is a good argument for the next-generation tanker. The tanker selected by the Air Force in 2008 (the NG A330) would deploy farther from the strike area and be able to remain aloft indefinitely (with crew rest areas) and be refueled while deployed. Because fifth-generation fighters operate as a combined strike, ISR, and communications asset, they need to be able to stay on deployment for a period based on the pilot's endurance, not on the fuel capacity or weapons load of the aircraft.

In short, by confronting the Chinese with a distributed 21st-century air CONOPS, the United States and its allies can prevail. If the Air Force operates alone and follows 20th-century air CONOPS and relies on the limitations of legacy aircraft, the United States loses. That is why it is imperative to focus on a 21st-century CONOPS and to build, buy, and deploy joint and combined assets that enable such a CONOPS.

Moving Forward

Acquiring fifth-generation aircraft in sufficient numbers to enable 21st-century air operations is crucial. Doing so could allow elimination of several legacy systems, such as AWACS, and dedicated electronic warfare assets, which would save money in terms of acquisition and logistics, as well as enhance the capability of U.S. operations. Leveraging legacy fleets is equally important. Here, the F–35, which will become the centerpiece of the 21st-century air operations fleet, with MADL and other post–Link-16 (such as TTNT) connectors for strike and defense fleets, is the clear centerpiece.

The F–35 has the further advantage of being a joint and coalition aircraft.[16] This means that the integration of a significant part of U.S. power projection forces—Air Force, Navy, and Marine Corps—is built into acquisition of the aircraft. And as coalition partners acquire the aircraft worldwide, working joint concepts of operations with those allies will enable both allies and the United States to operate in a 21st-century CONOPS.

Indeed, integration of the Navy and Air Force within an overall power projection force is suggested by such an approach. The Navy's first 21st-century carrier will carry F–35s and probably UCAS, which will allow the Navy to configure the carrier as a significant contributor to joint CONOPS. And the UCAS will precede any new bomber for the Air Force and will make an important technological and operational step toward defining how a new bomber can contribute to the joint battlespace.

By becoming much more closely integrated with the Air Force, the Navy can make intelligent decisions about the future of its surface fleet. The F–22 will play a key role as the lead element of a Navy or Air Force strike force, but the RAND analysis underscores the need for the United States to significantly increase the number of "bullets" that it can bring to the fight. The Navy can provide those bullets in terms of missiles deliverable from the surface fleet.

Unmanned contributors to the joint fight should be developed according to their ability to work with fifth-generation aircraft. Some will operate as decoys whereby the Chinese, for example, fire against what they think are deployed U.S. strike assets and so open themselves to a powerful counterstrike from distributed assets. Some will function as airborne routers operating in the battlespace to receive data from fifth-generation fighters machine systems and then distribute that data to the relevant assets in the battlespace. Airborne routers and other assets will also dump data to ships for further processing and distribution in determining strike and defense positions, which will then be provided to the shooters available to strike key targets. And some will function as weapons caddies carrying weapons to be targeted by manned aircraft or forward deployed UCAS.

In short, a 21st-century concept of air operations opens the way to an overall 21st-century concept of power projection. And shaping such an approach is crucial to defeating an adversary such as the one posed in the RAND report and to the general ability to link U.S. and allied capabilities into a collaborative force able to provide for a global security enterprise.

Notes

[1] Examples of nonkinetic effects are information and cyber warfare, electronic attack, intelligence, surveillance, and reconnaissance (ISR) and command and control contributions to ground forces, management of robotic ISR elements, and processing of information to support shared decisionmaking between air and ground forces.

[2] John Stillion and Scott Perdue, "Air Combat, Past, Present and Future" (RAND Project Air Force, August 2008). The report was not released officially, but an unauthorized version has been available on the Internet since shortly after it was presented. One source is available at <www.flightglobal.com/cgi-bin/mt/mt-search.cgi?search=baby+seals+brief&IncludeBlogs=108>. Among the articles that discuss the report are Wendell Minnick, "RAND Study Suggest U.S. Loses War With China," *Defense News*, October 16, 2008; Stephen Trimble, "Under Attack," *Flight International*, October 14–20, 2008; and "The F–35's Air-to-Air Capability Controversy," *Defense Industry Daily*, October 12, 2008.

[3] In the terminology of systems engineering, a forcing function is a parameter that controls the behavior of a system and makes its behavior regular and predictable. It is also known as a driver function or, in common parlance, a driver.

[4] A brief description of Tactical Targeting Network Technology is available at <www.darpa.mil/ipto/Programs/ttnt/ttnt.asp>.

[5] As Major General Charles Davis, USAF, the Program Executive Officer for the F–35, recently commented, "We know that we want to share targeting, data, threat or electronic warfare information with or from a UAV. The issue is not if we can do it. We've got the software. But it is a pretty big gorilla in terms of the number of aircraft that will have the capability. You've got to find the message and determine what it says. How do I want it to go from node to node? They haven't solved it, but it has highlighted the problems with a future networking system."

[6] As General Davis observed, "We will change processing systems twice within the next four years. We will do this by simply taking out the chip and replacing it. The F–35 is a flying computer able to manage the battlespace." See David Fulghum, "JSF Honchos Talk Program Future," *Aerospace Daily and Defense Report*, February 13, 2009.

[7] Douglas Barrie, "Quantity and Quality," *Aviation Week & Space Technology*, November 3, 2008, 66.

[8] Michael Sirak, "F–22A: The Next Stage-Raptor Rapture," *Jane's Defence Weekly*, January 18, 2006.

[9] "F–22 Demonstrates Sensor Data Transfer," *Defence Systems Daily* (May 6, 2008); "F22s May Deploy to Middle East," *Aviation Week & Space Technology*, March 31, 2008, 21; "Not Just Fighters," *Aviation Week & Space Technology*, June 25, 2007, 27.

[10] David Fulghum, "F–35 EW System Redefines Combat," *Aviation Week & Space Technology*, January 21, 2008, 50; David Fulghum and Graham Warwick, "New Missions for the F–35," *Aviation Week & Space Technology*, July 23, 2008, 13.

[11] Graham Warwick, "USAF Plots Path from F–22 to F–35," *Aviation Week & Space Technology*, September 29, 2008, 36.

[12] The Marine Corps argues for the F–35B as a "flying combat system." The Service's aviation command focuses on the F–35B as a "key enabler for distributed operations lethality" with "unprecedented situational awareness and connectivity with ground forces providing organic high-end ISR and electronic warfare capabilities." Also see Gareth Jennings, "Above and Beyond: F–35 technology offers a new vision of future combat," *International Defence Review*, June 2008.

[13] See General Davis' comments in Douglas Barrie et al., "Industrial Dogfight," *Aviation Week & Space Technology*, July 21, 2008, 24.

[14] "Though nearly identical in appearance to the F–35A, the F–35B incorporates a counter-rotating shaft-driven lift fan positioned directly behind the cockpit. The lift fan, produced by Rolls-Royce, is turned by a drive shaft from the F–35's massively powerful single engine, which features a swiveling rear exhaust nozzle that vectors thrust downward during vertical flight. The lift fan, engine, and stabilizing roll ducts beneath the F–35B's wings combine to produce 40,000 pounds of lifting force. Converting the F–35B from STOVL to conventional flight and vice-versa requires only the push of a button by the pilot. The system otherwise operates automatically." See "Lockheed Martin F–35B STOVL stealth fighter achieves successful first flight," available at <www.lockheedmartin.com/news/press_releases/2008/061108ae_f35B_firstflight.html>.

[15] David Fulghum, "Australia's Need for UAVs becomes Critical," *Aviation Week & Space Technology*, May 31, 2006.

[16] A key aspect of the F–35 not discussed here is the new manufacturing system, similar to the Boeing Dreamliner or Airbus 350, in providing automated production capabilities, subsystem integration, and global sourcing. For a discussion, see Robbin F. Laird, "The F–35 as a Manufacturing and Export Model," *Manufacturing News*, March 9, 2009, available at <www.manufacturingnews.com/news/09/0309/laird.html>.

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