The Joint Strike Fighter Program

Craig E. Steidle

The Joint Strike Fighter Program, formerly the Joint Advanced Strike Technology Program, is the DoD focal point for defining affordable, next-generation strike aircraft weapon systems for the Navy, Air Force, Marines, and our allies. This joint program was chartered to bring the Navy, Air Force, and Marine Corps together to work jointly at reducing costs of future strike warfare concepts by maturing and transitioning advanced technologies, components, and processes. The program provides the focus and direction to future strike technology by applying a strategy-to-task-to-technology process involving an integrated team of users and developers. User-defined future operational needs determine which technologies and demonstrations will be pursued and funded. The program thus serves as the critical link among the requirements community, the technology community, and the eventual acquisition program office, while focusing on reducing both cost and risk of technology, process, and concepts to meet future joint operational needs affordably.
(Keywords: Advanced strike technology, Affordability, Joint acquisition program, Joint Strike Fighter, Joint warfare.)

INTRODUCTION

In the summer of 1993, the Secretary of Defense Bottom-Up Review acknowledged the Services' need to affordably replace their aging strike assets to maintain the nation's combat technological edge. In September 1993, during the presentation of the Bottom-Up Review, the Secretary of Defense formally announced his intent to cancel the Navy Advanced Attack Fighter (AF/X) and the Air Force Multi-Role Fighter (MRF) programs and create the Joint Advanced Strike Technology (JAST) Program. Together, the AF/X and MRF programs were unaffordable. In October 1993, the Under Secretary of Defense for Acquisition and Technology (USD[A&T]) approved the initial joint Service plan for the JAST Program as a comprehensive advanced technology effort to prepare the way for the next generation of strike weapon systems. After announcing his approval of the joint Service plan to the Congressional Defense Committees and requesting their support, the USD(A&T) formally established the JAST (now the Joint Strike Fighter, JSF) Program in January 1994.

FY 1995 Congressional legislation merged the Defense Advanced Research Projects Agency (DARPA) Advanced Short Take-Off and Vertical Landing (ASTOVL) Program with the JSF Program. Additionally, the United Kingdom Royal Navy is committing $200 million to the current Concept Demonstration Phase of the JSF Program, extending a collaboration begun under the DARPA ASTOVL Program. Negotiations have been initiated with Norway, Denmark, and the Netherlands to include them in future cost–performance requirements generation validations.

THE JSF PROGRAM DEVELOPMENT PROCESS

To reduce the costs of development, production, and ownership of the JSF family of aircraft, the program is facilitating the Services' development of fully validated, affordable requirements. The following Service needs were presented to the program at its initiation:

- **Navy**: A first-day-of-the-war, survivable strike fighter to complement the F/A-18E/F
- **Air Force**: A multirole aircraft (primary air-to-ground) to replace the F-16 and A-10 and to complement the F-22
- **Marine Corps**: A STOVL aircraft to replace the AV-8B and the USMC F/A-18
- **United Kingdom Royal Navy**: A STOVL aircraft to replace the Sea Harrier.

Doing Business Differently

Numerous acquisition reform initiatives and major commissions have provided guidance and recommendations on how to reap financial benefits by applying streamlined, nontraditional business approaches. The JSF Program has adopted the recommendations of the 1986 Packard Commission:

- Get the warfighter and technologist together to enable leveraging cost–performance trades.
- Apply technology to lower the cost of the system, not just to increase the performance.
- Adequately mature technology prior to engineering and manufacturing development.
- Ensure that the solutions are joint.
- Instigate and catalogue acquisition reform.

This guidance has been aggressively embraced and implemented into the JSF affordability philosophy as reflected in Fig. 1, the strategy-to-task-to-technology process. The JSF Program has recently been added to the Major Defense Acquisition Program list as a joint DoD 5000 Acquisition Category 1D program. There are several important themes running through the 5000 documents, which have been demonstrated consistently in the strategy-to-task-to-technology approach of the JSF Program. These themes include the following:

- **Teamwork**. The JSF Program has operated on the principle of teamwork, involving government and industry working together in a true integrated product team.
- **Cost as an independent variable**. The JSF Program Office facilitated an innovative process that involved the warfighters early in the design process and led to the timely approval of a Joint Initial Requirements Document (JIRD), a definition of top-level initial requirements for the three Services. This process, supported by modeling, simulations, analyses, and trade studies, will continue in an iterative fashion leading to affordable requirements.
- **Best practices**. JSF acquisition activities have been characterized by a willingness to incorporate sound ideas for improvement in each solicitation, use of streamlined acquisition vehicles such as Broad Agency Announcements whenever appropriate, insistence on paperless, streamlined industry proposals, and electronic processes that streamline source selection. Because of their affordability, commercial items, components, processes, and practices have also been used.

The process shown in Fig. 1 is the key to "doing business differently." Using a very vigorous, facilitated quality-function-deployment process, the Program Office, with the Services' warfighters (Operational Advisory Group) and government and industry technical experts, executed a top-down strategy-to-task approach to requirements definition. This process led the team from National Security Policy through concept of operations and operational objectives, to specific warfighting tasks. This effort produced an auditable, credible trail of the decision-making process. The warfighter/technologist teams melded these derived tasks with Defense Intelligence Agency–supplied threats and future force structure in simulation-assisted wargaming analyses of the Defense Planning Guidance–based Major Regional Contingency scenarios.

Five major wargames were conducted to assess the capabilities of our strike forces projected in 2010 and to determine deficiencies in force capabilities. Integral to this activity was the examination of nonmaterial solutions (tactics, doctrine, procedures) to address deficiencies in accomplishing operational tasks. The baseline campaign results provide a robust deficiencies analysis, a required features and characteristics analysis for cost–performance trade studies, and a benchmark for future evaluation of contractor concepts for the JSF Program. Exploiting modeling and simulation in this way will support the creation of an affordable

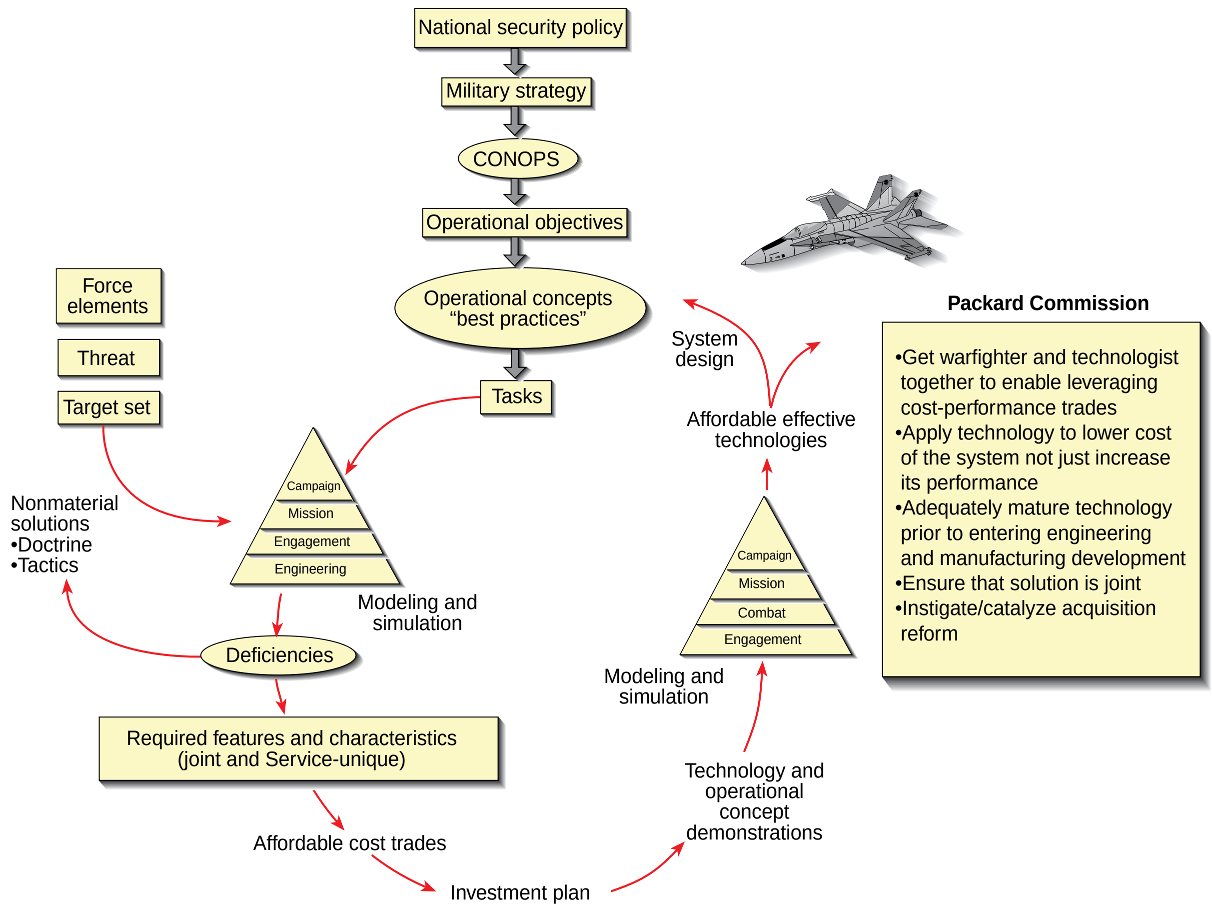

Figure 1. The strategy-to-task-to-technology process incorporates the guidance and recommendations of numerous acquisition reform commissions.

weapon system by providing early (user, government technologist, and industry) cost–performance trade studies.

An additional quality-function-deployment effort then generated the strategy-to-task-to-technology process that explicitly linked JSF technology projects to the derived material deficiencies, and thus to strike warfare tasks and strategies. Rigorous cost-performance trade study analyses, using cost as an independent variable, were required prior to defining the JSF Program investment plans. Each technology maturation project required a cost–performance trade study, a life-cycle cost perspective, and an operational objective in the strategy-to-task process. A cost-performance trade result with the JSF-derived analysis tool, the four-dimensional response surface, is shown in Fig. 2.

The technology maturation results are available to all JSF weapon system contractors teams, not just to those that perform the technology work. This innovative approach is working for both the government and industry, even in a highly competitive program environment.

As mentioned, developers and users together conducted the wargames and participated in trade studies to address key weapon system features and characteristics. This analysis provided the rationale for the JIRD, (Table 1), which was endorsed by the Joint Requirements Oversight Council.

Designed as a living document bridging the Services' mission needs to the Operational Requirements Document, the JIRD will undergo several refinements in a living, continual cost and operational performance trade analysis prior to the Operational Requirements Document release in FY 1999 (Fig. 3).

JIRD Characteristics

Sortie Generation Rate and Logistics Footprint

A weapon system with a lean footprint and an enhanced sortie generation rate can deliver impressive combat potential as a force application tool available to the Joint Force Commander. Historical DoD-sponsored studies (e.g., B-2 bomber and C-17) have consistently pointed to the value of achieving high sortie generation levels. Baseline Force Process Team campaign wargaming illustrated that the sorties available by current strike platforms delayed attainment of Joint Force Command-

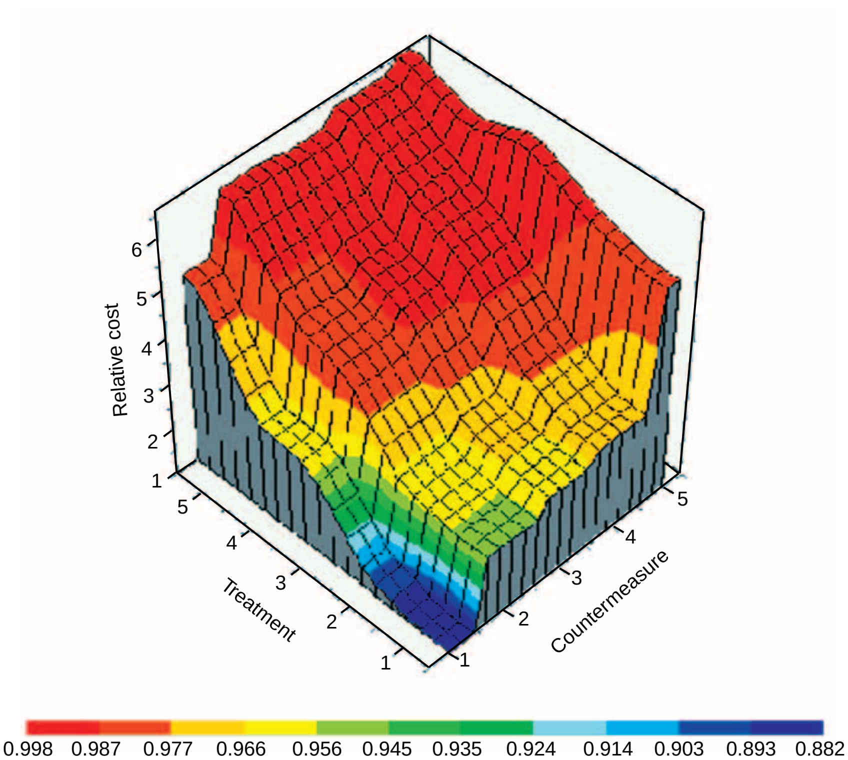

Figure 2. Modeling and simulation chart showing results of cost–performance trade analysis.

er objectives. Analyses determined that early-phase mission requirements would be optimized through combined improvements in the rate of force closure (achieved through reduced logistics footprint—number of C-141 loads) and high sortie generation rate capability. Lethality metrics such as kill rates show that a 25% increase in sortie generation rate and 50% reduction in deployment footprint have the best synergistic effect on campaign outcome. The JIRD-I values for sortie generation rate and logistics footprint fall within these ranges.

Key to JSF affordability is the commonality inherent in a core design from which all three Service variants are derived. The JSF Autonomic Logistics Support Concept defines a support infrastructure capable of generating the full range of initial surge and sustained combat sortie rates required by each Service. This infrastructure will also minimize the size of the initial combat sortie generation element and sustaining infrastructure. It exploits, to the greatest extent, the reliability, maintainability, supportability, and deployability characteristics found in the air vehicle design to maximize support system commonality and interoperability.

Autonomic logistics support is a new paradigm. It is the spontaneous logistics response to an initial status stimulus from enhanced onboard weapon system diagnostics. This response is concurrent with airborne updates via the command, control, communications, computers, and intelligence network through a fully interoperable joint logistics information system. The autonomic logistics process is analogous to the human nervous system, where basic functions respond without conscious thought. Autonomic logistics support exploits the full strength of enhanced

Table 1. The Joint Initial Requirements Document operational characteristics.

	USAF	USN	USMC
Sortie generation rate	Significantly greater than current F-16, F/A-18, and AV-8		
Logistics footprint	Significantly fewer than current F-16	N/A	Significantly fewer than current AV-8
Payload (internal) plus four external stations	1000-lb class AIM-120 and gun	2000-lb class JSOW AIM-120	1000-lb class AIM-120
IR signature	—	—	—
RF signature	—	—	—
Range (nmi)	450–600	600	450–550
Speed and maneuverability	Capabilities comparable to current multirole fighters such as F-16 and F-18		
Carrier aviation suitability	—	Yes	STOVL
Basing flexibility	—	—	Yes
Affordability	28M	31–38M	30–35M

Note: A dash indicates not applicable for this variant; STOVL = short take-off vertical landing.

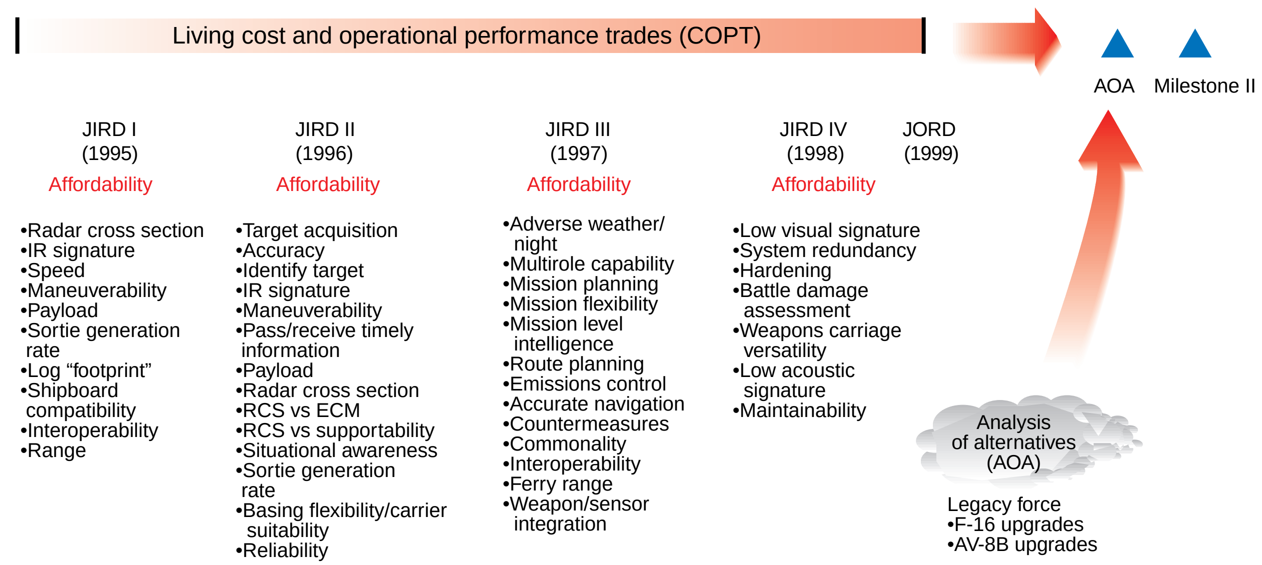

Figure 3. Continual cost and operational performance trade process leading to the Operational Requirements Document (RCS = radar cross section; ECM = electronic countermeasures).

diagnostics and expanded database management. Embedded in the "Smart" weapon system, enhanced with a multifunction portable maintenance aid, Joint Integrated Maintenance Information Systems diagnostics and database management can provide a responsible, precise logistics and support system to the Smart flightline technician. The autonomic logistics support redefines the interface among the weapon system, maintenance technician, and support infrastructure to sustain high sortie generation rates and reduce logistics footprint and total life-cycle costs.

Infrared and Radio Frequency Signatures

Initial survivability studies on radio frequency and infrared signatures and self-protection suite combinations using detailed campaign-, mission-, and engagement-level analyses demonstrate that high survivability provided by stealth is one of the more leveraging JSF attributes. Survivability is the key to weapon system persistence. Reduced signature allows for a reduction in the number of combat support sorties required.

Range

The JSF Program explored the unique target distribution of each of the Defense Intelligence Agency threat countries to determine the range required for the JSF to strike targets. When combined with all the resources available to the Joint Force Commander, a JSF range of 400 nmi into enemy territory is sufficient to strike 100% of the target set. The actual combat range required then becomes dependent upon service basing concepts. The Navy will operate from carriers offshore at a distance in concert with the threat and will require a minimum of 600 nmi combat range. The quantity of aircraft the Air Force would deploy into theater and the basing distribution of those aircraft will require an Air Force combat range of 450–600 nmi. The Marine Corps concepts of basing flexibility and forward basing, both afloat and ashore, produce range requirements of 450–550 nmi.

Carrier Aviation Suitability and Basing Flexibility

Carrier aviation (CV) suitability is fundamental to naval basing and operational employment. Basing flexibility in the Marine Corps provides the foundation for forward basing, which, in turn, increases responsiveness. This flexibility increases the number of airfields from which to conduct operations, decreases the response time of aircraft without the use of airborne support, and provides dispersal for high-value assets.

Speed and Maneuverability

Speed and maneuverability are characteristics where more capability is historically considered better. However, the increased requirements will rapidly accelerate cost. The JSF cost–performance trade analysis determined that we must retain capabilities comparable to current multirole aircraft. This level of performance is necessary and sufficient to successfully engage, counter, and survive both future air-to-air and future surface-to-air threats.

Affordability

Because cost was considered as an independent variable, the JSF acquisition strategy was based on a family of strike variants in order to enhance total system affordability. All requirements trades are being evaluated not only for their operational value, but cost as well. Performing continuous Cost of Operational Performance Trades will enable the program to optimize return on investment for DoD and remain within programmed funding levels.

JIRD-I was focused on qualities and characteristics that drive the outer mold line of the aircraft designs. JIRD-II (Fig. 4), nearing completion, will emphasize key avionics trades, especially target acquisition, weapon system deliveries, and accuracy; supportability versus radar cross section; and supportability versus diagnostics.

Virtual Strike Warfare Environment

As we have refined our modeling, simulation, and analysis process, we have moved through constructive simulation and interactive digital simulation and are on the verge of completing our virtual strike warfare environment (VSWE, Fig. 5).

This VSWE provides links to advanced tactical crew stations, reconfigurable cockpits, anechoic chambers, integrated technology demonstrations, risk reduction demonstrations, Advanced Capability Technology Demonstrations, and virtual avionics prototypes incorporating avionics hardware and software prototypes. This process significantly reduces the development cost and will drastically reduce future life-cycle, flight tests, and training costs.

In the near future, detailed trade studies involving the complete “System-of-Systems” will be addressed within the VSWE. For example, we have initiated a study to investigate the benefits of exploiting the vast amount of battlespace information available to current-generation aircraft. The study indicates that the delivery of ordnance against most of the targets that would be allocated to the JSF requires the use of onboard sensors. However, increased performance provided by exploiting and fusing offboard sensors and guided weapons will expand the target set the JSF can hold at risk.

Enhancements in situational awareness will require a paradigm shift in the way we manage information in the cockpit and a revolutionary approach to the distribution of intelligence, surveillance, and reconnaissance data. Twelve onboard/offboard avionics configurations were evaluated in our VSWE. The conclusions of this study were that offboard information can be used for detections, the data can be fused with onboard sensor tracks, information management can effectively regulate the pilot’s situational awareness, and avionics procurement costs could be reduced by up to 20% per ship set through the use of offboard information in the cockpit. Pilots found that use of offboard sensor data and information management policies yield measurable improvements in the ability to prosecute targets in a survivable manner. These preliminary results need to be extended by more robust analysis. These activities and insights, conducted in our VSWE, will be

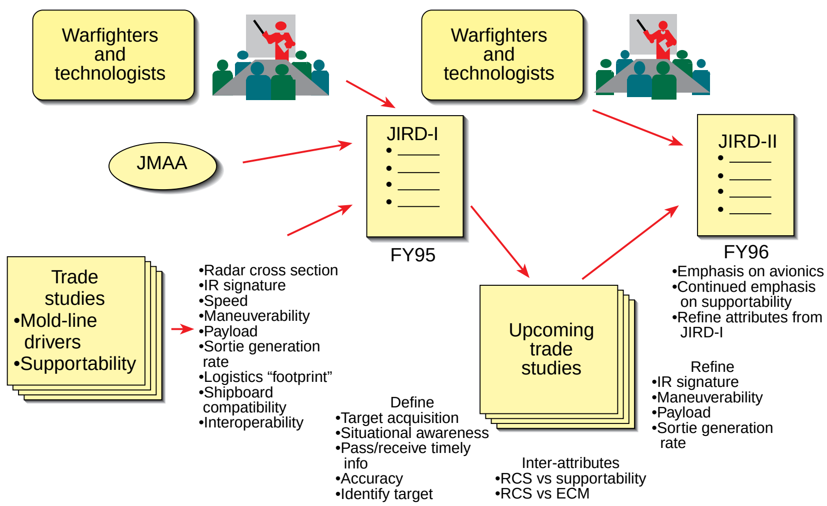

Figure 4. JIRD II areas of emphasis as defined through a continual cost–performance trade process (RCS = radar cross section; ECM = electronic countermeasures).

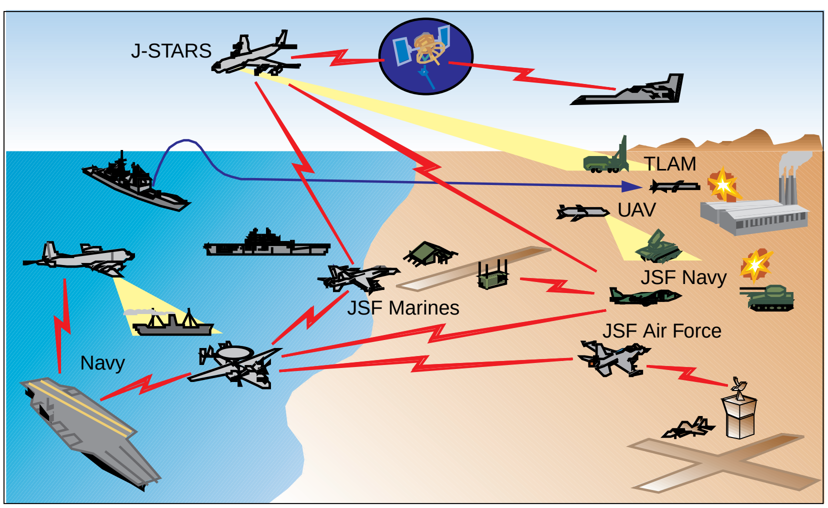

Figure 5. The JSF Program has developed a virtual strike warfare environment.

beneficial in the formulation of key avionics trade studies and resulting weapon system requirements for JIRD-II.

TECHNOLOGY MATURATION

As stated earlier, from the outset of this program, the JSF Program Office has worked closely with industry and other government organizations to identify high-leverage technologies with the potential to benefit the contractors' respective Preferred Weapon System Concepts. This task has been accomplished by government and industry integrated product teams. The Program Office has awarded numerous technology maturation contracts focused on technologies that will contribute to weapon system affordability and those that can be successfully transitioned into engineering and manufacturing development with low risk. A few of the technology maturation programs currently under way are described in the following paragraphs.

JSF Integrated Subsystems Technology (J/IST) Demonstration

Aircraft subsystems have traditionally been designed using a federated approach consisting of a number of independently designed subsystems. Effectively integrating key subsystems can significantly improve aircraft affordability and provide warfighting benefits through increased performance and dramatically reduced amounts of equipment. The JSF-sponsored J/IST Demonstration Program is maturing integration technologies for aircraft subsystems to enable transition to the Engineering and Manufacturing Development Program by FY 2001. The JSF-sponsored Vehicle Integration Technology Planning Studies projected that a 3–4% life-cycle cost savings could be achieved with these technologies versus 1995 state-of-the-art federated subsystems.

The integration technologies that are being matured are the Thermal/Energy Management Module and its integration with the engine, 270VDC power management and distribution, electric flight actuation, and associated controls to enable effective integration and demonstration. These technologies were identified by Boeing, Lockheed Martin, and McDonnell Douglas/Northrop Grumman/British Aerospace weapon system contractors as providing substantial cost and warfighting benefits to JSF weapon system concepts. The technologies encompassed in the J/IST Program allow 13 baseline-technology major subsystems to be replaced with five, as shown in Table 2.

The hardware and software components will be integrated into major subsystems-level ground and flight demonstrations in FY 97 and 98. The J/IST demonstration will conclude in FY 99–00 with systems-level demonstrations of the integrated subsystems suite running in concert with a representative propulsion system and with the flight testing of all flight critical components of a single integrated flight systems solution.

Virtual Manufacturing

In August 1995, the virtual manufacturing FAST-TRACK Program demonstrated that virtual manufacturing can provide dramatic cost benefits in the aircraft design process (Fig. 6). During the demonstration, McDonnell Douglas designed a new airframe former using off-the-shelf design and manufacturing tools. Adjustments were also made to the assembly jig during the design process to ease production floor assembly. The electronic database design information was then

Table 2. The JSF Integrated Subsystem Technology demonstration will effectively integrate key subsystems to improve aircraft affordability.

Traditional subsystems (13)		Integrated subsystems (5)	
Airframe subsystems	Engine subsystems	Airframe subsystems	Engine subsystems
Aircraft-mounted accessory drive	Engine power	Thermal/energy management module	Starter/generator
Auxiliary power system	Thermal management	Electrical power distributor	Fan duct heat exchanger
Emergency power system	Power takeoff	Integrated vehicle management system	
Air cycle environmental control system (ECS)			
Vapor cycle ECS			
Thermal management system			
Pneumatic engine start			
Hydraulic power distributor			
Electric power distributor			
Distributed vehicle management system			

transmitted seamlessly from St. Louis to the vendor (Remmele Engineering, Inc., Minneapolis, Minnesota), who machined the part using the McDonnell Douglas Aerospace electronic information and shipped it to St. Louis for fitting and assembly. The new former fit the first time on the production floor jig without the usual iteration process to adjust the jig and modify the part design.

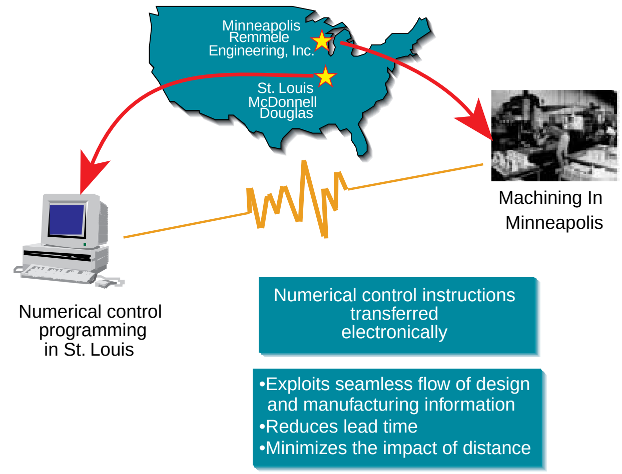

Figure 6. Virtual manufacturing provides a seamless flow of design and manufacturing information.

Advanced Lightweight Aircraft Fuselage Structure (ALAFS)

This program is a multiyear project involving a redesign of the F/A-18E/F center fuselage–wing section. The goals of the program are to reduce the cost of this section of the aircraft by 30% and reduce the weight by 20%. These goals translate to 6–8% life-cycle cost savings for the JSF Program. Technologies and focus areas encompass materials, structural design concepts, and manufacturing processes for improved fabrication and assembly. This project will identify and develop concepts and methodologies that will allow much greater integration of advanced composite structures. Unitized composite design concepts will be explored to enhance structural integrity at reduced weight, employ lower cost production concepts, and create volumetric efficiencies that are complementary to more electric concepts (Fig. 7).

The fabrication of the full-scale test article allows direct comparison with the baseline structure. Because the baseline design requirements for systems integration and interfaces have been maintained during the design of the ALAFS structure, a real assessment of the technology benefits can be determined. The schedule is designed to support an option for production incorporation of ALAFS (or a variant) in the F/A-18E/F in accordance with the JSF Program Office assessment.

TRAINING SYSTEMS

The JSF training system development is revolutionary in that it approaches training as a continuum that ranges from initial training to advanced deployed tactical fighter wing operations. A common, affordable, deployable, individually tailored, on-demand training system that is electronic, interactive, and linked directly to design, operator, and maintainer databases is our vision. The JSF training system must support specific needs of at least four Services using a common core, yet function within the joint training environment.

The JSF training system concepts are developed to sustain or improve effectiveness while reducing life-cycle cost. We reviewed two advanced visual systems in a joint effort with the Navy, Marine Corps, and Air Force to evaluate, on a task basis, the ability of advanced visual systems to train warfighters on strike and air-to-air tasks.

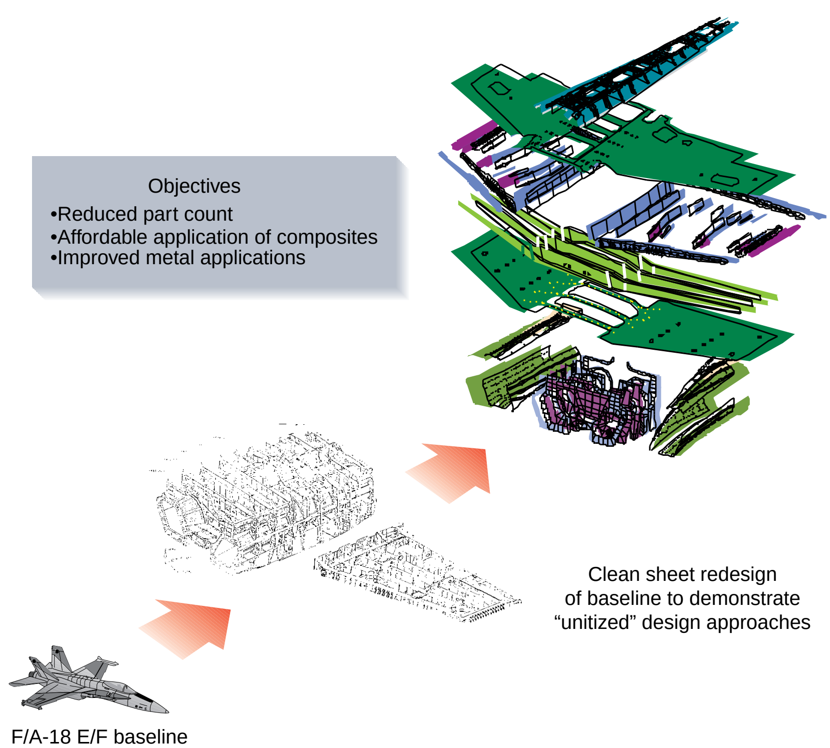

Figure 7. Advanced Lightweight Aircraft Fuselage Structure (ALAFS).

The systems evaluated were a Visual Integrated Display System and a CAE Electronics Advanced Fiber Optic Helmet Mounted Display. Whereas the results of this study show that more maturation is required for advanced strike and multiship tasks, the overall potential of the visual system technology to increase effectiveness while reducing life-cycle costs is tremendous. Its impact will be seen in pilot and maintainer training as well as mission planning and rehearsal.

The JSF Program Office has also evaluated virtual reality technology in a demonstration by Boston Dynamics, Inc., as a potential technology for replacing maintenance part task trainers. When the advances being made in visual technology are coupled with the haptic or force-feedback technology, there is the potential to provide the functionality of many part task trainers on a single work station. This technology could be kept current with software updates, and the hardware would be little more than a desktop computer.

The JSF training system will truly be a breakthrough in the use of technology to increase capability while significantly reducing life-cycle cost.

MISSION SYSTEMS

The avionics integrated product team streamlined its current program through a continuing filtering process that began with the survey of nearly 400 technology candidates in late 1993 (Fig. 8). By the summer of 1994, we categorized the highest affordability-leveraging candidates into six Integrated Technology Demonstration Plans and let contracts to study and demonstrate the critical enabling technologies with the potential to achieve a low-risk transition to engineering and manufacturing development.

Further refinement emphasized quality-function-deployment results, the architecture definition, the health of the science and technology seed base, and especially the feedback received from the weapon system contractors and senior technical experts. The result was a focused set of demonstrations in four areas: core processing, integrated RF sensors, integrated electrical optical/infrared sensors, and weapons integration and precision targeting. The product of this process is a demonstrated avionics concept that ensures both weapon system effectiveness and affordability.

Figure 9 is an architectural representation showing where the ongoing technology maturation efforts emphasize introducing enabling techologies to create cost-effective mission systems capabilities for the JSF. Technical managers examine software infrastructure issues in programming languages; real-time, fault-tolerant operating systems; software engineering environments; and secure avionics architecture. The reuse of legacy tactical weapon systems software is also under evaluation.

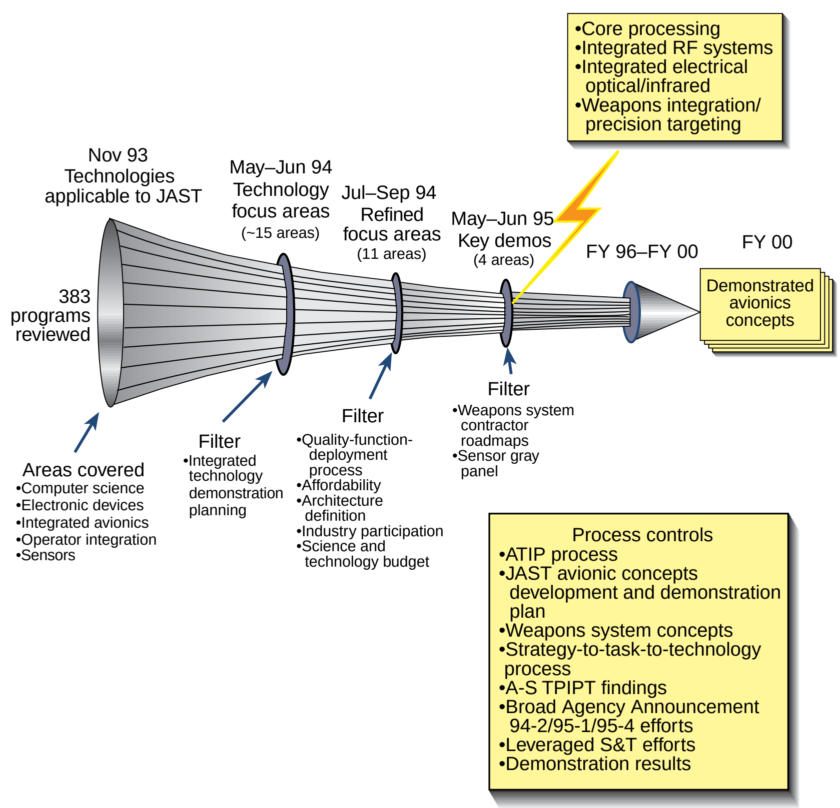

Figure 8. Avionics integrated product team filtering process of candidate technologies.

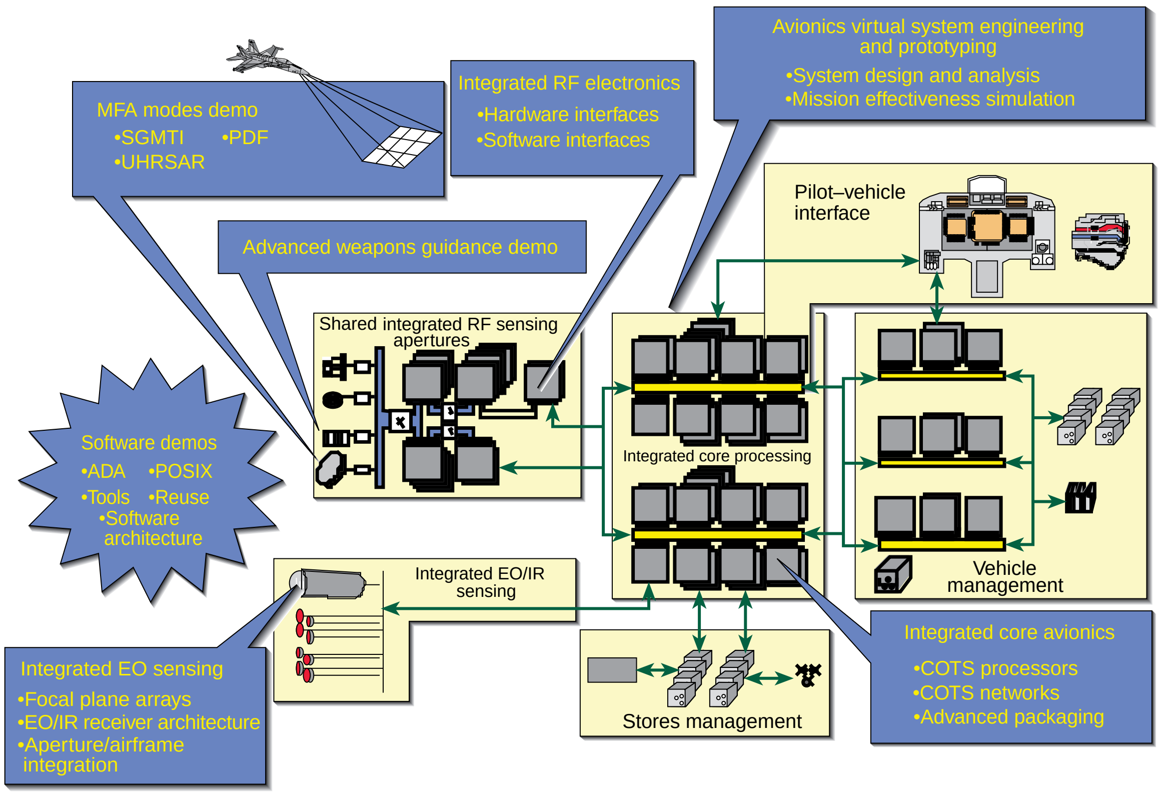

Figure 9. Mission systems integrated technology demonstrations. (EO = electro-optical; COTS = commercial-of-the-shelf; MFA = multifunction nose aperture)

The Avionics Virtual Systems Engineering and Prototyping activity provides a modeling, simulation, and analysis approach to integrate the mission systems (especially avionics) together in a virtual sense. Results from the other demonstrations can be inserted as appropriate to include hardware-in-the-loop and software-in-the-loop demonstrations. Together, these demonstrations provide a measure of affordable system-level performance with demonstrations in key areas to ensure adequate risk reduction of the more critical elements.

The Multifunction Integrated RF System technology maturation demonstration has the primary objective of reducing the risk of developing a low-cost, lightweight multifunction nose aperture—an active electronically scanned array—that meets the needs of the JSF Preferred Weapon System Concepts (Fig. 10). The cost breakdown of current generation integrated avionics shows that the entire RF system composes about 59% of the avionics flyaway costs, with the multifunction nose aperture representing about 19% of the total.

The Multifunction Integrated RF System concept supports the warfighters' requirements to navigate; maintain either active or passive situation awareness; either actively or passively search, detect, locate, and identify targets; support weapon delivery to either fixed or mobile ground and maritime targets, and airborne targets; and assess weapon effectiveness. These requirements are traded to ensure a cost-effective multifunction nose aperture.

Another high-leveraging activity is Integrated Core Processing, which will demonstrate critical technologies and software processes necessary to achieve an open architecture, information management, and displays necessary to support a single-crew aircraft (Fig. 11).

This philosophy allows for cheaper and quicker upgrades and significant growth capability. To ensure both affordability and robustness to handle the 2010+ mission, the next step will involve component demonstrations of advanced processors, manufacturing, and packaging technologies.

INITIAL WEAPONS DEMONSTRATION

Using shaping and materials, the JSF Program demonstrated a penetrating 1000-lb package as shown in test in Fig. 12. The JSF analysis process showed that an effective weapon of this type will permit a smaller aircraft platform with concurrent affordability and survivability benefits. The leveraging projects within the technology maturation program were initiated, predicated upon the results shown in Table 3.

Concept Definition and Development Phases

Whereas the Technology Maturation Programs continue, we completed the Concept Definition and

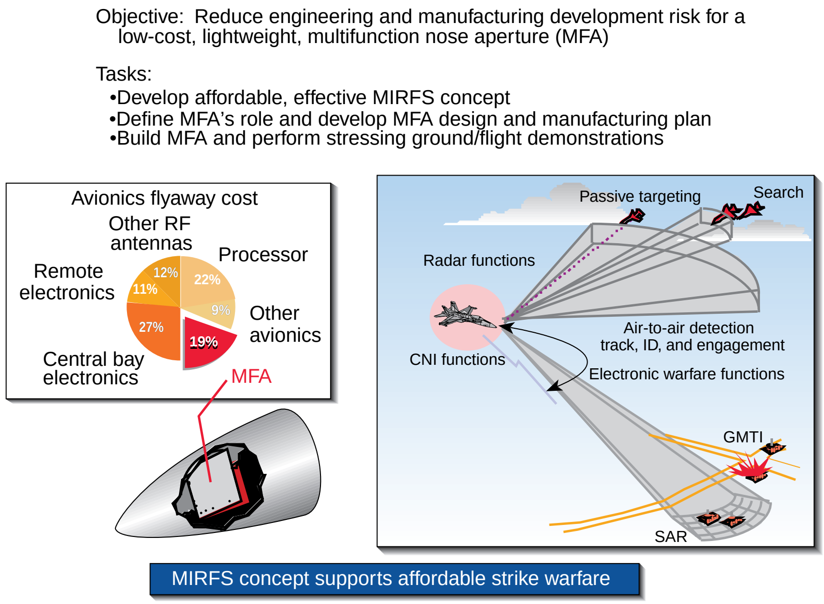

Figure 10. Multifunction Integrated RF Systems (MIRFS) Demonstration.

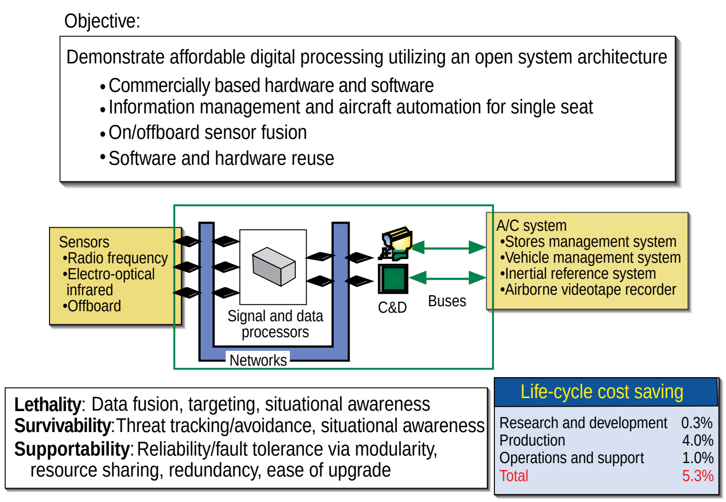

Figure 11. Integrated Core Processing demonstrates critical technologies and software processes necessary to support a single-crew aircraft.

Design Research (CDDR) phase of our program in the fall of 1996. Separate aircraft weapons system CDDR contracts were awarded to Boeing Defense and Space Group, Lockheed Fort Worth Co., McDonnell Douglas Aerospace, and Northrop Grumman Corporation in December 1994.

The three fundamental objectives for the JSF weapon system CDDR work were as follows: (1) identification of joint strike aircraft weapon system design characteristics and integrated weapon system concepts intended to meet warfighter (operator) requirements and contribute to significantly reduced cost for joint strike warfare; (2) identification of support and training concepts that contribute to lower life-cycle cost, enhance supportability, promote commonality, and enhance deployability; and (3) definition of a comprehensive plan for an aircraft demonstrator and associated ground demonstrations with maximum potential for achieving JSF Program objectives. Overall emphasis was on definition of innovative common and highly common joint strike aircraft concepts for the Navy, Air Force, and Marine Corps that reduce the cost of joint strike warfare, while maintaining U.S. combat superiority.

A significant result of this phase of the program was that a high level of airframe commonality is possible for a family of aircraft from a single production line (Fig. 13). With 100% commonality in displays, avionics, seats, software, test equipment, depot repair, commonality values exceed 70%. This is an extremely significant life-cycle cost reduction for the DoD.

The November 1996 downselect contract awards to the Boeing Company and Lockheed Martin Corporation kicked off the Concept Demonstration Phase. Each contractor will define those demonstrations it believes are crucial for its concept, vis-à-vis providing concept assessment and ensuring a low-risk technology transition to engineering and manufacturing development. This phase features flying concept demonstrators, concept-unique ground and flight demonstrations, and continued refinement of the contractors' preferred weapon system concepts. Specifically, each contractor will demonstrate commonality and modularity, short take-off vertical landing (STOVL) hover and transition, and low-speed handling qualities of their concepts. Pratt and Whitney will receive a contract to provide hardware and engineering support for the Weapon System Concept Demonstration efforts. A contract will also be awarded to General Electric for technical efforts related to development of an alternate engine source for production. Risk mitigating technology maturation demonstrations will continue as well.

The Concept Demonstration Phase acquisition strategy has several advantages, including the following:

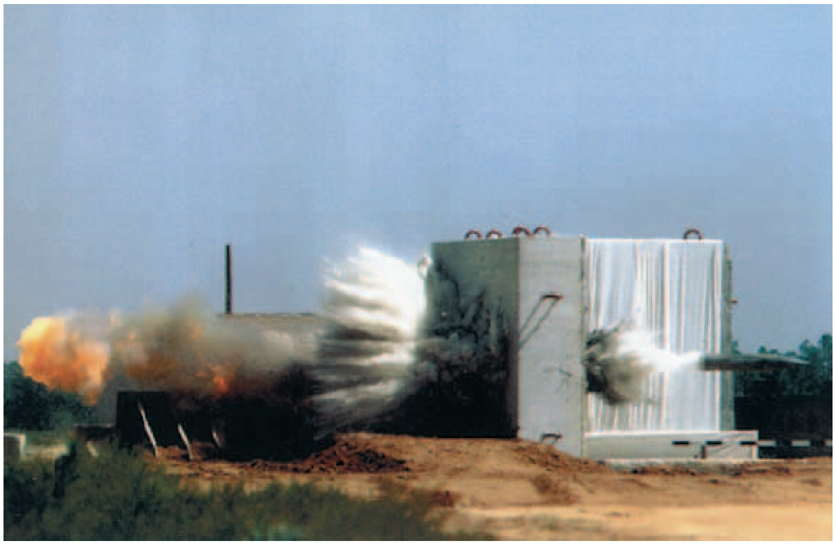

Figure 12. JAST-1000 (J-1000) penetrating a blockhouse.

Table 3. Significant unit- and life-cycle cost savings resulting from the JSF Technology Maturation Program.

	Unit fly-away savings ($M)	Life-cycle cost savings ($B)
Supportability		
Diagnostics	1.0	3–4
Training and mission planning	—	4–5
Support	0.6	2–4
Structures		
Advanced lightweight aircraft fuselage structure	1.7	2.2–2.4
Manufacturing	4.6	13–20
Avionics	5.0	15–20
Propulsion/nozzle	1.7	6.0
Weapons	0.5	3.5
Subsystems (more electric aircraft)	2.0	7.0
Percentage savings	30–31%	28–32%

- Maintains the competitive environment prior to engineering and manufacturing development and provides for two different STOVL approaches and two different aerodynamic configurations.
- Demonstrates the viability of a multi-Service family of variants; high commonality and modularity among conventional take-off and landing, carrier aviation, and STOVL variants are expected.
- Provides affordable and low-risk technology transition to the JSF engineering and manufacturing development in FY 2001.

A brief description of each contractor's concept follows:

Boeing Company. The Boeing JSF preferred Weapon System Concept addresses the affordability, survivability, lethality, and supportability needs of the Air Force, Navy, Marine Corps, and the United Kingdom Royal Navy (Fig 14). Boeing's concept employs a modular approach that has highly common structural modules (forebody, mid-fuselage, and wing) to reduce assembly cost. The single-piece wing structure (primarily thermoplastic composites) that acts as a primary load-bearing component is a unique feature of their design. It provides high internal volume at low weight, high fuel fractions, and excellent range and payload capability. The mid-fuselage arrangement is nearly identical for all variants with local modifications to accommodate the STOVL direct-lift system. The Boeing JSF designs share a common outer mold line. This characteristic allows high commonality in structural arrangements, materials, processes, tooling, and parts, and a single assembly line for all variants. Airframe part commonality, in combination with highly common avionics, propulsion, subsystems, and software, reduces development and production cost, and enables common spares, support, and training. The design significantly reduces part count by using unitized structural components and subsystem consolidation.

The engine for all variants is a single F-119 derivative that provides excellent up-and-away performance. The gas generator, augmentor, and cruise nozzle are common among variants. The direct-lift STOVL nozzles are installed within a common propulsion system envelope.

Boeing's designed-in supportability features include onboard diagnostics, a supportable signature suite, and a self-sustaining capability to enhance sortie generation rate and reduce logistics footprint.

Lockheed Martin Corporation. Lockheed Martin Tactical Aircraft Systems, Fort Worth, Texas, is the

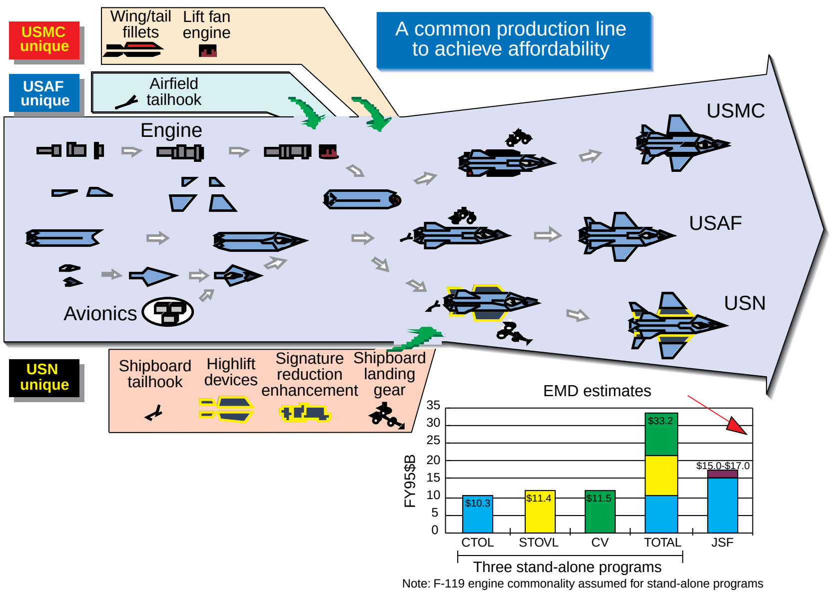

Figure 13. A single production line for a family of aircraft significantly reduces cost (EMD = engineering and manufacturing development).

corporate center of a virtual company competing to develop and build the JSF. Their concept is a highly common family of aircraft that meets multi-Service strike mission needs (Fig. 15). The three basic variants include CV, CTOL (conventional take-off and landing), and STOVL to be used by the Navy, Air Force, and Marine Corps, respectively. The STOVL variant will also serve the needs of the United Kingdom Royal Navy. The variants share the same fuselage with differences allowed for specific service-life needs such as structural reinforcement for Navy launch and recovery operations and Marine Corps vertical landing lift fan structural changes. A diverterless supersonic inlet reduces the weight and complexity associated with conventional inlet concepts while enhancing survivability attributes to RF signature. The internal weapons bay is a common size and configuration across the family. The wing carry-through structure is common for all three versions with high lift additions along the wing periphery for the Navy variant. Studies are ongoing to determine the appropriate mission systems required on the aircraft.

Figure 14. The Boeing JSF Weapon Systems Concept.

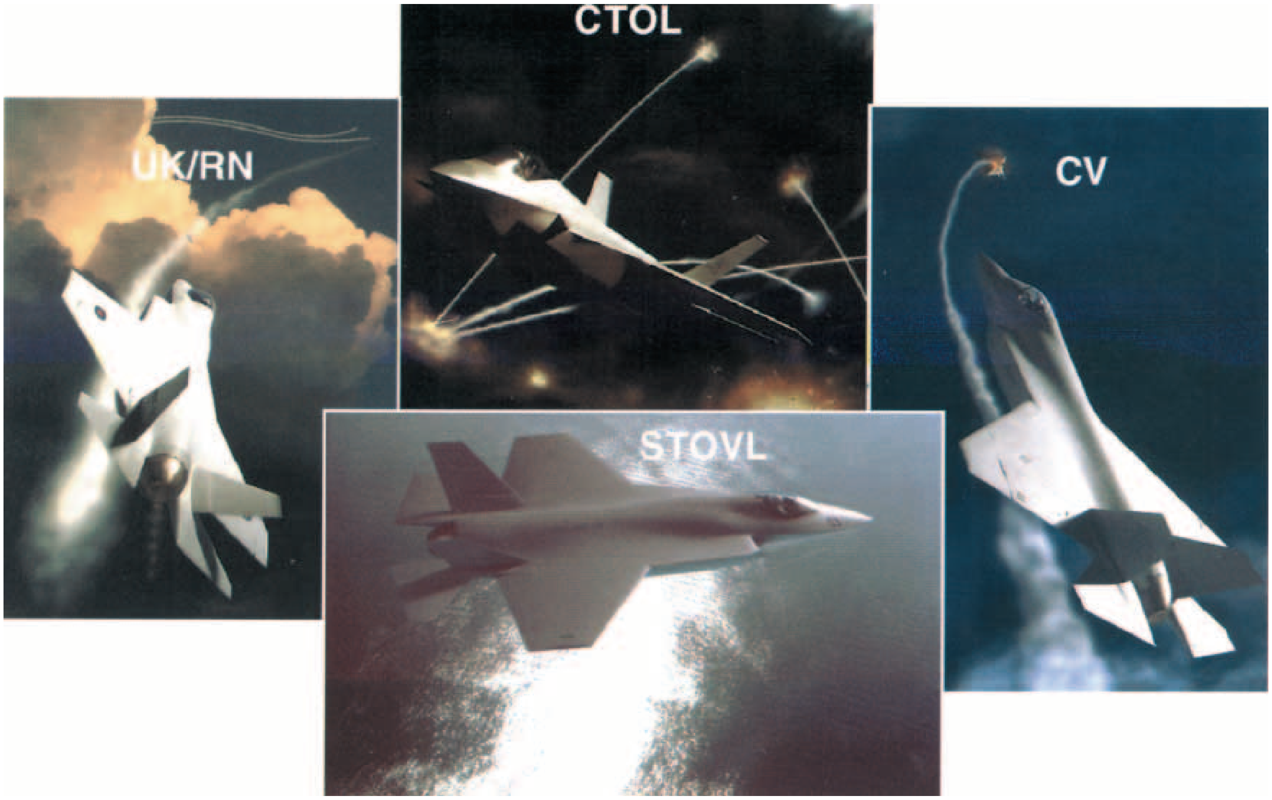

Figure 15. The Lockheed Martin JSF Weapon Systems Concept.

Common to the CV and CTOL variants is a derivative of the F119-PW engine, which will be developed as part of the JSF Program. The STOVL variant uses the same derivative F-119 for up-and-away operations but modifies it slightly to allow power extraction to drive a lift fan (Allison/Rolls Royce) for vertical landings. This shaft-driven lift fan concept, patented by Lockheed Martin, has been successfully demonstrated through a large-scale powered model (approximately 90% scale) built by Lockheed Martin Skunk Works Division in California. The STOVL variant features a unique three-bearing swivel nozzle. All variants will be designed to accommodate an alternative F120-GE engine derivative that will be available in the production phase. Lockheed Martin plans to perform unique demonstrations to reduce risk on its concept, and is an active participant in JSF Technical Maturation programs. Lockheed Martin is also engaged in the requirements definition process identifying appropriate cost versus technical performance trades to bring the JSF to fruition affordably.

SUMMARY

The Services remain strongly committed to this joint program to develop an affordable solution to their future strike warfare needs—the Joint Strike Fighter. The government and industry team is converging on a design concept for a family of strike aircraft weapon systems that, coupled with the other technology "building blocks," will yield continued technological superiority for our warfighters but much more affordably. To meet the fiscal and threat demands of the next century, the DoD clearly recognizes we must "neck-down" our tactical air forces with a focus on affordability, jointness, and commonality. The Joint Strike Fighter will make that goal achievable.

THE AUTHOR

CRAIG E. STEIDLE is a Rear Admiral in the U.S. Navy. He entered naval aviation after graduating with merit as an aerospace engineer from the U.S. Naval Academy in 1968. Additionally, he received M.S. degrees in aeronautical systems management from the University of Southern California in 1978 and in aerospace engineering from the Virginia Polytechnic Institute in 1979. After graduating from the Industrial College of the Armed Forces in 1986, he was Deputy Program Manager of the F/A-18 program, the manager of the Navy's Aerospace Engineers, and a Special Assistant for Air Combat to the Assistant Secretary of the Navy. In 1990, he was appointed Program Manager of the F/A-18 program and during this command established the F/A-18 E/F program. RADM Steidle became Deputy Director of the Joint Advanced Strike Technology Program (now, the Joint Strike Fighter Program) in 1994 and its Director in 1995. He has been decorated with many awards including the Legion of Merit, the Distinguished Flying Cross, and the Republic of Vietnam Gallantry Cross. The Secretary of Defense has presented him with the Navy's Outstanding Program Manager Award.