A View from Wright-Patterson Air Force Base

CROSS TALK spoke with Ronald D. Dubbs, F-22 Weapon System Chief Engineer at Wright-Patterson Air Force Base, Ohio. He has technical responsibility for overseeing the development and production of the F-22 Advanced Tactical Fighter. He led the F-22 Avionics team for two years during Engineering and Manufacturing Development before assuming his current position. The following article is based on an interview with Dubbs and the draft of the Independent Technical Assessment of the F-22 Avionics written in October 1999.

According to the Independent Technical Assessment (ITA) accomplished by the Software Engineering Institute (SEI), the F-22 fighter aircraft is a Department of Defense (DoD) acquisition of unprecedented scale with a highly complex avionics suite.

Last year, a 10-member ITA Team from the SEI conducted an independent technical assessment of F-22 avionics. The team was made up of a wide range of technical backgrounds, including computer science, systems engineering, avionics, space systems, F-15 simulation development, and integrated product and process development. The ITA Team found that major technical challenges for the F-22 included integrating the hardware and management of integrated resources, fusion of sensor data, and automation of pilot tasks. The major managerial challenges include the large number of contractors and the highly distributed workforce.

The ITA Team produced findings in three separate areas:
1) People
2) Process
3) Product

The ITA found that using integrated product teams (IPTs) to develop F-22 avionics was highly effective and a good model for continued use. They also found, with regard to people, that maintaining the capacity, capability, and full commitment of the entire workforce is vital to the continued success of the F-22 program.

In the process area, the ITA Team found the systems/software engineering environment (S/SEE) is critical to the success of the F-22 avionics software. Common technical processes are defined and used across the avionics IPTs, and management processes anchored in the IPT approach are highly effective. (See Figure 1.)

Among the findings in the product area were that sensor data fusion has a significant impact on overall system effectiveness, and that there are known performance issues with the common integrated processor (CIP) for real-time avionics performance. The team also learned that anomalies observed during testing of the inertial reference system (IRS) at Edwards AFB in the summer of 1999 had been resolved.

The ITA Team found that diminishing manufacturing sources (DMS) is a major issue affecting the F-22 over the weapon system’s life cycle. It is a problem you just cannot solve,” agreed Ron Dubbs, Chief Engineer for the F-22 Weapon System Products (formerly the F-22 Avionics IPT Lead). “You can come up with a strategy to deal with it, but you cannot solve it,” he said. “It definitely caused us to do some major redesign efforts to recover from that.”

Decisions must be made on whether to make a lifetime buy of old technology or go to redesign, he said. The ITA Team learned that DMS has been identified by the System Program Director, Maj. Gen. Michael Mushala, as a major issue for the F-22. The ITA recommended adoption of a longer range horizon for looking at DMS in the F-22, as well as to a larger Pentagon Engineering Office Fighters/Bombers portfolio strategy.

In addition to DMS, Dubbs noted that keeping good people was not easy to do. The F-22 team had a significant turnover in software engineers, particularly in geographical areas with strong, competitive markets. A steep learning curve and on-the-job training requires existing staff to help train new staff. The lengthy DoD security clearance process and difficulty in finding people with avionics domain experience further compounds the problem.

In other findings, the ITA team thought that the F-22 program has done a much better job than most avionics systems development programs in providing an architecture to guide designers and implementers.

“The architecture was set early on (1991-92), particularly the CIP architecture,” Dubbs said. “That architecture went through the straw man, wooden man, and iron man models, before being definitized.”

Dubbs added that the subsystem IPTs were provided with processor development stations early in their software development cycle, followed by partial CIPs, and full CIPs when needed. This allowed the IPTs to check out their software on the host system before sending it to the Avionics Integration Laboratory (AIL).

“Interface control has also been a challenge,” Dubbs said. Due to the complexity and interaction of the avionics subsystems, establishing and controlling interfaces is very important. The F-22 program has developed and is using automated tools to track interfaces. Without automated tools, the management of interfaces for 108 computer software configuration items (CSCIs) with more than 2 million source lines of code would be overwhelming.

Asked how they tied testing to requirements, Dubbs replied that all F-22 functional requirements and test requirements from the weapons system specification down to lower-level component specifications are documented and tracked in an automated tool called Requirements and Traceability Management (RTM). Using RTM, it is possible to select a requirement and trace its associated links up and down the requirements tree. Links between requirements and test are also maintained in the RTM database.

Dubbs identified an extensive array of testing facilities that have been absolutely critical to the program success thus far. The primary facilities include the Vehicle Management System...
Integration Facility (VIF), the Vehicle System Simulator (VSS), and the Tactical Aircraft System Integration Laboratory, all of which are located in Fort Worth, Texas. Also included are the AIL and the Boeing 757 flying test bed in Seattle and the Avionics Pole Model located at the Rome Air Development Center in upstate New York.

“We have the ability to test in open-air environments . . . [which is] a more dynamic form of test,” Dubbs said. (See images below.) The Block Ø operational flight program (OFP) is successfully flying on aircraft 4001, 4002 and, most recently, on aircraft 4003 (delivered March 6, 2000). Integration, test and certification were performed in the VIF and the VSS. For the remaining software blocks (Blocks 1, 2/3S, and 3), the OFP will be certified at the Boeing AIL in Seattle and flown on F-22 test aircraft 4004 through 4009.

Dubbs noted Block Ø has been very successful to date and that Block 1 avionics testing on the F-22 will commence this summer at Edwards AFB, Calif. (See Figure 2.) As noted by the ITA Team, the widespread use of modeling and simulation in the F-22 program is commendable. Modeling and simulation tools used for testing and analyzing mission software, in particular sensor track fusion, have been very effective.

The flying test bed provides a means to conduct real-time dynamic flight environment testing using real F-22 avionics sensors and laboratory instrumentation to evaluate integrated system performance, which helps reduce impact on F-22 flight schedules. Reflecting on what they would do differently, Dubbs said, “We probably should have planned on more assets to keep those laboratories going. Adequate assets is a key thing.”

If program funding allows, laboratory assets should remain in the lab and not be planned for transition to flight test aircraft. This type of situation creates an asset shortfall when particular laboratory efforts are extended due to schedule pressure. Another lessons learned is the common target processor and software run-time tools should be commercially available and mature by the time the application software is ready for integration.

“We should have gone more to common products and toolsets,” Dubbs said.

The System Program Office/contractor team identified best practices that were agreed to and validated by the ITA Team. These included the use of a common S/SEE and common procedures across IPTs, the widespread use of modeling and simulation, and IPT implementation.

The ITA team noted that the S/SEE components are outdated and there is a growing risk that vendors will no longer support the common tools. The ITA Team was also concerned about the lack of validation of the simulations. Due to budget constraints those validations will not occur.

The ITA Team also thought that there is a risk to the continued success of the IPTs as some parts of the program wind down and experienced people move to other programs. This, however, is a normal occurrence in major development programs and program management must plan for personnel changes as the program moves to a maintenance mode. Minimal staffing for maintenance is the norm. Budget constraints that limit travel and face-to-face meetings may also adversely impact some IPTs. Additionally, the ITA Team recommended involving all stakeholders in any future revisions to F-22 Team Joint Procedures. The ITA Team expressed concern that management is focusing on budgetary issues and tracking known problems rather than using a set of techniques for identifying risks and implementing a mitigation strategy.

The F-22 Team and the SEI ITA Team identified the same best practices and agreed to a large degree on software risk reduction processes, while at the same time sharing many of the same concerns for life cycle risks.

The first avionics Raptor (4004) is scheduled for its first flight in the skies over Marietta, Ga. in early summer. Following several check out flights, aircraft 4004 will ferry to Edwards AFB to begin avionics flight testing. The flight-certified version of the Block 1 operational flight program was to deliver to the airplane in April 2000. The first flight of Raptor 04 will be another major milestone for the F-22 program.

Notes
1. See page 14 for more on the Independent Technical Assessment.
2. See pages 4 and 5 for Bolton’s comments on the IPT as a best practice. See page 8 for Brandt’s comments.
3. See page 6 for Brandt’s comments on the S/SEE.
4. See pages 13 and 14 for comments by Beverly Moody of Wright-Patterson AFB on the CIP.
5. See page 7 for Brandt’s comments on diminishing manufacturing resources.
6. See pages 7 and 8 for Brandt’s comments on software engineer turnover.
7. See page 4 for Bolton’s comments on the block approach.
8. See page 6 for Brandt’s comments on modeling and simulation.
Figure 1. F-22 Team-Wide Software Development Processes

- **Verification and Validation**
  - Internal Independent Verification & Validation (IIV&V)
  - Perform on:
    - Safety Critical CSCIs
    - Safety Significant and Mission Critical CSCIs
  - Software Walkthroughs

- **SW Development Management**
  - Integrated Product Team Membership
    - Systems Engineers
    - Software Engineers
    - Test & Evaluation Engineers
    - Software Configuration Management
    - Material/Subcontract Management (as applicable)
    - Software Quality Assurance
    - Data Management
    - Program Control
    - System Safety
    - System Security
    - Computer Resources
    - Others (as applicable)

- **Software Development Tools**
  - System/Software Engineering Environment (S/SEE)
  - Interleaf
  - PCMS
  - RTM
  - IDT
  - Teamwork

- **Operational Flight Program (OFP) Build Process**
  - OFP Build Concept of Operations (SPD90325D)
  - OFP Build Technical Reference Manual (SPD90326)
  - OFP Software Procedures (SDP00811)
  - OFP Build System (OBS)

- **Team Communication**
  - Meetings
  - Documents/Correspondence
  - F-22 S/SEE
  - F-22 Wide Area Network
  - Video Teleconference Facilities

- **Contractor Facilities**
  - SW Development Laboratories
  - Subsystems Integration and Test Facilities
  - System Integration and Test Facilities

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Figure 2. F-22 Block 1-and-On Integrated Systems Product Flow

- Aircraft #4-9
- OFP Build Configuration Set AIL • Boeing
- System I • PMA & DTC
- VCC
- OFP Process
- VCC (to A/C)
- VMS Integration Facility/ Vehicle Subsystem Simulator (VIF/VSS) LMTAS
- Vehicle System Simulator LMTAS
- VMS Integration Facility LMTAS
- IMIS SDL LMTAS
- Avionics Integration Lab (AIL) Boeing
- Tier III Integration
- Displays to VIF/VSS
- Displays to VIF/VSS
- Prelim OFP Build
- EOS

- Tier IV Development
- BLOC 3S
- Tier I/II 
  - System Acceptance Test
- SW Development Laboratories
- Subsystems Integration and Test Facilities
- System Integration and Test Facilities

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