The Joint Strike Fighter has to be affordable. Currently, it is not.

Make or Break for the F-35

The sun rises on six Air Force F-35As awaiting flight testing at Edwards AFB, Calif., in June. After lackluster testing progress in 2010, test sorties are mounting rapidly in 2011 as the test fleet grows.

As the Pentagon's biggest and most expensive program, the F-35 is getting intense scrutiny, both from Pentagon managers and Congress. Now that tight fiscal limits put every defense dollar under threat, the F-35 needs to prove itself—and fast.

There's been a whirlwind of action on the F-35 over the last 18 months. The program has been shaken up and restructured—twice—prompted by severe cost and schedule overruns. The Nunn-McCurdy law requires the Defense Secretary to scrutinize such programs and decide whether the requirement can be met some other way.

Ashton B. Carter, the Pentagon's acquisition, technology, and logistics chief, told the Senate Armed Services Committee in May that after this analysis: "We didn't come up with any better alternatives to the Joint Strike Fighter. We want it."

However, Carter immediately added, "At the same time, it has to be affordable; and at the moment, … it's not."

Carter said that during the last decade, the F-35's per-aircraft cost "has doubled in real terms." That has happened, in part, because as the nation was fighting two wars at once, money was flowing to the Pentagon, and there was "an erosion of focus on affordability," he admitted.

This doubling of the F-35's price is "unacceptable," Carter acknowledged, but will come true "if we keep doing what we're doing." He pledged to the senators that DOD is doing all it can to break out of habits that drive cost up, and he expressed cautious optimism that it can drive cost out of the program.

Following the Nunn-McCurdy breach, Defense Secretary Robert M. Gates certified that the F-35 program is essential and must continue in order to accomplish a massive modernization of US fighters, many of them nearing the end of their useful service lives.

However, he ordered sweeping changes to the project. Flight testing, well behind schedule, was extended, and he added $4.6

Time

By John A. Tirpak, Executive Editor

Lockheed Martin photo

billion and two years to the development program. Correspondingly, he slowed purchase of production-representative aircraft to just 32 to 35 aircraft per year for three years, representing an overall reduction of more than 220 F-35s from the Future Years Defense Program.

That move was meant both to keep the program within spending limits and reduce concurrency—what Carter described as the "balance" between building airplanes "too fast [or] too slow," given that discoveries made in flight test can force changes in design and costly rework of early production aircraft. Carter also told the SASC that to keep risk down, the production rate will only increase by a factor of 1.5 a year.

Gates put the F-35B short takeoff and vertical landing version—STOVL for short—on a two-year "probation." He did so because, of the three variants in the program, the STOVL was causing the most problems with regard to design and disruption of production, and its problems were slowing down the pace of testing the other two versions. Those versions are the conventional takeoff F-35A for the Air Force and carrier-capable F-35C for the Navy. Gates said if the F-35B can be brought up to snuff within two years, the Marine Corps can still buy it. If not, the STOVL JSF will be terminated, and the Navy and Marine Corps alike will use the F-35C model.

Gates based his decisions on a top-to-bottom evaluation by JSF Program Executive Officer Vice Adm. David J. Venlet. Called the Technical Baseline Review, it reset the clock on the F-35 program, with new timetables and new expectations of the contractor, Lockheed Martin, and its suppliers.

"There will not be another rebaseline of this program," Lockheed Martin CEO Robert J. Stevens told reporters at a company press event in May. "There will not be; we understand that."

Before the baseline review, Carter said the Pentagon largely relied on Lockheed for F-35 cost data. Now, having added hundreds of contracting experts to DOD's ranks, and with review

data in hand, Carter said the Pentagon has better knowledge of the F-35 program "than we've ever had," and this will improve oversight and management of the project.

The emphasis on restraining F-35 costs is not simply proactive management on Carter's part. It's also the law. The Weapon Systems Acquisition Reform Act of 2009 requires, among other things, that the Pentagon use much more realistic metrics for predicting costs on a program.

Venlet told the SASC that he's committed to "realism" on the F-35, and told reporters this spring that he's determined not to overpromise on the program, since so many previous expectations have not panned out.

Previous F-35 program managers insisted there was no comparison between how legacy fighters were designed and built and how it would be done on the F-35.

The F-35 was to be designed in a whole new way, using digital blueprints that suppliers all over the world would use to make parts. Theoretically, when the parts were brought together, they would mate perfectly. The same digital database would streamline the assembly line and aid in the building of tooling. Test aircraft would be built on production tooling. The airplane could be "flown" virtually to prove out the design before it ever flew, using computers far more powerful than those used on any previous airplane.

In fact, because early flight tests matched well with performance predicted in simulators, it was decided to rely more heavily on the simulations. Flight tests were taken out of the program several years ago, to speed it along and reduce time and cost.

Lockheed Martin photo by Paul Weatherman

F-35s line up at Edwards AFB, Calif. The Air Force's F-35 test force is making the quickest progress, as the short takeoff and vertical landing F-35B is on "probation" and the F-35C is still new to flight testing. Arguably the least complicated model, USAF's version will be produced in the largest numbers.

Deliveries Accelerate

That move, Pentagon Director of Operational Test and Evaluation J. Michael Gilmore told the SASC, was "a mistake." The hops have since been added back in, and at a cost premium.

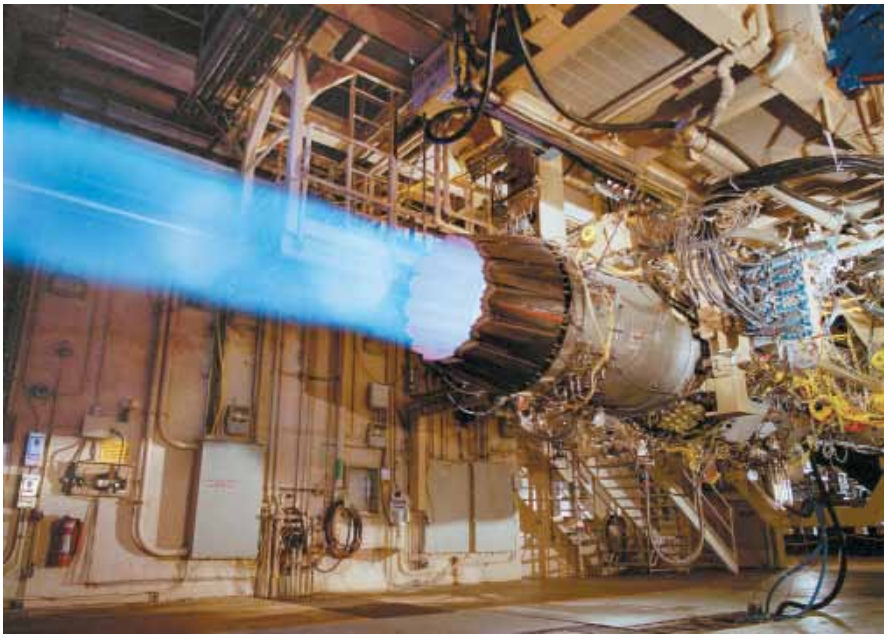
Steve O'Bryan, Lockheed Martin F-35 vice president, said the criticisms are, to a degree, fair.

Costs were higher "than we had hoped and planned," he said. Initial production lots took longer and cost more because changes—things discovered in flight test or found to be unworkable on the production line—were "much more disruptive than planned." The original single-piece wing needed a major redesign into smaller subassemblies, and a bulkhead failed prematurely in durability testing. As a result of these and other detours, tooling was altered and test aircraft did not appear on the promised timetable.

Kevin J. Smith, Lockheed's Air Force F-35 production manager, said slow deliveries early on delayed the pace of testing. In an interview at the company's Fort Worth, Tex., F-35 plant, Smith said the delays were due to many factors: There were engineering changes requiring rework, and parts were late or of insufficient quality from vendors. This disrupted the assembly line and forced work to be done out of sequence, which costs more.

O'Bryan believes that pattern is now "mostly behind us," saying that changes have dwindled in number, adding predictability to production and allowing deliveries to accelerate. Moreover, the learning curve and the results of actions to reduce cost are "better than we thought."

Compared with the new plan, Lockheed in May was 20 percent ahead of the new Technical Baseline Review schedule on test flights accomplished, and 33 percent ahead on test points, Stevens reported. That means more flights are taking place, and each one is more



Lockheed Martin photo

The F135 engine powers up on a Pratt & Whitney test rig. The alternate F136 engine has been terminated, but GE-Rolls Royce wants to keep at it, with company funds.

Lockheed Martin photo

An F-35 in production at Fort Worth, Tex. More than 60 are under construction, but deliveries have slowed to give testers more time to prove out the design.

productive. He said that these are signs "that the program is stabilizing."

Ironically, using the new, more "realistic" metrics on the program may very well make it possible to beat cost estimates in the future, when counted against the new cost and schedule.

For example, a much-ballyhooed trillion-dollar cost estimate for the F-35 program—contained in a recent Pentagon quarterly acquisition report to Congress and based on all related lifetime acquisition and sustainment costs for the program, using inflated dollars over five decades—was calculated in part on the assumption that it would cost the same to operate the F-35 on a per-aircraft basis as it does for the F-16 and F/A-18, two of the aircraft it is to replace. Lockheed thinks the F-35 will be cheaper to own than its predecessors.

Besides performance requirements such as speed, range, and payload, the F-35 program specifies reliability and maintainability as two key performance parameters, or KPPs.

"Meet those KPPs and you're twice as reliable as an F-16 Block 40 and 50," said O'Bryan, in an interview.

On reliability and maintenance, "we are either exceeding the requirement or exceeding the objective," which is the desired, nice-to-have performance level over and above threshold minimums, O'Bryan said. If the F-35 requires only half the required maintenance actions, the services can look hard at the manning levels required for F-35 maintenance squadrons, which could be a huge cost reducer, he said. So far, no change in manpower has been taken into account.

The three variants of F-35 will also have common logistics, training gear and syllabus, parts and ground support gear, an autonomous self-reporting, self-diagnostic onboard system, and a centralized sustainment center that automatically tracks trends in parts consumption and makes sure needed parts are available when required.

The Volume Efficiency

That single support system replaces the individual logistics and training tails of the F-16, AV-8B, and F/A-18C/D.

The savings of consolidating separate logistics systems into one "has to be profound," O'Bryan insisted.

Another factor the Pentagon is not taking into account in figuring F-35 costs, O'Bryan claimed, is the overseas market for the airplane. Since the beginning of the program, he said, affordability has been a product of volume. In addition to the US requirements—1,763 for the Air Force and 680 for the Navy-Marine Corps—eight international partners on the F-35 collectively plan to buy about 700 aircraft.

Pentagon estimates currently only assume about 350 of those export aircraft will actually be built, even though the partners—Australia, Britain, Canada, Denmark, Italy, Netherlands, Norway, and Turkey—have largely stuck to their commitments to buy the F-35. The volume efficiency, O'Bryan argued, is undercounted.

Beyond the eight original partners, the US has given briefings to five more countries that have signaled their interest in buying the F-35 under foreign military sales. Collectively, those five countries—Israel, Japan, Singapore, South Korea, and Spain—have a requirement for 700-plus airplanes—more than the partner countries themselves, O'Bryan said.

He noted that more than 4,500 F-16s have been built and will need replacement, and there are "a couple thousand" F-18, AMX, F-111, Tornado, and other type aircraft the F-35 could backfill.

The Pentagon, O'Bryan said, hasn't "adequately looked at the FMS quantities."

Lockheed Martin also says the F-35 is a good deal because additional capabilities usually bought a la carte to "bolt on" to a late-model F-16 or F/A-18 are included on the fighter. Systems such as the Sniper or Litening electro-optical targeting pods, electronic warfare pods, pylons, additional fuel tanks, an AESA radar, etc., are all internal equipment on the F-35, Smith said. "We have it all."

Performance-wise, the F-35A can still maneuver at nine Gs and Mach 1.6, even with all of that gear on the

Lockheed Martin photo

Two USAF F-35s on a test hop. Pentagon leaders say there's no alternative to the fighter, but that its present estimated cost is too high.

Lockheed Martin photo by Andy Wolfe

A Navy F-35C makes an impromptu visit to the open house at JB Andrews, Md., in May. Unqualified success over the next year is deemed critical to the program's future.

airplane. Legacy aircraft "couldn't do that without dropping munitions and sensors," Smith said.

Making the same point, O'Bryan asserted that, at maturity—meaning after all US F-35s have been delivered, circa 2035, and their cost is averaged out—"a fully operational F-16 or F-18 costs about the same as a fully combat-capable F-35," a price he quoted as "about $65 million in 2010 dollars." Moreover, those airplanes would not be stealthy, fifth generation airplanes, he said.

(Boeing, maker of the F/A-18E/F, promptly challenged O'Bryan's figure, saying its Super Hornet will cost $53 million at maturity, with all the bells and whistles. Boeing defense president Christopher M. Chadwick also said his company considers the fifth generation argument "irrelevant," and the Super Hornet can be just as survivable as the F-35, by using electronic warfare as a substitute for stealth features.)

The trillion-dollar figure also represents a sudden shift in how the Pentagon counts life cycle costs. Previously, these were counted as costs over a 30-year lifespan. Now the predicted service life of the F-35 is counted as 52 years, and that "includes the price of fuel," O'Bryan said, questioning how the government can rationally predict the price of fuel five decades hence.

He also said that the government made some changes of its own: For example, it wants more simulators for training pilots, seeing a potential significant cost reduction by doing more training in a virtual cockpit than in a real-world F-35.

When Gates restructured the F-35, he took out of the equation some $614 million in award fees that were calendar-driven, not event-driven. He said at the time that Lockheed could earn those award fees through performance on critical milestones.

Talking with reporters in April, Venlet said that in 2010, Lockheed had a chance to earn $35 million in award fees, as there were five milestone events, each valued at $7 million. However, he said Lockheed only hit one milestone on time—delivery of CF-1, the first Navy aircraft—and thus only earned $7 million in award fees. The $28 million it did not get is gone, Venlet said, and can't be reclaimed later in the program.

The No. 1 Threat

In the same press conference, Venlet said that while a recent visit he had made to the Fort Worth plant was "confidence building," he noted it was "chock full of rework."

Smith said the 2011 milestones, which could earn Lockheed $35 million in bonuses this year, are:

- begin ship testing with the STOVL version,
- complete land-based carrier tests with the F-35C,
- complete static tests on the F-35C,
- deliver Block 1B software to flight test, and
- update the training program.

Now that structural and durability testing is nearly complete on the F-35A and is well under way for the B and C models, O'Bryan thinks the biggest potential "discoveries" that could yet be found on the F-35 lie in its high angle-of-attack performance and in software.

Twin-tail aircraft have often suffered from a problem called "wing drop"—a sudden loss of lift on one side of an aircraft in certain flight regimes, usually associated with carrier operations. This was a serious and costly issue with the F/A-18 Super Hornet.

Rather than wait and see if the F-35 suffers from wing drop, a fix—which O'Bryan described as a small wing fence outside of the wing fold on the carrier model—was designed into the F-35C. If wing drop manifests in flight testing, "we would be able to fix it with those spoilers." If it turns out wing drop isn't an issue, "we'll pull them out of the airplanes [and] reduce cost and weight."

Carter and Gilmore both described software as the No. 1 threat to the F-35's schedule. To try to get ahead of the problem, Lockheed has added 150 software engineers, boosting its F-35 code-writing cadre by 50 percent. Software proved to be the F-22's developmental Achilles' heel, and Lockheed officials said they had learned many lessons from that program and were applying them on the F-35.

For instance, software is flown on a flying testbed, using F-35 hardware, before it is even loaded onto an F-35 test aircraft. This approach serves as a pathfinder and identifies software issues well in advance.

Another potentially serious problem is with the F-35 helmet.

While the F-35's "dashboard" is a single flat-panel display that can be configured by the pilot to show whatever information he wants, the helmet is meant to be the primary status display. No matter where the pilot looks, projected on the helmet faceplate will be the altitude, speed, weapons, and other aircraft information—which in previous aircraft was projected on a head-up display in the forward canopy only.

Integrated with the helmet is the DAS, for Distributed Aperture System. This series of cameras around the aircraft is supposed to allow the pilot to "look" at the surrounding landscape in total darkness and see it as if it were daylight. DAS even allows him to look "through" solid pieces of the aircraft, such as below his seat. The overall system is meant to allow the pilot to see 360 degrees around him and cue weapons no matter where he looks.

In testing, however, the helmet system is suffering from two problems: The data display has a distracting jitter, and the infrared night image suffers from latency—a time lag, and sometimes a less-than-seamless transition as the pilot's view moves from one camera to another.

Second Engine, Second Guessing

Early in the F-35 program, because the anticipated production run was so large, program managers envisioned developing a second engine for the single-engine fighter, with the idea of competing the two power plants to drive down cost and increase quality. This had worked with great success in the "Great Engine War" of the 1980s, which pitted Pratt & Whitney against General Electric on the F100 and F110 engines, respectively, to power the F-15 and F-16.

Pratt & Whitney builds the F135 engine used on all variants of the F-35 fighter. General Electric and Rolls Royce have partnered to develop the F136 engine as the alternative engine—now lauded as the "competitive engine" by supporters and derided as the "unnecessary engine" by detractors.

Throughout the program, the engines were intended to be interchangeable—their operation to be "transparent" to the pilot and using the same equipment for removal and repair.

For years, however, Defense Secretary Robert M. Gates tried to terminate the alternative engine program, describing it as an "unnecessary, wasteful" use of taxpayer funds. Modern engines are so reliable—and a sole-source engine supplier has worked so well on other programs, such as the F-22—that there's no need for the second engine, Gates has argued. His acquisition managers and service Secretaries in recent years have concurred.

Congress has countermanded Gates all along, insisting that competition will save money over the long run. It has consistently added funds to the defense budget to keep the program going. GE has said the savings could be as high as $20 billion.

However, Congress finally relented this spring, when the Pentagon issued a statement that it was terminating the F136 development project, and Congress declined to add money to the budget to continue it.

General Electric and Rolls Royce subsequently announced they will continue development of the F136 for the next two years with their own funds, hoping the Defense Department—and now Congress—will have a change of heart.

Pentagon acquisition, technology, and logistics chief Ashton B. Carter told the Senate Armed Services Committee in May that while the company's move is unprecedented, it has not changed the Pentagon's view that the second engine is unnecessary.

One F-35 pilot said that the helmet "sometimes has a problem in one jet, and then you go to another jet with the same helmet, and it's fine."

Gilmore told the SASC there are several approaches to fixing the helmet issue. One is to keep working on the existing system and try to correct its problems. A second is to use an existing helmet-mounted cuing system, supplemented with night vision goggles for flying in darkness.

"That's the way pilots do business at night now," Gilmore said, but it's an awkward arrangement and one officials hoped to fix on the F-35.

"As a very last resort, the program would consider incorporating a heads-up display," Gilmore said, but this is the least desirable of the options because it would require, in his words, "a major modification of the aircraft."

Although flight testing still has another five years to go, training of F-35 operational pilots could begin as soon as this fall. A schoolhouse has been built at Eglin AFB, Fla., where Air Force, Navy, and Marine Corps pilots will train together. The first Eglin aircraft, AF-8, was to arrive as early as July. The training aircraft will only fly if the Block 2 software is delivered in a timely way; this software puts enough of the F-35's mission capability in the aircraft such that pilots can fly the fighter without their missions being monitored by a mission control-like test facility, which remotely checks the health of the aircraft.

The Affordability Track

Lt. Gen. Herbert J. Carlisle, USAF's deputy chief of staff for operations, plans, and requirements, told senators in May that the Air Force has given a lot of thought to when the F-35 will be available for combat.

Although it will be up to the head of Air Combat Command to declare initial operational capability—which would be 12 to 24 F-35s loaded with Block 3 software, which provides all basic weapons and combat power—Carlisle said that even if this milestone has not yet been achieved, the F-35 could be called on for combat.

If combatant commanders ask for the F-35 in 2017-2018, before IOC is declared, "then we would clearly provide it," Carlisle said. By then, the Air Force will have "on the order of 100" F-35s in an earlier, Block 2B configuration. While less capable than the Block 3, the Block 2B version will still offer "very impressive" capabilities, Carlisle said, and they would be far beyond those of even an updated F-16.

Pilots will have thoroughly learned flight maneuvers as well as tactics, techniques, and procedures, and there will be a functional maintenance capability. If the software is deemed safe, "we would … be ready to go" even short of IOC, Carlisle testified.

This would not be a unique situation: The E-8C JSTARS aircraft went to war long before it was officially operational, and the Global Hawk reconnaissance drone has gathered intelligence over numerous battlefields without having reached official IOC status.

Carter made much of the fact that the F-35's Lot 4 production contract was negotiated for a fixed-price contract. This is a reason for optimism that the program is headed in the right direction, and also challenges the government and Lockheed to meet cost goals. Lot 4 also came in at a lower-than-expected unit cost, Carter said.

Asked if Lot 5 will deliver a still-lower price, Lockheed Martin officials were noncommittal.

Lockheed's bid is in, but "there's a variant change," O'Bryan said. "We go from 17 STOVLs to three. So that's a challenge on [our] supply chain." The government, he said, is doing a "should-cost" analysis on Lot 5, and negotiations will follow.

"The way I look at it," he said, "the goal is to maintain that affordability track."

Carter said the Pentagon's should-cost analysis will identify each piece of the F-35 bill in great detail, so "we're only going to be paying costs that we understand and are willing to justify." If costs have grown in the last 10 years, DOD is going to ask, "Why is it larger?" and what can the department do to "drive it back to where it was when the program started?" Carter explained, adding, "We'll do that both for production and for sustainment."

Even though the Pentagon believes there is no alternative to the F-35, Sen. John McCain (R-Ariz.) told Carter at the May hearing if the F-35's cost is indeed unaffordable, then "it seems to me we have to start at least considering alternatives."

McCain did not specify what those might be. ■