SYSTEMS ENGINEERING AND THE JOINT STRIKE FIGHTER: *THE FLAGSHIP PROGRAM FOR ACQUISITION REFORM*

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The Joint Strike Fighter program, which aims to provide a new aircraft that will satisfy needs of the U.S. Navy, Air Force, and Marine Corps, the United Kingdom, and other non-U.S. services, is a challenging undertaking. Adding to the challenge is that it is being conducted under DoD's acquisition reform initiatives. Here we compare its progress to that of past aircraft programs.

The Joint Strike Fighter (JSF) program represents the largest potential aircraft contract for the U.S. Department of Defense (DoD) in the foreseeable future. It will provide replacement strike fighters for the U.S. Air Force, the U.S. Navy, and the U.S. Marine Corps, as well as for the United Kingdom and probably many other non-U.S. services. The objective of meeting the different needs of many services with variants of a single airplane is a very difficult challenge, especially when the number one consideration is affordability.

As part of the plan to achieve an affordable solution, the JSF program will be conducted under the DoD's acquisition reform initiatives begun in 1994. These initiatives mandate a new and innovative way of doing business, canceling many government military standards and specifications and stating the services' needs in performance-based terms. No longer will the government mandate compliance to military specifications with "design-to" guidance, requiring certain materials and processes. The government will simply state what it needs the JSF weapon system to perform and allow the contractor to provide the optimum solution based on a balance of technology and best commercial practices.

This article highlights the differences between the JSF program and past aircraft

programs. It concentrates on the application of best systems engineering practices and the use of performance-based specifications, and provides insights into how customer-contractor relationships will achieve the common goal of an affordable solution to the warfighter's needs.

THE PROGRAM

The tactical aircraft modernization plans of the U.S. Air Force and Navy have something in common—the JSF. The competing industry developers, Boeing and Lockheed-Martin, are in the middle of assembling the first of two JSF concept demonstrator aircraft, which will undergo flight evaluations this year.

The JSF program aims to develop an affordable family of next-generation multirole attack aircraft with high commonality for the Air Force, Marine Corps, Navy, and U.S. allies. It has been described as a supersonic, single-engine, single-seat airplane; it's an F–16/F/A–18 class performer, but it's stealthy. The three JSF variants are: a conventional takeoff and landing (CTOL) replacement for the U.S. Air Force's F–16 to complement the F–22; a Navy aircraft carrier-based attack (CV) variant with extra stealth to complement the F/A–18E/F; and a short take-off and vertical landing (STOVL) replacement for the U.S. Marine Corps' AV–8B *Harrier* jump jet and F/A–18C/D aircraft and the U.K. Royal Navy's *Sea Harrier.* The Air Force may also buy some STOVL variants to replace its A–10s in the close air support role.

About 3,000 of the three variants are planned: the first will become operational around 2008. Exports could total another 2,000 aircraft over the life of the program. Following flight testing of their concept demonstrator aircraft in 2000, only one of the two competing industry teams will be selected the following year to continue into the engineering and manufacturing development (EMD) phase of the program, subsequently building those 5,000-plus airplanes.

Both Boeing and Lockheed-Martin will use their concept demonstrators to show the fundamental characteristics of their CTOL and CV variants, and prove out basic STOVL variant performance. The competitors, in particular, must demonstrate the commonality and modularity of their three variants, STOVL hover and transition, and low-speed handling qualities that are needed for carrier landings.

A key to high commonality among the three variants is the propulsion scheme chosen by each competitor to link its CTOL/CV and STOVL designs. Boeing's X–32 JSF uses a direct-lift system similar to the *Harrier*'s, with stowable Rolls-Royce lift nozzles on its Pratt & Whitney JSF119-614 engine, as well as small pitch, roll, and yaw nozzles fed from engine exhaust air. Lockheed Martin's X–35 design, for STOVL propulsion, uses its JSF119-611 engine to drive a separate Rolls-Royce Allison lift fan, located behind the cockpit, which blows cool air downward. It also uses a three-bearing swivel exhaust nozzle on the main engine and roll-control ducts in the wings.

PATHS TO AFFORDABILITY

As noted on the JSF program's Internet website (http://www.jast.mil):

> The focus of the program is affordability—reducing the development cost, production cost, and cost of ownership. The program is accomplishing this by facilitating the Services' development of validated, affordable operational requirements and by lowering risk by investing in, and demonstrating, key leveraging technologies and operational concepts prior to the start of the engineering and manufacturing development (EMD) phase of the JSF in 2001.

Development of the leveraging technologies by various firms has been funded under technology maturation contracts, the results of which benefit both Boeing and Lockheed Martin. All of the data will go to both teams, who are free to use any of this proven technology in their final proposals if it is, in fact, low risk and contributes to the affordability of the weapon system.

Operational Requirements

The scope of the JSF program's joint operational requirements development process has been unprecedented. Begun in 1994, it has involved the full-time participation of "warfighter" representatives, experienced pilots, logisticians, and maintenance officers assigned by each service to support the JSF program. No similar requirements document has ever been produced by warfighters with such a plethora of information on which to base decisions on requirements.

The services have a robust set of models and simulations with which they can look at generic performance levels for a JSF, coupled with associated cost estimates provided by industry and the program office. The goal is to balance costs with operational performance requirements and do tradeoffs to ensure that the requirements the Services are asking for will meet their needs—and make sure that the aircraft will come in at a cost that the Services' budgets can afford. The emphasis is on cost as an independent variable (CAIV), and the unit flyaway cost targets that the JSF program hopes to beat are $28 million for the CTOL variant, $35 million for the STOVL version, and $38 million for the CV variant (in fiscal year 1994 dollars).

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JSF as the Flagship Acquisition Reform Program

The JSF program is the first major aviation acquisition effort that emphasizes the acquisition reform initiatives first mandated by William Perry in 1994 as Secretary of Defense. The objective of these initiatives is to break the accelerating upward spiral of the cost of military aircraft programs (Figure 1) by streamlining the DoD's acquisition process. The central feature of these initiatives is the cancellation of thousands of DoD military standards and specifications (MIL-STDs and MILSPECs). These documents overspecified requirements, mandated "design-to"

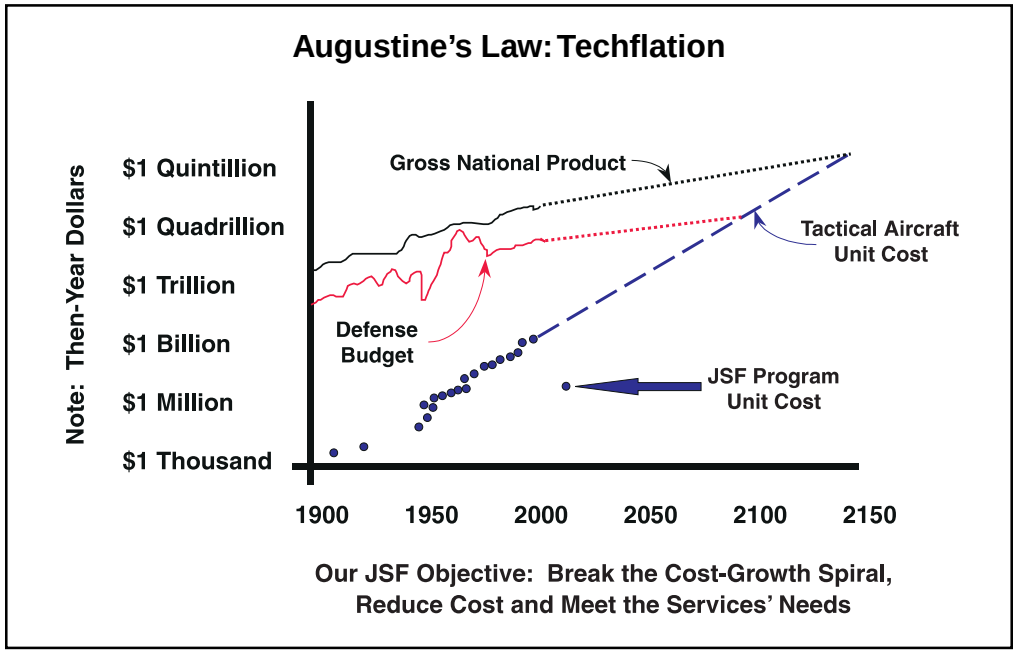

Figure 1. The JSF Objective: Break the Cost-Growth Sprial, Reduce Cost and Meet the Services' Needs

details, and limited the contractors' flexibility in providing an optimized product.

The key feature of the reformed process is performance-based specifications (PBS) (attributes shown in Figure 2), wherein the government states a need for a capability by specifying functional performance, the environment in which the system must operate, the interfaces to existing or planned systems, and the expected operating and support characteristics. PBS does not specify detail design requirements that lock the contractor into specific designs, does not specify requirements for materials, assemblies, or components, does not specify "how-to" or process standards.

An example: instead of specifying that the JSF have a radar and requiring specific design features such as power output, pulse repetition frequency, scan rate, etc., the government would specify a need to detect, track, and identify targets at tactically significant ranges. The contractor may or may not decide to use a radar to satisfy this need; there may be some other onboard (or offboard) sensor that may perform better and be more affordable. The point is that the contractor has the flexibility to use best design practices and leverage available technology in order to meet the need. Figure 2 summarizes some of the objectives that make the JSF program different.

To operate in this new PBS environment, the Joint Program Office (JPO) established a PBS working group (see Figure 3) in December 1996 to develop the JSF model specification. This group is made up of representatives from JPO, Boeing,

Government Objectives:

- Get warfighter and technologist together to enable leveraging cost-performance trades
- Apply technology to lower cost of the system not just increase its performance
- Adequately mature technology prior to entering EMD
- Solution must be joint
- Instigate/catalyze acquisition reform
- Develop system under extremely constrained cost and schedule goals

These objectives and internal management focus on "Thinking-X" led to a Boeing JSF streamlined and distributed Systems Engineering Organization.

Figure 2. Why JSF is Different

and Lockheed-Martin who have strong systems engineering backgrounds, especially in requirements development. They are charged with developing the model spec that shall:

- define system performance that meets the requirements defined in the Joint Interim Requirements Document/Joint Operational Requirements Document (JIRD/JORD);

DO

- Specify Functional Performance/Results
- Define the Environment in Which System Must Operate
- Define the System Interfaces
- Define the Operating and Support Characteristics
- Utilize Measurable and Verifiable Requirements

DO NOT

- Specify Detail Design Requirements that Lock Ktr into Specific Design
- Specify Requirements for Materials, Assemblies or Components…
- Specify "How-To" or Process Standards

Figure 3. Performance Based Specifications (PBS)

- include the minimum essential requirements necessary on contract for the government to manage the program;
- be included in the request for proposal (RFP) and tailored in the contractors' EMD proposals;
- be developed in a timely manner to support JSF scheduled events; and
- allow the government and contractor to minimize surprises in the "down-select" process.

The model spec is intended to concentrate on the key or critical performance requirements that would make or break the program, and would include only the performance minimums contained in the JIRD/JORD. The adjacent box lists the major attributes of the JSF model spec. The JIRD/JORD will also include desired "objectives" which the contractors may decide to design to in order to have a competitive advantage.

Now what this all means is that the JSF model spec, which will form the basis of the contract spec, will contain, as a goal, 150 to 200 requirements. Contrast this number with the more than 16,000 contractual requirements on the F/A-18E/F and more than 6,000 on the F–22. The model spec will be "contractor generic"—that is, the same for each competitor, as shown in Figure 5, and its development is paid for by the government during the concept demonstration phase.

Each contractor will develop a "JSF contract specification" specific to its design, which will capture all of the model specifications. However, contractors are be free to sign up to meet additional requirements if they feel it is to their competitive advantage. This contract spec, which will be provided in response to the RFP, will also contain the verification plan for ensuring that the requirements are achieved.

The JSF Specification Shall:

- Define the System Performance that Meets the Requirements Defined in the JORD
- Include the Minimum Essential Requirements (MERs) Necessary for the Government to Manage the Program
  - Concentrate on Key/Critical Performance Requirements
  - Relatively Limited Number of Requirements are Expected
  - Express Requirements at Highest Aggregate Level Practical
- Use Performance-Based Approach
  - State Required Results,
  - Not "How-to", Design Details/Solutions or Process Standards
- Be Included in the CFI and Tailored in the Contractor's E&MD Proposal

Figure 4. JSF Specification for EMD

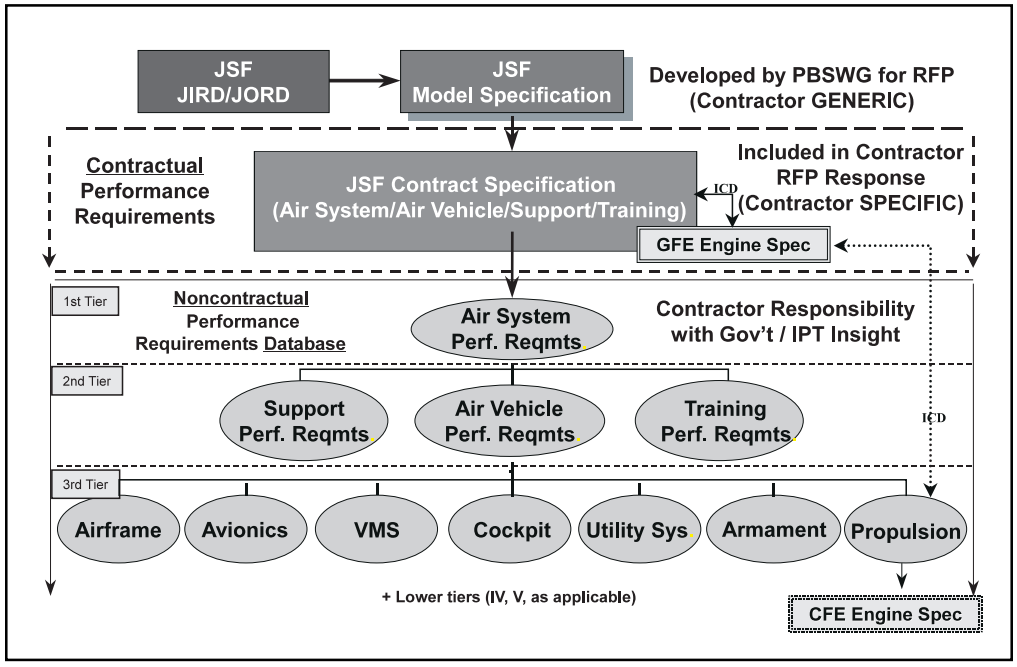

Figure 5.
The Program Develops a Performance-Based Specification Tree

- **What is "JSF Model Spec"?**
  - A Generic, Non-Contractor-Specific Format for Statement of Performance Requirements (Section 3 Only) in the EMD Solicitation (95% Solution)
  - RFP Solicitation Version Should Have No TBDs (= No Surprises)
  - Includes the Minimum Essential Requirements (MER) Necessary for the Government to Specify System Performance That Meets the Requirements Defined in the JORD
  - What is "Proposed JSF Contract Spec"?
  - The Contractor-Specific, Tailored Version of the JSF Model Spec Submitted in the Contractor's EMD Proposal (100% Solution)
  - All Section 3 Completed and Section 4 Completed with Proposed Verifications
- **What is "JSF Contract Spec"?**
  - The Agreed-to Document That Goes on Contract; Essentially the Same as the "Proposed JSF Contract Spec" with Final Verifications
  - Includes the Minimum Essential Requirements (MER) Necessary for the Government to Manage the Program and Receive the Desired Capability/Product

Figure 6. Specsplanation of Terms

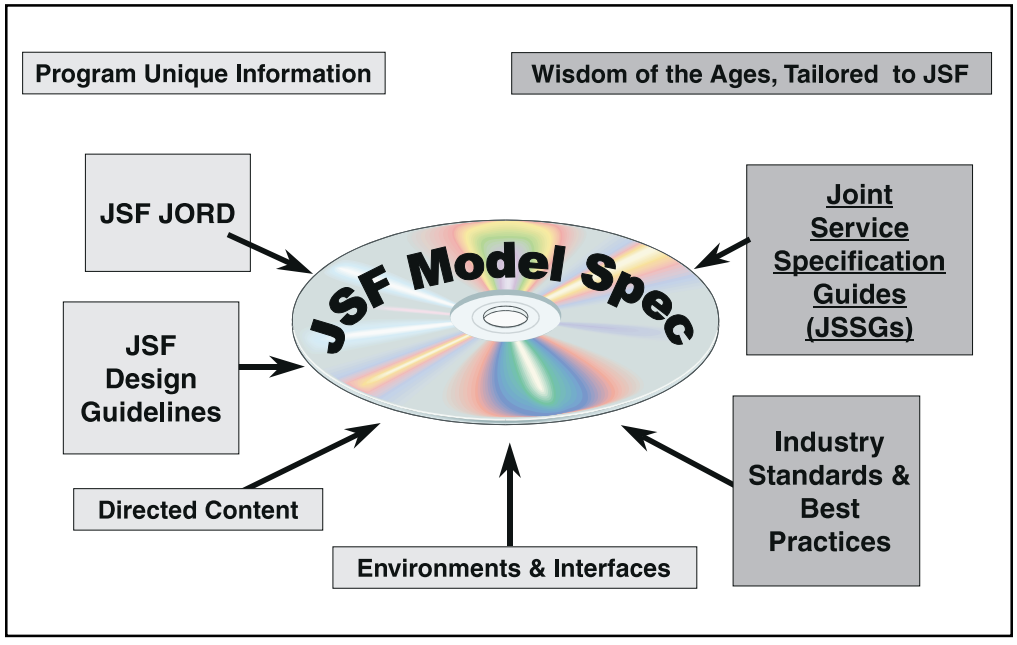

Figure 7. Program-Unique Specification

Note that in Figure 5 all of the supporting lower-tier specifications, which were on contract in past programs, will now be noncontractual items. In order to allocate requirements to the various product areas which make up the air system, all of these

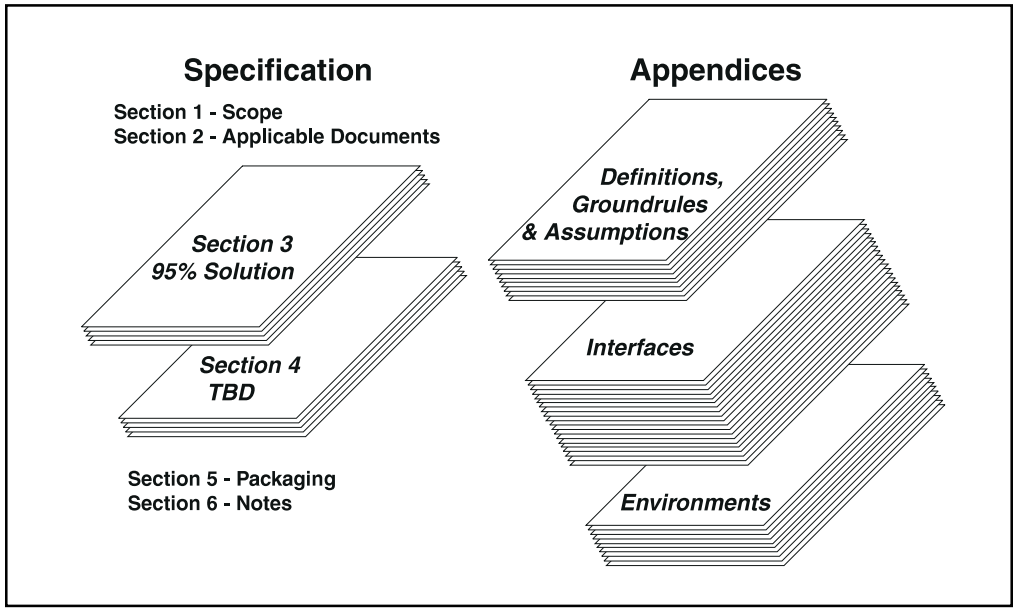

Figure 8. JSF Model Specification Structure

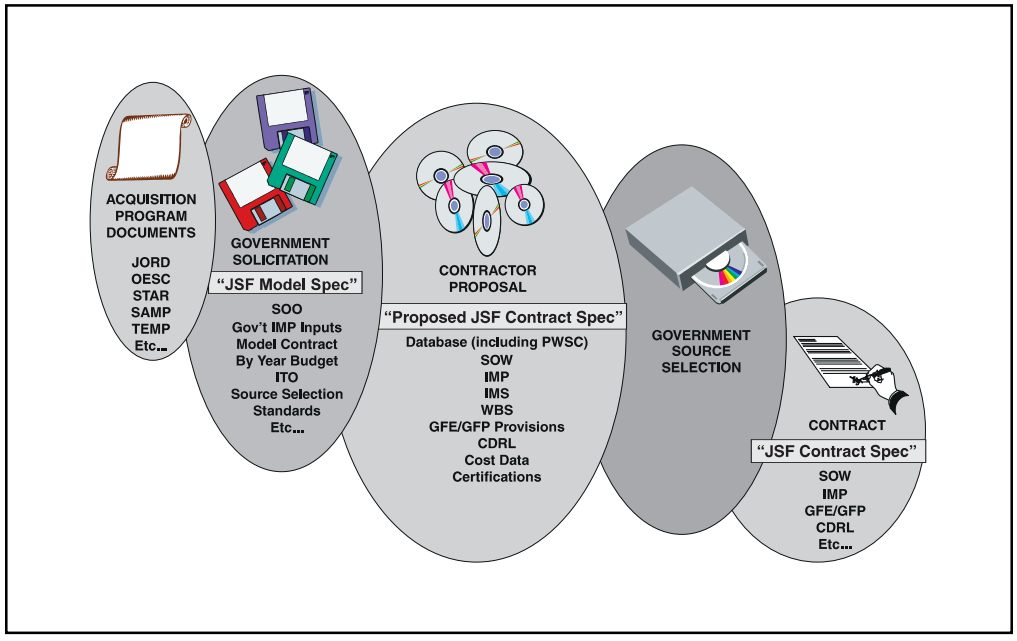

Figure 9. Technical Content from Requirements to Contract

lower-tier specifications must still be developed as on more traditional programs, the difference is now that they are not on contract, and the contractor is free to make design changes internally. In this way, trades of structures versus avionics systems, for

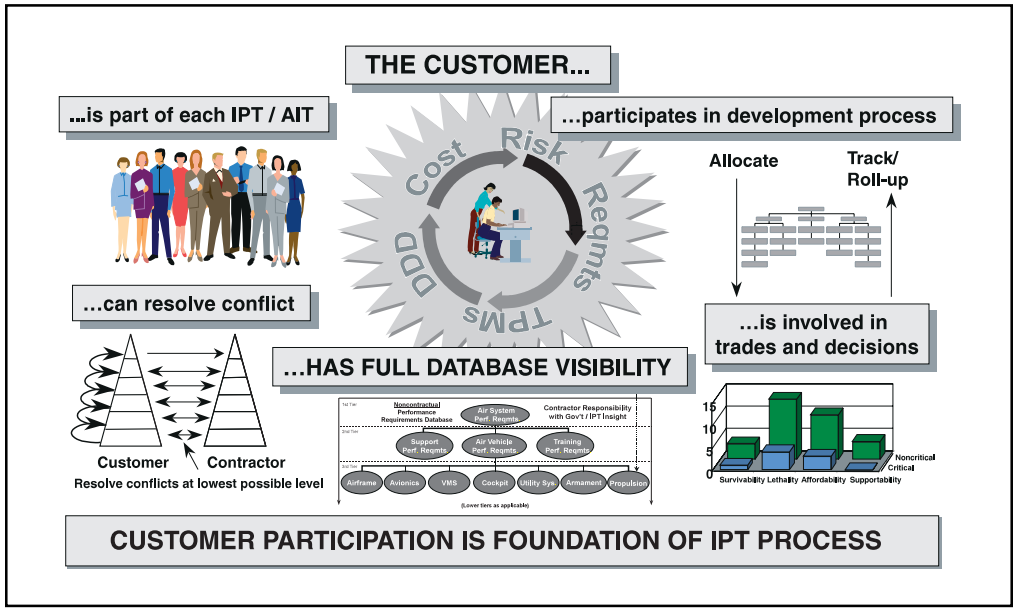

Figure 10. In Acquisition Reform, IPT Activities are Customer-Oriented

example, may be made in order to optimize the entire system with an eye toward performance and affordability.

This flexibility actually represents an increase in the difficulty of the contractor's job, because they are tasked to maximize creativity and best practices. The key to reducing cost and cycle time is that this flexibility means that when detail design changes are made at levels below the contract spec, contract changes are not required, therefore, contracts and legal personnel are not involved. The adjacent box ("'Specsplanation' of terms") summarizes the definitions of the model and contract specs.

Systems engineers lead both the creation of the model spec and each contractor's response to it. They coordinate the many inputs that influence the model spec (Figure 7), such as the JIRD/JORD, JSF design guidelines, directed content, environments and interfaces, Joint Service specification guides, industry standards and best practices, and the "wisdom of the ages, tailored to JSF."

Figure 8 shows the JSF model spec structure. Section 3 contains the limited set of very top-level requirements, and Section 4 (which when added will transform the model spec into a contract spec) will contain the associated verification schemes. The appendices will contain definitions, ground rules, and assumptions as well as the environments and interfaces required. However, the model/contract spec is only a small part of the entire RFP and response, as shown in Figure 9. The government solicitation will also include the statement of objectives, budget information, source selection standards, etc. And the contractor proposal will contain the statement of work, integrated master plan, work breakdown structure, etc. But the contract spec is the foundation of the entire effort.

- Minimum Essential Requirements to Manage the Program & Deliver Warfighter Capability /Product
  - Concentrate on Critical Requirements - KPPs, CPPs
  - Maximize Contractor's Responsiveness to Key Performance Requirements
  - Maximize Available Trade Space
  - Class I Configuration & Change Management Burden Minimized
- Enables Optimum CAIV Implementation
  - Promotes Maximum Flexibility in Addressing Affordability via Performance vs. Cost Trades
- Maximum Contractor Flexibility in Product Development and Subcontractor/Vendor Relationships
- Innovative Specification Approach supports JSF as Acquisition Reform Flagship Program

Figure 11. Acquisition Reform Reduces Cost and Cycle Time

Of course, as with any new process, there will be reluctance to change, both on the part of the government customer and the contractor. Figure 10 shows the key to the success of this new way of doing business. The customer must have daily access to and participate in the systems engineering processes such as risk manage-ment, trade studies management, configuration management, technical performance metric evaluation and tracking, and requirements and verification development.

The government IPTs must have complete confidence that, even in the absence of the "hammer" of lower-tier specs, the contractor will meet their needs. This is critical: When the contract spec only says, "the JSF shall be compatible with CVN-68 *Nimitz*-class and subsequent carriers," the government customer must be convinced that the contractor understands what this means, can capture the essential aspects of that requirement, allocate that requirement down through the lower-tier teams, design to the requirement, and, most important, provide verification that the requirement will be met.

Further, this acquisition reform process will only be optimized when the prime contractors promote a relationship with their teammates and subcontractors that focuses on performance-based specifications and the other aspects of acquisition reform.

THE CHALLENGE

Acquisition reform is intended to reduce cost and cycle time by minimizing contract changes, as shown in Figure 11. This is achieved by specifying only the minimum essential requirements to manage the program and deliver warfighter capability. The contract specifications must concentrate on only the key and critical performance parameters, which define the program. This will maximize the contractor's responsiveness to these parameters by maximizing the available trade space, and minimizing the contract and configuration management burden.

This approach, using PBS, enables optimum CAIV implementation and promotes maximum flexibility in addressing affordability via performance versus cost trades. It maximizes contractor flexibility in product development and subcontractor and vendor relationships and the ability to take advantage of best commercial practices.

Systems engineers lead the effort to meet the challenge of acquisition reform, and their development of an innovative specification approach supports JSF as the acquisition reform flagship program.

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