



# F-35 Lightning II Program

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## THE F-35'S NEW OODA LOOP

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As the dogfighting age gives way to the information age, naval aviation's cutting-edge stealth fighter is rewriting the John Boyd playbook. 'There is a partly justified criticism that peacetime generals are always fighting the last war instead of the next one.'

That sentiment, expressed in a 1937 edition of the *Dallas Morning News*, has appeared many times with varying degrees of accuracy. While the U.S. military has spent most of the last few decades engaged in combat operations, fighter aircraft have flown largely in a low-threat environment unchallenged by advanced adversaries. These aircraft, in fact, faced their biggest threat in 2012 while parked on the flight line. 1 So are today's "generals" once again fighting the last war as they develop the next generation of fighter aircraft?

In the case of the F-35 Lightning II, U.S. and allied pilots around the world will be impressed by a fighter built to fight the next war, with the versatility to dominate today's conflicts. One of the primary design elements of the F-35 was executing a fifth-generation version of John Boyd's well-known Observe-Orient-Decide-Act (OODA) loop. 2 This fifth-generation OODA loop uses information as its key attribute, while taking into account current technology and tactics, which have changed greatly since Boyd helped shape the design of the F-16 in the 1970s. Using this updated paradigm to shape the next generation of fighters yielded an F-35 designed around information flow, rather than dogfighting, as fourth-generation fighters such as the F-16 and F/A-18 were. This shifted emphasis may come as a surprise, given the success those fourth-generation fighters have enjoyed over the last 40 years. The fifth-generation OODA loop, however, has produced a fighter that is unmatched in lethality, survivability, and versatility. Thankfully, the "generals" were not enamored with yesterday's wars when it came to the F-35—designed to fight and win in the changed battlespace.

As the first service of the first country to declare initial operational capability (IOC), the U.S. Marine Corps is on the leading edge in bringing this fifth-generation fighter on line. 3 As the Marine Corps recently reached this milestone, many have written about the F-35 and its future in combat. With the Marines' first operational squadron, the Green Knights of Marine Fighter Attack Squadron (VMFA) 121, prepared to fly into harm's way, it is important to understand why fighter pilots across the world will appreciate flying the F-35 in combat, not just in airshows.

Simply dispelling the many myths about the F-35 could easily warrant full-time employment. It is difficult to sift through the litany of government reports on the F-35's progress and draw any sweeping conclusions, but there are certain undeniable facts. No, the F-35 is not the most expensive aircraft the United States has ever purchased, or even the most expensive fighter. 4 Nor is the F-35 perfect, as reliability and supportability improvements through software and hardware updates will continue to correct flaws and add capability over the life of the aircraft. But yes, F-35s are getting cheaper to buy year after year as the cost per aircraft continues to come down with each successive contract. 5

Although the F-35 is unlike any current fighter, all new platforms entering service face challenges, and in this sense, the F-35 will be no different. It is the first stealth fighter in naval aviation, and it will take some education at all levels to fully utilize its unique capabilities. Key leadership must realize that the F-35 is not a Harrier or a Hornet and should not be limited to being employed like these fourth-generation aircraft. Experience on the flight line will grow as the next generation of pilots and maintainers gain significant experience with the aircraft.

Pilots transitioning to the F-35 will learn to maximize its strengths; in addition, their frame of reference will change regarding what a fighter is capable of accomplishing. The F-35 will win over critics with its impact on the battlefield just as the MV-22 Osprey did on its first combat deployment. 6 This is not your father's fighter of the 1970s, and when employed with today's weapons and tactics it produces groundbreaking results.

With the unprecedented success the United States has enjoyed with fourth-generation fighters, it may be tempting to think that the characteristics that made these aircraft successful are the same ones required for future success—"generals" once again preparing for the last war. While these dated characteristics do not translate to a fifth-generation fighter, the philosophy that determined their strengths does. This philosophy, the aforementioned OODA loop, was developed by Air Force fighter pilot John Boyd in the 1970s, and he used it to shape fourth-generation fighter design, taking into account the weapons, technology and tactics of that era. 7

Military, business, and sports strategies have long employed the OODA-loop concept, and while its details are complex, the basic idea is that the winner of a conflict will be the one able to execute the four phases of the loop faster than one's adversary, always staying a step or two ahead. 8 Boyd's OODA loop of the 1970s valued maneuverability in a fighter because it could help a pilot gain a firing position or deny an adversary an attacking position. 9 Boyd's point of reference was flying F-86 Sabres in Korea, and dogfighting in that war was something a fighter pilot could expect in combat. The weapons and tactics of 1970 required a pilot to visually acquire an adversary, and then point his aircraft to employ weapons. Pilots depended almost exclusively on maneuverability to engage their adversaries. Designing a fourth-generation fighter around maneuverability based on these ideas seems obvious today, but Boyd's concepts were unconventional at the time.

Maneuverability was the key to Boyd's OODA loop in 1970, but a lot has changed since then. The nearly 45 years since the design of the F/A-18 and F-16 is a long time in military history, but an eternity in aviation. To put "aviation years" in perspective, the first Marine aviator, First Lieutenant Alfred Cunningham, made his first solo flight in 1912, reaching a blistering top speed of right around 50 mph. 10 Only 35 years later, Chuck Yeager shattered the so-called sound barrier at right around 700 mph.

Over the last 40 years, fighter capabilities have grown tremendously. It is no longer necessary for fifth-generation pilots to acquire an enemy visually, in the air or on the ground, before engaging them. Nor are they required to point their aircraft at an enemy in a dogfight. An F-35 pilot can turn his head, look at another aircraft off his wing, and shoot it with a missile without turning the aircraft at all. This revolution scraps the idea that a fighter's turning performance should be the overwhelming design priority it once was. While maneuverability allowed a fourth-generation fighter pilot to operate the OODA loop at a faster tempo than his enemy in a dogfight, this is not the primary conflict a fifth-generation fighter is designed around. Today's designers optimized the F-35 to execute a coordinated OODA loop between a flight of F-35s performing an air-to-air or air-to-ground engagement with today's weapons and tactics, not a 1970s one-on-one dogfight.

Signs have been around for years that the U.S. fighter industry realized that performance no longer carried the tactical significance it once did. Shortly after the introduction of the F/A-18E/F Super Hornet, Boeing test pilots began to perform at airshows configured with heavy inert ordnance, which had the same weight and shape as combat ordnance. The intent was to highlight the combat capability of the Super Hornet to potential customers, and it was impressive. A stripped-down clean aircraft would have been capable of a technically better show, but would have been less impressive to a potential customer.

The idea that pure aerodynamic performance is not the most critical fighter attribute is also catching on around the world. Fourth-generation fighters are moving toward sacrificing performance for a reduced radar cross-section and improved sensors. In early 2014 the Indian Air Force publicly criticized the Russian-Indian codevelopment program of its advanced stealth fighter primarily because of poorly designed radar and stealth features, not aerodynamic performance. 11 It's no secret that fighters have not been required to dogfight in combat for many years.

The F-35 still requires a solid baseline of aerodynamic performance comparable to, but not necessarily exceeding, its fourth-generation counterparts. The F-35 hits the mark in this area as well. Having flown hundreds of hours in the F-35 carrying both air-to-air and air-to-ground ordnance, I can attest its performance with a combat load is impressive. While more performance is always better, the "generals" were wise not to compromise the F-35's stealth or avionics in exchange for outperforming other aircraft. The OODA loop is faster when an F-35 pilot turns his head to engage an adversary, not the aircraft. Since excessive performance doesn't enhance the pilot's ability to execute the fifth-generation OODA loop, it didn't make the cut.

Tactics have changed quite a bit in the last 40 years as well. Boyd could only have imagined the weapons and sensors available to an F-35 pilot. Marine Corps, Navy, and Air Force weapon schools are continuously refining tactics to take advantage of these weapons and sensors, maximizing the aircraft's strengths. F-35s have recently been involved in multiple large-force exercises as part of this refinement process, and the initial results, not surprisingly, have been exceptional. 12 F-35 tactics will continue to evolve as weapon schools gain more experience with the aircraft and as new weapons and capabilities are added.

If superior performance is not required to win the next war, what is? What characteristics will allow a fifth-generation fighter pilot to execute the OODA loop at a faster tempo than his enemy in a combat scenario he is likely to encounter? The answer, in a word, is information. The architects of fourth-generation aircraft couldn't have imagined how today's technology brings volumes of data directly to everyone's fingertips and is changing life around the world. Neither could they imagine how information in the cockpit is changing the way we fight wars—and design fighters. A fighter pilot with the right information at the right time will not have to dogfight his aircraft, because the enemy will already be defeated. This is not just a lofty theory; it has proven itself in the years since the Vietnam War, as the United States has not downed any enemy fighter with a gun since that war ended.

Driven by information, a pilot executes the fifth-generation OODA loop in the same manner as the fourth-generation version, with a few key differences. No longer are the pilot's eyes his primary means to gathering information nor maneuverability his primary tool for executing the OODA loop, as it was in a one-on-one dogfight. Today's fighter pilot uses aircraft sensors to collect information and modern tactics to execute the OODA loop as a coordinated flight. Fighters have always flown missions together with wingmen, but an F-35 pilot can maximize the capability of his flight by coordinating with his wingmen like never before. This coordination enables the fifth-generation OODA loop to operate at a rapid pace, generating a new level of effectiveness in both air-to-air and air-to-ground missions.

Designed to gather critical information to feed the OODA loop, the F-35 uses a suite of the most advanced sensors in the world. These sensors include advanced radar, infrared search and track (IRST), an electronic-warfare suite, and advanced data-links. Unique sensor-fusion algorithms integrate these sensors with advanced weapons and tactics to create an OODA loop that no fourth-generation fighter can match.

The F-35's active electronically scanned array radar is one of the most advanced fighter radars in the world. Optimized for a broad spectrum of capabilities, it excels at air-to-ground high-resolution mapping, ground moving-target detection and tracking, combat identification, and electronic warfare in addition to air-to-air engagements. The performance of this radar from the cockpit has exceeded expectations, and is still improving. There is no fighter with a more effective radar in the world to get the OODA loop started.

A superior radar is not the only sensor the F-35 brings to the fight. Today's tactics also involve passive targeting, performed with the F-35's electro-optical targeting system (EOTS) and IRST. Located just beneath the nose, the EOTS performs air-to-ground targeting as well as air-to-air passive targeting to complement or replace radar targeting. In addition, the F-35 has a passive 360-degree, spherical, infrared awareness system. This system prevents an aircraft or missile from surprising an F-35 from any direction.

To ensure the pilot receives the right information at the right time, the F-35's sensor fusion correlates targets from each of the sensors, equipping the pilot with a clear tactical picture to execute his OODA loop, not just heaps of data. F-35s can collect this information and efficiently share it with other F-35s, creating a two- or four-aircraft unit capable of its own information-driven OODA loop.

Stealth also has a place in the fifth-generation OODA loop. Just as maneuverability could deny a firing position from a fourth-generation adversary in a dogfight, stealth denies targeting information to the fifth-generation adversary. If the enemy can't find you, his OODA loop cannot move forward. Stealth is not required to be effective throughout an entire engagement, only long enough for the F-35 to stay a step or two ahead in the OODA-loop cycle. Stealth is a key piece, but only one piece of the F-35's fifth-generation design, enabling it to execute an effective OODA loop.

As the F-35 enters service around the world, fourth-generation aircraft will continue to play a key role in air warfare for the foreseeable future. Still relevant, these aircraft must integrate effectively with fifth-generation aircraft for the next 20 to 30 years. The F-35 is equipped with a legacy data-link, Link-16, which allows critical information-sharing across fourth- and fifth-generation platforms in addition to its stealthy, fifth-generation datalink.

Designed to employ information in executing the fifth-generation OODA loop, the F-35 is capable of defeating the advanced threats of tomorrow, in addition to performing today's missions. It maintains a high level of combat performance while carrying a substantial air-to-air or air-to-ground ordnance load and while remaining stealthy. It is the only aircraft in existence with this combination of lethality and survivability, and precisely why other aircraft designers around the world are trying to imitate its formula for success.

With the versatility to operate from land bases, amphibious carriers, and large-deck carriers, the F-35 will deliver a fifth-generation capability to combatant commanders across the globe with unprecedented flexibility. The "generals" got it right this time: The F-35 is poised to fight and win the next war, not the last one.