JOINT ADVANCED STRIKE TECHNOLOGY PROGRAM

AVIONICS ARCHITECTURE DEFINITION ISSUES/DECISIONS/RATIONALE DOCUMENT

VERSION 1.0

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JAST Avionics Architecture Definition Issues/Decision/Rationale Document

1.0 Purpose

The JAST Avionics Architecture Definition Issues/Decision/Rationale Document is a companion document to the JAST Avionics Architecture Definition report. It is a living document that provides a record of the issues, decisions, and rationale resulting from government and industry interaction.

The original JAST Avionics Architecture Definition Version 0.0 was developed by a group of Navy and Air Force experts and published for industry (and others) comment. An avionics architecture review board was established, which included industry and government personnel, to review the comments and decide on any necessary action. This first issue represents the results of decisions and corresponding rationale resulting from this process.

2.0 Scope

The architecture issues are partitioned into COTS (Commercial Off the Shelf), Interconnects, Electrical Power, Packaging, Stores Management System, Processors, Software, and Sensors. For each area, where significant/widespread comments were received, the summarized issue is provided along with the current decision followed by the rationale for the decision. Decisions may change as time goes forward and more is learned about an issue. A cross-reference to Version 0.0 of the JAST Avionics Architecture Definition Document is also provided with each issue.

3.0 Issues/Decisions/Rationale

3.1 Commercial Off-the-Shelf (COTS)

3.1.1 Issue. The use of COTS technology. (Ref. Para. 2.4 and 3.9)

3.1.1.1 Decision. Maintain emphasis on COTS technology for affordability and determine the relative cost impact of COTS chips, COTS packaging, COTS supportability, and cost savings of COTS software reuse.

3.1.1.2 Rationale. The consensus of the comments agreed that the affordability focus mandates heavy COTS investigation. Significant trades across all aspects of COTS (system, software, board level, component level) will determine the maximum level of affordable effectiveness for avionics. Additional issues include the use of commercial production lines to produce military equipment, the current reliability of various chips versus mil-qual parts, and component packaging to further relieve manufacturers of expensive modifications to their normal commercial runs to achieve greater reliability. A major area for affordability enhancement is moving from the development environment to the actual weapons systems with limited changes.

The use of commercial technology may also have an adverse impact on the supportability of avionics. Commercial technology does not support the level of testability and diagnostics typically required by the military. The use of commercial technology with numerous different versions of the same IC presents a problem with configuration control and supportability requiring the right parts at the right place at the right time. Another area of concern is that the typical life of military systems is in the order of 30 to 40 years and commercial technology life cycle is less than five years. This will present a problem with supporting the system when the technology is not upgraded in a timely manner. There is a possibility that the use of contractor logistics support will be required for the life of the system, instead of organic depot capability.

3.2 Interconnects

3.2.1 Issue. Use of a unified interconnect protocol. (Ref. Para. 3.4)

3.2.1.1 Decision. Pursue the unified interconnect concept with demonstrations using SCI. Track other networks such as Fibre Channel, ATM, F-22 networks, etc.

3.2.1.2 Rationale. A unified network has been identified as having significant potential to reduce cost and weight compared to current systems employing multiple specialized data channels. A closely related issue involves selection of a specific unified network protocol such as the Scalable Coherent Interconnect. SCI was the subject of many of the comments on the version 0.0 document. There was a wide variety of opinions both supporting and not supporting SCI. Many of these said it was too early to settle firmly on an interconnect standard while issues of commercial acceptance and a real-time standard remain open. Supporting comments emphasized the benefits of SCI's functional capability, its low latency, wide area of applicability, and resulting design flexibility.

The major argument for selecting an interconnect standard early is that it would provide industry with the needed framework of interface standards for an open architecture and allow them to focus their resources on developing processor (and other) modules--thus stimulating a healthy multi-vendor competition in the module market and promoting affordable modules. This decision also has significant impact on the planning and execution of many elements of the avionics concept demonstration. It is also recognized that the JAST office must carefully observe how the commercial market is responding to various approaches in the future.

3.3. Electrical Power

3.3.1. Issue. Primary Power Voltage. (Ref. Para. 3.5).

The JAST Avionics Architecture power distribution system begins with aircraft generator prime power which, in its lowest weight form, is a multi-phase variable amplitude/variable frequency voltage. Currently aircraft generators produce 115V per phase, centered at 400 Hz, but advanced commercial aircraft power systems may be standardizing on 230 V per phase varying with engine RPM over 1200 ± 400 Hz to reduce weight and increase performance. Navy carrier deck power units also supply 115V, 400 Hz three phase primary power for aircraft support. The F-22 is the first major aircraft program which does not distribute multiphase AC generator output directly; instead, it distributes rectified and filtered 270 Vdc as primary avionics power. Other fighter aircraft generally distribute 115V, 400 Hz, three phase as primary power. The JAST issue is which of these alternatives to adopt for use in EMD.

There is a related Sensor Input Power issue where the position of the RF sensor community is that 270 Vdc input power is extremely important. A single stage power conversion scheme using 270 Vdc prime power and producing the voltage needed by RF sensors has important advantages. It reduces the need for filters to control noise spikes and holds down aircraft weight.

3.3.1.1. Decision. This issue will be reviewed. In the interim, 270 Vdc will continue to be assumed.

3.3.1.2. Rationale. This decision is consistent with the F-22 point of departure, based on extensive trade studies involving efficiency, cost, weight, volume, and spectral purity in the avionics. This also satisfies the RF sensor requirement, with a single stage converter used to generate the consumption voltage. However, we concur with industry that this decision can and should be delayed. The alternatives remain under consideration and additional trades will be completed due to Navy carrier requirements and existing flight deck support equipment.

3.3.2. Issue. Intermediate Power Voltage. (Ref. Para. 3.5).

With the two stage conversion approach, two contending intermediate voltages have been proposed, 48V and 28V. The higher voltage allows rack power to be distributed on fewer or lighter gauge backplane traces and may use fewer pins in the module connector. The lower voltage is widely used in current systems and has some advantage in terms of personnel hazard. In particular, 28 V has a commercial and military aircraft heritage in flight control/vehicle management safety of flight considerations, and 28V batteries are widely used as backup for primary power. The 48V intermediate voltage is a telecommunications industry standard and would allow leveraging of COTS.

3.3.2.1 Decision.. The JAST avionics baseline incorporates 48V as the intermediate (on backplane) conversion level for module power.

3.3.2.2 Rationale. The preference for 48 volts is based on the desire to maximize the power conversion efficiency and save pins and weight in the backplane and connector and most importantly be compatible with the commercial telephone industry standard. 28V will remain under consideration. A final JAST decision will be made after discussions with the FCS/VMS IPT are completed and tradeoff data on affordability and low weight becomes available.

3.3.3. Issue. Single Stage Power Conversion , 270V Module Input Voltage. (Ref. Para. 3.5)

A choice is required between single and double stage power conversion schemes. The proposed alternatives are distribution of 270 Vdc on the backplane with local conversion to consumer voltage vs. enclosure-level conversion of prime power (see issue 3.3.2) to an intermediate voltage. A 270V module input voltage eliminates the intermediate power conversion hardware and minimizes power supply current on the backplane. A 48 Vdc intermediate voltage allows two stages of regulation/filtering for high power quality and EMI rejection and eliminates a potential personnel hazard.

3.3.3.1 Decision. The JAST avionics baseline incorporates a two stage power conversion with 270 Vdc prime power, 48 Vdc intermediate power, and on-module generation of device bias voltage(s).

3.3.3.2. Rationale. The advantages of the two stage approach are judged to outweigh those of the one stage scheme. Industry inputs and continuing trade studies will be used to finalize the decision prior to EMD start.

3.3.4 Issue. Analog Electronics Power Supply Voltage. (Ref. Para. 3.5)

The analog rail voltages are currently ± 15V on some system backplanes. In other cases, "uncorrupted" bias voltages are generated on-module for low noise circuitry. Trends toward lower supply voltages for analog devices require that ± 5V be considered as well. A decision is required on the voltages to distribute on the backplane.

3.3.4.1. Decision. This is an open issue.

3.3.4.2. Rationale. Insufficient data exists at this time to support a decision, and the decision can be deferred without impacting the process of defining an avionics concept for EMD. The JAST program will use industry inputs, data on the types and amounts of analog electronics to be incorporated in the avionics suite, and related trade studies to resolve this issue prior to EMD.

3.4 Packaging

3.4.1 Issue. Module Form Factor and Connector. (Ref. Para. 3.6 and Appendix E.4)

3.4.1.1 Decision. Utilize the SEM-E module form factor as the Preferred System Concept. Further trades studies (and perhaps demonstration programs) will be performed to determine whether some other form factor could meet environmental and other requirements and be significantly more cost effective. Technical issues to be investigated include connector, on-module DC to DC conversion, commercial MCM compatibility, and manufacturability.

3.4.1.2 Rationale. A majority of the comments received agreed that the SEM-E form factor is the preferred alternative for JAST. However questions were raised over the commercial acceptance and thus the affordability of the SEM-E format. The F-22, F-15 P^{3}I, and F-16 Block 50 already are employing SEM-E board size to meet critical shock and vibration requirements. Extensive environmental trades have been performed by F-22 to meet module reliability requirements. If liquid cooling is used, there is strong incentive to make the F-22 module an avionics industry-wide standard.

3.4.2 Issue. Module Cooling Technology. (Ref., Para. 3.6 and Appendix E.4)

3.4.2.1 Decision. LFT (Liquid Flow Through) cooling remains the preferred method although conduction cooling and air flow through cooling remain as options.

3.4.2.2 Rationale. LFT has the advantage that it can cool very high density (high heat load) modules while keeping low junction temperatures. LFT will help ensure reliable operation of processing elements that will be selected in the future. LFT has already passed stringent testing for F-22 and further iterations will be performed over the JAST timeframe. Some comments however raised the issue of the use of LFT, and more specifically the coolant PAO, in a Naval shipboard environment. The use of PAO in this environment will be investigated. Although some comments were received which expressed the view that the projected use of lower voltage devices for digital processing will eliminate the need for LFT cooling, the majority industry opinion was that increasing clock speeds and denser packing will offset this trend.

3.5 Stores Management System

3.5.1 Issue. Should the SMS (Stores Management System) be functionally integrated with the integrated processing unit.

3.5.1.1 Decision. The JAST preferred approach is to keep the SMS unit separate.

3.5.1.2 Rationale. The functionality of the SMS software could easily be integrated into the integrated processing unit. The rationale to keep a separate unit is system safety, isolating the weapons interface from the rest of the avionics system. This subsystem performs complex, time critical operations and generally has a separate hardware based weapon jettison capability. In addition, it may be cost effective to reuse a SMS from another aircraft system (e.g. F-22, F/A-18). A system trade study should be performed to assess this issue.

3.6 Processors

3.6.1. Issue. Should only Form, Fit, Interface Specifications (F^2I) be used in describing JAST architecture building blocks or should Functional Specifications (F^3I) also be included. This issue impacts the selection of a processor family. (Ref. Para. 3.9)

3.6.1.1 Decision. Specify F^2I as the Preferred System Concept.

3.6.1.2 Rationale. F^2I enables technology transparency, allowing actual board content to be determined in EMD to maximize leverage of rapid commercial technology developments. Technology transparency allows increased functional integration possibilities which would not be available if F^3I were specified. In addition, Application Program Interface (API) concept demos and Rapid prototyping of Application Specific Signal Processors (RASSP) toolset repository will allow EMD teams to select a processor family based on the latest commercially available technology at that time while meeting specific functional requirements. The critical issues involved in creating new F^2I specifications are interface, reliability, maintainability, testability, qualification, and potential procurement strategies.

3.7 Software

3.7.1 Issue. Use of a standard OS (operating system) interface. (Ref. Para. 4.2)

3.7.1.1 Decision. The IEEE 1003 POSIX is selected as the preferred operating system interface for JAST.

3.7.1.2 Rationale. There is a need to isolate application software from underlying processor hardware with a standard interface and provide services that every computer program needs such as I/O and program execution control. In addition, a standard interface supports software portability and reuse and minimizes custom computer hardware specific code development.

Most of the industry comments supported the idea of a commercially based OS interface. No specification of the underlying OS was mentioned in the architecture document. Only the interface between the application and the application programming language and the OS are part of the POSIX standard. In a number of areas the POSIX standard is not complete. Scheduling hard real time applications is one of the incomplete areas. The Navy NGCR program is actively working these issues and JAST will become an active participant where appropriate. The JAST program is planning an early demonstration of POSIX/Ada 9X to prove that this that this is a technically feasible and affordable concept. A number of commercial OS's are available which meet the basic POSIX standard including an announcement of a B2 level secure Unix based POSIX compliant OS for delivery this year. The fallback is to build or modify an OS for the JAST application.

3.7.2 Issue. Use of Commercial-Off- The-Shelf (COTS) Software. (Ref. Para. 4.2)

3.7.2.1 Decision. Make maximum practical use of COTS products.

3.7.2.2 Rationale. Practical use of COTS software will reduce costs. For example, programming custom software is more expensive than purchasing a similar commercial capability. An economy of scale results because the commercial product's development costs are spread across many customers as opposed to a single customer. Furthermore, widespread use of COTS software allows many users to test the software and identify problems. The probability of finding potential errors is now greater, helping to minimize risk. In addition, prior experience with the COTS software product among programmers contributes to the software's maturity. Finally, the software development schedule is reduced by purchasing COTS software. When applied correctly, COTS software can contribute to cost reductions.

The advantages of using COTS must be weighted against several risk factors. The biggest risk factor is the COTS software vendor going out of business or no longer supporting the product. This is of particular importance considering the long life span of current weapon systems. However, this problem now exists among COTS software development tools and hardware. Another tradeoff for consideration is the amount of code that needs to be developed for integrating the COTS software into the system. If the integration coding effort is massive, then COTS usage would have to be reconsidered. The final risk factor is the quality of the COTS software vendor. Measuring the quality of the vendor's software process is difficult if one is just purchasing software.

3.7.3 Issue. Secure operations and maintenance of JAST avionics software systems. (Ref. Para. 4.2)

3.7.3.1 Decision. Use software technology consistent with avionics software systems that have been certified as multi-level secure, and consistent with avionics software development processes that have been approved as trusted, at the start of JAST engineering and manufacturing development.

3.7.3.2 Rationale. Elements of the software system must be capable of functioning in a multi-level secure manner so as to ensure the accuracy, integrity, and security of classified and other sensitive data and functionality. Design features which provide multi-level security must be capable of functioning in a manner which does not frustrate the success of mission operations. This brings up a number of concerns which must be addressed.

It is imperative that avionics mission subsystems and related software applications of differing levels of classification be isolated in such a manner that there is no possibility of compromising the accuracy, integrity, or security of their internal data. Interfaces between subsystems must be designed, specified, and documented so as to assure there is no possibility of classified data, algorithms, or functionality being compromised or inappropriately revealed.

It is similarly imperative that avionics support subsystems and related software services and common functions can be trusted to perform so as not to frustrate multi-level security requirements. JAST prefers to rely on COTS operating systems and support services which meet JAST avionics mission requirements, and which have been certified to meet MLS requirements, and which are compatible with established standards that will lead to both interoperability as well as facilitate post-EMD evolution of JAST avionics software.

3.7.4 Issue. Higher Order Programming Language for JAST Software. (Ref. Para. 4.4)

3.7.4.1 Decision. The preferred High Order Programming Language for JAST is Ada 9X.

3.7.4.2 Rationale. There are obvious legal and technical reasons for using Ada as the programming language for JAST. First, public law requires Ada to be used when cost effective. Second, Ada supports the use of quality software engineering practices. Third, Ada was designed for and has been used successfully in large, complicated systems such as F-22 and Boeing 777 aircraft.

Ada 9X will be approved as a national and international standard by the end of 1994. Already, two compiler vendors have announced products that allow users to begin moving from Ada 83 to Ada 9X. These products will be available by the end of 1994 or early 1995.

Trained Ada software engineers and programmers will be available for developing JAST Ada software. The number of institutions offering Ada courses has been growing about 5% a year for the last 6 years. By the end of 1994, about 230 institutions will be offering over 550 total Ada courses. In addition, the DoD has recently awarded 19 contracts for Ada curriculum-development and training course development.

Besides being used on several significant DoD projects such as the F-22 effort, Ada is expanding into the non-DoD world. For example, Boeing has programmed over a million lines of Ada code for its new 777 commercial airliner. In addition, the French national railroad organization is programming its railroad signaling and train control system in Ada. Non-DoD organizations have chosen Ada for these large efforts because of economic and technical reasons.

The JAST program recognizes that new software written in Ada will have to integrate with software components written in other programming languages in order to reuse software from previous developments and use COTS products. JAST and the AJPO are investing in several technology maturity demonstrations to make sure this is possible for EMD.

Higher order languages, i.e., domain specific languages, may become useful in real time applications by 1999. This could significantly change the way software is written , but this technology is considered too risky to be mature by EMD.

3.7.5 Issue. Software reuse. (Ref. Para. 4.7)

3.7.5.1 Decision. Make maximum practical use of previously built software artifacts.

3.7.5.2 Rationale. Software reuse offers significant cost savings if correctly applied. This involves reusing a wide variety of "artifacts" that result from a development effort or a domain engineering effort, e.g., parts of existing requirements documents, specifications, designs, test plans, and code.

Reuse reduces cost, improves quality, and reduces development schedule. The reduction in cost and development schedule is clear when time and effort do not have to be put into recreating something which already exists. The improvement in quality occurs when reusing a mature product which has already been successfully used.

Most of the hurdles preventing successful software reuse relate to code. For example, large amounts of existing code have not been built with reuse as a goal. There is a certain level of rework that is involved. This also applies to code that resides in reuse libraries. Software reuse becomes feasible when the amount of rework is less than conducting an original development.

Liability is another concern with code reuse, and this issue may not be quickly or easily resolved.

On the other hand, reuse of non-code artifacts and ideas can provide a great increase in productivity without the liability concerns of code. A great deal more time and effort has gone into the specification of requirements and design of similar systems than has gone into their code. Also, already completed domain analyses and other domain engineering efforts for the fighter aircraft domain can provide powerful productivity artifacts upon which to build the JAST application.

3.8 Sensors

3.8.1 Issue. The original data rate and throughput projections are low based on projected availability of better A/D converters and the benefits of moving preprocessing to the core processing area. (Ref: Para. 2.7)

3.8.1.1. Decision. Industry comments have been incorporated by adjusting data rate and throughput projections.

3.8.1.2. Rationale. Industry comments have resulted in increasing data rate projections in the Version 1.0 document. **(ISSUE CLOSED.)**

3.8.2. Issue. The integrated RF system has high technical and schedule risk, although industry concurred that this approach needs development because of potential cost savings. (Ref. Para. 5.1)

3.8.2.1. Decision. The JAST avionics preferred concept will continue to include the concept of an integrated RF System and support a risk reduction demonstration to validate the extent to which this concept can be incorporated into the JAST Avionics Architecture.

3.8.2.2. Rationale. The integrated RF system has a high potential to significantly reduce cost, weight and volume for RF subsystems. Through the risk reduction demo, the program office will obtain data to support a decision on the feasibility of the full integrated RF system. At a minimum, a common set of modules will be defined and demonstrated to prove concept feasibility to support downstream EMD decisions.

3.8.3 Issue. Industry comments raise the issue that the integrated RF aperture concept may be high cost and high risk although the concept may have significant payoff. (Ref. Para. 5.2)

3.8.3.1 Decision. The JAST avionics preferred concept incorporates the concept of integrated RF apertures to reduce the cost and number of apertures.

3.8.3.2 Rationale. Due to the growing cost of sensors on tactical aircraft, the integrated RF aperture concept provides a means of containing this cost growth. A risk reduction demo will be supported by JAST to definitize the extent to which integrated RF apertures can be incorporated. This program will also be closely coupled with an integrated sensor architecture trade study. The review board concurs with industry that risk and cost issues exist, particularly for the high levels of aperture integration, and that the degree of integration that is cost-effective must be determined.

3.8.4 Issue. Problems associated with a single integrated nose aperture, including timesharing and RF interference due the integration of multiple functions into a single aperture, should be investigated. (Ref. Appendix E Para. E.1)

3.8.4.1 Decision. To reduce cost, weight and volume requirements for the RF sensor, the integration of multiple RF functions is highly desirable. Thus the JAST avionics preferred concept incorporates a multifunction RF aperture in the nose.

3.8.4.2 Rationale. A single integrated nose aperture would maximize the use of limited space in the aircraft nose and minimize the number of holes in the leading edge of the wing, the integration of IFF, CNI and Radar functions into a single aperture. The JAST program will support two risk reduction demonstrations, an integrated sensor resource manager effort to address the timeline issues and an integrated forebody effort to address the RF interference and observability concerns.