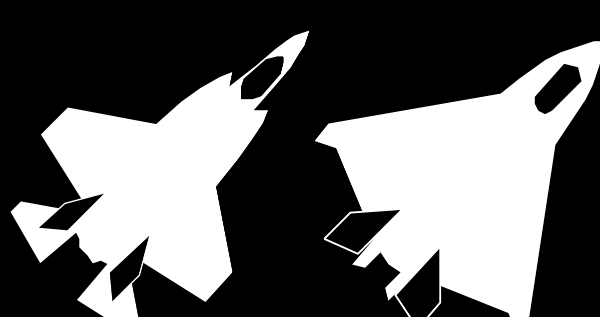
The Joint Strike Fighter is moving from concept studies and designs toward real hardware.

Scoping Out the New Strike Fighter

By John A. Tirpak, Senior Editor



THE Joint Strike Fighter *won't* set any records for speed or altitude, nor will it pioneer revolutionary new forms of air combat. It isn't meant to.

In fighter design, the last few percentage points of performance are usually the hardest and most expensive to obtain, and they are capabilities rarely, if ever, used in actual combat. For the JSF's makers, the challenge is to build a state-of-the-art precision strike airplane that can do the job very well, be flexible enough to be relevant for the next 40 years of warfare, and cheap enough to be bought and operated within the budget allowed.

It's a tall order, but all indications are that the Air Force, Navy, and Marine Corps which will buy the JSF, and the contractors competing to build it, are pursuing efficiency with fervor. They realize that, no matter how good the design turns out to be, it will never be built in the numbers required—nearly 3,000 aircraft—if it won't fit within the budget top line.

The last few years have been spent in perhaps the most intense process of requirements definition and risk reduction yet seen in aircraft development. There have been thousands of hours of simulated combat to determine the optimum mix of stealth, speed, range, and weapons. New manufacturing processes have been invented. Specifications—which often lead to unnecessary weight and cost—have been all but abolished. Commercial practices have been substituted for the old, lumbering style of federal procurement. "Streamlining" has taken on a whole new meaning, and the process isn't over yet.

There has been unprecedented cooperation among the armed services. Since commonality is the No. 1 cost-cutter on the JSF, each service has had to refrain from demanding capabilities in the airplane that can't be reconciled with those of the other branches, lest the price get out of hand or one of the partners break ranks. So well has the interlocking Air Force and Navy management of the program worked so far that its director, Maj. Gen. Leslie F. Kenne, reports that other programs have come calling to watch and learn "how you do a good joint acquisition."

Harmonizing requirements has been a problem for services accustomed to buying systems unique to their own needs, but Kenne reports that the process "is working entirely well." Kenne, an Air Force officer, works for the Navy's acquisition executive, and her deputy is a Marine two-star general. When the Marine succeeds Kenne at the head of the program, he will report to the Air Force acquisition executive, and his deputy will be a USAF two-star. Kenne's predecessor was a Navy two-star admiral.

The Air Force needs 1,763 Joint Strike Fighters to replace its A-10s and F-16s. The JSF is to have better range, stealth, and reliability than the F-16 but won't necessarily be faster or more agile. Lockheed Martin's offering is shown here.

What USAF Needs

The Air Force holds the biggest JSF requirement. It needs 1,763 airplanes to replace its A-10s and F-16s. Replacing the F-16s is a pressing matter: Bought in big lots through the 1980s and 1990s, these single-engine fighters will start to wear out in large numbers in seven years. The first JSFs won't arrive for 10 years. In the interim, there will be shortfalls, but USAF may be able to bridge the gap with F-16 life extension modifications or other "workarounds."

relatively inexpensive "low end" Air Force strike fighter complementing the more costly "high end" F-22 air dominance fighter. As then–Air Force acquisition executive Arthur L. Money told Congress earlier this year, "The F-22 is the force enabler; the JSF is the force."

The Navy is in dire need of a so-called "first-day-of-the-war" medium bomber. The sea service some years ago retired its A-6 Intruder because of advanced age. The intended replacement, the stealthy A-12, was canceled in 1991 because of major technical, schedule, and cost problems. Subsequent efforts known as A-X and A/F-X were dumped as unaffordable, forcing the Navy to rely on an assortment of F/A-18 Hornet variants until JSF reaches carrier decks around 2010. The Navy needs 480 JSF carrier-based variants as the "high end" complement to the F/A-18E/F Super Hornet fighter, now in production.

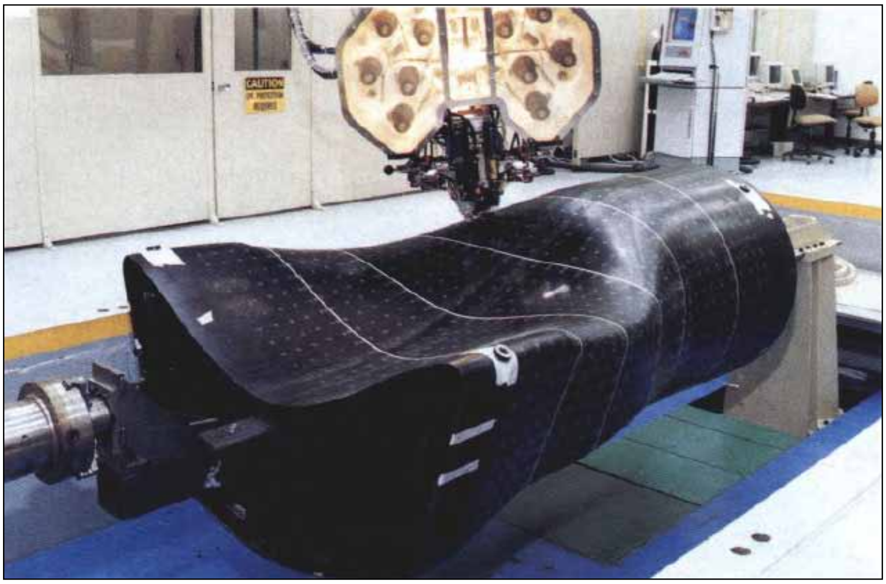
The Marine Corps wants a Short Takeoff/Vertical Landing "jump jet" JSF variant to fly off amphibious ships or from small forward strips ashore. The STOVL variant happens to be the most technically difficult version to build, in that it will have to operate vertically, go supersonic, and still carry a credible weapon payload—a feat never before achieved in an airplane at any price. The Marine Corps needs 609 JSFs to replace their AV-8B Harrier IIs and F/A-18s.

All told, the services need 2,852 JSFs, a number that is down marginally from the originally planned 2,978. The modest cut stemmed from analysis by the 1997 Quadrennial Defense Review.

The British Royal Navy is also committed to buying 60 of the STOVL variant to replace its Sea Harrier airplanes and is a full partner on the project.

The services want an airplane that, at a price scarcely higher than that of today's F-16, has lots more capability—be it in range, payload, ease of maintenance, or stealth. In most

The JSF will reduce cost by limiting parts count. Almost the entire wing/upper fuselage of the Boeing design is a single piece of thermoplastic composite, the same for all variants. Commonality—avoiding unique parts—cuts unit cost.



No longer just a "paper" airplane, the JSF is taking shape as a technology demonstrator aircraft. Not quite prototypes, the X-32 and X-35 will prove out flight characteristics and controls. Boeing's X-32 will use this inlet duct.

cases, the planned improvement tops 30 percent.

Half the Cost?

By buying together, the military services not only save the cost of designing separate airplanes but also get the benefits of spreading overhead costs over a much larger number of aircraft. Then, by keeping the airplanes highly common in design, they save by having many identical spare parts, common maintenance, and common software and upgrades. Doing it this way, the services hope to modernize their air fleets for about $100 billion over 20 years—roughly half of what it would cost the old way.

The JSF has moved on from being just a "paper airplane." Lockheed Martin and Boeing, the finalists in the competition, now have begun to bend real metal to build flying test beds to further refine and prove out their concepts. Boeing's version has been dubbed the X-32 and Lockheed Martin's the X-35.

"It's important to note that these are ... 'X-planes' and not prototypes," Kenne said. She noted that the demonstrators will lack the avionics, weapon systems, and other insides that would be expected in true prototypes, because their purpose is to prove that the design—or Preferred Weapon System Concept, as the program office calls it—will have the predicted flying qualities.

Only the winning design will advance to the stage of full-up prototype. The X-planes will be rough drafts, relying on off-the shelf parts and other cost-saving features to the greatest extent possible. For example, Rick Baker, X-35 product manager and assembly boss at Lockheed Martin Skunk Works in Palmdale, Calif., said his airplane will use the nose gear from an F-15E, the main gear from an A-6, actuators from an F-15C, and so on.

Each company will build two aircraft. The first will be representative of the Air Force version, with Conventional Takeoff and Landing characteristics. The second will be the STOVL version to be used by the Marine Corps and UK's Royal Navy. Later, the CTOL versions will be modified to show how they will perform as carrier aircraft. Thus, three types of airplanes will be demonstrated with only two airframes. Again, it's part of the JSF's constant cost avoidance and drive to squeeze more out of the dollars available.

Kenne prefers to call the X-planes "technology maturation flight demonstrators." They are intended to "ensure that we lower the risk" such that the eventual choice between the competitors can be made with high confidence that the riskiest parts of the proposed airplanes will really work.

Risky Business

She said that, for both the X-32 and X-35, the riskiest element of all will be the "integration of the flight controls and propulsion system."

The two teams have each selected the Pratt & Whitney F119 engine core as their basic power plant. The F119 also powers the F-22; besides its advanced design, it offers engine commonality and, presumably, savings. Each of the two X-planes will use a different, uniquely configured F119 derivative engine, however.

"Clearly, two new derivative engines ... are a risk," Kenne continued, but the JSF office is "quite pleased" with initial testing of the two power plants, she said.

This Lockheed Martin STOVL wind tunnel model is defining the thrust generated by its lift fan concept. The lift fan, not needed for conventional takeoff, would be deleted on the USAF version and replaced by a fuel tank.

JSF Costs

The three services need the JSF to come in at a cost only marginally higher than that of the F-16 and lower than that of the F/A-18E/F. Unit recurring flyaway cost is as follows:

	Base Year (FY94 $)	Current Year (FY98 $)
USAF (CTOL) variant	$28 million	$30 million
Navy (CV) variant	$31 million–$38 million	$33 million–$41 million
USMC (STOVL) variant	$30 million–$35 million	$32 million–$38 million

JSF Requirements

Size	Must fit in "deck spot" of F/A-18E/F Super Hornet
Dry weight	CTOL/STOVL, about 22,000 lb.; CV, about 24,000 lb.
Max takeoff weight	All variants, 50,000 lb.
Internal fuel	CTOL/STOVL, 15,000+ lb.; CV, 16,000+ lb.
Payload	CTOL/STOVL, 13,000+ lb.; CV, 17,000+ lb.
Combat radius	600+ NM for all types

CTOL stands for Conventional Takeoff and Landing and STOVL for Short Takeoff/ Vertical Landing; CV designates the aircraft carrier version.

Like the F-16, the JSF will have but a single engine. Originally, the Navy wanted the JSF to have a pair of engines, so as to keep single engine failure from causing an over-water disaster. The single-engine JSF is a reality that the Navy accepted after years of flight data showed that today's single-engine jets have safety comparable to that of older twin-engine types such as the F-14 Tomcat.

Lockheed Martin's X-35 STOVL version couples the single engine to a shaft-driven lift fan behind the cockpit. The lift fan hoists up the front of the airplane and the rear nozzle swivels down to push up the rear. Small exhausts under the wing will provide roll control. The approach adds 4,000 pounds to the Lockheed Martin JSF. Even so, "we get much more than the 4,000 pounds back ... in what we can lift," according to Fran Ketter, the company JSF manager for propulsion integration. The lift fan delivers 60 percent more lift than an F119 relying on direct lift, Ketter claimed.

In a post–Cold War irony, Lockheed Martin consulted with the Yakovlev design bureau of Russia early in the JSF design process because the Yak-141 used a similar approach, though that airplane never made it to series production.

Boeing's X-32 STOVL version will employ two downward "posts" of thrust in front and a vectoring nozzle for the back. It, too, uses under-wing nozzles for roll control—though these are not directly connected to the engine—as well as small nozzles in the rear for yaw control.

Kenne explained that the Air Force CTOL versions "will demonstrate up and away" performance, the Navy aircraft carrier version will demonstrate low-speed handling required for carrier approach, and the Marine STOVL version will demonstrate short takeoff, make a transition to wing-borne flight, and then another transition to vertical landing.

The contractors are to conduct government-funded explorations of cost-lowering technologies in manufacturing, avionics, weapons integration, materials and structures, flight systems, propulsion, and supportability. The resulting body of knowledge "will be available to both contractors," Kenne said, to allow each to make the lowest-possible cost proposal for the all-up system. "We're interested in ... any technology that can reduce parts count and life-cycle cost," she said.

The X-planes will fly sometime in 2000 and be flight-tested for about a year.

Buy Ins and Buyouts

Even as flight tests take place, the companies and program office will continue to conduct computer simulations pitting the JSF contenders against a wide variety of threats to gather more data on how they stack up. Sometimes, the simulations show that spending a little extra on some aspect of the design—a sensor or an extra weapon station, perhaps—yields a disproportionate increase in effectiveness. For that reason, JSF is not entirely about cutting cost.

"Anything can 'buy' its way onto this airplane," said Kenne, though she noted that every add carries a price of some kind. The ongoing modeling and simulation effort is geared toward finding the optimum mix of performance, capabilities, weapons, supportability, durability, and cost.

About the time flight demonstrations begin in 2000, the final Joint Operational Requirement Document will end its long evolution, and the list of capabilities detailing must-have and "desired but not required" features on the JSF will at last be released to the contractors for bid.

Armed with this requirements list, the manufacturing and other risk-reduction knowledge generated by the program, and flight data, the contractors will make their proposals, and a winner will be chosen in 2001. Development would take about four additional years and production would begin around 2005. The first operational aircraft would be delivered in 2008.

Paul G. Kaminski, the former undersecretary of defense for acquisition and technology, and Gen. Ronald R. Fogleman, retired USAF Chief of Staff, both suggested that the Air Force may buy some examples of the STOVL version for Air Expeditionary Force operations out of austere fields.

However, Kenne said, no one up to this point has altered USAF's part of the program in order to accommodate this proposal, and she gave little indication that it would happen anytime soon. "The Air Force is studying that," she said, but has made no decisions to proceed. She added, "In all honesty, there's no sense of urgency" about an Air Force STOVL buy. "If they want to opt for a STOVL version ... it will be available."

Lockheed Martin's proposed JSF bears some family resemblance to the company's F-22. It has a conventional wing and tail configuration, which company program manager Frank Capuccio said was a conscious choice.

"We felt ... this configuration offered the most flexibility" for the various missions JSF will have to perform, Capuccio said. The program office told Lockheed Martin that its concept made it to the final round of JSF competition "because they thought we had a much lower-risk approach to the STOVL requirement," he claimed. "We did not require a technical miracle" to achieve the required short takeoff performance. The Lockheed Martin airplane is also "mostly aluminum rather than composite," again, in order to lower risk. The X-35 design philosophy dictates that "we'll only get exotic if we have to," he added.

In the USAF and Navy versions of the Lockheed airplane, the lift fan behind the cockpit is deleted, and the vacant space is used for fuel or avionics.

With Boeing's STOVL airplane, the chin intake can be expanded substantially to take in the huge amounts of air necessary to feed the voracious vertical-lift flight requirements. In the conventional versions, the STOVL hardware is eliminated.

The Lockheed Martin design philosophy in its JSF, Capuccio said, is that "it can be easily 'tuned' as the government modifies its requirements." He maintained that his team embraced the program's mantra of "cost as an independent variable" early on and kept things flexible because of it.

Creep Control

Unlike previous programs, in which legions of acquisition workers could all insert costly requirements simply because they were traditional boilerplate, the JSF's computer-aided design and single design database make that almost impossible now, Capuccio said. "Some major can't add a change without my catching it," he observed. Computer design has sharply curtailed "requirements creep," he observed.

Frank Statkus, Boeing's JSF program manager, said his company was told by the government it made it to the final round because "we had a good configuration with a lot of potential, because of the technological innovation in the airplane itself." Boeing's design involves extensive use of new materials such as thermoplastics, which make not only large, single-piece manufacturing possible but hold out the prospect for extended life expectancy.

A STOVL airplane has a voracious appetite for air. Boeing's Marine version cranks its mouth open extra wide to gulp it in. The STOVL versions will handle just like the CTOL variants; controls will be "transparent" to the pilot.

Boeing also strives for parts commonality by starting with basic structures and adding "thickeners" for strength only as they will be needed for a given variant. This permits commonality while carrying only as much weight as necessary. If testing shows more strength is needed in a given area, Boeing can add it without going through a major redesign, Statkus said.

Using three-dimensional computer modeling—as Lockheed Martin is also doing—is making the JSF trade-offs and refinements process possible, Statkus added. "All the wiring, tubing, and fasteners have all had to go together before" any real-world parts were made, he observed. "By the time you assemble the airplane, you've already 'built' it a number of times."

Engine War II

In the 1980s and 1990s, the Air Force conducted a major competition between Pratt & Whitney's F100 and General Electric's F110 to provide power plants for the F-15 and F-16 fighters. The competition was credited with saving billions and inspiring constant improvement and innovation. Kenne said the JSF program will try to repeat this process.

A team of GE, Allison, and Rolls–Royce is working on a derivative of GE's F120 power plant, which lost out to the F119 in the F-22 program, as an alternative fighter engine for the JSF. The team has been given some seed money

What About UCAVs?

Gen. Ronald R. Fogleman, the former USAF Chief of Staff, was fond of speculating that Uninhabited Combat Aerial Vehicles might become so pervasive in the next 20 years that the Block 50 version of the JSF might be a robot with no humans aboard.

Boeing JSF program manager Frank Statkus said, "It wouldn't surprise me a bit" if, at some point, "you pull the man out of the fighter to prove you can" run a complex fighting aircraft by remote control. Lockheed Martin JSF program manager Frank Capuccio said Fogleman's robotic JSF is "theoretically feasible," given that the airplane's avionics architecture will accommodate such a conversion.

However, both men expressed skepticism about such a thing happening anytime soon.

Said Capuccio, "What the Air Force has to come to grips with is, who is really going to commit to release ... a missile or drop a JDAM" without a human being in the cockpit to "look the target over?" He held out the possibility of an uninhabited JSF as a wingman for a piloted JSF, or such an airplane serving as a relay of targeting data, but as for "dropping iron on the target? Not in my lifetime. You won't see an operational commander who will authorize that when our troops are on the ground."

for the project but won't be funded to do detailed design until an airframe winner is announced. Again, the JSF program is seeking to avoid unnecessary—or premature—expenditures.

The competition will only affect the JSF; the F-22 won't be built in great enough numbers to justify a second production source for the engine. Moreover, the GE–led team will not be given the F119 design to copy; it will offer strictly an F120 variant.

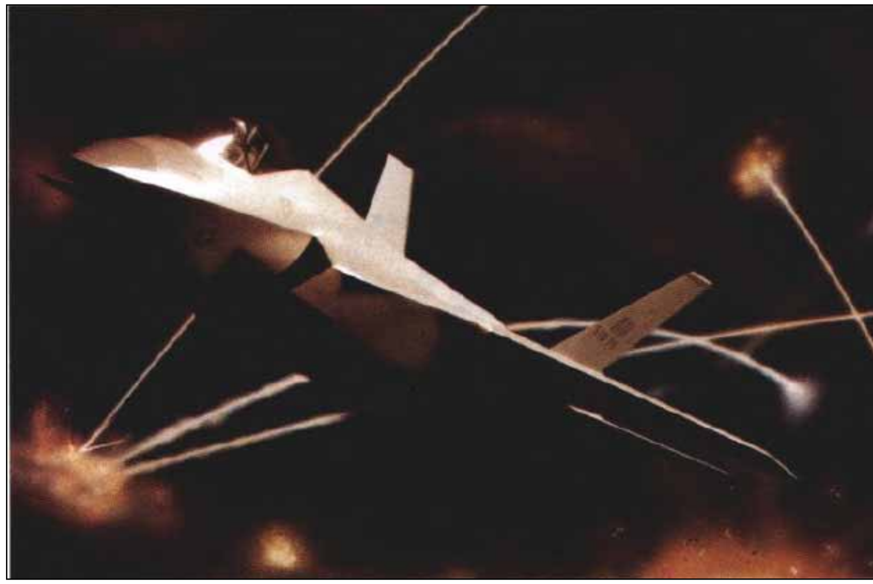
Although requirements on the JSF program are not hard-and-fast—the government does not want to specify solutions and thus rule out a potential cost-saving innovation—the target for commonality between the three types of airplanes is over 80 percent. Both Boeing and Lockheed Martin claim to be able to beat that figure by a wide margin.

As the JORD evolves, more and more of the blank spaces in the final requirement are being filled in. For instance, it was thought as the program began that much of the sensor requirement—radar, infrared, target designation, and so on—could be done offboard, meaning that information could be piped into the JSF from satellites, Joint STARS, AWACS, and other platforms, thus saving the weight and cost of having the systems onboard. That idea has been discarded, according to David Sundstrom, Lockheed Martin's director of JSF systems and software integration.

While initial versions of the requirements document allowed for reliance on offboard sensors, more recent versions call for the airplane to carry out its mission autonomously if downlinks are cut. Moreover, the "field of regard" and self-protection requirements clearly call for a "fully capable system," Sundstrom said. "No one is ready to commit to an airplane that's not full-up in its own right," he observed. The use of offboard sensors exclusively "has yet to be proven."

Sundstrom noted that the JSF will be able to take advantage of sensor software written for the F-22, as well as some legacy software from the weapon systems aboard the F-16. Again, the goal is to avoid the cost of doing anything new unnecessarily.

The JSF will likely employ many technologies unfamiliar to aviators of even 10 years ago. Fiber optics will be present in large quantity, not only for their lightness but because they're unjammable. Digital strain gauges will run along spars and other key components and tell the onboard diagnostics system how fatigued certain parts are and when they will need repair or replacement. Innovations such as these will save millions in maintenance previously done on a recommended schedule but which may or may not have been necessary. Both teams will make greater use of unified parts, or single-piece castings of complex pieces that previously would have required numerous parts, fasteners, welding, testing, and "lots of touch labor," Capuccio noted.



Despite a family resemblance, Lockheed Martin's JSF is no F-22 carbon copy. Manufacturing and avionics technologies—even stealth—have progressed since the F-22 was designed and will advance further by the time JSF rolls out.

Global Reach

There are no restrictions on foreign partnerships on the JSF, Kenne said. Indeed, foreign teaming is encouraged in the program's charter, and contractors have been encouraged to make "full use of the global market" in seeking the best and lowest-cost designs, parts, or manufacturing capabilities.

The United Kingdom is a full partner in the program, Kenne noted. That means the UK has contributed money to the development program and may have a direct say in influencing requirements. Denmark, Norway, and Netherlands—all users of the F-16—are also involved as associate partners, Kenne continued. They have contributed less money and can suggest requirements, but these will not be added "unless they provide a benefit to all," she said. Canada is on board as an informed partner, meaning it likely will buy the final product of the JSF program but cannot influence the requirements process.

More than 20 countries fly the F-16; a half-dozen more fly the F/A-18 and AV-8B, so the prospects for foreign sales of the JSF are excellent. In fact, the program charter recognizes that, in addition to being the force-building airplane of the US armed forces, it will also be the nation's export fighter in the early 21st century. Officials from both JSF contractors peg the overseas market conservatively at 1,500–2,000 airplanes, with a value of $50 billion to $65 billion.

Capuccio said stealth is well understood in the US fighter industry. "Low observables is really a commodity now," he said, and "signature reduction is almost ... free," since the knowledge that makes stealth possible is no longer exotic and is incorporated right into an airplane's basic design. The lessons learned from making doors, cracks, windows, and antennas stealthy on the F-22—on which Lockheed Martin and Boeing are partnered—means that on JSF, these techniques will be greatly improved.

"It's good on the F-22," Capuccio said. "We'll do an even better job on this airplane." ■