REPORT OF THE

DEFENSE SCIENCE BOARD

TASK FORCE

ON

JOINT ADVANCED STRIKE TECHNOLOGY (JAST) PROGRAM

SEPTEMBER 1994

OFFICE OF THE UNDER SECRETARY OF DEFENSE
FOR ACQUISITION & TECHNOLOGY
WASHINGTON, D.C. 20301-3140

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DEFENSE SCIENCE
BOARD

03 NOV 1994

MEMORANDUM FOR UNDER SECRETARY OF DEFENSE (ACQUISITION & TECHNOLOGY

SUBJECT: Report of Defense Science Board Task Force on Joint Advanced Strike Technology Program

I am pleased to forward the final report of the Defense Science Board (DSB) Task Force on the Joint Advanced Strike Technology (JAST) Program which was chaired by Admiral Wesley McDonald and General Larry D. Welch. This study examines, in great detail, the JAST Program concept which was addressed briefly in the 1993 DSB Report on Tactical Air Warfare.

The key findings and recommendations are summarized in the report's executive summary. In developing its recommendations the Task Force benefited from an exceptionally experienced and diverse group of industry leaders and retired military aviators. The active involvement of the Services and the JAST Joint Program Office was critical to the success of this Task Force also.

I endorse the Task Force's conclusions and recommendations with respect to the JAST program. Particularly, that portion of the report that deals with technology as an affordability driver highlights potential solutions which may be applicable to other programs as well.

David R. Heebner

David R. Heebner
Acting Chairman

OFFICE OF THE SECRETARY OF DEFENSE
WASHINGTON, D.C. 20301-3140

DEFENSE SCIENCE BOARD

30 SEP 1994

MEMORANDUM FOR CHAIRMAN, DEFENSE SCIENCE BOARD

SUBJECT: Report of Defense Science Board Task Force on Joint Advanced Strike Technology (JAST) Program

We are pleased to forward the final report of the Defense Science Board Task Force on the JAST Program. This study responds to an Under Secretary of Defense (Acquisition & Technology) request that the Defense Science Board examine several aspects of this program. Those aspects include: its structure; the schedule and sequencing of activities; the emphases and levels of effort appropriate to the program; and those potentially innovative, high pay-off concepts which could be included in the program.

The Task Force's findings and recommendations are centered in five key areas:

- The JAST program's objective, mission, and relationships;
- Multi-Service requirements;
- Technology for affordability;
- Risk assessment and reduction;
- Industry capabilities and motivations.

The Task Force saw the JAST organization and approach as a special situation in which the limited though important purpose was to address advanced next-generation strike systems needs. The Task Force went to some lengths to ensure that responses were focused on the terms of reference specifically for the JAST program. At the same time, a portion of the Task Force's work is applicable to a far wider range of acquisition policy and management issues. The Task Force strongly recommends that this work be used in that broader context as well as in support of the specific purposes of the JAST program.

Wesley McDonald
Admiral,
U.S. Navy (Retired)
Co-Chairman

Larry D. Welch
General,
U.S. Air Force (Retired)
Co-Chairman

CONTENTS

FIGURES

GLOSSARY

ALAFS	Advanced Lightweight Affordable Fuselage Structure
ASRAAM	Advanced Short-Range Air-to-Air Missile
ASTOVL	Advanced Short Takeoff and Vertical Landing
ATD	Advanced Technology Demonstration
AWACS	Airborne Warning and Control System
BIT	Built-in-Test
BUR	Bottom-Up Review
C3	Command, Control and Communication
CAD	Computer-Aided-Design
CE	Concurrent Engineering
CFD	Computational Fluid Dynamics
CIP	Common Integrated Processor
CNI	Communication, Navigation, Identification
COTS	Commercial Off-the-Shelf
CSCI	Computer Software Configuration Items
DAIRS	Distributed Aperture Infrared Sensors
DIS	Defense Information Service
DoD	Department of Defense
DSB	Defense Science Board
EFA	European Fighter Aircraft
EIS	Electronic Imaging System
EMD	Engineering and Manufacturing Development
EO	Electro-Optical
GPS	Global Positioning System
ICNIA	Integrated Communication-Navigation-Identification Architecture
IDM	Improved Data Modem
IEOSA	Integrated Electronic Sensor Architecture
IEOSS	Integrated EO Sensor Suite
IHPTET	Integrated High Performance Turbine Engine Technology
INEWS	Integrated Electronic Warning System
IOC	Initial Operational Capability
IPPD	Integrated Product Process Design
IPT	Integrated Product Team
IR	Infra-red
JAST	Joint Advanced Strike Technology
JPO	Joint Program Office
JSTARS	Joint Surveillance Target Attack Radar System
JTIDS	Joint Tactical Information Distribution System
LCC	Life-Cycle Cost
LO	Low Observable
MRF	Multi-Role Fighter
NATF	Navy Advanced Tactical Fighter
NATO	North Atlantic Treaty Organization
NGSF	Next-Generation Strike Fighter

O&S	Operating and Support
OSD	Office of the Secretary of Defense
R&D	Research and Development
R&M	Reliability and Maintainability
RCS	Radar Cross Section
RF	Radio Frequency
S&T	Science and Technology
SASSY	Shared Aperture Sensor System
SCI	Scaleable Coherent Interface
SPO	System Program Office
SRM	Sensor Resource Manager
STOVL	Short Takeoff and Vertical Landing
T&E	Test and Evaluation
TADIL	Tactical Data Information Link
TIBS	Tactical Information Broadcast Service
TOR	Terms of Reference
TQM	Total Quality Management
USAF	United States Air Force
USMC	United States Marine Corps
USN	United States Navy
V/STOL	Vertical/Short Takeoff and Landing
VLO	Very Low Observable

EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

A. INTRODUCTION

In 1993, with a new administration and significant changes in the national security environment, the Office of the Secretary of Defense initiated a Bottom-Up Review (BUR) to address the balance among budget priorities, national military strategy, and forces. Initially, the BUR defined a broad range of future contingencies that could require U.S. military forces—land, sea, air, and space—and a force level to meet those contingencies.

At that time, there were plans to acquire four new aircraft over the next decade and a half—the Air Force's F-22 and Multi-Role Fighter (MRF), and the Navy's F/A-18E/F and A/F-X. In addition, a Science and Technology program was under way at the Advanced Research Projects Agency focusing on the Marine Corps requirement for an Advanced Short Takeoff and Vertical Landing (ASTOVL) aircraft.

The Air Force's F-22 was envisioned as the means to sustain an adequate margin of air superiority capability over any future adversary. The MRF was designed to be the future mainstay multi-mission sortie generator in the Air Force inventory. The F-16—currently filling that role—is expected to reach the end of its useful service life 15 years hence.

The Navy's needs were more immediate. First was a more capable, longer-range variant of the F/A-18 for use by both the Navy and Marine Corps. The F/A-18E/F program was well into development. Second, the cancellation of the A-12 in 1991 left the Navy with the unfulfilled requirement for first-day-survivable, stand-alone, longer-range strike capability. The A/F-X was to satisfy that requirement.

The ASTOVL program objective was to produce one or more test articles to demonstrate improved short/vertical take-off and landing capabilities that could satisfy the Marine Corps requirement more substantially than could the AV-8B. It might also fill some future Navy ship-based aircraft needs. A second conventional take-off and landing variant configured with additional fuel tanks in place of the ASTOVL's lift propulsion was envisioned for possible use by the Air Force.

The BUR's deliberations reviewed the *need* for these programs and whether they were *affordable*. The BUR found that there were not enough resources to support all these programs in the Future Years Defense Program. Still, there was a valid need for the diverse capabilities they were intended to provide. The decision was to continue with the F-22 and F/A-18E/F programs and to cancel the A/F-X and MRF. The decision on ASTOVL was to continue that research, but to require some commitment of resources by at least two of the three Services before building a flying prototype.

The BUR also confirmed the Services' continuing needs that were to be addressed by the cancelled A/F-X and MRF programs. That led to establishing the Joint Advanced Strike Technology Program in July 1993. Throughout the remainder of this summary and in the full report, this program is referred to simply as JAST.

In an Appendix to its November 1993 report on Tactical Air Warfare, the Defense Science Board (DSB) provided some early suggestions to the Under Secretary of Defense (Acquisition & Technology) on the structure and focus for the JAST Program. Subsequently, in April of 1994, the Defense Science Board was asked to form a Task Force to examine several areas in more detail—"the structure of JAST; the schedule, sequencing of activities, emphases and levels of effort appropriate; innovative, high payoff concepts for inclusion in the program; and the acquisition strategy for aircraft that might result." This report responds to that request and addresses the nine questions in the Terms of Reference (TOR) memorandum (signed 10 May 1994). The TOR is at Appendix A.

The Task Force saw the JAST organization and approach as a special situation in which the limited though important purpose was to address advanced next-generation strike systems needs. The Task Force went to some lengths to ensure that responses were focused on the terms of reference specifically for the JAST program. At the same time, most of the Task Force's work is applicable to a far wider range of acquisition policy and management issues. The Task Force strongly recommends that this work be used in that broader context as well as in support of the specific purposes of JAST.

The Task Force first convened in April of 1994 and met periodically through early September. The Task Force members are listed in Appendix B. The meeting schedule and other events are listed in Appendix C.

B. ORGANIZATION OF THE REPORT

The nine questions in the TOR are addressed with findings and recommendations in this summary and in the main body of the report. The report is organized into the following five sections:

- Objective, Mission and Relationships
- Multi-Service Requirements
- Technology for Affordability
- Risk Assessment/Reduction
- Industry Capabilities and Motivation

C. FINDINGS AND RECOMMENDATIONS

1. Objective, Mission and Relationships

There must be no confusion about the JAST role in maturing technologies to obtain affordable solutions to the Services' requirements. Direction must reaffirm that the JAST role is *exploitation* of Science and Technology (S&T) programs and not broad technology development. JAST should be a *customer* for S&T programs technologies, not the manager or funding source for the spectrum of strike-relevant S&T programs. The aircraft turbine engine area serves as a useful analogy. The Integrated High Performance Turbine Engine Technology (IHPTET) Program furthers the technology advances of airbreathing engines across the spectrum of performance characteristics for engines. The Engine Model Derivative Program takes the IHPTET technologies and transitions them into relevant application-specific sizes. Similarly, JAST should not be responsible for IHPTET but should exploit the available IHPTET technologies and focus on the relevant *size* engine(s) needed for demonstration to meet JAST-derived strike requirements.

The key JAST mission objective is to exploit and position technology building blocks in the appropriate application for one or more next-generation strike fighter programs. Engineering and Manufacturing Development (EMD) should then be the responsibility of Service or Joint Service program offices.

Figure ES-1 summarizes findings and recommendations.

- The program office should sharply focus on:
  - Service requirements for advanced strike systems within a defined end-to-end strike architecture
  - Affordable processes and end products
  - Transitioning technologies to form building blocks leading to EMD
  - Demonstrating the building blocks for high confidence EMD programs
  - One or more advanced strike aircraft to serve some combination of:
    - » Carrier-based first-day-survivable stand-alone strike capability
    - » Land-based multi-role sortie generation aircraft
    - » Marine Corps battlefield preparation.
- The Office of the Secretary of Defense needs to continually ensure that JAST is a *customer* for technology, not a technology developer.

Figure ES-1. Findings and Recommendations—Objective, Mission and Relationships

2. Multi-Service Requirements

The Task Force reviewed the work of the Services, the BUR, the Joint Chiefs of Staff, the JAST Program Office, and previous DSB efforts to gain appreciation and understanding of mission needs and requirements for next-generation strike systems. More definition of broad requirements is needed to lead to JAST products with characteristics that will provide useful military options to help meet diverse challenges to U.S. national interests in the post-cold war environment.

Analysis and the lessons of recent history suggest that key JAST requirements for new aircraft should include the capability to (1) operate with minimum support in the theater, (2) operate in small formations or as single aircraft with minimum or no close escort or penetrating supporting elements, (3) operate in high threat areas with minimum attrition, and (4) deliver precision weapons that provide high lethality against a variety of targets, while precluding unwanted collateral damage. Further, noting the diversity and global nature of the possible future challenges to U.S. interests, we stress the importance of a family of advanced strike capabilities available from land- and sea-based options.

The Task Force considered requirements from two perspectives—sustaining force levels (quantity) and force modernization (quality). Needs are grouped into three time periods; near- , mid- , and far-term, with JAST-based products addressing the mid-term. There are shortfalls in sustaining force levels in the near-term before the planned IOC of a JAST-based aircraft (2007-2010), but the magnitude of that problem is not compelling, as there are procurement, remanufacture, or service life extension options that can meet Services' needs to sustain the force.

The key need for JAST-based products is force modernization in the mid-term. The Air Force, Navy, and Marine Corps presented diverse needs. The Navy requirement is for a "first-day-survivable, stand-alone, strike fighter"—a capability they need today. However, in the absence of a near-term solution, that is a need to be addressed by JAST. The Air Force requirement is for a future replacement for the F-16, their current "multi-role sortie generator." The timing of that need is consistent with a plausible IOC for a JAST-based next-generation strike fighter. The Marine Corps is seeking a STOVL aircraft with better payload and survivability than that of the AV-8B. As with the Air Force, the timing of the Marine Corps' requirement fits the achievable JAST schedule.

These diverse requirements are difficult to reconcile in a multi-Service vehicle. The Task Force supports the need for the FA-18E/F to fill the near-term need for a Navy multi-mission, sortie producer. However, that solution defers satisfying the Navy's need for a "high-end" strike aircraft. We are concerned with the projected 15-year wait for a Navy strike aircraft that would have adequate first-day survivability while delivering precision weapons.

The Task Force did not attempt to present a particular solution or to stipulate particular requirements. The Task Force did emphasize that there will be no solution to multi-Service strike system needs until joint requirements are better defined.

The Task Force found that the numbers of new aircraft needed to sustain force levels in all three Services require that there be revolutionary improvements in aircraft affordability.

Figure ES-2 summarizes findings and recommendations.

- As an urgent task, the Services should clearly state a range of acceptable requirements
  - The JAST Program multi-Service steering committee should bring workable compatability to affordable multi-Service requirements
  - Industry requires multi-Service convergence of needs prior to initiating the demonstrator phase
- An affordable fly-away cost range should be established as a goal
- The requirements process should emphasize qualities that are particularly vital in the post-cold war environment—including capabilities to:
  - Deploy rapidly, world-wide, with minimum support
  - Operate effectively in small formations or as single aircraft from the first day of conflict
  - Operate in high threat areas, with low attrition
  - Concentrate lethal firepower across the spectrum of targets to include deep-strike, hardened and/or heavily defended targets
  - Attack with lethal precision precluding unwanted collateral damage
- Global contingency potential requires advanced strike capabilities from the full range of land- and sea-basing options
- The JAST process of transitioning technologies into building blocks should:
  - Be ruthlessly product-oriented to lead to EMD of affordable advanced strike systems
  - Also lead to insertion into current and developing systems to improve affordability, supportability and capability
- JAST should promote at least evolutionary improvements in performance and supportability, and revolutionary improvements in affordability
- While the Services will experience near- and mid-term force quantity shortfalls before JAST-based systems IOC, JAST should focus on:
  - Capability needs for the mid-term
  - Systems that can be produced in quantities satisfying mid- to far-term force structure needs
- JAST should be sharply focused on products for the mid-term (2007-2020)
- Technologies and building blocks also should contribute to farther-term needs
- JAST-based aircraft should be designed to leverage the strike architecture to include off-board systems
- The Services should consider subordinating the marginal safety issues of one vs. two engines to affordability and commonality
- JAST should quickly sort out the relative merits of incremental improvements from the two person crew and the added affordability of a single cockpit design
- JAST also should quickly sort out the need for internal vs. external carriage of weapons against the range of scenarios, threats, and targets addressed
- The Navy should carefully consider the viability of current planning that allows carrier-based stand-alone strike capability to be significantly lacking for 15 years
- Required work to evolve and evaluate solutions:
  - OSD and JROC need more quantitative analysis in support of strike needs—target sets and range, payload, survivability needs
  - The Navy and Air Force need to state an acceptable range of requirements to meet their needs
  - JAST should give high priority to exploring the limits of available technologies and approaches to modular designs

Figure ES-2. Findings and Recommendations—Multi-Service Requirements

3. Technology for Affordability

The key enabling technology for JAST is affordability. A comprehensive consideration of relevant technologies resulted in a range of technology focus recommendations for JAST. Given the emphasis on affordability and risk reduction for JAST, manufacturing and design technologies, including appropriate applications of modeling, simulation, and virtual environments, warrant top billing, followed closely by supportability. Performance has received sufficient billing to date and does not require as intense a focus in JAST as do areas that directly address affordability. The list of technologies recommended for exploitation, Figure ES-3, has strong agreement with the priority list identified by the JAST Program. Appendix D includes the full list of the technologies considered, and the rationale for those selected.

- Airframe/Systems
  - Advanced Very Low Observables (including Antennas/Apertures)
  - All/More Electrical System Aircraft
  - True Advanced Composite Structure Design
  - Virtual and Rapid Prototyping of Hardware
  - Modular Construction
  - Reduced Tail/Tailless Fighter Configuration
  - Technologies Enabling STOVL
  - Conformal Carriage for LO and Drag
  - High Lethality Payloads
  - Weapons Integration Affordability
- Propulsion
  - Enhanced Thrust/Weight and Durability
  - Reduced IR Design
  - Thrust Vectoring Nozzle Design/Integrated Flight-Propulsion Control
- Avionics (including Software)
  - Digital Communications Links from On- and Off-Board Sensors
  - Integrated RF Sensors
  - Integrated EO Sensor Architecture
  - Multi-Function Apertures
  - Anti-Jam GPS
  - Advanced Avionics Architecture—Hardware and Software
  - Open Avionics Architectures to Accommodate Commercial Components
  - Common Integrated Processing and Processors
  - Virtual and Rapid Prototyping of Software
  - Reusable Software (Modular Software)
  - Sensor Fusion/Decision Aids
  - Information Fusion
- Manufacturing Methods and Tools
  - Paperless Design to Manufacturing
  - Leveraging Composites for Manufacturing
  - Reduced Parts Count Through Design
  - Common Subsystems/Components
  - Virtual Factory
- Operations/Training (including Supportability)
  - Paperless Integrated Technical Data and Smart Diagnostics/BIT
  - Avionics Packaging and Maintenance-Free Avionics
  - Low Maintenance LO Materials and Coatings
  - Simulation of User Requirements
  - Integrated Virtual and Live Training

Technologies considered priority by the Task Force are covered in JAST or elsewhere

Figure ES-3. Selected Technologies for Affordability

4. Risk Assessment/Reduction

The risk assessment/reduction area received intense attention. Technology is often considered the central focus of risk assessment and risk reduction. However, program structure and program management often contribute more to program risk than does technical risk. Technical difficulties are often the initiator, yet the eventual damage to the program can be far out of proportion to the cost and time required to overcome the technical obstacle. Technical obstacles encountered in EMD can raise doubts about the marginal military worth of programs and erode Service, DoD and Congressional support.

The JAST program should produce Services' agreements on requirements, funding, and schedule. In addition the Services need to agree to reduce program risk in transitioning mature technology. This includes specifying an affordable cost range. JAST should focus on an acceptable range of requirements with flexibility to adjust as technology expectations collide with reality.

JAST should mature and exploit high potential technologies *before* EMD. Additional time and attention to risk reduction before EMD can provide a shorter time to IOC. Dealing with the reality-expectation mismatch (performance, cost or schedule) *during* EMD jeopardizes programs. A significant cause of technical problems in EMD is the gap between the technologists definition of on-the-shelf and the program mangers' definition of off-the-shelf. JAST should contribute to maturing technologies in demonstrators of appropriate size so that EMD starts at a lower level of technical risk with more truly off-the-shelf technology. The Task Force felt that the JAST program should strongly emphasize designing affordable manufacturing into the technology focus for vehicle design, and manufacturing processes and facilities. We also devoted extensive attention to the subject of commercial practices and their relevance to defense acquisition. In our treatment we tried to focus on workable gains from commercial practices rather than seeking a comprehensive victory.

In addition to applying the range of simulation technologies as noted above, JAST will need to define a range of pre-EMD hardware and software demonstrations for risk reduction/low risk entry into EMD, including air vehicle flight demonstrations for critical integration challenges, flying test beds for avionics integration, ground demonstrations, simulations and models, and management systems to provide notable, accurate, timely and well-presented information of program progress. The Task Force also stressed that demonstrations and use of simulation are key contributors to reducing program planning and management risk as well as technology risk.

Figure ES-4 presents the findings and recommendations for this section.

- The JAST program should produce timely convergence and agreements on requirements, funding, schedule, and Services' acceptance to reduce program risk in addition to transitioning mature technology
- Focus on an acceptable convergence of requirements with flexibility to adjust as technology expectations collide with reality
- Exploit and mature high potential technologies before EMD
- Additional time and attention to risk reduction before EMD can provide a shorter time to IOC. Dealing with reality-expectation mismatch in performance, cost or schedule during EMD jeopardizes programs
- Enter EMD with a minimum of unresolved risk—accepting anything beyond low risk in EMD should be a deliberate decision with a fall-back plan
- Full commitment to cost and schedule by the Services and OSD must be a condition of entry to EMD
- Strongly emphasize designing affordable manufacturing into technology focus, vehicle design, program management, and manufacturing processes and facilities
- Commit ruthlessly to "best practices" (commercial, traditional DoD, mixes). To the extent possible, defense acquisition should be made compatible with commercial practices to foster integrated enterprises
- Define the range of pre-EMD demonstrations for low risk entry to EMD:
  - Air vehicle flight demonstrations for critical integration challenges
  - Flying test beds for avionics integration
  - Ground demonstrations, simulations and models
  - Management systems to provide notable, accurate, timely and well-presented information on program progress
- Emphasize developing and using combinations of live, virtual and constructive (models) simulations for military worth, capabilities trade-offs, systems operation, management systems, manufacturing, etc.

Figure ES-4. Findings and Recommendations—Risk Assessment/Reduction

5. Industry Capabilities and Motivations

The risk reduction theme is also appropriate to industry capabilities and motivation. Questions addressed in this section also can have a powerful effect on affordability. In particular, lean and flexible manufacturing, an important part of affordability, is heavily dependent on program management approaches. The same is true of linking design, manufacturing and support through Integrated Product/Process Teams.

Industry is attracted to ventures that provide profit opportunity in each phase of a program, provide short-term and long-term business development potential, focus on mission-oriented products with clear measures of success, and are based on credible expectations and plans.

Confidence in the success of defense programs has diminished in recent years. Industry believes success in the future will be driven strongly by the degree of DoD commitment to a product-oriented program and business approaches that emphasize best practices that are compatible with partnerships or joint ventures within the defense environment.

Foreign participation in the development of next-generation strike fighters should be measured by credible expectation of value added, and focused on market exploitation. Next-generation strike fighters should be designed with the foreign market in mind; this implies affordable cost, and versions of aircraft in which technologies can be adjusted to the export market (e.g., low observability characteristics).

Figure ES-5 provides the findings and recommendations for this section.

- JAST should strongly encourage lean and flexible manufacturing approaches, and integrated product/process teams in the design-manufacturing-support process
- Industry is attracted to ventures that:
  - Provide profit opportunity for performance in each phase
  - Provide short-term and long-term business development
  - Focus on mission-oriented products with clear measures of success
  - Are based on credible expectations and plans
- Confidence in the success of DoD programs has diminished in recent years. Industry believes success in the future will be strongly driven by:
  - The degree of DoD commitment to a product-oriented program
  - Business approaches that emphasize practices compatible with partnership with government, innovation in contracts, etc. Industry is looking for "best practices"
  - Value-added specifications—performance-based measures, not detailed specifications and standards. How-to specifications are particularly onerous
- Foreign participation in development of next-generation strike fighter should be:
  - Measured by credible expectation of value added
  - Focused on market exploitation
- Next-generation strike fighters should be designed with the foreign market in mind
  - Affordable cost
  - Versions with technologies that can be adjusted for exportability

Figure ES-5. Findings and Recommendations—Industry Capabilities and Motivations

6. Ten Key Points

Finally, the Task Force picked the ten most important points from the findings and recommendations; these are presented in Figure ES-6 and in the main body of the report.

1. JAST should: a) transition and mature selected technologies from S&T programs; b) bring workable compatibility to multi-Service requirements; and c) provide building blocks and demonstrations for low-risk EMD for next-generation strike fighters
2. JAST should be a *customer* for selected maturing technologies from S&T programs; JAST should not be the manager or funding source for the spectrum of strike-relevant S&T
3. The requirements process should emphasize qualities that will be particularly vital in the post-cold war environment—deployable, survivable, affordable, precision weapons, and night/weather capabilities
4. Joint Programs must reflect Services' requirements or the programs cannot survive; this includes an affordable cost range
5. Technology exploitation must stress affordability and performance
6. Full Services' and OSD support must be a condition to begin EMD
7. Commit ruthlessly to "best practices," whether they be commercial, defense, or a mix
8. Emphasize developing and using a range of combinations of live, virtual, and constructive (model) simulations to assess military worth, capabilities trade-offs, systems operations, systems testing, manufacturing, and management systems, etc.
9. Provide credible expectations and plans to industry, with short- and long-term business development and profit opportunities in each phase of programs
10. Design and develop with the foreign market in mind.

Figure ES-6. Summary—Ten Key Points

REPORT OF THE DEFENSE SCIENCE BOARD TASK FORCE ON THE JOINT ADVANCED STRIKE TECHNOLOGY (JAST) PROGRAM

DEFENSE SCIENCE BOARD
Joint Advanced Strike Technology (JAST) Program
Task Force Report

The Defense Science Board was asked to convene a Task Force to provide recommendations for implementing the Joint Advanced Strike Technology Program in the FY95-00 period. Draft Terms of Reference (TOR) were provided in April 1994. A signed TOR was available on 10 May 1994. The Task Force was to provide a report by the end of September 1994. This report is presented in chart format with accompanying text, preceded by a brief executive summary.

Given the number of issues the Task Force was asked to address and the desire to make the report more digestible, the sections, while related, also can stand alone. To give them a stand-alone quality, there is some repetition of cross-cutting themes such as affordability, manufacturing, and acquisition process and policy.

TERMS OF REFERENCE

1. Requirements Definition & Process
   Is the JAST analytical framework (scope, depth, tools and processes) adequate for evolving fully validated strike warfare requirements?
2. Leveraging Technologies
   What strike warfare technologies, operational concepts and weapons systems should be included under the umbrella of JAST to ensure the program is addressing new affordable solutions within the broad context of warfighting?
3. Manufacturing Technologies
   What innovative, high-leverage manufacturing technologies/processes, including modular construction, show potential for significantly reducing production costs of highly common, multi-role, multi-Service aircraft?
4. Simulation & CAD
   Are new development and operational testing philosophies required for JAST in light of advanced design tools, testing techniques, and simulation?
5. Risk Assessment/Reduction
   Which key demonstration objectives should be included in JAST?
6. Industry Capability & Motivations
   How can DoD ensure a timely, viable conduit of high-leverage technology from the aerospace industry to JAST? Include recommendations on how JAST can capitalize on other national and international sources.
7. DoD Organization & Responsibilities for JAST
   What is the appropriate interaction between JAST and existing DoD science and technology efforts?
8. Acquisition Process & Policy
   What strategies could permit an expeditious fielding of technologies before these technologies become obsolete?
9. Foreign Military Sales
   What are the benefits and disadvantages of international cooperation intended to produce favorable foreign sales of JAST products, thereby reducing overall cost to the U.S.?

The terms of reference identified nine specific questions of interest to the sponsor. The Task Force categorized the topics as underlined on this chart. This report includes advice, observations and recommendations in each area.

TASK FORCE FOCUS

	TOR Questions Addressed
• Objective, Mission and Relationships	7
• Multi-Service Requirements	1
– Force Sustainment	
– Strike Force Capability Modernization	
• Technology for Affordability	2, 3, 4
– Manufacturing	
– Simulation and Computer-Aided Design	
– Supportability	
– Performance	
• Risk Assessment/Reduction	4, 5, 8
– Program Management Approach	
– Commercial Practices Application	
– Program Technical Approach	
– Demonstrations of Technologies (Hardware and Software)	
– Use of Simulation	
• Industry Capabilities and Motivations	6, 9
– Lean and Flexible (Product and Rate) Manufacturing	
– Foreign Participation	

To lend more coherence to the report, we arranged the terms of reference as shown here. This outline covers the terms of reference and outlines the report. The question in the terms of reference is also identified by number.

We found that clearly defining the objectives, mission and relationship of JAST to other development and acquisition programs to be a necessary prelude to discussing other terms of reference questions. We also considered very important the process for defining multi-Service advanced strike requirements. JAST progress in that area has high interest.

Technology for affordability includes design, manufacturing, and simulation technologies and is treated in a single section. Here the purpose was to ensure a comprehensive consideration of technologies while still recommending a manageable range of areas of focus for JAST. The order shown in the sub-bullets is significant. Given the emphasis on affordability and risk reduction, manufacturing and design technologies warrant top billing, followed closely by supportability. Putting performance in last place does not suggest lack of importance. It does recognize the prior focus placed on performance.

The risk assessment/reduction area received intense focus. Here the order of the first two bullets is significant. We found that technology is frequently the central focus of risk assessment and reduction. However, program structure and program management decisions often contribute equally or more to *program* risk than does technical risk. We struggled with the subject of commercial practices to include reviewing voluminous prior work on the subject. In our treatment we tried to focus on workable gains from commercial practices rather than on a comprehensive victory. Consequently, demonstrations and use of simulation need to contribute to reducing program planning and management risk as well as to reducing technology risk.

The risk reduction theme extends into industry capabilities and motivations. In addition, the subjects covered under this section have a powerful effect on affordability.

TASK FORCE FOCUS

- **Objective, Mission and Relationships**
- Multi-Service Requirements
  - Force Sustainment
  - Strike Force Capability Modernization
- Technology for Affordability
  - Manufacturing
  - Simulation and Computer-Aided Design
  - Supportability
  - Performance
- Risk Assessment/Reduction
  - Program Management Approach
  - Commercial Practices Application
  - Program Technical Approach
  - Demonstrations of Technologies (Hardware and Software)
  - Use of Simulation
- Industry Capabilities and Motivations
  - Lean and Flexible (Product and Rate) Manufacturing
  - Foreign Participation

Turning first to objective, mission and relationships in the JAST Program.

JOINT ADVANCED STRIKE TECHNOLOGY JAST PROGRAM OBJECTIVE *

- The Joint Advanced Strike Technology Program is a *comprehensive advanced* technology effort to preposition the building blocks for the next-generation of strike weapon systems
- Key Program objectives are to signficantly reduce the cost of performing joint strike warfare, demonstrate the critical operational concepts, and identify and demonstrate innovative solutions/approaches to *affordable* joint strike warfare

* JAST Program Master Plan, May 1994

The Task Force started with the JAST statement of the objective and mission. There are several noteworthy features of this objective and mission statement. JAST is not a technology development program. JAST is a customer for technology for use in forming building blocks leading to the EMD of next-generation strike weapon systems. That also implies that JAST is not to be the developer of the next generation of strike weapon systems. Service buy-in and acceptance of the product will require Service or joint Service program office management of the EMD phase. We also noted the emphasis on affordability and reflected sensitivity to key affordability issues throughout the report.

JOINT ADVANCED STRIKE TECHNOLOGY JAST PROGRAM MISSION

- The *Joint* Advanced Strike Technology Mission is to define requirements with direct end-user involvement and to transition technology for affordable next-generation *strike systems*
- *"Joint"* means multi-Service rather than an agency above the Services
- *"Strike systems"* includes requirements for strike force sustainment and strike capability modernization with emphasis on:
  - Navy strike needs
  - Air Force multi-role needs
  - Marine Corps need to prepare the battlefield
- JAST-based strike systems' designs should consider foreign market potential

The Task Force suggests that the objective on the previous slide be supplemented as shown here. We emphasize the need to define requirements that can be translated into affordable strike systems. We also emphasize jointness in a multi-Service context. Jointly acceptable multi-Service weapons systems in core Service roles and functions must come from an acceptable multi-Service management approach. The need to focus on requirements comes from the complex challenge to be found in reconciling and harmonizing some widely divergent demands. A near-term demand for Navy strike systems is for first-day-survivable stand-alone strike capability (similar to that provided by the land-based F-117). The Air Force's nearest-term need is for a multi-role high sortie producer that is affordable in large numbers beginning in about 2010. The Marines' most urgent need is for a more capable short takeoff-vertical landing aircraft for quick response to support the close battle. In addition to these needs, it was the view of the Task Force that designs filling Services' needs should also consider the potential of the future foreign market.

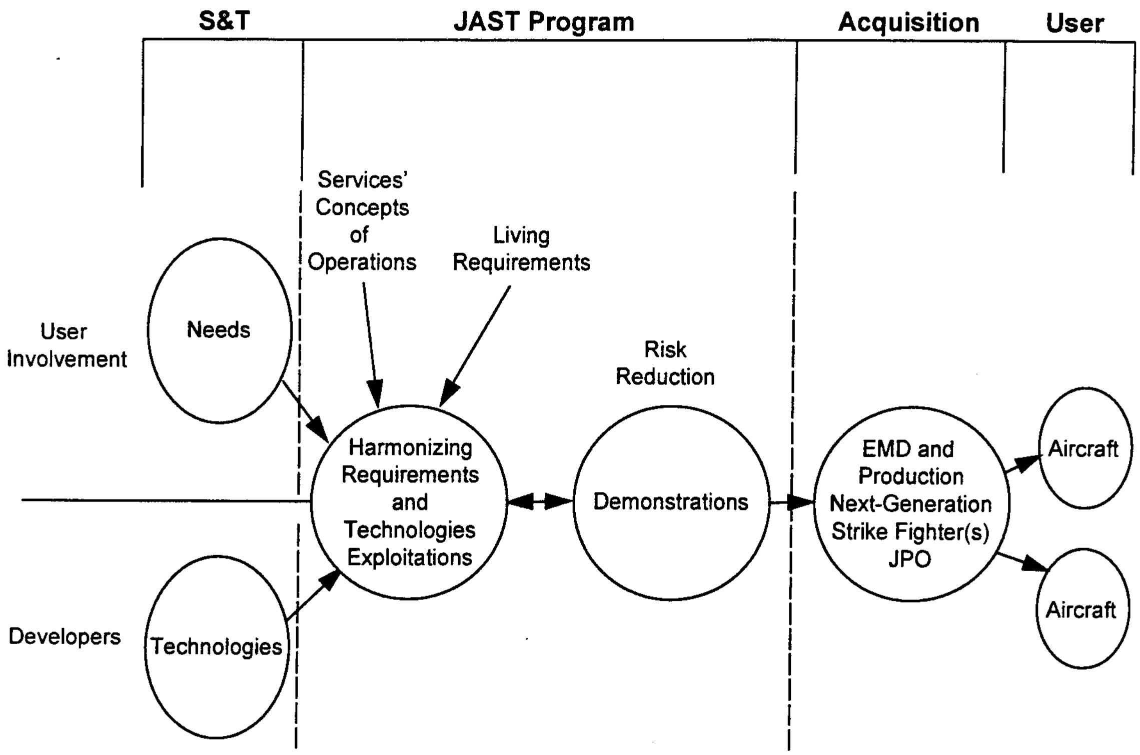
FIGHTER/ATTACK STRIKE FORCE CAPABILITY NEEDS

	Present - About 2007	About 2007 - 2020		Post 2020
	Current Force Deficiencies	**Emerging Force Deficiencies**	**Mid-Term Options**	**Far-Term Deficiencies**
Air Force		**Multi-Role Sortie Generator**	**JAST-Based NGSF**	**Deep Strike**
Navy	**First-Day-Survivable Stand-Alone Strike**		**JAST-Based NGSF**	**Multi-Role Sortie Generator**
Marine Corps	**VSTOL Payload VSTOL Survivability**		**JAST-Based NGSF (ASTOVL)**	

This chart depicts the Task Force interpretation of the Services' needs for manned aircraft strike systems. The purpose is to put those currently divergent needs in better perspective with the JAST objective and mission and with other technology and acquisition programs.

The Navy and Marine Corps presented the current deficiencies shown on this chart to the Task Force. They did not identify near-term possibilities to meet the needs for sea-based, first-day-survivable stand-alone strike and for more capable, more survivable VSTOL capability. The Navy presentations accepted the reality of 2007 to 2010 if a JAST-derived next-generation strike fighter is the solution to the current deficiency. Beyond that period, the Navy will also need an affordable, more survivable multi-role sortie generator. The Air Force need for an affordable high sortie generator fits into the 2007-2020 period—a likely period for a JAST-derived aircraft to reach IOC. The Air Force also will need a replacement in the "deep strike" role as the F-117 and F-15E age. The post 2020 period is identified as the area of interest for that JAST target.

This does not imply that JAST should not lead to aircraft to serve the Navy and Marine Corps needs. It *does* imply that the first Navy need could be considered more urgent than the JAST pace. The section on requirements will address these issues in more detail.



This illustration is to further clarify where the Task Force saw JAST fitting into the larger strike systems technology and acquisition picture. S&T program direction and funding should continue to be guided by a broader combination of user needs and enabling technologies. JAST should be a key customer for promising results. However, the technology developer's definition of on-the-shelf and the weapons system developer's definition of off-the-shelf are seldom in harmony. Thus there is an evaluation and transition function that is a vital prelude to a smooth, successful EMD program. This is an important JAST role. The evaluation and transition function must also include demonstrations to provide confidence that the building blocks are in place (and affordable) to exit JAST and enter EMD. At that point, JAST would transition the task to the acquisition process that conducts EMD and subsequent procurement. The JAST program office could transition to become the joint Service SPO.

JAST MISSION

Should Be:	Should Not Be:
• To address the overall architecture, strike mission elements, and technologies	• The avenue to the *full* set of modernized strike capabilities (e.g., surveillance, C4, etc.)
• To lead to one or more affordable next-generation strike fighters (NGSFs)	• The common solution to all Services' strike force structure needs
• To transition technology for affordable EMD	• The creator or integrator of the broad range of strike-relevant technologies
• To be a customer of strike-relevant S&T	• The manager or funding source for S&T
• To provide risk reduction demonstrations necessary to transition directly to Service or joint Service EMD	• The OSD manager of EMD programs

Continuing on the subject of the JAST role, the Task Force felt strongly that DoD leadership needs to eliminate ambiguity about the role of JAST. The above *Should Be—Should Not Be* formulation is designed to help do that. The first point is a reminder that JAST should address more than next-generation strike fighters; it should also play a role in defining the broader overall strike mission architecture and elements. This includes encouraging and promoting technology development to support the broader mission area. However, it would be a serious overload if a broad range of near- , mid- and far-term strike system needs were swept into JAST. More specifically, JAST should provide the building blocks for one or more next-generation strike fighters to reach IOC in the 2007 to 2010 period. Both nearer-term and farther-term needs could and probably should be addressed outside the JAST Program.

Again, a reminder that JAST is a customer for enabling technologies but should not be the developer or the financier for technologies.

The JAST product should be building blocks enabling a smooth, rapid, successful EMD. The JAST should not be the manager of EMD unless transitioned to that purpose as a joint program office. If JAST can serve the *Should Be* column, it will make an important contribution. If it expands into the *Should Not Be* column, it is likely to generate opposition from the Services, who should be its customers. It could also collapse from overweight.

FINDINGS AND RECOMMENDATIONS—OBJECTIVE, MISSION AND RELATIONSHIPS

- The program office should sharply focus on:
  - Service requirements for advanced strike systems within a defined end-to-end strike architecture
  - Affordable processes and end products
  - Transitioning technologies to form building blocks leading to EMD
  - Demonstrating the building blocks for high confidence EMD programs
  - One or more advanced strike aircraft to serve some combination of:
    - » Carrier-based first-day-survivable stand-alone strike capability
    - » Land-based multi-role sortie generation aircraft
    - » Marine Corps battlefield preparation.
- The Office of the Secretary of Defense needs to continually ensure that JAST is a *customer* for technology, not a technology developer.

TASK FORCE FOCUS

- Objective, Mission and Relationships
- **Multi-Service Requirements**
  - Force Sustainment
  - Strike Force Capability Modernization
- Technology for Affordability
  - Manufacturing
  - Simulation and Computer-Aided Design
  - Supportability
  - Performance
- Risk Assessment/Reduction
  - Program Management Approach
  - Commercial Practices Application
  - Program Technical Approach
  - Demonstrations of Technologies (Hardware and Software)
  - Use of Simulation
- Industry Capabilities and Motivations
  - Lean and Flexible (Product and Rate) Manufacturing
  - Foreign Participation

TASK FORCE APPROACH TO JAST REQUIREMENTS REVIEW

- Review BUR situations that may challenge U.S. future interests
- Define evolution in strike concepts for conducting air warfare
- Derive associated requirements and needed capabilities
- Review the JAST analytical framework for defining multi-Service platforms and timing for force sustainment and strike force capability modernization

To ensure a logical strategy to task to system approach to requirements, the Task Force adopted the chain of logic illustrated here. We do not specifically address the "threat" in this report, although we heard traditional presentations on the threat. Instead, we regard the broader objective to be: to provide military options that are useful in the post-cold war environment so as to help meet challenges to U.S. national interests around the globe. That includes winning America's wars. The Bottom-Up Review (BUR) provided a menu of such challenging situations. We then used the work done by the 1993 DSB Task Force on Tactical Air Warfare to identify important strike force concepts relevant to the new world situation and challenges to U.S. interests. From that, we identified a list of generic demands for advanced strike systems. Finally, we translated the generic demands into considerations for specific needs and sought to understand the process and the adequacy of the process that will translate those needs into achievable, affordable requirements.

EVOLVING STRIKE CONCEPTS

From:	To:
• In-place forces for initial critical needs	• Ready deployable forces to meet rapidly developing crisis
• Massive force packages with non-precision weapons	• Small formations, or single stand-alone survivable aircraft with lethal precision weapons
• Success measured over time; theater objectives addressed sequentially over time	• Campaign success or failure sometimes hinging on early (one) day's operations; near-simultaneous attack of critical set of targets in compressed time
• Moderate to high attrition for initial days of combat	• Low attrition a condition for initiating most air activities
• Collateral damage an expected by-product of air attacks	• Many situations where collateral damage is a key issue
• Conditional, periodic, local air superiority	• Early, near complete, freedom of operation in adversary airspace
• Accuracy shortfall constrains effectiveness	• Time-responsive target location and C3 shortfall constrains effectiveness
• Limited inter-Service C3 connectivity	• Seamless C3 connectivity
• Drastically reduced capabilities at night	• Around-the-clock operations (with affordable through-the-weather capability) to provide large advantages to U.S. forces

The 1993 DSB Task Force on Tactical Air Warfare spent considerable time and effort on understanding the relationship between challenges and capabilities that are particularly relevant to the post-cold war world and to emerging technologies and related capabilities. The above is a short list of fundamental changes in Tactical Air Warfare concepts and capabilities to evolve the concepts that are most relevant to the requirements for advanced strike systems.

The first is the need for rapid response with a wide variety of options and with no assurance of in-place capability. This shift emphasizes the need for the full range of early responses from a variety of basing modes. Arguments about the relative merits of land- and sea-based tacair or fighter/attack and bomber capabilities are not productive. The range of U.S. interests around the world includes situations where a vital early response could demand any or all of the possible responses—land-based tacair, sea-based tacair, long-range bombers or sea-based cruise missiles.

The Desert Storm experience provided compelling evidence of both the fact and the value of a shift from the constraining need for complex, inflexible penetrating force packages. Now, modern precision systems can provide lethal, survivable, flexible, small formations or single aircraft. Stand-alone does not imply autonomous-without-off-board assistance.

Increased lethality provides demonstrated, decisive results from early air operations as opposed to the grinding, attrition-oriented approach that might or might not lead to success over time. The attrition approach in earlier times allowed the adversary time to adjust, repair damage, replace losses and deny friendly forces' objectives. In contrast, high survivability and lethality provides for successful and simultaneous synergistic assaults on sets of key targets.

A key change has been away from the expectation and the acceptability of attrition. Assurance of high survivability is likely to be a prerequisite to a viable military option in many contingencies.

A further change has been the acceptability of unintended damage to adversaries. Assurance of precise, discriminant attacks will be a prerequisite in some situations.

The roll back concept that allows a gradual build up of offensive strike missions is incompatible with the expectations for early strike effectiveness. Freedom to conduct effective strike operations from the outset is a priority need, including the contribution to air supremacy. Some significant set of the strike assets must operate freely on day one. This demands that some part of the strike force provide stand-alone survivability with high lethality.

But needs for strike systems include more than delivery platforms and kill mechanisms. The shift in the primary constraint to strike force effectiveness may qualify most as a paradigm shift. In the Vietnam era, the constraint was lethality. While locating targets presented formidable challenges, success in locating targets provided no assurance of target destruction. Literally squadrons of effort were required to generate significant damage to key targets. In contrast, a single F-117 or F-15E provides a high probability of destroying multiple targets on a single aircraft mission. That added lethality with improved survivability makes responsive target location and C3 to direct forces to the targets at the right time the primary constraint in strike force effectiveness. An added key consideration is *joint* strike force effectiveness. Joint strike force effectiveness will depend on interoperable doctrine and control systems. Strike platform and weapons technology will exacerbate that condition unless far more attention is given to theater surveillance and deployable C4I systems.

Finally, there is the long standing issue about the feasibility and value of around-the-clock and through-the-weather operations. In Desert Storm, we saw a shift from night as a time of sanctuary and recovery for adversaries to a time of maximum advantage for U.S. tactical air (and armored forces). All-weather is valuable in many circumstances. But, effective, precision through-the-weather capability is still expensive and will challenge affordability. In contrast, precision night capability is in hand and its utility has been clearly demonstrated. That puts a premium on effective, affordable night capability.

STRIKE CAPABILITY NEEDS SUMMARY

- Flexible joint Service force components
  - Land- and sea-based fighter/attack aircraft
  - Bombers and air-delivered cruise missiles/stand-off weapons
  - Sea-based cruise missiles
  - Manned/unmanned reconnaissance vehicles
  - Architecture of systems to provide targeting information and direction
- Rapidly responding concentration of combat power
  - Give potential opponents second thoughts
  - Stop invading forces before critical losses
- Force lethality to support parallel attacks against target spectrum
  - Accurate, responsive targeting across the spectrum
  - Affordable, around-the-clock strike operations
  - Precision weapons for all delivery modes/targets
- Highly lethal and survivable small penetrating formations or single penetrating aircraft

These evolving strike concepts point to the set of strike capabilities needs that are summarized here. The truly global potential for demand for highly effective strike forces requires a variety of basing modes. At the same time, the increased leverage of better target location and direction compels us to greater emphasis on targeting information. We say no more about this subject in this report since several other study efforts emphasize these needs.

Again, the need for rapid reaction across a spectrum of needs calls for a variety of basing modes. It also calls for high initial effectiveness requiring a minimum of early support—forces that can credibly threaten potential adversaries or, if the threat fails to deter, can contain the situation until greater numbers of forces can arrive.

Strike capability requires high lethality and around-the-clock operations with the effectiveness available from precision weapons.

Responsiveness and effectiveness will depend on high lethality and survivability in small forces or even single aircraft. Again, this does not preclude off-board support.

This list could be greatly expanded in scope and detail. But, if JAST leads to a significant increase in these capabilities, it will have greatly enhanced the capability of tactical air strike forces to help meet challenges to U.S. interests.

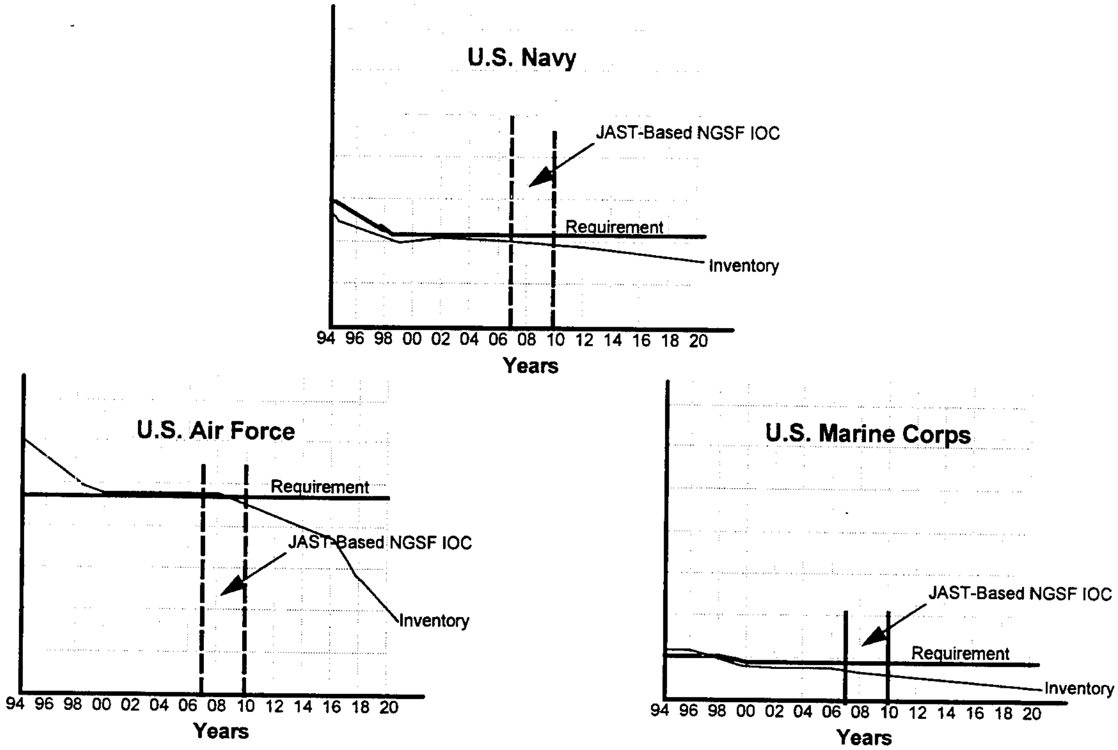
MULTI-SERVICE PLATFORM ISSUES

- Force Sustainment
  - Sustain fighter/attack force
- Strike Force Capability Modernization
  - Accept evolutionary capability improvement in design for:
    - » Performance
    - » Supportability
  - Pursue revolutionary capability improvement for:
    - » Affordability in design and manufacturing
  - Insert proven new technology in current production and operational aircraft for:
    - » Affordability
    - » Supportability, reliability, and maintainability
    - » Capability
    - » Achieving/extending Service life

This chart narrows the focus to delivery platform issues. There are two distinct classes of needs—sustaining the quantity of forces (force structure) and providing the needed future quality of forces (modernization). Quality and force capability issues also have a timing element. Advanced strike technologies can and must lead to new platform development over time. The emphasis on these technologies could and should lead to affordable improvements in performance and supportability. But, evolutionary changes in performance added to capabilities of systems now in development can meet the need. The revolutionary need is for a focus on technologies, concepts and cost.

Further, enroute to the goal of fielding needed new systems there will be important opportunities for enhancing current systems, including achieving their planned Service lifes. This seemingly secondary goal may be as essential to the success of JAST as is the prospect for fielding new capabilities. Interim, product-oriented successes will be important both to the providers of resources and to industry partners.

THE FORCE SUSTAINMENT (QUANTITY) TIMING ISSUES—
CURRENT SERVICES' PROGRAMS



This chart shows there are quantity issues to be addressed before the planned IOC of a JAST-based aircraft. However, the magnitude of the problem is not compelling between now and the hoped for IOC. Further, there are interim options for sustaining the force size—retaining F-15s, continuing the F-16 buy, increased F-16 life extension, increased F-18 buy, more AV-8B remanufacture, etc. Further, JAST is not the right vehicle for addressing near-term force sustainability or near-term force quality needs. JAST should focus on the mid-term (2007-2020) capabilities needs of the Services as presented in the next chart.

FIGHTER/ATTACK STRIKE FORCE CAPABILITY MODERNIZATION ISSUE

	Present - About 2007	About 2007 - 2020		Post 2020
	Current Force Deficiencies	**Emerging Force Deficiencies**	**Mid-Term Options**	**Far-Term Deficiencies**
Air Force		**Multi-Role Sortie Generator**	**JAST-Based NGSF**	**Deep Strike**
Navy	**First-Day-Survivable Stand-Alone Strike**		**JAST-Based NGSF**	**Multi-Role Sortie Generator**
Marine Corps	**VSTOL Payload VSTOL Survivability**		**JAST-Based NGSF (ASTOVL)**	

This chart puts the capability needs timing issue in perspective with JAST timing. As suggested earlier, the Navy need for first-day-survivable, stand-alone strike capability is now. It is difficult to reconcile this current need with an optimistic hope of meeting needs with a 2007 to 2010 IOC. If the urgency of the need does not warrant earlier action, it will be difficult to make the case for the urgency of attaining that capability after fifteen years of operating without it. After such a long period, the argument is likely to be that there are other ways to provide first-day-survivable capability. The Navy presentations to the Task Force seemed driven by sensitivity to the need to give top priority to the F/A-18E/F to modernize the multi-role high-sortie-producing capability in the fleet. The Task Force endorses that emphasis. Still, the need for a nearer-term solution for the first-day-survivable stand-alone strike capability should be clarified. A clear conscious decision should be made regarding the approach to the near-term. Simply deferring to a mid-term solution may have unintended roles and missions implications for Naval aviation.

There was neither high urgency nor a near-term possibility identified to address the existing Marine Corps deficiency.

The mid-term needs that most clearly match the timing for a JAST-based aircraft are the Air Force's need for a multi-role sortie generator and the Marine Corps need. But, if there is no nearer term solution to the Navy need, then a JAST-based solution will remain a priority.

There will remain far-term needs requiring technology transition products from JAST. Beyond the mid term, the Air Force will eventually need an F-117 and F-15E replacement and the Navy will need a more survivable multi-role sortie generator.

The next three charts are intended to further emphasize the need for the Services to establish and evaluate the impact of the range of acceptable requirements. This is not a suggestion that JAST be burdened with a set of rigid, premature requirements. It does declare that the current state of requirements definition precludes resolution of inherent incompatibilities in the multi-Service needs both in capabilities and in timing.

REQUIREMENTS COMPATIBILITY FOR MULTI-SERVICE SOLUTIONS

If the Navy first-day-survivable, stand-alone strike aircraft requirement approaches the A/F-X requirements (high end):

- Satisfying the Navy's requirement with a JAST-based NGSF will leave the Navy without such strike capability for almost 15 years
- Navy requirement is for modest numbers—probably about 200
- Capability exceeds Air Force requirements for a mid-term, multi-role sortie producer—Air Force needs large numbers—1500?
- Capability could match far-term Air Force need for deep strike replacement
- Not compatible with Marine Corps need for improved capability over the AV-8B

Continued

The first case applies if the Navy strike requirement approaches the A/F-X set of requirements. In spite of Navy caution in discussing such requirements, that appeared to be the current inclination.

In that case, satisfying the requirement with a JAST-based aircraft will leave the Navy without such capability for some 15 years. Further, this high-end requirement is for a relatively small number of aircraft. It exceeds that needed in the larger numbers of lower cost aircraft for the Air Force, or the ASTOVL for the Marine Corps. However, a high end aircraft to meet Navy needs could be the basis for the far-term Air Force need to replace F-117s and F-15Es.

REQUIREMENTS COMPATIBILITY FOR MULTI-SERVICE SOLUTIONS (Concluded)

If the Navy first-day-survivable, stand-alone strike aircraft requirement is more modest than the A/F-X (high end):

- The Navy and Air Force mid-term requirements could be compatible if an NGSF is sufficiently modular in construction
- The Air Force and Marine Corps requirements could be compatible if an NGSF is sufficiently modular in construction
- The Navy and Marine Corps requirement could be compatible if Navy requirements could be met with a STOVL system with no catapault or arrested landing
- If first-day-survivable, stand-alone strike requires VLO, then a JAST-based NGSF would still leave the Navy need unsatisfied for almost 15 years

If, instead, Navy requirements are more modest, Navy and Air Force requirements could be more compatible as could Air Force and Marine requirements. However, for Navy and Marine requirements to be compatible, the Navy would have to forego arrested landing and catapult takeoff capability. That seems unlikely given larger force and operational considerations. In any case, it would still leave the Navy with a 15-year gap in capability.

There are other variations on these themes. The purpose here is not to present a favorite solution, but to illustrate that:

there will be no solution until there is more convergence in multi-Service requirements.

The Task Force found the JAST program office analytical framework for evolving requirements to be comprehensive. However, Service inputs have not been specific enough for JAST to actually evolve towards compatible multi-Service requirements.

ASTOVL GOALS & PROJECTIONS

- Overall Goals to Support the Marine Corps
  - Multi-role performance of F/A-18
  - Battlefield preparation superior to AV-8B
    - » Ten minute response
    - » Improved useful load (payload/fuel)
    - » Improved survivability
- Operating Concept for Battlefield Preparation
  - Stage forward for response
  - Short landing with a combat load
  - Recover to the logistics base—to include vertical landing with bring-back load aboard ship (LHD/LHA/LPH)

STOVL Loads (Fuel and Armament)

	Vertical Landing		Short Landing (Load/Roll)
	Goal (lbs)	Capability (lbs)	Capability (lbs/ft)
AV-8B	N/A	2,500 (Actual)	9,000/3,500 (Actual)
ASTOVL	3,950	5,500 (Projected)	13,000/850 (Projected)

The Task Force found the ASTOVL program and its relationship to JAST and the Marine Corps operating concept in need of clarification. This chart provides that perspective.

The Marine Corps stated a need for an aircraft combining the multi-mission attributes of the F/A-18 with the basing flexibility and battlefield responsiveness of the AV-8B. However, the stated highest priority Marine Corps need is to respond within ten minutes to urgent demands for support of the close battle. That need could only be satisfied with an aircraft that can operate from forward locations closer than the amphibious platform or prepared airfields. The concept is to land at a forward location with a suitable fuel and armament load, launch to meet quick response needs, and recover to the logistics base (land or ship) and recycle. As the operating concept emerged more clearly, we understood that the specified vertical landing capability is based on a bring-back capability for recovery with high value ordnance on the amphibious platform. For the forward-based operation, the concept depends on short landing and takeoff on highway strips or other suitable surfaces. The forward operating location during Desert Storm was one half of a semi-abandoned 8,000 foot runway. With an operating surface of about 1,000 feet, the ASTOVL could operate with a payload superior to that of the AV-8B operating from a longer surface. However, the ASTOVL concept does not currently require very low observables and could impose undesirable limits on design for survivability. Still, it could provide a significant improvement over the AV-8B.

IMPORTANT AFFORDABILITY DRIVERS—
DESIGN CHARACTERISTICS

- Speed, range, payload, maneuverability
- VLO/LO—autonomous survivability
- Modular construction
- Avionics architecture, common avionics, and subsystems
- Sortie generation
- On-board vs. off-board sensing and processing
- One vs. two seats
- Round-the-clock operations
- Autonomous through-the-weather air-surface operations
- STOVL vs. catapult/arrest
- One vs. two engines—common engines
- Internal vs. external payload

This chart lists some important design characteristics that are affordability drivers. Besides the usual consideration of size, speed, maneuverability, etc., there are some specific issues listed here that derive from requirements. The level of very low observable (VLO) is a cost driver. VLO to Radar is important but should be balanced with other observables. Significant savings in filling barely compatible multi-Service needs will depend heavily on modularity in airframe design and common avionics.

The chronic argument about one vs. two seats probably will not be settled based on operational capability. The Air Force has successfully demonstrated single seat approaches to air superiority and night attack but believes that all-weather air-to-surface attack needs the two man crew. The Navy has shown wider preference for two man crews. One approach is to specify a single seat design, then challenge the cockpit integration designers to do the best they can in providing single seat capability. That may mean limited autonomous through-the-weather capability and more reliance on off-board support for targeting and guidance.

The issue of one vs. two engines also will be difficult to resolve with convincing logic. There have been many studies on the subject. Most show a safety edge for two engines given rough equality in mission and operating conditions but none of the studies is conclusive. So, one versus two engine decisions have been primarily based on thrust needs rather than on safety. The F-14, F-15 and F-18 needed the thrust from two engines. The F-16 did not. The STOVL design virtually dictates a single high-thrust engine. In any case, the Task Force concluded that, with modern engine reliability, the one vs. two engine question is not a conclusive flight safety issue. Affordability and performance should be the drivers.

Given the range of thrust output of available modern engines, it might be wise to consider simply mandating single engine designs because of affordability.

Another issue bearing on affordability is the degree to which the payload must be carried internally or externally. There are significant factors bearing on the aircraft design such as frontal area, low observability, weapons drag, and structural considerations that will impact on affordability.

FINDINGS AND RECOMMENDATIONS—MULTI-SERVICE REQUIREMENTS

- As an urgent task, the Services should clearly state a range of acceptable requirements
  - The JAST Program multi-Service steering committee should bring workable compatability to affordable multi-Service requirements
  - Industry requires multi-Service convergence of needs prior to initiating the demonstrator phase
- An affordable fly-away cost range should be established as a goal
- The requirements process should emphasize qualities that are particularly vital in the post-cold war environment—including capabilities to:
  - Deploy rapidly, world-wide, with minimum support
  - Operate effectively in small formations or as single aircraft from the first day of conflict
  - Operate in high threat areas, with low attrition
  - Concentrate lethal firepower across the spectrum of targets to include deep-strike, hardened and/or heavily defended targets
  - Attack with lethal precision precluding unwanted collateral damage
- Global contingency potential requires advanced strike capabilities from the full range of land- and sea-basing options
- The JAST process of transitioning technologies into building blocks should:
  - Be ruthlessly product-oriented to lead to EMD of affordable advanced strike systems
  - Also lead to insertion into current and developing systems to improve affordability, supportability and capability
- JAST should promote at least evolutionary improvements in performance and supportability, and revolutionary improvements in affordability
- While the Services will experience near- and mid-term force quantity shortfalls before JAST-based systems IOC, JAST should focus on:
  - Capability needs for the mid-term
  - Systems that can be produced in quantities satisfying mid- to far-term force structure needs
- JAST should be sharply focused on products for the mid-term (2007-2020)
- Technologies and building blocks also should contribute to farther-term needs
- JAST-based aircraft should be designed to leverage the strike architecture to include off-board systems
- The Services should consider subordinating the marginal safety issue of one vs. two engines to affordability and commonality
- JAST should quickly sort out the relative merits of incremental improvements from the two person crew and the added affordability of a single cockpit design
- JAST also should quickly sort out the need for internal vs. external carriage of weapons against the range of scenarios, threats, and targets addressed
- The Navy should carefully consider the viability of current planning that allows carrier-based stand-alone strike capability to be significantly lacking for 15 years
- Required work to evolve and evaluate solutions:
  - OSD and JROC need more quantitative analysis in support of strike needs—target sets and range, payload, survivability needs
  - The Navy and Air Force need to state an acceptable range of requirements to meet their needs
  - JAST should give high priority to exploring the limits of available technologies and approaches to modular designs

TASK FORCE FOCUS

- Objective, Mission and Relationships
- Multi-Service Requirements
  - Force Sustainment
  - Strike Force Capability Modernization
- **Technology for Affordability**
  - Manufacturing
  - Simulation and Computer-Aided Design
  - Supportability
  - Performance
- Risk Assessment/Reduction
  - Program Management Approach
  - Commercial Practices Application
  - Program Technical Approach
  - Demonstrations of Technologies (Hardware and Software)
  - Use of Simulation
- Industry Capabilities and Motivations
  - Lean and Flexible (Product and Rate) Manufacturing
  - Foreign Participation

The affordability issue is central to the JAST Program and was a central focus of the Task Force. However, we found that affordability issues embrace technology availability, maturation and exploitation for design, test, manufacturing and support to meet requirements and concept of operations. Of equal or greater impact on affordability are the acquisition strategy, schedule, financing (Defense budget), and perhaps most important, industry investment and motivation.

AFFORDABILITY ISSUE—FOCUS WHERE THE DOLLARS GO

	Future Strike Aircraft (500-1,000 Aircraft Program)
• By Phase in Program Life-Cycle	
– Development	10% - 15%
– Procurement	55% - 60%
– Operating and Support (20 - 25 years)	25% - 35%
• By Subsystem (Procurement)	
– Airframe/System Components*	55% - 60%
– Propulsion	12% - 20%
– Avionics	25% - 30%

* About 2/3 airframe, 1/3 systems

This chart reinforces the affordability focus on drivers of airframe costs—manufacturing technologies, commercial practices, simulation contribution to design and manufacturing, modular construction, single vs. dual cockpits, one vs. two engines, etc. The cost of avionics and the contribution of avionics and engines to life-cycle costs are important, but can focus attention away from the dominance of airframe and procurement in future system costs. The data suggest that considerations of the cost of developing and procuring future strike aircraft overshadow life-cycle costs. While that may be contrary to conventional wisdom, the increased sophistication of aircraft and the focus on supportability has and will continue to make acquistion costs the dominant factor. Further, the prospect of lower life-cycle cost has not provided a convincing argument to generate support for funding to meet front-end budget demands.

IMPORTANT AFFORDABILITY DRIVERS—TECHNOLOGY

- Airframe/Systems
  - Balanced observable requirements—RF, IR, etc.
  - Airframe size
  - Airframe parts count (total and dissimilar) and interchangeability
  - Airframe materials
  - Crew station(s)
  - Number of engines
- Propulsion
  - One engine vs. two engines
  - Improved specific fuel consumption
  - Improved thrust-to-weight
  - Improved durability
- Avionics
  - Fully autonomous vs. off-board assistance
  - Electronic countermeasures, RF passive/active emissions control, etc., balanced with physical observables
  - Modular avionics at the MMIC level and below
  - Leveraged commercial practices in avionics components
  - Software architectures and tools
- Manufacturing Methods and Tools
  - Reduced parts count (total and dissimilar)
  - Modular construction—common parts
  - Minimize hard tooling—emphasize soft tooling
  - Leveraging composites for manufacturing
  - Minimize specialized labor content
  - Virtual factory modeling and simulation
- Operations and Training
  - Two-level vs. three-level maintenance
  - LO maintenance
  - High reliability parts

This chart relates affordability more specifically to technologies. Some key airframe affordability drivers have already been discussed.

In the propulsion area, the one vs. two engines issue has been discussed. Here, commonality and supportability are major cost drivers.

Improved specific fuel consumption is a shared high priority with the commercial world. For fighter/attack aircraft, it allows greater capability from smaller airframes—a major cost driver. Improved thrust-to-weight is also a major driver of military airframe size, weight and cost. However, it is not as strong a commercial priority.

Improved durability is primarily an operating cost issue, but it also impacts the perception of the safety acceptability of a single engine.

In the avionics area, a key driver is autonomous vs. off-board capability, particularly for the more demanding missions such as through-the-weather air-to-surface strike.

Survivability is heavily dependent on ECM, controlling emissions and observables that provide high payback. Careful tradeoff and balance can reduce costs. For example, reducing radar observables simplifies the ECM task. Similtaneously, ECM can provide survivability with less demanding VLO. The key is to balance the requirements and their evolution over time rather than allowing zealots in any area to drive requirements.

Modular avionics at the detail level can increase commonality and thereby reduce costs. It may be difficult to provide commonality in major black boxes without accepting a design weight penalty, but the cost of the components in the black boxes can be significantly reduced through commonality at the card or integrated circuit level.

The commercial practices issues are discussed later, but avionics is a key area where the DoD should leverage the abilities, agility and dominance of the commercial sector. The potential benefits are in both cost and performance. For example, incompatibility between the pace of computational systems development and the defense acquisition system denies both the cost and performance benefits of commercial development. Acquisition managers should be ruthless in forcing the defense acquisition system into the dual-use mold for avionics.

Software architecture and development tools also deserve high priority. Software productivity in development and maintainability in operational use are key drivers of systems development cost and schedule, and operating costs.

Manufacturing methods and tools could be first in importance for affordability. The Task Force heard and saw much from industry that warrants excitement in this area. This chart is a short list from what could be a much longer set of exciting possibilities. We noted though, from long shared experience, that manufacturing has been the poor cousin in the world of technology. It will take determined emphasis to change the culture to make these manufacturing technologies first among equals. The Services generated a cultural change of similar magnitude in elevating the status of reliability and maintainability in aircraft design. With determined leadership, cultural change of the kind needed is achievable.

The appropriate use of technologies in operations and training also provide significant cost reductions with a resulting impact on affordability. Two-level maintenance rather than three-level maintenance is one area where significant savings are possible. Improvements are needed in lowering the cost of maintaining LO aircraft. High reliability parts will reduce required maintenance actions and improve availability rates of aircraft.

KEY TECHNOLOGIES AREAS

- Airframe/Systems
- Propulsion
- Avionics (including Software)
- Manufacturing Methods and Tools
- Operations and Training (including Supportability)

To ensure comprehensive consideration of technologies, the Task Force gathered information from a wide variety of DoD and industry sources. We then listed those that seemed pertinent, without regard to the criteria for eventually recommending them for emphasis as candidates for transition to the JAST building block task. We then applied affordability and capability weighting criteria to narrow the list. The technologies were sorted into the areas listed here. The list of technologies considered and rationale for those selected are in Appendix D.

SELECTING PRIORITIES FOR JAST TECHNOLOGY FOCUS

- Purpose: Identify priority technologies that can be made ready for transition to Service EMD
- Criteria:
  - Is the technology proven?
  - Is the technology ready for low-risk EMD in the JAST time period?
  - Is the technology high leverage—for affordability and/or capability?

These are the criteria used to produce the recommended list of high potential technologies.

WHY THIS TECHNOLOGY IS HIGH PRIORITY—
GENERIC OUTLINE

Program Objective Addressed	***Technical Approach***
• **State Technology Program Objective Addressed** – **Objective(s) and why important**	• **Describe Technical Approach** – **Steps that need to be followed to accomplish program**
Demonstration Elements	***System Payoff***
• **List Demonstration Elements** – **Simulation, laboratory, ground, air**	• **List System Payoffs expected from successful accomplishment of program**

For each recommended technology, Appendix D contains the chart illustrated here, providing expanded rationale.

SELECTED TECHNOLOGIES FOR AFFORDABILITY

- Airframe/Systems
  - Advanced Very Low Observables (including Antennas/Apertures)
  - All/More Electrical System Aircraft
  - True Advanced Composite Structure Design
  - Virtual and Rapid Prototyping of Hardware
  - Modular Construction
  - Reduced Tail/Tailless Fighter Configuration
  - Technologies Enabling STOVL
  - Conformal Carriage for LO and Drag
  - High Lethality Payloads
  - Weapons Integration Affordability
- Propulsion
  - Enhanced Thrust/Weight and Durability
  - Reduced IR Design
  - Thrust Vectoring Nozzle Design/Integrated Flight-Propulsion Control
- Avionics (including Software)
  - Digital Communications Links from On- and Off-Board Sensors
  - Integrated RF Sensors
  - Integrated EO Sensor Architecture
  - Multi-Function Apertures
  - Anti-Jam GPS
  - Advanced Avionics Architecture—Hardware and Software
  - Open Avionics Architectures to Accommodate Commercial Components
  - Common Integrated Processing and Processors
  - Virtual and Rapid Prototyping of Software
  - Reusable Software (Modular Software)
  - Sensor Fusion/Decision Aids
  - Information Fusion
- Manufacturing Methods and Tools
  - Paperless Design to Manufacturing
  - Leveraging Composites for Manufacturing
  - Reduced Parts Count Through Design
  - Common Subsystems/Components
  - Virtual Factory
- Operations/Training (including Supportability)
  - Paperless Integrated Technical Data and Smart Diagnostics/BIT
  - Avionics Packaging and Maintenance-Free Avionics
  - Low Maintenance LO Materials and Coatings
  - Simulation of User Requirements
  - Integrated Virtual and Live Training

Technologies considered priority by the Task Force are covered in JAST or elsewhere

The recommended technologies are summarized here. After compiling this list, the Task Force determined that these technologies are being addressed. Some require little or no added impetus from JAST. Some require significant focus to transition S&T to JAST building blocks.

TASK FORCE FOCUS

- Objective, Mission and Relationships
- Multi-Service Requirements
  - Force Sustainment
  - Strike Force Capability Modernization
- Technology for Affordability
  - Manufacturing
  - Simulation and Computer-Aided Design
  - Supportability
  - Performance
- **Risk Assessment/Reduction**
  - Program Management Approach
  - Commercial Practices Application
  - Program Technical Approach
  - Demonstrations of Technologies (Hardware and Software)
  - Use of Simulation
- Industry Capabilities and Motivations
  - Lean and Flexible (Product and Rate) Manufacturing
  - Foreign Participation

We turn now to risk assessment and reduction. Risk reduction has traditionally been directed primarily at technical risk. And, technical problems have usually played an initiating role in program delays, cost increases and eventual failure. A familiar pattern has been a technical problem leading to a schedule slip and cost increase, followed by an escalating series of adjustments to fit the available budget. That, in turn, produced increases in cost, adversely impacting subsequent years' budgets. The result was often a descending path into program cancellation or curtailment. Still, while technical problems may be the initiator, other facets of program risk often multiply the impact on program slips and failure. Therefore, we will first discuss the broader subject of program risk and then turn to technical risk and demonstrations to reduce both technical and program risk. We also have some things to say about the use of simulations to reduce risk.

#1	#2	#3	#4
Rigid Exit Criteria	**Adjust in Crisis**	**Design to Cost and/or Non-DoD Market**	**Requirements Neck Down**
Stone Tablet • Speed • Range • Load • Maneuver • Observables • Schedule • Cost	**Permanent Ink** • Speed • Range • Load • Etc.	**Near Blank Sheet**	Performance Schedule Cost
Some Notable Examples: F-111, F-4, F-14, F-15, B-1	B-2, C-17	A-10, International Fighter, Lightweight Fighter, F/A-18 A/B	F-22, F-18E/F, JDAM
Some Characteristics: • Spec Oriented • Senior decision makers certify unknowns • Seniors disengage from approval to crisis • Little operator input • Little continuing cost-benefit trade-off • Military worth subordinate to contract specifications	• Spec Oriented • Sporadic senior involvement • Sporadic cost-benefit trades	• Flexible use of mil specs • Innovative orientation • Agile decision process	• Goal Oriented • Continuing senior developer, user & oversight involvement • Continuous cost-benefit trade-off • Agile decision process • Performance and event milestones

A prime cause of program turbulence leading to program failure lies in early, unrealistic expectations. The approach to handling mission needs can be central to realistic requirements and to adjustments as reality clashes with expectations.

This chart illustrates four different historical approaches to dealing with requirements issues from inception to IOC.

Approach #1 was the conventional approach for a wide range of successful and some not so successful programs. In this approach, once requirements were approved, they became contract requirements and were often treated as ends in themselves. Extraordinary marginal cost and effort were expended to meet marginal requirements. For example, the F-15 specification called for Mach 2.5 at 40,000 feet. The F-15A capability approached that speed without extraordinary effort. However, it took massive effort and extraordinary solutions to achieve the last (and never subsequently used) increment of speed. Similarly, tens of millions of dollars were spent in an attempt to reach speed and altitude requirements for the F-111. These efforts continued long after the users concept was to operate primarily at low altitudes at high subsonic speeds. This blind pursuit of specifications set in stone was often without benefit of user input or senior decision-maker involvement. Nor was there adequate evaluation of the incremental military worth of the incremental performance.

In approach #2, lessons from years of approach #1 provided some benefit. While requirements were still at least written in permanent ink, program managers sought senior involvement to avoid massive effort to fill in the edges of the requirements. Cost-benefit trades could override contract specifications, although with significant jeopardy to the program.

Across the time frame of approaches #1 and #2, approach #3 was used in special cases. Here, cost or a foreign market, or both, strongly drove requirements and adjustments to the requirements. For example, the A-10 was designed to a set cost with requirements adjusted and balanced as needed. The International Fighter Program (the F-5) called for adequate performance with the major emphasis on cost and maintainability. The Lightweight Fighter was conceived as a low mix force structure filler at cost and performance levels that would also make it an attractive competitor to the French Mirage. The F/A-18A/B was also an outgrowth of the Lightweight Fighter competition. This approach produced a series of successful, affordable aircraft with convincing military worth.

The last approach shown, Requirements Neck Down, seems to be successful in producing realistic requirements in high performance vehicles. Design goals are set, but not in concrete. Senior decision-maker involvement makes sensible adjustments possible without bureaucratic delays or jeopardy to the program, while holding the program to the highest practical standards of performance. As the aircraft proceeds into and through EMD and risks are more clearly understood and mitigated, the requirements become better defined and less flexible.

Combinations of the last two approaches enhance program survivability and utility. Program requirements do not lock decision makers into pursuit of unrealistic goals. Program managers do not stubbornly pursue edges of performance envelopes when reality reveals higher cost and greater difficulty than expected. Therefore, requirements are adequately specified but with needed flexibility until there is high confidence that the requirements are achievable at affordable cost.

Traditional DoD	Best Practices					Commercial
<u>Technology Verification/Transition</u>						
• Leads technology in materials, sensors, integrated avionics, embedded software, signal processing			X			• Leads in processors, buses, displays, inertial navigation systems, design tools
• Exploit the state-of-the-art in technology		X				• Propensity for on-the-shelf demonstrated technology
• Manage risk of pushing the state-of-the-art in EMD				X		• Products resulting from low level of technical risk in EMD equivalent
<u>Requirements Approach</u>						
• Advancing the state-of-the-art during major system development—promise/performance driven				X		• Adapts technologies with demonstrated reliability and durability
• Development driven by the threat and defense mission	X					• Development driven by competitive posture and market opportunities
• Customer drives the level of risk	X					• Developer/Producer bears risk
• Cost a consequence of performance requirements			X			• Design to cost

The Task Force heard many briefings lauding commercial practices but found it challenging to translate the rhetoric into practical national defense policies and practices. We found comparing and contrasting traditional DoD practices to pure commercial practices a useful step in developing understanding. This and the following three charts serve that purpose.

The Task Force found that "best" practices is a mix of traditional DoD and Commercial. The "Best Practice" column indicates the Task Force judgment about the best mix of current DoD and Commercial practices. The X's indicate the Task Force's judgment about the mix of best practices. An X in the far left column indicates the traditional DoD practice is best for DoD, and so on.

We first found it useful to recognize that different needs and motivations have produced different levels of progress in a range of technologies. DoD will need to continue to follow their traditional approach in pursuing selected technologies but must take advantage of commercial investment in other technologies.

A basic underlying difference in DoD and commercial motivation will impose some limitation on DoD use of commercial practices. One difference is the need for DoD to push the state of the art to ensure an adequate margin of mission superiority over potential adversaries. For DoD, an affordable system that does not meet a required mission need is not worth the investment. In contrast, commercial practice is to design at a low level of technical risk.

Still, while DoD cannot fully adopt the commercial motivation, it is possible and desirable to do more risk reduction before committing to a fast-paced EMD program.

That basic difference in motivation also drives the approach to requirements. In DoD the customer sets the requirements and is usually highly motivated to advance the state of the art. In the commercial world, the drive for low risk emphasizes the requirement for demonstrated reliability and durability. DoD can benefit from more attention to maturing technologies before imbedding them in programs.

The defense mission drives DoD requirements. Commercial requirements are driven by the marketplace. Again, DoD cannot totally adopt this commercial practice but can mitigate the risk with pre-EMD demonstration and development programs.

The customer defines the level of risk for defense systems and must therefore share the risk. In the commercial marketplace, the developer bears the risk. This heavily drives the commercial propensity for mature, proven technologies.

Traditional DoD	Best Practices					Commercial
<u>Life-Cycle Planning</u>						
• Organic or competitive contract logistics support				X		• Logistics support from the producer
• Limited use of warranties in production—risk shared by government	X					• A variety of guarantees play an important role
<u>Financial Risk</u>						
• Government initiation—government accepts preponderance of risk	X					• Company initiates after a market is researched and customers commit—company bears the risk
• Financing subject to year-to-year change with multiple decision levels and centers				X		• Long-term life of type financing from the outset
• Profit level set by government (FARS/DFARS)		X				• Profit level set by company/market/ performance

In the area of life-cycle planning, DoD has a heavy preference for organic logistics support. Commercial customers are content to rely on the producer for life-cycle support. DoD could apply the commercial practice to more systems that do not require putting logistics support in harm's way.

The commercial world makes warranties or guarantees work. In contrast, the Task Force could find little enthusiasm for warranties among DoD customers. Self insurance still seems the most workable approach for DoD.

Since the government initiates requirements, the government accepts the risk—financial and technical. Commercial practices mitigate the risk and industry shoulders the remaining risk. While this is an inherent difference, this report contains discussion of and recommendations intended to mitigate the risk for both government and industry in defense acquisition.

In recent years, financing has been among the most disruptive factors in defense acquisition. In contrast, commercial projects are financed for the duration. The Task Force found no defense formula to overcome the Congress's predilection for annual budgets. We did review some data that indicate that DoD budget decisions are more of a problem for program stability than are Congressional changes.

Moving from the DoD cost-based to the commercial price-based system would settle the profit issue. However, the Task Force found no formula for moving sharply to commercial practice.

Traditional DoD	Best Practices					Commercial
<u>Management Risk</u>						
• Multiple levels and centers of management decision making. Frequent changes in principal decision makers					X	• Life-of-type-equipment team from exploration into production
• Annual decisions by multiple levels over multiple administrations and Congresses				X		• Management commitment for the life of the program
• Schedule frequently adjusted as program assumptions change					X	• Realistic Schedule Estimate a condition of program start – Schedule driven by commitment to customers and the market
• Multiple constraints to management innovation—contract, DAB approvals, specification/standards, social program goals					X	• Aim for performance-oriented products within a reasonable and defined performance-schedule-cost trade-off space and certification requirements (safety of flight)
<u>Investment in Development/Production Processes</u>						
• Program funded investment in tooling, quality and inspection, other processes subject to government specific program management decisions, oversight and direction					X	• Company decisions based on overall company goals and long-term needs
<u>Test/Demonstrations</u>						
• Both performance- and specification-oriented—rigid exit criteria—multi-level certifications—heavy oversight at multiple levels and decision centers					X	• Flexible, performance-oriented
• Specific test techniques specified				X		• Focus on proof of function
• Focus on performance as first priority		X				• Focus on reliability, durability, cost of ownership

The Task Force found the most gain in moving from traditional to commercial practices in the area of management risk.

Authority and stability characterize commercial program management. It will take considerable courage for DoD to adopt this obviously beneficial approach.

DoD cannot guarantee Congressional commitment but can increase the probability that, once into EMD, DoD commitment is for the life of the program.

Once entered into EMD, decisions impacting program flow should be by exception. DoD decision makers must have the faith in program management to do this. Commercial programs maintain the schedule because the entering risk allows that. We have already said much about reducing risk at EMD entry for DoD programs.

Performance- vs. specification-oriented contracts will free both DoD and industry managers to build products rather than contracts and reports.

Both the investment and test comparisons on this chart reflect the performance-oriented vs. specification-oriented approach in commercial practice. The Task Force strongly recommends DoD move sharply to commercial practice in these areas.

The DoD mission will continue to dictate high priority on performance.

Traditional DoD	Best Practices					Commercial
<u>Customer Interface</u>						
• Customer involvement during development and decisions sporadic —indirect exchange between developer and customer				X		• Customer is the end-user and is always the focus—direct exchange
<u>Business Relationship</u>						
• Adversarial					X	• Producer and customer cooperate to produce effective and profitable products
• Detailed on-site and off-site oversight and direction					X	• Cooperative customer participation in design and development (IPT)
<u>Industrial Base</u>						
• Competition by decree					X	• Competition and long-term performance- and cost-based vendor relationship

DoD practice inserts multiple layers between the industry developer and the user customer. While DoD will need to retain the separation of contracting functions, the user should be intimately involved in decisions before and during approval and execution.

Again, partnership with trust on both sides produces products faster, cheaper, and better than does an adversarial relationship.

This also applies to the relationship between prime developers and their vendors. That relationship should be contractors' business. The trust that comes from performance may often be more value added than is competition at this level. In any case, that should not be government business.

ACCELERATING THE FIELDING OF TECHNOLOGY

- Technology development requires time—cannot be "scheduled" absolutely
  - Problems show up in all technology-oriented programs
  - Exploit and mature the technology in demonstrations before EMD
- Overoptimism about technology maturity in EMD is a critical problem
  - Technologists definition of "on-the-shelf" not the same as Program Managers definition of "off-the-shelf"
- Affordable approach (commercial philosophy) requires technologies in hand from Demonstration Phase
- There are actions that can be taken:
  - Quantitative assessments of technologies—tools need to be developed
    - » Exploit simulations for assessment and screening
  - Open architecture for avionics upgrades as available
  - Design for P3I for airframe/weapons/propulsion upgrades—stress block approach
  - Hardware and software demonstrations at component and system levels

This chart conveys some additional thoughts about the subject of fielding technology faster. The Task Force was skeptical about realistic possibilities to accelerate technology. Reinforcing this skepticism, the Task Force saw little in the track record to suggest real motivation for acceleration. Instead, unpredictable budget levels, unforeseen technical challenges, changing priorities, and an imperfect view of future needs all tend to stretch programs rather than produce motivation to accelerate fielding technology. We have already suggested that the long gestation periods for many major programs, and some outright cancellations, have been caused by program risks other than technical. Hence, faster overall results are likely to come from more careful attention to maturing and transitioning technology.

Technology dislikes planning schedules. The overall approach should not attempt to rush technology to maturity. That almost guarantees the program will take longer.

The approach should instead motivate maximum realism about technology maturity and insist on affordable, mature technologies for EMD. When there is sufficient urgency to carry risky technologies into EMD, it should be a deliberate decision with fall-back plans.

That does not mean that nothing can be done to accelerate technology.

The first need is for better tools to confidently assess the status of technologies. Advanced simulation technology can play a major role, but needs the pull of demanding customers.

Systems, particularly avionics systems, need open architectures that can easily accept incremental upgrades with advanced technology components.

There needs to be recognition that growth should be pre-planned for complex systems.

There should be heavy emphasis on hardware and software demonstrations at the level needed to bring the technology developers' on-the-shelf technologies to the systems developers' view of off-the-shelf.

GENERIC PRE-EMD DEMONSTRATION NEEDS FOR JAST

- Air vehicle flight demonstrations (critical characteristics)
  - Airframe/engine integration
  - Flight control mechanization
  - Weapons bay acoustic environment
  - Integration of LO, maneuver, and speed requirements
  - Carrier suitable
  - Vertical operations
  - Modular features with critical flight implications
- Flying test bed demonstrations
  - Avionic/antenna integration
  - Software tools and integration
  - Key computer software configuration items (CSCIs)
- Ground demonstration/labs
  - Large scale RCS models
  - Pilot production process (could be simulations)
  - Cockpit integration
  - Engine altitude and pre-flight certification (if new engine)
  - Structures and materials testing
  - Modular construction
  - Software tools and integration
- Evaluation models/simulations
  - Selection, configuration control, verification of models and simulations
- Management risk
  - Evaluate acquisition strategy/program management/management information system
  - Simulation of user requirements—validate requirements

The Task Force interpreted the guidance to JAST as defining it as a pre-EMD program. This chart provides our view of likely minimum demonstration needs.

Demonstration/Validation has come to carry the connotation of an air vehicle flight demonstration as a prelude to EMD. We avoided this term and instead identifed a range of important demonstrations. There are areas where a flight vehicle demonstration is needed to provide the needed risk reduction confidence. While modern simulations are essential to airframe/engine integration work, the proof, particularly on the edges of the envelope, is to be found in flight.

The same is true of flight control mechanization. Again, ground demonstrators and simulations are essential but there are always things that need to be learned in flight. That will be particularly true if vectored thrust has a major role, as suggested in the section on technologies.

Since one or more JAST-based aircraft are likely to be VLO with weapons bays, the acoustics problems need to be explored in flight.

Further, the integration of the conflicting demands of low observable shapes and maneuver and speed requirements should be demonstrated in a flight vehicle. The same is true of the flight handling aspects of carrier suitability.

Adequate confidence in other areas can come from flying test beds. The short list of examples shown here is self-explanatory.

There is yet another longer list where ground demonstrations should suffice prior to EMD. This list extends beyond weapons system characteristics and includes manufacturing issues.

Simulations will play a heavy role in assessing and reducing risk prior to EMD and in development and testing during and after EMD. This is an area deserving considerable attention within JAST to ensure that appropriate simulations are identified and validated.

Finally, there are non-technical issues that need to be demonstrated, including the management information system that will tie together multiple contractors and the program office.

As suggested in several places in this report, valid, accepted, attainable requirements are vital to risk reduction and affordability. This includes high confidence initial assessment of requirements and convincing insight into the impact of requirements adjustments as reality collides with expectations.

We will discuss uses of simulation more fully on the next two charts.

USES AND VALUE OF SIMULATION

Evaluating the changing demands on modern systems requires extensive credible simulations along with open air testing

- Open air testing limited by:
  - Cost, facilities, and safety constraints of live operations
  - Complex, interacting factors impacting optimization
  - Range and scope of design parameters demanding evaluation
- Decision makers need to visualize results from:
  - Technology screening
  - Initial concept analysis and approval
  - Initial cost and performance tradeoffs
    - » Rapid access to the 85% answer
    - » Identify critical areas for more detailed analysis
  - Simulated manufacturing environment
- Continuing adjustments to requirements as risk reduction and EMD illuminate challenges
  - Agreed-to authority and process for convergence

Continued

Simulation has moved beyond being a supplement to open air testing. Open air testing will continue to play an important role both in measuring results and providing confidence. However, evaluating the complex interactions that drive and measure the military worth of a modern weapons system will require extensive use of advanced simulation technology.

Open air testing is limited by the cost and availability of open air ranges and facilities matched against the complexity of the factors and design parameters that must be understood and evaluated.

Further, to appreciate the impact of the interactions and to have confidence in that understanding, senior decision makers need to be able to visualize the results. The cost of systems and the cost of poor decisions defy the "trust me" approach. These insights are needed at the outset and as the unfolding program demands adjustments.

USES AND VALUE OF SIMULATION (Concluded)

- To include a spectrum of individual aspects, and interactions among them against an agreed level of threat, to include, for example:
  - Individual weapon lethality
  - Engagement effectiveness
    - » Use of off-board and on-board information
  - Detection and tracking
  - Weapons operational envelopes
  - Countermeasure susceptibility
  - Survivability
- Evaluating military worth of concepts or real systems increasingly demands:
  - Valid open air testing of appropriate factors—performance parameters, crew station integration, etc.
  - Man-in-the-loop advanced distributed simulation combining live, virtual and models
  - End-to-end engagement effectiveness
  - Insights from visual depictions of ongoing operations and results

Simulation is no longer only an adjunct to open air testing and exercising. Increasingly it is an integral part of the approach to gaining broader credible insights into requirements and military worth

Here we see a partial list of some aspects of an aircraft system that require detailed simulation.

High confidence decisions will demand continuing open air testing and man-in-the-loop simulations and the ability to use these simulations to visualize results.

The bottom line is that simulation is not just an adjunct to open air testing or paper studies. It is increasingly important to good decision making.

FINDINGS & RECOMMENDATIONS—RISK ASSESSMENT/REDUCTION

- The JAST program should produce timely convergence and agreements on requirements, funding, schedule, and Services' acceptance to reduce program risk in addition to transitioning mature technology
- Focus on an acceptable convergence of requirements with flexibility to adjust as technology expectations collide with reality
- Exploit and mature high potential technologies before EMD
- Additional time and attention to risk reduction before EMD can provide a shorter time to IOC. Dealing with reality-expectation mismatch in performance, cost or schedule during EMD jeopardizes programs
- Enter EMD with a minimum of unresolved risk—accepting anything beyond low risk in EMD should be a deliberate decision with a fall-back plan
- Full commitment to cost and schedule by the Services and OSD must be a condition of entry to EMD
- Strongly emphasize designing affordable manufacturing into technology focus, vehicle design, program management, and manufacturing processes and facilities
- Commit ruthlessly to "best practices" (commercial, traditional DoD, mixes): To the extent possible, defense acquisition should be made compatible with commercial practices to foster integrated enterprises
- Define the range of pre-EMD demonstrations for low risk entry to EMD:
  - Air vehicle flight demonstrations for critical integration challenges
  - Flying test beds for avionics integration
  - Ground demonstrations, simulations and models
  - Management systems to provide notable, accurate, timely and well-presented information on program progress
- Emphasize developing and using combinations of live, virtual and constructive (models) simulations for military worth, capabilities trade-offs, systems operation, management systems, manufacturing, etc.

TASK FORCE FOCUS

- Objective, Mission and Relationships
- Multi-Service Requirements
  - Force Sustainment
  - Strike Force Capability Modernization
- Technology for Affordability
  - Manufacturing
  - Simulation and Computer-Aided Design
  - Supportability
  - Performance
- Risk Assessment/Reduction
  - Program Management Approach
  - Commercial Practices Application
  - Program Technical Approach
  - Demonstrations of Technologies (Hardware and Software)
  - Use of Simulation
- **Industry Capabilities and Motivations**
  - Lean and Flexible (Product and Rate) Manufacturing
  - Foreign Participation

The final area in the report deals with industry capabilities and motivations in participating in JAST and follow-on programs. In this section we discuss some further program management issues. They relate to affordability, manufacturing issues, and the timing and scope of desirable foreign participation.

IMPORTANT AFFORDABILITY DRIVERS—LEAN MANUFACTURING

- Major Goals are:
  - Low product cost
  - Improved quality
  - High productivity
  - Efficiency at lower scale of production
  - Rapid product development
  - Product mix diversity
  - Continuous improvement
  - Reduced cycle time
- Lean Manufacturing Environment vs. Current Environment
  - Flexible work force vs. craftsmen
  - Flexible tooling vs. rigid tooling
  - Self-assurance quality vs. inspect-in quality
  - In-process verification vs. end-of-process inspection
  - Just-in-time vs. stored inventory
- Business Approaches
  - Best practices
  - Partnerships; Government with industry and within industry
  - Activity-based costing and management
  - Minimum contract requirements
  - Lean government program offices
- Integrated Product Teams
- Value-Added Specifications
  - Commercially friendly
  - Performance-based measurement instead of detailed specifications and standards—no "how-to" specifications
  - Encourage alternative solutions to military specifications/standards

Lean manufacturing, an important part of affordability, is heavily dependent on program management approaches.

Lean manufacturing (and resulting affordability) has to be integrated into every facet of the program from system concept to the contracting approach.

It starts with lean business approaches based on best practices—a mix of traditional DoD and commercial.

An important element of commercial practices is the basic concept of a partnership relationship instead of the all too common adversarial approach. That subject was discussed in an earlier section.

Activity-based costing assigns direct and indirect cost to the activity generating the work. It is an essential prerequisite to breaking free of the fixed overhead mentality that allows quantity to over-drive unit cost.

Contracts should be enabling devices based on partnership rather than voluminous tomes restricting or at least discouraging innovation in business practices, manufacturing, system design or program execution.

Integrated Product Teams have moved beyond the slogan stage. The Task Force saw them at work in several ongoing programs.

Value-added specifications are receiving top level attention and little more needs to be said about the principles or the importance. This short list of important characteristics and goals of value-added specifications is intended to lend support to ongoing efforts.

INCENTIVES FOR INDUSTRY TO PROVIDE HIGH-LEVERAGE TECHNOLOGY FOR JAST

- Financial
  - Timely funding adequate to task objectives—pay-as-you-go
  - Attractive ventures for short-term and long-term—profit-as-you-go
  - Stable funding commitment/award fee basis
  - Building future business base and competitiveness
- Program Planning and Technology
  - Mission-oriented goals and options based on credible mission analysis
  - Clearly articulated program objectives
  - Established peg points for affordability and performance goals
  - Review involving developer/producer and end-users to adjust peg points as reality unfolds
  - Product orientation
    - » Clear government strategy and technology focused on products
    - » Credible implementation plan and expectations
    - » Long-range goals but with intermediate pay-offs and products
    - » Demonstrations that focus and pace technology with clear metrics to measure progress against mission performance objectives

The greatest program risk has been and continues to be financing the venture. Instability in financing has also been a major enemy of affordability. The most sensible requirements, affordable designs, lean manufacturing and good management at the contractor and program manager level will not produce affordable products unless the financing meets the criteria shown.

Companies can no longer afford to accept loss leader development, betting on subsequent procurement and support contracts to recover investment. Profit-as-you-go is essential to industry motivation. The current aerospace industry business environment also forces companies to make business decisions based on longer term prospects. Therefore, companies are most interested in technologies that build the business base and contribute to competitiveness.

Given that the risks to program success and survival are more in the program area than the technology area, careful attention to risk reduction on the program level will be an important part of providing incentives to industry. Risk reduction was discussed in an earlier section.

Program planning and technology elements are repeated here for emphasis and continuity. The first point—mission-oriented goals—goes to the issue of lasting military worth. The next three points are related to the issue of requirements that have some flexibility until there can be confidence in technology and program integration maturity.

Industry is product-oriented. Technology development, to be interesting, has to promise a path to a product. Program development also must be guided by realistic and initially adjustable expectations.

Long range goals are accepted and welcomed but interim progress, preferably in products, is also highly desirable. With JAST, interim products can be insertion into existing or developing systems.

Industry is also motivated by the opportunity to show tangible, measurable results. Demonstrations are a form of interim product. They provide insights and confidence. They also provide motivation.

FOREIGN PARTICIPATION

Pro	Con
• Strengthen alliance capabilities, cohesion and support base	• Risk strengthening adversary capabilities and support base
• Help in maintaining the U.S. industrial base	• Develop competitive foreign industrial base
• Acquire leading technologies	• Reduce lead in key technologies/loss of decisive advantage
• Cooperative development of technologies	• Longer development due to multi-national complications
• Larger market through cooperative system development	• Longer development, less capable systems due to multi-national complications
• Reduced cost to the U.S. government	• Increased overall program time and cost
• Shared funding	• Shared authority over products

There are strong pros and cons related to the general subject of foreign participation. Some are more germane to development, some to procurement.

The contrast between the desirable effect on alliances and the undesirable build-up of adversaries is exacerbated by the greater difficulty in predicting who will be which.

It would be useful to conduct a deeper study into the track record on benefits to maintaining the industrial base vs. building future competition. For example, aerospace industries have proliferated all over the world, some directly based on U.S. exports, e.g., Japan, Turkey, etc.

Given the position of the U.S. in technology, we are more likely to export technology than to import needed technology. Even in most of the international ventures considered successful, U.S. companies had little need for the foreign partners technologies.

A prime benefit expected from foreign participation is better access to foreign markets. Foreign participation in a U.S. program may also preempt a competitive foreign program. However, that potential advantage can be offset by the complication of needing to field systems with competitive timing and performance.

A more extensive analysis is required to document reduced cost to the government from foreign participation.

A prime motivation, within U.S. industry, for foreign participation is assistance in funding for major projects such as new commercial engine development.

FOREIGN PARTICIPATION ISSUES
Some Aviation/Weapons Examples

Co-Develop	Design to Market	Post IOC Market
EFA ASRAAM NAAWS CFM-56 AV-8B Concorde Tornado	F-5 F-16 F-20	F-84 through F-4 F-14, F-15, F-18 Maverick AIM-120 AWACS P-3 E-2 AV-8 Harpoon

- Co-Develop—mixed record at best
- Design to Market—success depended on an initial or dual (U.S. or foreign) known market
- Post IOC Market—proven and accepted in U.S. inventory

This chart provides some insights into what works.

Co-development efforts have sometimes produced only expense and bad feeling. In other cases, it produced systems that worked but at high cost. Of the list shown, the CFM-56 and AV-8B are widely considered successful multi-national development programs. The CFM-56 program success depended on a serendipitous set of circumstances and personalities that might be difficult to duplicate. The AV-8B was a follow-on to a fielded system.

Designing with the foreign market in mind has been more successful. The F-5, successful by any criteria, was initially for a guaranteed four-country market and was then successfully marketed worldwide. The F-16 was designed for USAF use, but with a strong foreign market motivation and design influence. In contrast, the market for the F-20 disappeared with the change in China policy. The company invested almost $2 billion in the program with no sales.

Over the years, post-IOC sales of systems designed for USAF and USN use have dominated the market. However, it is not clear that systems designed without consideration for the foreign market will be successful in the marketplace in the future. Cost and exportability of technology will play a major role.

FOREIGN PARTICIPATION ISSUES—SOME CONCLUSIONS

- Co-Development should be minimized
  - Successful in special cases—upgrade existing system (AV-8) or commercial market (CFM-56)
  - Complicates/extends requirements development
  - Inhibits requirements flexibility and agile program decisions
  - Suboptimal division of labor
- Design to market considerations will be important to foreign sales
  - Can contribute significantly to the overall success of the program
  - Requires understanding foreign requirements
  - Emphasizes affordability and plan exportable versions
  - Some level of participation during development may be the price of market entry
- Key technology transfer issues
  - Stealth
  - Avionics and off-board interfaces

The Task Force concluded that foreign participation in co-development of next-generation strike fighters, other than limited participation for special reasons, would complicate the program to the point of reducing the probability of success.

At the same time, one or more of these aircraft might be strongly influenced by the potential foreign market. That will require some design considerations in how sensitive technologies are employed. The affordability issue will drive U.S. needs strongly; that aspect needs little further emphasis for foreign market considerations.

FINDINGS AND RECOMMENDATIONS—
INDUSTRY CAPABILITIES AND MOTIVATION

- JAST should strongly encourage lean and flexible manufacturing approaches, and integrated product/process teams in the design-manufacturing-support process
- Industry is attracted to ventures that:
  - Are based on credible expectations and plans
  - Provide profit opportunity for performance in each phase
  - Provide short-term and long-term business development
  - Focus on mission-oriented products with clear measures of success
- Confidence in the success of DoD programs has diminished in recent years. Industry believes success in the future will be strongly driven by:
  - The degree of DoD commitment to a product-oriented program
  - Business approaches that emphasize practices compatible with partnership with government, innovation in contracts, etc. Industry is looking for "best practices"
  - Value-added specifications—performance-based measures, not detailed specifications and standards. How-to specifications are particularly onerous
- Foreign participation in development of next-generation strike fighter should be:
  - Measured by credible expectation of value added
  - Focused on market exploitation
- Next-generation strike fighters should be designed with the foreign market in mind
  - Affordable cost
  - Versions with technologies that can be adjusted for exportability

SUMMARY—TEN KEY POINTS

1. JAST should: a) transition and mature selected technologies from S&T programs; b) bring workable compatibility to multi-Service requirements; and c) provide building blocks and demonstrations for low-risk EMD for next-generation strike fighters
2. JAST should be a *customer* for selected maturing technologies from S&T programs; JAST should not be the manager or funding source for the spectrum of strike-relevant S&T
3. The requirements process should emphasize qualities that will be particularly vital in the post-cold war environment—deployable, survivable, affordable, precision weapons, and night/weather capabilities
4. Joint Programs must reflect Services' requirements or the programs cannot survive; this includes an affordable cost range
5. Technology exploitation must stress affordability and performance
6. Full Services' and OSD support must be a condition to begin EMD
7. Commit ruthlessly to "best practices," whether they be commercial, defense, or a mix
8. Emphasize developing and using a range of combinations of live, virtual, and constructive (model) simulations to assess military worth, capabilities trade-offs, systems operations, systems testing, manufacturing, and management systems, etc.
9. Provide credible expectations and plans to industry, with short- and long-term business development and profit opportunities in each phase of programs
10. Design and develop with the foreign market in mind.

APPENDIX A

TERMS OF REFERENCE

THE UNDER SECRETARY OF DEFENSE

3010 DEFENSE PENTAGON
WASHINGTON, DC 20301-3010

ACQUISITION AND
TECHNOLOGY

MAY 1 0 1994

MEMORANDUM FOR CHAIRMAN, DEFENSE SCIENCE BOARD

SUBJECT: Terms of Reference -- Defense Science Board Task Force on Joint Advanced Strike Technology Program

You are requested to form a Defense Science Board Task Force to provide recommendations for implementing a Joint Advanced Strike Technology Program (JASTP) in the FY95-00 period. The scope of your effort should include the following general areas: the structure of the JASTP; the schedule, sequencing of activities, emphases and relative levels of effort appropriate; the innovative, high payoff concepts for inclusion in the program; and the acquisition strategy for aircraft that might result.

The Defense Science Board recommendations should address the following specific questions:

• Is the JASTP analytical framework (scope, depth, tools and processes) adequate for evolving fully validated strike operational warfare requirements?

• What strike warfare technologies, operational concepts and weapons systems should be included under the umbrella of the JASTP to ensure the program is addressing new affordable solutions within the broad context of warfighting?

• What innovative, high leverage manufacturing technologies/processes, including modular construction, show potential for significantly reducing production costs of highly common, multi-role, multi-service aircraft?

• How can DoD ensure a timely, viable conduit of high leverage technology from the aerospace industry to JASTP? Include recommendations on how JASTP can capitalize on other national and international sources.

• What is the appropriate interaction between JASTP and existing DoD science and technology (S&T) efforts?

• What strategies could permit an expeditious fielding of technologies before these technologies become obsolete?

• Are new development and operational testing philosophies required for JASTP in light of advanced design tools, testing techniques, and simulation?

• Which key demonstration objectives should be included in the JASTP?

• What are the benefits and disadvantages of international cooperation intended to produce favorable foreign sales of JASTP products, thereby reducing overall cost to the U. S.?

This effort should focus on advanced strike concepts as well as on platform issues. A primary framework for this effort is affordability. Commonality, producibility and capability issues must all be considered as a means to an end -- namely affordability. The Task Force should include an assessment of the potential impact of its recommendations on military readiness for those recommendations where such an assessment is appropriate. The Task Force should submit its final report by September 1994.

The Director, Tactical Warfare Programs will sponsor this Task Force, providing funding and other support as may be necessary. General Larry D. Welch, USAF (Ret) and Admiral Wesley L. McDonald, USN (Ret) will serve as Co-Chairmen of the Task Force. Captain Doug Connell, USN will serve as Executive Secretary and Commander Robert Hardee, USN will serve as the Defense Science Board secretariat representative. It is not anticipated that this Task Force will need to go into any "particular matters" within the meaning of Section 208 of Title 18, U. S. Code, nor will it cause any member to be placed in the position of acting as a procurement official.

Noel Longuemare

R. Noel Longuemare
Principal Deputy Under Secretary of
Defense (Acquisition & Technology)

APPENDIX B

TASK FORCE MEMBERSHIP

TASK FORCE MEMBERS

Co-Chairmen: ADM Wesley McDonald, USN(Ret)
GEN Larry D. Welch, USAF(Ret)

Members:

Stephen Campbell
Werner Dahm
Don Fredericksen
RADM Chuck McGrail, USN(Ret)
GEN Bob Russ, USAF(Ret)
Jack Welch

Paul Bavitz, Grumman
Jack Gordon, Lockheed
Dick Hardy, Boeing
Del Jacobs, Northrop
Les Lackman, Rockwell
Mark Landau, Hughes
Jim Sinnett, McDonnell-Douglas
Jack Twigg, Martin-Marietta

Executive Secretary
CAPT Doug Connell, USN

DSB Liaison
CDR Robert Hardee, USN

APPENDIX C

MEETINGS AND OTHER EVENTS

22 April	Aeronautical Systems Center, Wright-Patterson AFB, OH
26, 27 April	Institute for Defense Analyses (IDA), Alexandria, VA
3 May	IDA
10, 11 May	IDA
15 May	The Boeing Company, Seattle, WA
6 June	Naval Air Systems Command, Washington, D.C.
8 June	McDonnell Douglas Company, St. Louis, MO
29, 30 June	IDA
5, 6 July	IDA (Government Only)
8 July	Lockheed Advanced Technology Company, Palmdale, CA
19, 20 July	IDA
26 July	General Electric Company, Evendale, OH
2, 3 August	IDA
16 August	IDA (Executive Meeting with JAST Program Office)
9 September	IDA

APPENDIX D

TECHNOLOGY FOR AFFORDABILITY:
RATIONALE CHARTS

KEY TECHNOLOGIES—
AIRFRAME & SYSTEMS

	Priority Technology *
• **Advanced Very Low Observables (including Antennas/Apertures)**	X
• **All/More Electrical System Aircraft**	X
• Smart Structures	
• **True Advanced Composite Structural Design**	X
• **Virtual and Rapid Prototyping of Hardware**	X
• High Temperature Materials and Coatings	
• **Modular Construction**	X
• Modular "Stealth" (incremental stealth)	
• Advanced, Safer, Pilot Protection System	
• Smart Cockpit	
• Realtime CFD/NASTRAN/3D External/Internal Loads	
• Lightning Protection/Repair Associated with Composites	
• Industry Standard for Composite Allowables/Margins	
• Adaptive Flexible Wing Design	
• Highly Integrated Airframe—Engine Subsystems	
• Highly Integrated Airframe—Weapon/Fire Control	
• Reconfigurable Flight Control	
• **Reduced Tail/Tailless Fighter Configuration**	X
• **Technologies Enabling STOVL**	X
• Advanced Aircrew Vision Protection	
• Super Subsystem	
• Advanced VMS	
• Life Prediction	
• Reaction/Thrust Vector Control	
• Photonics (Fly-by-Light)	
• **Conformal Carriage for LO and Drag**	X
• Smart Tactical Weapons, Airborne Launched	
• Self-Determining Damage Assessment	
• High Power Microwave System	
• Advanced Hydraulic Launchers	
• All-Weather Autonomous Seeker on Weapon	
• Increased Hard Target Penetration	
• Penetrating Warhead for Deep Underground Targets	
• Non-Lethal Systems	
• Advanced Gun System (with higher lethality and smaller weight and volume)	
• SAR Weapons Guidance Integrated with Aircraft Radar	
• **High Lethality Payloads**	X
• **Weapons Integration Affordability**	X

* Very high leverage on affordability and capability for the JAST Program

WHY THIS TECHNOLOGY IS HIGH PRIORITY—
ADVANCED VERY LOW OBSERVABLES

Program Objective Addressed	Technical Approach
• Develop affordable advanced LO materials and components that minimize performance impacts while maximizing system survivability and effectiveness	• Develop high performance materials for RF and IR signature reduction that are affordable, broad band, light weight and durable • Develop components that contribute to signature reduction including antennas, apertures, edges, engine treatments and air data systems • Develop integrated LO designs for vehicles that provide for external weapons carriage
Demonstration Elements	**System Payoff**
• Ground testing of appropriate component models • Flight test of components appropriate to JAST-derived design(s) • Flight test of JAST technology prototypes	• Improved survivability • Enhanced lethality • Reduced cost per target kill • Increased flexibility of force packaging

The Gulf War has made firm requirements of what previously had been goals as DoD prepares to respond to future crisis situations with reduced resources. Our ability to rapidly respond with a flexible, lethal force will be a crucial element in providing a credible conventional deterrent. Further, the expectation is that we will minimize casualties, avoid POW situations, and reduce collateral damage even against sophisticated air defense threats. Including Advanced Very Low Observables in future advanced strike aircraft can provide the leverage or margin to accomplish these objectives.

Today's stealth designs have performance and cost impacts that are in the 5 to 25 percent range, depending on the stealth level achieved and the required performance characteristics. While investments of this magnitude are cost effective due to increased survivability and effectiveness, future resource constraints will require that these incremental costs be reduced.

Industry has a number of alternatives that can contribute to fielding Advanced Very Low Observables. A JAST priority should be to accomplish early demonstrations of the most promising of these technologies so they can be incorporated into a future strike design, from its inception, with low risk.

WHY THIS TECHNOLOGY IS HIGH PRIORITY—
ALL/MORE ELECTRICAL SYSTEM AIRCRAFT

Program Objective Addressed

- **All Electrical Systems to Replace:**
  - **Hydraulic systems**
  - **Hot engine bleed air ducting**
  - **Air turbine starter**
  - **Engine gear box (long-term)**
  - **APU/EPU or IPU (long-term)**

Technical Approach

- **Establish load and performance specifications**
- **Conduct architectural & design analysis**
- **Complete component design**
- **Fabricate hardware**
- **Build demonstrator/prototype systems**
- **Perform system T&E**

Demonstration Elements

- **Component fabrication & test**
- **Copper Bird system build & test**
- **Hardware flight demonstration**
- **Demonstration/validation EMD**

System Payoff

- **Increased survivability through reduction in vulnerability to combat damage**
- **Enhanced maintainability due to reduction of high-maintenance subsystems**
- **Enhanced safety due to increased reliability of systems**
- **More efficient power operation**
- **Significant LCC savings**

State-of-the-art electrical system technology has advanced to the stage where it is feasible and desirable to begin replacing aircraft subsystems that are vulnerable to combat damage as well as to routine failure in flight. Examples are hydraulically actuated or powered subsystems, hot engine bleed-air-activated components and auxiliary power and engine starting units. All-electrical systems promise to reduce weight, space and maintenance requirements. They can simplify aircraft design by providing the designer great flexibility in component placement and redundancy for routing of key and/or critical wiring to safety of flight power-carrying lines.

The elimination of hydraulic systems for flight control and utility systems alone would serve to greatly increase survivability through reduction in vulnerability to combat damage. A program to design, build and test a virtually all-electric aircraft prototype system prior to JAST aircraft entering EMD appears to have only moderate technical and programmatic risk at this time.

WHY THIS TECHNOLOGY IS HIGH PRIORITY—
TRUE ADVANCED COMPOSITE STRUCTURAL DESIGN

Program Objective Addressed	**Technical Approach**
• Tailor specific composite material characteristics to optimize design strength, stiffness, aeroelastic tailoring, and durability • Apply new composite material properties to achieve design advantages and processes	• Design integrated structural elements that prove material suitability and process maturity • Prove out flexible tooling processes for selected advanced composite applications
Demonstration Elements	**System Payoff**
• Demonstrate tailored structural elements built-up from integrated composite components • Demonstrate integral large scale composite structural major airframe parts (wings, empenage, fuselage, modular components)	• Lighter weight more durable airframes with improved dynamic response characteristics (Aero and RF) • Reduced airframe assembly time and cost (fewer fasteners, fewer assembly man-hours) • Integrated structural properties which improve Aero, RF, IR observables

Composite materials have inherent capabilities for integrating multiple functions into the structure of the airframe. Mechanical and electrical properties can be tailored to meet functional requirements in the areas of aeroelasticity, static and fatigue strength, stiffness, and low observables. This tailoring can eliminate or reduce parasitic materials, enhance structural performance and, ultimately, vehicle effectiveness, while reducing cost through consolidation of functions into a single hardware element. In addition, sensors can be embedded to perform mission-level functions and/or self-diagnostic evaluation of structural health. To date, the full potential of these materials has not been realized. In many instances, composites are used as direct replacement to aluminum structure (sometimes referred to as "black aluminum") with little consideration given to the unique design solutions possible with a new design approach aimed at leveraging the inherent capabilities of this class of material.

WHY THIS TECHNOLOGY IS HIGH PRIORITY—
VIRTUAL AND RAPID PROTOTYPING FOR HARDWARE

Program Objective Addressed	Technical Approach
• Revolutionize the way aerospace products are designed and manufactured in order to reduce acquisition cost	• Common geometry/product database, including suppliers • Integrated scheduling • Process-based cost sensitivities • Feature-based design • Manufacturing process flow and assembly simulation • Streamlined certification • Vertical partnering with suppliers • Exploit commercial simulation products
Demonstration Elements	**System Payoff**
• Develop virtual assembly technology (F-18/F-22) • Develop design/manufacturing tools • Develop virtual prototype • Establish cost benefits • Develop JAST virtual prototype	• Lower acquisition cost • Reduced design/build cycle time • Improved product quality with reduced scrap/rework • Less inventory • Paperless shop • Reduced tooling cost • Improved R&M • Reduced risk • Inter-Service commonality

Program Objective

A significant reduction in acquisition and life-cycle costs is desired in order to survive as an industry in today's shrinking defense budgets. Defense budgets can no longer accommodate today's prohibitively high acquisition and life-cycle costs for new weapons systems. A revolutionary approach to designing and building new weapons systems is needed to achieve dramatic reductions in acquisition cost that must be realized to survive in today's environment. Various forms of design and manufacturing simulation will allow virtual prototypes to be built which will provide a try-before-you-buy approach that is expected to significantly improve affordability. The use of more fully developed, integrated design and analysis tools will provide the ability to obtain better product and process definition earlier in the design process which will reduce the amount of rework and in turn improve affordability.

Technical Approach

A virtual prototyping environment will be established through integrating critical disciplines and using advanced tools. A common geometry database will be generated and provide each discipline with consistent geometry and product definition from which integrated schedules and process-based cost sensitivities can be generated. Product definition will include extensive use of feature-based design that will enable a parametric definition of the product and reduce the effect of design changes. Additionally, simulation techniques for manufacturing flow and assembly will use the consistent common geometry to ensure "best" manufacturing decisions are made early in the product definition. Streamlined certification will provide product validation under design conditions through the use of high fidelity computer simulations and analysis. Real life testing will be used to model "virtual testing" scenarios. Vertical partnering with suppliers will allow us to develop agreed-to requirements and higher quality design iterations earlier in the process. Commercial simulation products will be utilized.

Demonstration Elements

A plan will be developed consistent with JAST Program requirements to develop and validate the virtual prototyping process. Virtual assembly technology will be developed to establish the effect of assembly simulation on reducing the learning curve and tooling costs. Design and manufacturing tool sets and the processes for their use will be developed and can be demonstrated selectively on the F-18 or F-22 project or in conjunction with Advanced Lightweight Affordable Fuselage Structure (ALAFS). Development of the virtual prototype processes will include producing sufficient hardware to substantiate virtual data to physical hardware correlation and the process used to produce the hardware. The ability to predict costs in the virtual environment will be compared to actual costs to establish cost benefits. The resulting capability will then be exercised to develop a JAST virtual prototype.

System Payoff

The key benefit from instituting a "virtual prototyping" system will be reduced acquisition cost. Shorter design/build-cycle time will reduce the product cost and allow a more complete evaluation of product alternatives thus reducing risk. Product quality will be increased because critical aspects of the product will have been demonstrated and tailored through simulation. Savings in reduced tooling cost, improved reliability and maintainability due to early inputs into the design are anticipated. Additional benefits will be obtained from sharing and integrating product data with the supplier and customer base.

WHY THIS TECHNOLOGY IS HIGH PRIORITY—
MODULAR CONSTRUCTION

Program Objective Addressed

- **To prove that modular aircraft fabrication and assembly techniques meet technical requirements and reduce production costs**

Technical Approach

- **Prove with both analytical assessment and physical demonstration the tolerance limits of modular construction techniques**
- **Apply the limits to an assessment of the savings potential to production costs**

Demonstration Elements

- **Develop an analytical assessment of a modular structure**
- **Design an interchangeable modular structure with multiple unique parts**
- **Fabricate and assemble the modular structure**
- **Gather measurements and compare to theoretical tolerances**
- **Estimate reductions in production costs**

System Payoff

- **Dramatic reduction in assembly and tooling costs for production**
- **Simplified tooling system**
- **Simplified incorporation of changes due to digital-product-based system and tools**
- **Flexible assembly line for multiple variants of common aircraft**

The concept of modular construction in aircraft allows the manufacturer to satisfy a broad range of customer requirements without the associated infrastructure and overhead of the traditional separate assembly line approach. The development costs of a modular aircraft family is significantly less than the cost of developing multiple separate aircraft systems. The objective of a modular aircraft construction program is to demonstrate that actual aircraft hardware fabricated in a modular manner can be fabricated and assembled to analytical tolerances.

In tactical aircraft applications, modularity will be applied to the structural airframe, the level of stealth (if planned for ahead of time), and systems to be installed for each customer such as avionics, armament or landing gear and single versus two-place cockpit. The technical approach and plan call for the fabrication of representative hardware and comparison to predicted analytical tolerances.

The keys to modularity include the early identification and agreement on complete sets of requirements with each customer and the use of an integrated requirements database; digital product definition of the aircraft and the module interfaces; gageless tooling; and the use of flexible manufacturing methods which eliminate costly tooling. The above-noted technologies will be proven by the modular construction program.

WHY THIS TECHNOLOGY IS HIGH PRIORITY—
REDUCED TAIL/TAILLESS FIGHTER CONFIGURATION

Program Objective Addressed	*Technical Approach*
• Determine amount of cost savings potential of reduced tail/tailless for next-generation strike aircraft – Develop design database – Define constraints (e.g., carrier suitable) – Quantify cost/performance benefits • Demonstrate feasibility and safety	• Integrate thrust vectoring, active flexible control and other innovative control effectors to enable reduced tail/tailless • Capitalize on prior work – Studies - USAF/WL FAPIP – T/V Flight Demonstration: X-31, F/A-18 HARV, F-16 MATV – X-31 Tailless Feasibility Demonstrations • Develop design database sufficient and timely for JAST demonstrations • JAST demonstrates specific Advanced Strike System configuration payoffs
Demonstration Elements	*System Payoff*
• Wind tunnel tests concept for reduced tail and tailless – Support feasibility demonstrations on existing platform – Support design of JAST flight demonstrator • Tailless Simulation – Requirements definition – Concept validation • Flight Demonstration of Tailless Control – Feasibility—existing platform – Proof of operational payoff —JAST demonstration	• Lower Life Cycle Cost due to: – Lower weight – Reduced drag – Fuel cost savings – Reduced RCS associated treatments • Improved survivability due to reduced signature (RCS and visual)

Program Objective

Based upon initial ongoing studies, the tailless or reduced tail design configurations appear to offer very high potential to improve affordability in both system acquisition and O&S cost elements of the total Life-Cycle Cost (LCC).

The objectives of this program are to quantify those LCC savings and to demonstrate that tailless or reduced tail designs are low risk and viable for next-generation strike aircraft.

Technical Approach

Previous efforts, such as the X-31, F/A-18 HARV, and the F-16 MATV thrust vectoring demonstrations and the X-31 quasi-tailless feasibility demonstrations, coupled with other enabling technologies, such as active flexible and innovative control effectors, will be focused toward the specific program goals and used as the starting point for maturation and validation through demonstrations. The multi-axis thrust vectoring control laws will be integrated into the flight control system for reduced tail/tailless air vehicle control. Safety and carrier suitability parameters will be included in the flight control system. Design databases that result from the above efforts will be used to develop the requirements and perform the integration required for a reduced tail/tailless JAST demonstrator configuration.

Demonstration Elements

The key elements in demonstrating the viability of tailless designs are:

- Near-term integration of various design elements through simulation
- A period of risk-reducing flight demonstrations using existing test aircraft such as X-31, F/A-18 HARV, and/or F-16 MATV.

The resulting level of enabling technologies into a JAST flight demonstrator is necessary to validate the system payoff and operability to a sufficient level to allow the technology to enter an EMD program for the next generation Joint Strike Aircraft.

System Payoff

Life-cycle cost savings are due to lower weight and less drag, resulting in lower manufacturing costs and fuel savings (depending on the design mission and configuration). Costs associated with RCS treatments are also reduced, while survivability is improved due to lower RCS and visual signatures.

WHY THIS TECHNOLOGY IS HIGH PRIORITY—
TECHNOLOGIES ENABLING STOVL

Program Objective Addressed	***Technical Approach***
• **Reduce the technology risk so that STOVL can be transitioned into an operational aircraft development program** – **Powered lift system** – **Integrated flight propulsion control** – **STOVL integration** – **STOVL aerodynamics**	• **Reduce technology risk through:** – **Systematic small and large scale model tests** – **Manned simulation activities** – **Parallel design studies** • **Assess the capability and affordability of a STOVL strike fighter design incorporating these technologies** • **Validate the capability and affordability through a flight demonstration program**
Demonstration Elements	***System Payoff***
• **Conduct comprehensive small scale model testing** – **Evaluate STOVL aerodynamics and integration** – **Determine powered lift system performance** • **Demonstrate full scale lift system performance through ground test** • **Verify STOVL aerodynamics with large scale model test** • **Validate IFPC operability with manned simulations** • **Flight test ASTOVL/CTOL tech demonstrator**	• **Expand expeditionary task force effectiveness** – **Amphibious ships with more effective strike fighters** – **Airfields with damaged runways** – **Exploit austere forward bases** • **Realize affordability advantages** – **Force neckdown and increased military sales** – **High commonality with CTOL strike fighter**

Program Objective
A risk reduction program is designed to mature critical STOVL technologies to enable low risk initiation of an affordable ASTOVL/CTOL strike fighter program.

Technical Approach
A comprehensive risk reduction plan addresses the key elements of each critical STOVL technology as summarized here:

- Powered Lift System
  - Thrust Augmentation
  - Power Transfer
  - Thrust Vectoring Nozzles
- Integrated Flight Propulsion Control
  - STOVL Regime
  - Transition To and From Wingborne Flight
- STOVL Integration
  - Weight and Size
  - Performance
  - Supportability

- STOVL Aerodynamics
  - STOVL Inlet Performance
  - Hot Gas Ingestion
  - Jet Induced Lift Loss
  - Undersurface Environment

Demonstration Elements

Extensive subscale model testing is being conducted to reduce the risk STOVL aerodynamics and integration. Small-scale powered lift system tests are in progress to generate STOVL performance predictions. A full-scale powered lift system will be tested to demonstrate this performance and then will be installed in an airframe model. This model will be used to validate STOVL aerodynamics characteristics with wind tunnel and outdoor facility testing. Results of model testing are integrated into manned flight simulations conducted in parallel to ensure Integrated Flight Propulsion Control system operability. Final validation of STOVL technologies will be by the design, manufacture and flight test of two factory reconfigurable demonstrators.

System Payoff

Advances in propulsion technology permit the incorporation of STOVL technology in a modern supersonic fighter aircraft. This aircraft integrates improved warfighting capabilities with STOVL technology to provide increased operational utility for the strike fighter forces of the military Services.

WHY THIS TECHNOLOGY IS HIGH PRIORITY—
CONFORMAL CARRIAGE FOR LO AND DRAG

Program Objective Addressed	***Technical Approach***
• Demonstrate affordable LO external weapons capabilities for future strike warfare systems **– Reduce overall weapon system cost by reducing dependence on internal bays** **– Provide aircraft survivability before and after weapon launch** **– Increase lethality by increasing weapon loadout without sacrificing survivability** **• Provide confidence in design maturity through flight demonstration**	**• Refine and validate high-payoff, affordable LO external carriage options** **– System simulation to establish necessary design parameters** **– Develop preliminary design details for canister, conformal, podded concepts** **– Conduct testing to validate signature/ aero/structural/supportability characteristics** **– Verify weapons separation characteristics through analysis and simulation** **– Flight demonstrate selected concepts**
Demonstration Elements	***System Payoff***
• Identify and refine high payoff options **• Evaluate and rank high payoff options through manned simulation** **• Analyze and wind-tunnel-test drag, environment, and safe separation** **• Demonstrate supportability and logistical benefits** **• Validate low observable characteristics in large scale model test** **• Demonstrate functional operation in ground and flight test** **• Verify weapon integration concept in LO flight test**	**• Reduce size and cost** **• Reduces overall system cost by providing an external LO carriage option** **– Provides survivability and high weapon loadout on Day 1 of the war** **– Provides uniform external weapons integration** **– Provides loadout flexibility for weapons** **– Common racks and suspension equipment** **– Alleviates requirement for special designed weapons**

Program Objective

This effort is a four-phased, Low Observable (LO), external weapons integration program that culminates in a flight test demonstration of affordable and mission-flexible weapons integration concepts. Historically, LO aircraft have relied on internal weapons carriage to achieve their LO characteristics. However, relying solely on internal carriage has increased aircraft size, weight, and cost and restricted weapon quantities and types. Non-internal weapons carriage concepts, such as conformal carriage, cocooned, shrouded, and podded weapons installations, and advanced pylon, LO weapon and canister carriage, offer the potential to reduce the dependence upon internal carriage and improve the lethality without sacrificing aircraft survivability. The objective of this project is to demonstrate affordable, mission-flexible LO external carriage capabilities for not only advanced strike fighter aircraft, but for current strike systems as well.

Technical Approach

Conduct system simulation exercises to establish the necessary weapon and weapon carriage design parameters. Performance characteristics of before, during, and after launch conditions as well as the characteristics of the weapons in flight must be included in the exercises. Based on these results, develop preliminary design packages for external weapons carriage concepts, including weapon canisters, conformal carriage, and cocooned and podded weapon installations. Downselect to one or two high payoff and affordable weapon carriage concepts using the strategy-to-task-to-technology process. Conduct wind tunnel testing, supportability testing and signature testing to validate the results of the simulation and analysis. Select the preferred concept for structural and functional ground and flight tests. Combine the results and conduct LO performance and function flight tests on LO test aircraft.

Demonstration Elements

Demonstration elements can be conducted in four phases. The first phase consists of design, analysis, simulation, and wind tunnel tests and could be 15-18 months in duration. The second phase consists of supportability and signature ground tests and might be 12 months in duration. The third phase is a ground and flight test program that demonstrates functional characteristics and could be about 21 months in duration. The fourth phase is the LO/functional flight program and might be 24 months in duration.

System Payoff

Reducing the dependence on internal carriage allows a reduction in size and cost of the weapons system platform (aircraft). External carriage increases the numbers and varieties of weapons carried in highly survivable LO configurations which increases the effectiveness over aircraft with traditional internal bays; more weapons per sortie means fewer sorties. In addition, overall system costs are reduced because advanced multi-Service strike aircraft utilize common weapons carriage approaches and equipment for the varieties of weapons employed during a conflict.

WHY THIS TECHNOLOGY IS HIGH PRIORITY—
HIGH LETHALITY PAYLOADS

Program Objective Addressed	***Technical Approach***
• **Demonstrate enhanced lethality weapon effectiveness** • **1:1 comparison of advanced and projected JAST inventory weapons** • **Show high system payoff in terms of reduced weapon/aircraft size, lower cost, and improved lethality per unit volume**	• **Evaluate ongoing enhanced lethality approaches** • **Define requirements and do tradeoffs to select demonstration configurations** • **Fabricate weapon hardware using state-of-the-art technology** • **Perform essential ground and air drop tests**
Demonstration Elements	***System Payoff***
• **Develop objectives, test matrix** • **Define detailed test configurations** • **Fabricate several classes of weapon sizes to demonstrate size vs. lethality comparisons** • **Conduct arena/sled tests, as required** • **Perform selected flight tests**	• **Greatly reduced aircraft size for equal bomb effectiveness** • **Greatly increased effectiveness per sortie compared to fixed load of current weapons/bombs** • **Major cost savings due to reduced aircraft size** • **Leap ahead in effectiveness for JAST in conjunction with precision weapon navigation approaches**

The notion of weapons of the size or smaller than the current family that possess a major leap-ahead in lethality would have enormous leverage of JAST. Industry must be challenged to present technologies that can be proven to demonstrate new high-lethality attributes that would lead to reduced aircraft size and thereby reduced costs. A demonstration program would, for example, compare by test the effectiveness of 500, 1000, and 2000 pound class bombs with a new generation of more highly lethal payloads. The leverage, when implemented in conjunction with affordable precision navigation methods, will be a key attribute for new strike systems.

Overall weapons system affordability is enhanced by providing the platform a significantly more effective weapon which in turn allows the platform (the strike aircraft) to be reduced in size since it will have to carry fewer weapons to achieve its assigned target kills. The size reduction has positive affordability ramifications across all elements of life-cycle cost.

WHY THIS TECHNOLOGY IS HIGH PRIORITY—
WEAPONS INTEGRATION AFFORDABILITY

Program Objective Addressed	**Technical Approach**
• Reduce direct weapon integration time and cost • Develop standardized aircraft effects, weapon, software, and suspension and release equipment modeling and prediction tools • Provide confirmation of design maturity of developed tools with ground simulations and selected flight demonstrations	• Standardize weapon separation effects and ballistics based on common form factor weapons • Enhance tools and methods for vehicle flow field and separation predictions • Standardize weapon delivery software for reduced numbers of common form factor weapons and delivery modes • Standardize and characterize weapon suspension and release equipment performance to allow software mode selection and control • Create detailed weapon delivery simulation including aircraft separation, weapon performance, suspension and release equipment and delivery mode effects
Demonstration Elements	**System Payoff**
• Validate simulation tools with empirical data and predicted component performance • Validate suspension and release equipment, vehicle and weapon separation effects for selected weapons and delivery modes • Validate weapon delivery codes • Demonstrate selective weapons separation and performance characteristics, ballistics and software-driven hardware	• Reduced weapon integration • Reduced software development • Reduced cost to forward fit/reduced number of common form fit weapons • Reduced support equipment, technical publications, training and airlift costs

Program Objective

Certification of new or existing weapons is a significant weapon system acquisition and support cost driver. This cost is driven by the need to methodically characterize in software simulation and with actual weapon delivery flight testing weapon aerodynamic performance and ballistics in the aircraft near-flow-field effects under a variety of aircraft performance delivery conditions. Certification of new weapons on several aircraft which employ different delivery modes and utilize a variety of carriage and release equipment further drives the simulation and subsequent flight testing of the weapon. This technology demonstration should develop and validate enhanced simulation tools which characterize aircraft separation effects, weapon ballistics, software, and suspension and release equipment effects for selected weapons and delivery modes.

Technical Approach

The initial phase will develop a weapon integration simulation. This simulation will include mass properties and ballistics of a limited set of representative air-to-ground common form factor weapons, baseline aircraft near field flow field characteristics, and notional software performance-driven suspension and release hardware. This simulation will iterate representative weapon delivery simulations under differing aircraft/weapon and weapon delivery conditions to establish baseline time and cost data. Where appropriate, existing aircraft weapon certification data will be integrated into the simulation to reduce development time and cost and validate selected elements.

Demonstration Elements

The weapon delivery simulation must be validated using all available empirical data from wind tunnel, ground test, and flight. Flight test of selected weapons and delivery modes will be required to build confidence in the accuracy of the simulation.

System Payoff

Weapon System Life-Cycle Cost (LCD) should be significantly enhanced by this weapons integration simulation approach, which is based more on ground-based modeling and simulation than is the traditional approach which depends upon a methodical and costly weapon drops throughout the desired envelope. This approach has the potential to reduce required test flights and the associated weapon/aircraft/personnel/range costs. Fewer numbers of common form factor weapons and software-driven suspension and release equipment also should contribute to more affordable weapons integration. Reduced numbers of parameters in the weapons integration equation (ballistics and separation characteristics) should provide for more cost-effective modular software. Fewer weapons software modules and suspension and release equipment types also should contribute to significant reduction in acquisition, support and logistics costs.

KEY TECHNOLOGIES—
PROPULSION

	Priority Technology *
• **Enhanced Thrust/Weight and Durability**	**X**
Advanced Materials and Coatings	
Metal Matrix Composite Materials	
Advanced Cooling	
• Reduced Parts Count	
• Vaneless Turbines	
• Reduced Vulnerability to Battle Damage	
• **Reduced IR Design**	**X**
• Reliability Advances for Single-Engine Application	
• Life Prediction	
• **Thrust Vectoring Nozzle Design/Integrated Flight-Propulsion Control**	**X**

WHY THIS TECHNOLOGY IS HIGH PRIORITY—
ENHANCED THRUST/WEIGHT AND DURABILITY

Program Objective Addressed	***Technical Approach***
• **Develop light weight, high temperature materials and design methods to increase significantly engine thrust to weight and durability** – **Advanced materials and coatings** – **Metal metrix composite materials** – **Advanced cooling**	• **Validate basic manufacturing and design technology** • **Validate durability in core and engine tests** • **Validate flight test and production readiness** • **Perform aircraft mission/engine cost/performance analysis to determine optimum technology levels**
Demonstration Elements	***System Payoff***
• **Component development and test** • **Engine development ground test** • **Flight testing where appropriate**	• **Lower cost, smaller, higher performance aircraft** • **Greatly enhanced capability for vertical landing aircraft** • **Increased potential for engine commonality between aircraft due to low penalties for oversized engines**

Program Objective
Advanced materials and design methods could significantly increase thrust to weight and durability and reliability of engines for tactical aircraft. During the 1980's, airframers participated with engine companies to identify engine technology payoffs. These studies led to the cooperative industry/joint Services program IHPTET (Integrated High Performance Turbine Engine Technology) under which this engine development work is largely being done.

Technical Approach
The airframers evaluate reductions in airframe weight and cost as functions of engine weight, length, diameter, and fuel consumption. Evaluations may include new inlet/engine/nozzle layouts made possible by reduced engine weight and size. The evaluations can then quantify the cost benefits of candidate engine technologies.

Demonstration Elements
In particular, increased engine thrust to weight has high leverage in capabilities of Short Takeoff Vertical Landing (STOVL) aircraft. Some estimates predict 30 percent or more reduction in STOVL aircraft weight.

System Payoff
This technology will enable production of lower cost, higher performance aircraft, due largely to reducing aircraft size and weight needed for a given mission. Reduced aircraft weight reduces both airframe cost and required engine size at a constant aircraft thrust to weight.

Use of a common engine for different aircraft results in penalties with some aircraft being "overpowered." Compact, high-thrust-to-weight engines minimize these penalties and thus provide the opportunity to use engine commonality to reduce aircraft development and maintenance costs.

WHY THIS TECHNOLOGY IS HIGH PRIORITY—
REDUCED IR DESIGN

Program Objective Addressed	***Technical Approach***
• **Demonstrate a variety of technologies that reduce the IR signature of the propulsion system and thus enhance aircraft survivability**	• **Demonstrate hiding composite rear frames to shield the turbine from outside (IR)** • **Demonstrate special coating to reduce IR signature** • **Demonstrate Mil Power plume suppression** • **Evaluate designs to eliminate the need for serpentine-type inlets and nozzles**
Demonstration Elements	***System Payoff***
• **Perform IR measurements during ground test** • **Flight test of components appropriate to JAST-derived design(s)**	**Affordability** • **Less system complexity and lower system weight** • **Longer intervals between repairs** **Capability** • **Less performance loss** • **Reduce exposure to the threat and increase exchange ratio**

Program Objective
Future attack aircraft must survive in a high threat IR environment. Since propulsion systems are a key contributor to IR signature, further demonstrations are needed to maximize the effectiveness of hiding, cooling and coating.

Technical Approach
Propulsion systems must balance requirements for thrust, weight, size, performance and LO. The goal of this effort is to demonstrate IR control while minimizing the impact on other key propulsion parameters.

Demonstration Elements
IR ground test measurements are an extremely useful evaluation tool, establishing a baseline signature level, providing insights into various component contributions, and allowing a matrix comparison of the impact of various coatings and designs on baseline signature.

Flight testing is the ultimate proof of concept, demonstrating the value of the selected IR reduction techniques to the overall flight system signature. The flight test can also provide indications of the durability and supportability of the various IR treatments under operational conditions.

System Payoff

We must first demonstrate that challenging IR goals can be achieved with acceptable trades on other key design parameters. The specific IR technologies must perform as advertised in reducing system signature and improving survivability, but must also integrate well so as not to have a negative impact on other aspects of the flight system (performance, weight, supportability). As an example, IR coatings can also enhance the life of exhaust system parts by functioning as a thermal barrier coating, thus extending the time between repair intervals.

WHY THIS TECHNOLOGY IS HIGH PRIORITY—
THRUST VECTORING NOZZLE DESIGN/INTEGRATED
FLIGHT-PROPULSION CONTROL SYSTEM (IFPCS)

Program Objective Addressed	**Technical Approach**
• Optimize the use of integrated flight propulsion control to provide improved mission performance at reduced cost: – Lower cruise and climb fuel consumption – Combat performance at lower weight • Develop the control system architecture • Define nozzle concept • Determine the trades between level of integration and requirements	• Conduct trade studies to determine most affordable: – Flight/propulsion control integration – Nozzle/airframe integration • Capitalize on existing work (X-31, F-16 MATV, F-18 HARV) • Demonstrate feasibility and relevant cost savings • IR suppression
Demonstration Elements	**System Payoff**
• Simulation of flight/propulsion control integration • Ground test of nozzle/airframe integration concept • Flight test of selected affordable solution	• Affordable Design & Acquisition – Integration reduces design effort – Optimized cruise performance for reduced drag/weight R&M, cost • R&M, Supportability, and Survivability Cost Reductions – Less complicated system (e.g., single control system) – Fuel cost savings – Reconfiguration – Tail reduction/elimination

Program Objective

Integration of a multi-axis thrust vectoring nozzle with the conventional aerodynamic control effectors could offer substantial improvements in aircraft affordability through improved mission performance at reduced operating costs. This emanates from the capability to optimize the aerodynamic configuration for minimum fuel consumption while still performing all mission tasks. Additionally, the concept provides higher operability levels by enabling more control system reconfiguration as mission demands change. The objective of this program is to demonstrate improved mission performance at reduced cost through optimized use of integrated flight propulsion control. Supporting objectives are development and definition of nozzle concepts, control system architecture, and definition of the appropriate level of integration.

Technical Approach

The recommended technical approach is to initially demonstrate feasibility and relevant cost savings through simulation, followed by ground tests of an integrated nozzle airframe configuration, leading to a JAST flight test demonstration. The simulation and design trade studies will capitalize on the existing ground and flight test database from the X-31 program. Moreover, a database to support implementation of the technology into a JAST flight demonstrator will be validated by flight test using an existing asset (e.g., X-31, F-18 HARV, F-16 MATV) and correlating the resulting data to ground test and simulation.

Finally, the approach will allow IR suppression to be shown by optimally blending conventional control with the vectoring nozzle to minimize or specifically orient the engine exhaust IR signature.

Demonstration Elements

The initial element of the flight propulsion control integration demonstrations are simulations. These simulations start with models to define the control schemes and architecture. They then evolve to real time activities (without hardware-in-the-loop) to define system requirements. These requirements should be verified by selective flight testing using an existing test bed such as X-31, F-18 HARV, or F-16 MATV. Finally, as the JAST demonstrator design matures, real-time hardware-in-the-loop simulation can assist in verifying system design viability for flight qualification in parallel to the simulation activities. The nozzle airframe integration viability will be demonstrated in ground test on both propulsion test stands and in structural laboratories. The final demonstration element is that of flight testing the integrated system on a JAST flight demonstrator.

System Payoff

The integrated design approach reduces design and acquisition costs through reduction of design effort and reduced drag and weight. R&M, supportability, and survivability costs are reduced because the integrated systems are less complicated and the aerodynamic and weight reductions save fuel. The integrated design also supports the viability of tailless aircraft designs with its associated cost saving.

KEY TECHNOLOGIES—
AVIONICS (INCLUDING SOFTWARE)

	Priority Technology
Digital Communications Links from On- and Off-Board Sensors	X
Towed Array Jammers	
VHSIC and MMIC Insertion	
Fiber Optic High-Speed Data Bus and Optical Switch Networks	
Integrated RF Sensors	X
Integrated EO Sensor Architecture	X
Multi-Function Apertures	X
Anti-Jam GPS	X
Advanced Avionics Architecture—Hardware and Software	X
Open Avionics Architectures to Accomodate Commercial Processor Components	X
Common Integrated Processing and Processors	X
Virtual and Rapid Prototyping of Software	X
High Reliability Packaging and Maintenance-Free Avionics	
Reusable Software (Modular Software)	X
Sensor Fusion/Decision Aids	X
Information Fusion	X
Rapid Reconfigurable Crew Stations	
Photonic Material & Devices/Commercially Available Avionics	
Non-Cooperative Target Recognition	
Helmet-Mounted Sight/Display	
Advanced Information Architecture	
Software Environment and Design Tools (e.g., Case)	
Modeling and Simulation—Electronic Environment	
IPPD/CE/TQM—Management Environment	
Rapid Software Prototyping & Architecture Simulation	

WHY THIS TECHNOLOGY IS HIGH PRIORITY—
DIGITAL COMMUNICATIONS LINKS FROM ON- AND OFF-BOARD SENSORS

Program Objective Addressed	***Technical Approach***

• **Increase effectiveness by maximizing use of off-board information**
• **Provide real-time robust information to shooters**
  – **Intel, surveillance, tactical**
• **Deliver next silver bullet**
  – **Information superiority**
• **Establish OTH/AJ/LPI communications**
	• **Define information architecture for intra-flight strike fighter aircraft**
	  – **Concept of operations**
	  – **Comm. architecture/connectivity**
	  – **Information transfer requirements**
	• **Recommend concepts for inter-platform communications enhancements**
	• **Lab demonstration/simulation**

Demonstration Elements	***System Payoff***
• **Requirements/concept of operations development** • **Link requirements and development** • **Simulations/risk reduction** • **Demonstrations**	• **Enhanced mission effectiveness** • **Reduced platform fly-away cost** • **Reduced information latency/redundancy** • **Common/joint links with seamless interconnectivity** – **Interoperability (USAF, USMC, USN, USA, NATO,....)**

The most difficult part of this problem is establishing the correct information/communications architecture between the strike aircraft and the various correlation centers. AWACS, Joint STARS, and Rivet Joint use their existing JTIDS/TIBS connectivity to pass information between platforms. AWACS uses TADIL A to communicate to all fighters within their line of sight. Joint STARS uses an IDM link to pass target-specific information to the fighters. Rivet Joint uses JTIDS, TADIL A, or TADIL C to pass information to the fighters.

An integrated approach is required to minimize the fly-away communications cost of a multitude of strike/fighters vs. limited numbers of support assets.

WHY THIS TECHNOLOGY IS HIGH PRIORITY—
INTEGRATED RF SENSORS

Program Objective Addressed	***Technical Approach***
• Develop and demonstrate an integrated RF sensor system utilizing shared, common RF modules and a sensor resource manager to perform CNI, EW, and radar functions	• Leverage PAVE PACE/ISS results to refine requirements and allocation to RF modules • Refine ISS design concentrating on frequency plan, module types, and standard interfaces • Design, develop, and test RF SEM-E modules (i.e., converters, receivers, preprocessors, etc.) • Develop a sensor resource manager • Integrate components and demonstrate the ISS' ability to perform CNI, EW, and radar functions
Demonstration Elements	***System Payoff***
• Verify ISS system design, module design, and an overall integration approach • Test ISS ability to meet allocated requirements • Prove the ability of a sensor resource manager to meet simultaneity requirements with shared assets • Verify potential cost savings of ISS over other approaches • Provide low risk ISS system for EMD program	Affordability • Avionics at half the cost of current solutions • Common modular approach improves economies of scale • Resource sharing reduces total number of modules • Reconfiguration significantly improves system reliability Capability • Improved RF compatibility through lower level asset control • Improved situational awareness through sensor fusion ***ISS Substantially Reduces Cost, Weight, and Volume Over Current Generation RF Sensor System (i.e., ICNIA, INEWS, Radar)***

Program Objective

Historical data show that sensor systems account for as much as 65 percent of the total avionics flyaway costs. In light of this fact, PAVE PACE evolved the JIAWG/Pave Pillar avionics architecture by extending the same concepts into the RF sensor systems. The objective of the ISS Program is to develop an ISS and demonstrate the ability to simultaneously perform CNI, EW, and Radar functions.

Technical Approach

Leveraging the results of the PAVE PACE program, the mission requirements and the allocation to the ISS and subsequently to the individual RF modules would be refined. The RF modules (i.e., switches, converters, receivers, preprocessors, modulators, etc.) would be built as standard SEM-E modules and tested as stand-alone entities to ensure requirements were met. In parallel with hardware development, a Sensor Resource Manager (SRM) would be designed, coded, and tested. RF modules would be integrated as threads first (i.e., CNI, EW, Radar) and finally as a complete system with the SRM. The demonstration would include CNI, EW, and Radar functions operating simultaneously on the time-shared RF modules.

Demonstration Elements

The technical approach results in a verified ISS system design including the control scheme, a standard frequency plan, and the correct partitioning within the hardware. With respect to RF system performance, detailed testing ensures module, thread, and system performance including noise figure, dynamic range, etc. The final demonstration proves the ability of a Sensor Resource Manager (SRM) to meet all simultaneity requirements with shared resources and the ability to detect, isolate and reconfigure the system in the presence of faults. The net result is a low risk, affordable sensor system ready to be transitioned into an EMD program.

System Payoff

The PAVE PACE program has shown that an advanced architecture, and in particular an Integrated RF Sensor System (ISS), can achieve avionics at 1/2 the cost, 1/2 the weight, and 3 times the reliability when compared to current generation ATF avionics. Specifically, ISS is able to achieve full RF performance at savings of $5.1M/shipset, compared to F-22-class technology, through common, time-shared RF electronics. For example, for a conceptual fighter/attack aircraft, ISS reduced the total number of RF modules from 345 to 169 over comparable F-22-based sensor systems. ISS promises to provide affordable avionics for future aircraft as well as providing cost and reliability improvements for today's tri-Service front line aircraft (F-15s, F-16s, F/A-18s, C-17s, B-1s, B-2s, AH-64s, etc.) through module-level technology insertion. However, transition opportunities must have a solid foundation in R&D investment. Working with various government program offices, it is apparent that ISS modules can affordably solve key parts obsolescence issues and provide long-term avionics growth through an open architecture approach. Aircraft program managers are counting on ISS R&D investment to reduce risk by addressing the technical issues and proving the ISS concept in the laboratory.

WHY THIS TECHNOLOGY IS HIGH PRIORITY—
INTEGRATED ELECTRO-OPTIC SENSOR ARCHITECTURE

Program Objective Addressed	***Technical Approach***
• **Develop an integrated electro-optic (EO) sensor architecture for tactical aircraft** – **Shared Aperture Sensor System** – **Distributed Aperture and Infrared Sensor System** – **Integrated Core Processing**	• **Benchmark multi-function electro-optic (EO) sensor design configurations** – **Distributed Aperture Infrared Sensor System** – **Shared Aperture Sensor System** • **Benchmark Commercial Off-the-Shelf processor design** • **Demonstrate utility, operability of modular and open-system architecture**
Demonstration Elements	***System Payoff***
• **Develop and test EO sensor configuration** • **Develop open-system processor architecture** • **Demonstrate modularity and operability (IEOSS)*** • **Conduct integrated demonstration with cockpit** • **Flight test and transition EO sensor architecture** * Proposed US Navy '97 ATD: Integrated Electro-Optic Sensor Suite	**Affordability** • **Reduced number of sensor design configurations** • **Greater hardware commonality** • **Lower EO sensor life-cycle costs** • **Enhanced reliability and supportability** **Capability** • **Upgrades to existing aircraft systems** • **Increased coverage** • **Improved pilot vehicle-sensor interface** • **Improved situation awareness** • **All aspect fire control** **Supports Laser Eye-Protection Design Concepts**

Program Objective

Future aircraft will require a cost effective approach which will satisfy pilot's visual, safety, situation awareness, and aircraft installation requirements. Commercial and military aircraft are increasingly making use of various electro-optic (EO) sensors to enhance the pilot's awareness of the vehicle status and external environment. Taking advantage and building upon the development of distributed, wide, field-of-view sensors such as Distributed Aperture Infrared Sensor System (DAIRS), and shared aperture high-performance sensors such as Shared Aperture Sensor System (SASSY), along with commercial off-the-shelf processor technology, can satisfy both the offensive and defensive EO operational requirements.

The objective of this program is to develop and transition an advanced EO common module architecture that creates a comprehensive global scene for navigation and missile warning while also satisfying the tactical long-range targeting, off-boresight designation and tracking operational needs.

Technical Approach

Integrated EO Sensor Architecture (IEOSA) leverages off Navy programs such as Cyborg Eye (aka Electronic Imaging System (EIS)), DAIRS, and SASSY developments. The approach will benchmark the multi-function/waveband sensor configuration which will best satisfy the EO operational needs. Commercial Off-The-Shelf (COTS) processor architecture also will be evaluated and a modular open-system design benchmarked. This architecture also will build upon the developments under PAVE PACE. These standards can then be integrated to achieve the overall IEOSA. IEOSA should be flight tested to effectively demonstrate the full operational utility and modularity to transition into current and future aircraft.

Technical issues to be addressed are the EO defensive and offensive operational performance needs. Long-range high-performance offensive operations may require the large aperture size and multi-waveband system similar to the SASSY program efforts. Close-range defensive operations may best be satisfied by a

DAIRS type system. These sensor suite and operability needs may be addressed with a proposed '97 Navy Integrated EO Sensor Suite (IEOSS) Advance Technology Demonstration (ATD) program.

Demonstration Elements

The following are demonstration elements for an integrated EO sensor architecture:

- Develop and test EO sensor configuration
- Develop open-system processor architecture
- Demonstrate modularity and operability (IEOSS)
- Conduct integrated demonstration with cockpit
- Flight test and transition EO sensor architecture

System Payoff

IEOSA has several aircraft cost and performance benefits over current federated EO approaches. IEOSA focuses on a standard EO sensor design configuration with a common module processor architecture. Because the number of sensor design configurations and hardware will be reduced and fed into a common processor architecture, there will be a significant improvement in the overall life-cycle cost for current and future aircraft.

Performance advantages are multi-faceted because of the open-system architecture. This highly integrated architecture design also incorporates the use of the helmet display for viewing the global sensor images and enhancing situation awareness. Furthermore, designing the sensor configuration with laser hardening, the pilots can be protected from laser threats with an opaque visor and relying on IEOSA for viewing the outside world.

WHY THIS TECHNOLOGY IS HIGH PRIORITY—
MULTI-FUNCTION APERTURES

Program Objective Addressed	***Technical Approach***
• **Develop multi-function aperture technology, design requirements, and integration concepts to meet JAST requirements**	• **Define candidate mission/aircraft requirements** • **Derive avionics functional requirements** • **Flow down requirements to RF/EO apertures** • **Define minimum number of apertures/types** • **Assess aperture technology maturity** • **Develop LO integration concepts** • **Define aperture/avionics interface** • **Perform aperture performance/RCS testing**
Demonstration Elements	***System Payoff***
• **Demonstrate tactical capability of functional fields of regard in virtual warfare center** • **Measure RCS of aperture and integration concepts** • **Measure isolation between RF aperture functions** • **Measure EO transmissivity and antenna gains** • **Demonstrate simulataneous multi-function aperture operation with avionics**	**Affordability** • **Fewer antennas yield decreased integration costs** • **Less maintenance required** • **Affordably adding new functions to existing aircraft** **Capability** • **Lower overall RCS to meet advanced RF signature goals** • **Improved functional utility over larger field of regard** • **Resource timeline management improves EMC** ***Multifunction Apertures Promise Reduced Weight, Volume, and Life-Cycle Cost***

Program Objective

Aircraft apertures, both RF and EO, contribute significantly to the Radar Cross Section (RCS) of a vehicle. LO aperture life-cycle costs are high due to field maintenance and replacement of LO apertures. In the future, it will become increasingly difficult to balance avionics performance and low observables as basic LO airframe technology advances. The life-cycle cost of LO antennas will continue to increase unless new integration approaches are developed that reduce the number of apertures and protect the aperture from damage. Multi-function Apertures (MFAs) are one solution to decreasing the RCS and number of apertures on advanced aircraft. Antenna/radome and window technology can be developed to perform multiple functions in a single aperture. Technical issues such as functional simultaneity, time sharing of apertures, antenna gain and window transmissivity, cost, weight, size, power, reliability/maintainability, and integration on the aircraft and into the avionics architecture must be considered during the MFA technology development. Although the F-22 has taken the first steps in applying MFAs, many issues remain to address the full range of RF functionally and frequency bands.

Technical Approach

Enhanced aircraft survivability and weapon system effectiveness depend on development of low RCS apertures with improved sensor performance. Aircraft missions and aircraft requirements such as the level of stealth are first flowed down to avionics requirements and subsequently to aperture requirements. The aperture concept should include use of MFAs located in a few ideal locations to meet field-of-view, low observables, and avionics performance requirements simultaneously. A key issue is defining the minimum number of common aperture types to satisfy the requirement, i.e., defining six antenna types that result in a total of 12 apertures is probably more cost effective than is reducing the total number to a total of ten apertures, but all of different types. (Note that establishing the optimum types involves establishing notional aircraft and resulting aperture configurations that satisfy requirements.) Technologies that meet this and other needs must be examined for maturity and developed as part of the overall aircraft weapon system design. To lower aperture life-cycle cost while improving avionics and RCS performance requires improved integration of apertures with the airframe, weapon system functional requirements, and avionics architecture. Fewer antennas, and integration of apertures and RCS treatments in the skin, are required. Multi-function aperture concepts will be developed to be compatible with mission requirements and the avionics interface. Tests are then performed in anechoic chambers and antenna ranges to validate performance.

Demonstration Elements

The first demonstration element is to use the Virtual Warfare Center to validate the tactical capability of candidate aperture configurations during the initial configuration definition phase, prior to selection of technologies. For example, significant savings may result if performance trades are made in the performance at some aspect angles. This is very technology-dependent. The RCS of the aperture/aperture integration of resulting configurations can then be measured in an anechoic chamber. Performance, including isolation, is measured on the antenna range. The antenna range is also used to demonstrate simultaneous operation of all the required functions when connected to appropriate avionics. This is required to fully validate the isolation between the various functions of the multi-function aperture.

System Payoff

Increased functionality demands a larger number of apertures and more area "real estate" or extensive use of MFAs. For instance, the F/A-18 already has over 35 antennas, with plans for adding more avionic sensors. Limited real estate is available on tactical aircraft that meets the field-of-regard requirements with a large number of antennas. The MFA approaches promise to reduce the overall system integration and life-cycle costs, including maintainability. New lower risk MFA technologies may change the current methods of system integration for tactical fighter avionics and thus improve overall RCS.

WHY THIS TECHNOLOGY IS HIGH PRIORITY—
ANTI-JAM GPS

Program Objective Addressed	Technical Approach
• Provide jamming immunity for the low-cost GPS/inertially guided weapon systems • Provide GPS acquisition and tracking capability at high jamming levels • Demonstrate low-cost precision guidance system ready for EMD	• Lowest cost closely coupled GPS receiver and INS for multi-acquisition/track aiding • Multi-channel and multi-correlator receivers (receiver agility) • Fast response multi-node steerable nulling antenna array • Low power strapdown seeker for autonomous end game
Demonstration Elements	**System Payoff**
• Twenty-four (24) month program to make ready for production and reduce cost of current NDI technology • Laboratory integration of guidance system • Captive flight testing • Free flight demonstration testing • All against simulated jamming threat	• Reduced cost of GPS/INS hardware • All-weather GPS weapon immunity to future jamming threats • Fast GPS acquisition after missile launch • GPS guidance accuracy available all-the-way to target • No data link required • Reduces requirement for terminal guidance – Lower cost weapon system

Program Objective

The objective is to provide enhanced overall weapons system effectiveness and reduced cost by using a low cost anti-jam guidance system for weapons. GPS/INS technology provides very accurate mid-course and terminal guidance and is resistant to low power jamming. The goal of this program is to reduce the cost of a present GPS/INS by a factor of 2 and provide resistance to high power jamming levels.

Technical Approach

The approach is to use the results of the Tactical High Altitude Anti-Jam GPS (THAAG) program as a starting point. Lower cost GPS receivers, which are closely coupled to the INS, are becoming available. These low-cost GPS/INS units will be used with current high-power anti-jam techniques to form an integrated highly accurate, anti-jam mid-course, and terminal guidance system. A lower power low-cost seeker will be integrated into the weapon for the terminal phase. Performance data from flight tests will be evaluated along with cost data, and a plan for EMD will be provided.

Demonstration Elements

The overall demonstration approach is to integrate the low cost GPS/INS with high-power anti-jam capability and the low-cost seeker into an existing air-to-ground weapon. The initial demonstration element is in a ground-based environment primarily to show integration of the guidance system. The integrated air-to-ground weapon will next be tested and demonstrated in a captive flight test environment. The third element is a free flight demonstration, performed on a test range with high-power jamming and fixed targets.

System Payoff

The anti-jam guidance system will take advantage of available low-cost GPS receivers integrated with the INS and present high-power jam resistant techniques to provide a very accurate, low-cost guidance system mid-course and terminal guidance. The resulting improvement in terminal guidance accuracy reduces the power requirements for the autonomous end game terminal seeker, thus reducing the cost of this seeker.

WHY THIS TECHNOLOGY IS HIGH PRIORITY—
ADVANCED AVIONICS ARCHITECTURE—HARDWARE & SOFTWARE

Program Objective Addressed	***Technical Approach***
• **Develop an open architecture for avionics that provides for growth updates to sensor and processing hardware with software changes** • **Leverage advanced commercial technologies**	• **Develop industry-wide standard avionics architecture that assumes fusion of vehicle and stores management, COM/NAV, sensors and defensive systems** • **Target reductions in power, weight and cost of 50 percent** • **Provide for maximum use of commercial products**
Demonstration Elements	***System Payoff***
• **Develop appropriate sensor/processor multi-chip module (MCM) standardization** • **Ground test of bus and modular architecture for selected elements to validate timing and bandwidth** • **Flight test of JAST avionics test bed to demonstrate full capability including representative upgrades**	• **Reduced acquisition costs** • **Reduced supportability costs** • **Fielded technology kept more current**

The pursuit of an Advanced Avionics Architecture Technology Program that leverages on commercial avionic/electronic technologies promises to provide excellent payoff for military tactical systems in terms of reduced acquisition costs, lower supportability cost, and increased performance.

This initiative is consistent with the vision for a national production base that is built on unified commercial/military technology programs. A vision that has been defined and advocated by new policies will allow the acquisition system to apply modern commercial products, processes, practices and standards with greater ease.

Many technologies involved in a modern avionic architecture are driven by initiatives and investments in commercial state-of-the art electronic/computer industries that outpace DoD progress and investment.

Examples include:

- Digital Computers, from general purpose to massively parallel super computers
- Signal Processing
- MMIC Technologies
- Digital Communications
- Photonics
- Software Technologies

Developments in each of these areas is rapid and dramatic. While the Department of Defense will continue to have "defense-unique" requirements, it must simultaneously learn to better apply modern commercial products, process and practices to DoD needs.

The technologies involved in Advanced Avionics Architecture are an excellent application of this new paradigm, and programs centered about a new industry-wide standard architecture can be models for leveraging commercial investments and initiatives for defense applications.

WHY THIS TECHNOLOGY IS HIGH PRIORITY—
OPEN AVIONICS ARCHITECTURES TO ACCOMODATE COMMERCIAL PROCESSOR COMPONENTS

Program Objective Addressed	***Technical Approach***
• **Use evolving commercial standards in hardware and software interfaces to increase the availability of commercial components in the processor, and to reduce the 'cost of entry' for open architecture modules available in next-generation avionics systems**	• **Using the common integrated processor as the point of departure, compare high bandwidth interconnect technologies (such as SCI) for suitability in avionics real time applications** • **Perform cost effectiveness analyses to quantify production and support costs of open architecture interconnect options** • **Perform operating system interface analyses and assist in POSIX RT definition for embedded avionics applications** • **Identify key drivers and risk reduction areas**
Demonstration Elements	***System Payoff***
• **Trade studies and COEAs** • **Risk reduction demonstrations** • **Refine EMD baseline**	**Affordability** • **Reduced development cost through the use of commercial standards** • **Potential for greater 'market-driven' upgrades and reduced cost of future P3I** **Capability** • **High bandwidth 'information superhighway' class interconnection to handle increased sensor I/O data rates**

The revolutionary re-use of common components in avionics gives more respect to total system cost than to optimized performance. Re-use of custom MIL-SPEC components results in one large increment of system cost-savings; re-use of commercially available components achieves another large increment of savings.

The common integrated processor (CIP), which makes extensive re-use of common components, is being developed by the F-22 program, about 10 years ahead of JAST. The Joint Program Office has established the F-22 as the point of departure for its avionics, the benchmark reference point from which excursions may be made into new technology. CIP has made extensive re-use of commercially available components—microprocessors, DSP chips, memories, gate arrays, etc. These components are specially processed, packaged, and worked into designs that reflect CIP's peculiar application domain—embedded military avionics. The potential, large savings encourage exploration of additional savings from re-use of other commercial developments, at a higher level of integration, in this case, standard communication protocols (e.g., the Scaleable Coherent Interface (SCI)) and standard operating system interfaces (e.g., POSIX).

CIP was designed to address the peculiar and revolutionary common integrated processing needs of embedded military avionics, thus CIP combines attributes unusual in commercial (and even in most military) domains. Among these are multi-level security, software integrity, strict message-oriented interprocess communication, service efficiency, integrability, maintainability, and careful design for availability. Therefore the technical approach is to explore insertion of new interface technologies into CIP while conserving its valuable domain-specific attributes. As has been true of the commercial hardware and software components used in CIP, the commercial interfaces may need special processes, packaging, and design features to reflect JAST's peculiar application domain.

The system payoffs for success here go beyond those enjoyed by F-22's initial use of commercial components in CIP (largely, reduced hardware development cost and economies of scale in parts cost). Interface commonality with commercial products promises repackaging of commercial hardware at the module level, instead of the chip level, and application development systems and laboratory demonstrations with substantial commercial hardware and software content.

WHY THIS TECHNOLOGY IS HIGH PRIORITY—
COMMON INTEGRATED PROCESSING & PROCESSORS

Program Objective Addressed	**Technical Approach**
• Reduced avionics cost, weight, volume, and power through the use of an open systems architecture, common-module-based, secure, real time common integrated processing suite	• Develop P3I roadmap with enhanced open-architecture attributes • Conduct cost vs. capability trade studies using the common integrated processor as the baseline. Trades to include module type reduction, advanced packaging (chip-on-board), two vs. one level maintenance, ... • Define risk reduction demonstration plans
Demonstration Elements	**System Payoff**
• Trade studies and COEAs • Risk reduction demonstrations • Refine EMD baseline	**Affordability** • Reduced production costs • Reduced logistics support **Capability** • Reduced weight, volume & power • Increased throughput & memory • Increased interconnection bandwidth for advanced sensors • Improved sensor fusion processing of on-board and off-board data sets

Physical integration of processors saves by sharing physical support structures (such as enclosures) among processors and by collocating the processors, reducing the costs of connecting them.

Functional integration of processing saves by sharing physical processor resources (such as backplane buses or processor modules) among processing tasks, reducing the costs of interprocess communication. Functional integration is an avionics industry revolution. For example, software created by an EW vendor and a radar vendor may now be integrated together into a single processor box, sharing hardware and software resources provided by other vendors; whereas conventionally the EW vendor and the radar vendor, individually, provided all the resources needed for one function, and each was held individually accountable for successful implementation.

Commonality is an attribute of re-use. When common hardware and software components can be suitably used for disparate functions, instead of function-specific components, development costs fall, improved economies of scale reduce production costs, and life-cycle costs decrease because there are fewer component types to be supported. Re-use of common components requires that the interfaces among components be standardized. When diverse agencies and companies are expected to re-use common components, the standards for them are best defined, supported, and controlled openly, with fairness perceived by all. Commonality is an avionics industry revolution. For example, the common hardware and software components available for assembling a function are now compromise designs that give more respect to total system cost (given satisfactory performance) than to optimized performance; whereas, conventionally function-specific components were customized to optimize functional performance for which the function vendor was held individually accountable.

The common integrated processor (CIP), which will provide these characteristics uniquely in the embedded avionics domain, is being developed by the F-22 program, about 10 years ahead of JAST. The Joint Program Office has established the F-22 as the point of departure for its avionics, the benchmark reference point from which excursions may be made into new technology. The valuable technologies and methodologies of CIP were forged in the foundry of the industry revolutions. Its design and process characteristics address the nature of the military avionics business and the system integrator's nightmares. They should not be wastefully re-invented for JAST, but should be carried forward, from the F-22 point of departure, as CIP evolves into whatever JAST avionics processors will be.

The technical approach is to map out CIP's evolution from its first implementation of the F-22, analyze the benefits and costs of various technical opportunities, and define which of them will justify investment in maturation and demonstrations of reduced risk.

The system payoffs are increments in the initial benefits the F-22 will enjoy through common integrated processing.

WHY THIS TECHNOLOGY IS HIGH PRIORITY—
VIRTUAL AND RAPID PROTOTYPING FOR SOFTWARE

Program Objective Addressed	**Technical Approach**
• Reduce cost and schedule risk associated with avionics software development by developing and demonstrating rapid prototyping processes, techniques, and tools	• Select tools and define prototyping environment • Define and integrate prototyping process into the software engineering process • Exploit reusable software • Integrate auto-coded and manually developed software
Demonstration Elements	**System Payoff**
• Environment definition • Define process • Integrate guidance, navigation & control software • Establish rapid prototyping demonstration	• Lower acquisition costs • Reduced changes in requirements • Critical software proven early • Eliminate software redesign due to verified requirements • Reduced duplication in software development • Reduced software development time

Program Objective

Software, a top-priority critical DoD technology, is a rapidly increasing cost to weapons system development. Software prototyping and automatic generation of Ada in high-performance advanced software architectures will increase the affordability and capabilities of our future products and upgrades. The objectives of this program is to produce a method for performing rapid prototyping and automatic code generation leading to improved productivity and reduced costs.

Technical Approach

The appropriate tools for rapid prototyping must be investigated/evaluated/enhanced. The industry has progressed to the point that rapid prototyping/code generating tools for specific domains are available. They have the potential of providing more affordable software prototypes and eventually production software. A set of tools is being identified and supporting utilities developed to create a prototyping environment.

With the advent of resuable software parts comes the need to incorporate those reusable parts into the prototyping system. A capability is needed to automatically encapsulate reusable parts to be incorporated in the rapid prototyping process.

A potential advantage to rapid prototyping is the use of the code produced in a production mode. To facilitate that reuse, the need exists to integrate automatically generated code produced in the rapid prototyping process with code that was produced through a separate process, such as manual coding. We need to determine the best mechanism for that integration to produce the software that not only meets functional requirements, but also performance requirements.

Demonstration Elements

A plan has been devised to develop and validate the rapid prototyping process. An initial software prototyping process (RAPIDS, Rapid Prototyping and Integrated Design System methodology) was successfully demonstrated on the DC-X program. This methodology provides a very good foundation for defining the processes to be used on future programs. New toolsets and processes can be enhanced and developed with feedback from the project community. Key programs should be defined as pilot efforts for demonstrating the prototyping processes. Costs for those efforts will be compared to costs without these processes to determine benefits.

System Payoff

Cost and time savings are expected to occur because integration engineers will be simulating the requirements of the system at an earlier stage and verifying the requirements. This will reduce the need for requirements changes and therefore software re-design. The simulations are developed as a by-product of this effort.

WHY THIS TECHNOLOGY IS HIGH PRIORITY—
REUSABLE SOFTWARE (MODULAR SOFTWARE)

Program Objective Addressed	Technical Approach
• Reduce program software development cost and increase system reliability through reused software. Ultimate goal is software reusability across platform types.	• Continue development of reusable software architecture/framework • Develop tools to ease carry-over of legacy software • Transition to more object-oriented/encapsulated design to isolate platform dependencies of the software
Demonstration Elements	**System Payoff**
• Reverse-engineering tools • Architecture/frameworks • Object-orientation, encapsulation	Affordability • Reduced amount of new development work • Object orientation reduces amount of work needed to adapt software Reliability • Reused software is more reliable than is new software • Framework provides commonly needed Services, enforces separation of concerns • Object orientation/encapsulation reduces software coupling and side effects

Reusable software benefits the JAST Program because it (1) reduces program cost since reusable software requires a small adaptation and reintegration cost, compared to the large cost to develop software from scratch, and (2) increases system reliability since reusable software has been thoroughly tested on other programs and most or all software errors removed.

Software architectures (application framework) have been successfully applied in multiple applications. Transition paths to future radar systems (e.g., with electronically scanned arrays) have been identified and are prototyping. There is a large amount of already-working avionics software that is potentially reusable, except that it is written in languages other than Ada. There are working software programs that automatically translate JOVIAL to Ada that have been demonstrated. Current avionics software systems typically use a large shared-memory database for communication among software functions. This approach has been very successful in building high-performance real-time systems, but has the drawback of not being easily maintainable or portable to other uses. Companies have had success with developing object-oriented software that encapsulates the hardware dependencies of the underlying platforms.

In summary, several significant accomplishments in the area of software re-use have been made. This technology helps JAST by taking advantage of already-proven techniques to increase software affordability and reliability.

WHY THIS TECHNOLOGY IS HIGH PRIORITY—
SENSOR FUSION/DECISION AIDS

Program Objective Addressed	***Technical Approach***
• Enhance long-range target detection, track, recognition and identification • Aid crew in assimilating and reacting to sensor data both rapidly and correctly	• Develop target acquisition/automatic target recognition concepts • Develop NCTR/BVRID system concepts and architectures • Implement single sensor enhancements and multi-sensor preprocessing and fusion • Augment on-board systems with cooperating platforms and UAVs
Demonstration Elements	***System Payoff***
• Algorithm/architecture/controls and displays definition • Algorithm development and code • Controls and displays development • Development of sensor fusion validation techniques • Virtual simulation/prototype • Flight test	• Higher P_s, P_k • Increased situation awareness • Low probability of intercept (LPI) operation • Improved cooperative operations (sensor cueing) • Increased detection range • Extended target timelines • Improved target state estimate (CLO) • Reduced crew workload—single seat operations • Reduced recurring system cost

Target detection, recognition, and hand-off to weapons are critical mission functions where pilot/crew performance directly affects mission effectiveness and survivability. The time required for the pilot/crew to search, detect, acquire/recognize, and attack the highest priority target(s) often exceeds the threat's time to react, thus reducing survivability. It is this segment of the mission that excessively burdens the pilot and requires a second seat. Advanced sensor developments have extended the pilot/crew ability to see, but his ability to process and act on what he sees has now become a critical element in accomplishing mission objectives and will become more critical in the future.

These advanced sensors will produce large amounts of target and threat-related data. Software (algorithms) and related improvements in control/display technologies will be required to aid the pilot/crew in assimilating and reacting to these data, both rapidly and correctly.

WHY THIS TECHNOLOGY IS HIGH PRIORITY—
INFORMATION FUSION

Program Objective Addressed	***Technical Approach***
• **Fuse Threat Information** – **Preflight INTEL data (Mission Plan System)** – **In-flight updates (SATCOM, TRAP, TIBS,...)** – **On-board sensors** • **Fuse Target Data** – **Pre-mission plan (MPS)** – **Time-critical target redirection/close air support (CAS) vector** – **On-board sensors and overheads/UAVs**	• **Define information/data availability and quality** • **Develop association/correlation/fusion concepts** • **Demonstrate fusion functionality and effectiveness in virtual simulation/prototype** • **Spring-board off TALON xxx and WARBREAKER efforts**
Demonstration Elements	***System Payoff***
• **Requirements/concept of operations development** • **Algorithm development and code** • **Virtual simulation/prototype** • **Demonstrations/refinement**	• **Single crew operation** • **Increased aircraft survivability** • **Increased situation awareness** • **Enhanced mission effectiveness** • **Supports covert operations** • **Ensures element of surprise** • **Reduces on-board sensor requirements**

The fielding of reconnaissance, intelligence, surveillance, and target acquisition (RISTA) systems have improved the quality of data being provided to theater commanders. These systems are well represented at the theater level by Joint STARS, AWACS, and Rivet Joint, although there are a plethora of additional systems that provide information at different levels.

The ability to directly process this information (in a usable fashion) in the strike aircraft would provide greater mission flexibility and improved situational awareness to the flight crew over existing methods. The utilization of this off-board information could also reduce the on-board sensor requirements, resulting in lower strike fighter acquisition cost.

KEY TECHNOLOGIES—
MANUFACTURING METHODS AND TOOLS

	Priority Technology
Paperless Design to Manufacturing	**X**
Minimize Hard Tooling/Low-Cost Tooling	
Leveraging Composites for Manufacturing	**X**
Reduced parts Count through Design	**X**
Revolution in Quality Inspection Associated with Paperless Drawing and Manufacturing "Tape"	
Quality Control on "Fabrication/Machine" Software	
Simulation Tools to Model the Manufacturing Processes	
Common Subsystems/Components	**X**
Virtual Factory	**X**
Virtual and Rapid Prototyping Manufacturing/Assembly	
Advanced Fabrication Methods (Drilling, Joining)	
CAD/CAM Simulation of User Requirements	

WHY THIS TECHNOLOGY IS HIGH PRIORITY—
PAPERLESS DESIGN TO MANUFACTURING

Program Objective Addressed

A common master digital database across design, tooling, fab and assembly that extends to suppliers and customers

- **Reduces cost and risk**
- **Reduces overhead**
- **Reduces changes due to error**
- **Helps manage required change**

Technical Approach

- **Evolve into fully digital product data base followed by demonstration on F-18 and/or F-22**
- **Bring remaining JAST suppliers into program**
- **Use full-up digital data base for JAST engineering and manufacturing development**

Demonstration Elements

- **Develop plan to evolve digital product definition**
- **Implement remaining paperless processes**
- **Demonstrate paperless design and build of flying technology**
- **Implemented paperless for production ships and remaining suppliers**
- **Begin paperless design and build of JAST aircraft**

System Payoff

Reduced Acquisition Cost Through:

- **Real time linkage of entire team**
- **Higher first time quality**
- **Less cost to change equals design agility**
- **Direct design to machine eliminates numerical control programming**
- **Improved tool quality and configuration control**

The aerospace industry is in the process of adapting a common digital database for the interfaces among the components of the integrated product/process development, definition and manufacture. Development efforts in most prime contractor organizations use fully digital definition processes. Interfaces among sections built by different company teams use common digital databases for precision splices. Programmers electronically translate parts-definitions from design databases into digital instruction for NC machines.

However, a number of interfaces are not yet a part of the digital product definition. Some teams release structural and assembly drawings to manufacturing and tooling using paper. Often the interface with many production suppliers uses paper. Direct use of digital design data for inspection is rare in some enterprises.

Use of a common digital database for development and production will be reduce defects, and result in a persistence of high quality, shorter cycle times and reduced man-hours, and hence, affordability and agility.

Program Objective

The purpose of this demonstration is to show use of totally digital product definition to control the interfaces starting with product definition and going through tool development, communication with suppliers, fabrication, assembly and inspection, delivery and supportability. The master database will also involve linkages to teamed companies, suppliers and the government customer.

Technical Approach

A JAST program represents an opportunity to prove out the benefits of a comprehensive use of a digital product definition database. The prime integrators could take the lead in implementing and proving out the digital master database approach; that is, evolving the needed digital processes as the program progresses through the pre-program phases and into manufacture of a flying demonstrator.

Demonstration Elements

The use of a totally digital database will be "prototyped" using the IPPD process for the flight demonstrator program. At the same time, digital interfaces and digital processes will be implemented at customer, teammate, and suppliers facilities ready for the design-to-manufacture phase of a JAST program.

System Payoff

"Virtual enterprises" involve a prime contractor, its teammates and suppliers, and the customer in a coherent design and manufacturing process that may be widely distributed within the U.S., and even internationally. An electronically transmittable and manipulatable digital design database supports efficient integration of produce components. Even at a single company location, pervasive use of digital master data bases for communicating product definition to manufacture avoids substantial wasted effort involved with changes, errors from using the wrong drawing, or mistakes in translation between electronic forms using paper. The precision of paperless systems enables new technical qualities such as shimless aircraft assembly or the manufacture of aircraft to closer tolerances. The customer perceives those benefits in terms of higher first-time quality, shorter IPPD-to-manufacture cycle times, less costly changes, lower schedule risk, new technical capabilities, and a smaller "hidden factory" of scrap and rework.

WHY THIS TECHNOLOGY IS HIGH PRIORITY—
LEVERAGING COMPOSITES FOR MANUFACTURING

Program Objective Addressed	***Technical Approach***
Gain full composites potential through: • **Larger one piece integral designs** • **More integrated low observables** • **Lower cost manufacturing** • **Higher quality laminates** • **Higher temperature materials**	• **Design, build, and test** – **Tip-to-tip one piece wing** – **Nose-to-tail one piece fuselage** – **Improved one piece inlet ducts** • **Optimize built-in low observables elements** • **Integrate promising low-cost processing technologies and flexible tooling**
Demonstration Elements	***System Payoff***
• **Design studies** • **Perform materials development** • **Develop manufacturing development** • **Perform testing** • **Integrate into demonstration aircraft**	• **Much lower assembly and finishing costs (better quality, fewer fasteners)** • **Lighter weight—better strength and durability** • **Potential for manufacturing automation with attendant reduction in fabrication costs** • **Significant reduction in parts count**

Program Objective
The primary objective here is to use composites to make advanced aircraft more affordable. Larger single-piece modules can be easier to fabricate, as well as less costly to assemble. Advancements in design tools, materials, and manufacturing and inspection processes are affected when a large-scale development project is pursued.

Technical Approach
Designing and building the ultimate optimized structure using integrated product teams over a multi-year time span will provide the opportunity to demonstrate the potential of composites to their fullest in aircraft structure. Setting ambitious goals of one-piece fuselage and one-piece wings establishes concepts that are beyond the current state-of-the-art.

Demonstration Elements
A top-level schedule framework will fit many concept and process improvements in support of the next-generation strike and fighter aircraft.

System Payoff
Payoff comes from lower assembly costs, lighter weight structure, and improved potential for automation of fabrication operations.

WHY THIS TECHNOLOGY IS HIGH PRIORITY—
REDUCED PARTS COUNT THROUGH DESIGN

Program Objective Addressed	*Technical Approach*
• **Drive down the cost of composite structures by developing designs and assembly processes that reduce part count, especially fasteners**	• **Innovative design, analysis, fabrication, and testing of structure using advanced materials and manufacturing processes** • **Thermoset/thermoplastic induction welding, co-curing, cobonding, z pinning, resin transfer molding, filament winding** • **Titanium, aluminum, Al/Li welding, diffusion bonding, super plastic forming, high-speed accurate machining, explosive forming** • **Metal matrices**
Demonstration Elements	***System Payoff***
• **Component manufacture and test** • **Module manufacture and test** • **Air vehicle manufacture and flight test where appropriate** • **Air vehicle structural and fatigue test where appropriate**	• **Reduced cost** • **Reduced assembly time** • **Reduced structural weight** • **Minimal requirement for fuel sealant** • **Minimized shimming** • **Reduced spare parts** • **Increased reliability, maintainability and repairability**

A major cost driver for a production program is the assembly process, especially when there are many fasteners (i.e., drilling, inspection, installation). Composites can be designed so that major modules are assembled by co-curing, co-bonding, or other methods which will eliminate the use of fasteners.

In addition, new advanced methods of assembly are being used in industry, i.e., z-pinning, and induction welding. These new assembly processes hold the promise that part counts can be reduced—especially fasteners—with accompanying reductions in acquisition and operating costs.

WHY THIS TECHNOLOGY IS HIGH PRIORITY—
COMMON SUBSYSTEMS/COMPONENTS

Program Objective Addressed	***Technical Approach***
• **Establish a common support system for next-generation strike system** • **Establish common subsystems and components usage to help facilitate a joint support system development**	• **Identify and select subsystems and components which will translate to common usage for joint-Service application** • **Special emphasis on avionics hardware/software transfer** • **Low risk coupled with affordability should drive system/component selection**
Demonstration Elements	***System Payoff***
• **Identify Service-unique systems** • **Develop common systems definition** • **Integration and ground demonstration** • **Flight demonstration**	• **Reduced spares buy/stocking** • **Reduced maintenance training costs** • **Reduced repair cycle times** • **Decreased support equipment requirements** • **Decreased total mobility airlift requirements** • **Reduced development costs in EMD** • **Reduced production costs**

There are significant differences among the Services in nearly all aspects of supportability. Application of common subsystems/components, as well as a common support system, would significantly reduce overall life-cycle costs. The objective is a next-generation strike system with a common/joint support system.

A study and plan is needed that identify specific systems/subsystems suitable for joint-Service application. These systems/subsystems would be subjected to a cost/benefit and risk analysis process.

Benefits also are expected in reduced maintenance costs for training, purchase and replenishment of spare and repair parts; decreased support equipment requirements at all levels of maintenance; complimentary decrease in deployment airlift requirements; and improved system/component availability in the combat environment.

WHY THIS TECHNOLOGY IS HIGH PRIORITY—
VIRTUAL FACTORY

Program Objective Addressed	**Technical Approach**
• Optimize the manufacturing and assembly process through simulation to minimize cost and maximize quality • Make the manufacturing and assembly process insensitive to rate	• Expand the integrated product team approach to consider factory requirements and layout during the design process • Create, expand, or bridge existing factory and process models to allow rapid evaluation of alternatives through simulation • Develop design concepts that minimize tooling and touch labor
Demonstration Elements	**System Payoff**
• Simulate an existing or past product line to benchmark programs • Develop enhanced factory and process layouts and improved design characteristics through simulation of the baseline • Optimize a critical piece of JAST hardware using simulation	• Reduced production costs • Higher quality product • Reduced sensitivity to programmatic rate changes

Advanced graphical factory simulation tools are critical to the realization of the virtual factory as they provide a tool by which alternate production concepts can be quickly explored and evaluated. The virtual factory requires companies to quickly assemble internal and supplier workcells into highly efficient production systems which can respond to programmatic rate changes. Simulation allows today's manufacturing engineer to design, evaluate, and improve factories without expending large amounts of time and capital while reducing overall project risk through the consideration of "what-if" scenarios.

A program is required that integrates the advanced graphical factory simulation tools with the common geometry database. This integration will give the Integrated Product Development Team (IPDT) the ability to rapidly evaluate alternative approaches in product design, fabrication processes, tooling concepts and assembly sequences. The team will then be able to optimize the product design and manufacturing plan to reduce their sensitivity to programmatic rate changes while minimizing labor and tooling costs.

The role of simulation in the virtual factory continues after implementation of the proposed product, process, and factory design by supporting continuous improvement activities, changes in work mix and delivery requirements, and simulating work periods using finite capacity schedule (FCS) techniques.

KEY TECHNOLOGIES—
OPERATIONS/TRAINING (INCLUDING SUPPORTABILITY)

	Priority Technology
Paperless Integrated Technical Data and Smart Diagnostics/BIT	**X**
Minimize (zero?) Flight-Line Maintenance Support Equipment	
Avionics Packaging and Maintenance-Free Avionics	**X**
Up to 8,000 Cycles Engine Durability	
Automatic Pilot "Squawk" System	
Low Maintenance LO Materials and Coatings	**X**
Simulation of User Requirements	**X**
Maintenance-Free/Extended Life Components	
Common ATE and TPSs	
Analytical Tools for Support	
High Reliability/Throw-Away Parts	
Common Subsystems/Components	
Integrated Virtual and Live Training	**X**
- On-Board Threat Generation	
- Remote/Virtual Training Flight Ranges	
Situation Awareness Aides/AI	
Virtual Environment Training for Manufacturing and Support Personnel	
Systems Simulated Training	
Automated Mission Planning	
Advanced Concepts for Support Training	
Multi-Spectrum Recording of Weapons Deliveries	
Incorporation of Radar VLO and LO in Air Combat Maneuvering Ranges	

WHY THIS TECHNOLOGY IS HIGH PRIORITY—
PAPERLESS INTEGRATED TECHNICAL DATA AND SMART DIAGNOSTICS/BIT

Program Objective Addressed	**Technical Approach**

• Contribute to affordability, and increase readiness and availability of new strike aircraft:
  • Improving reliability through more accurate failure data
  • Improving maintainability by reducing maintenance trouble shooting and improving efficiency of maintenance personnel
  • Reduce support equipment for intermediate maintenance as two-level maintenance is implemented
	• Computerized/automated technical documentation available at flight line in conjunction with smart diagnostics/built-in-test to find faults more rapidly and correctly and to reduce "cannot-duplicate" actions and "retest-ok" actions
	• Reduce other support equipment at I-level that would need to be at base or deployed with system

Demonstration Elements	**System Payoff**
• Concept development • System integration and simulation • Ground demonstration	• Improve strike aircraft LCC affordability • Increase strike aircraft readiness and availability

The technological improvements in computers, particularly lap-tops with large memory capacity, allow the documentation found at bases and depots to be automated and available for immediate use at flight lines and depot repair lines. Maintenance personnel should be able to work smarter and faster with this information readily available.

On-board computers are becoming increasingly sophisticated and are now able to test internally for those Line Replacable Units (LRUs) and Shop Replacable Units (SRUs) that are working properly or have failed and caused a part of the aircraft avionics to fail. Built-in-Test (BIT) will identify the failed unit for quick replacement in the field and can be used to diagnose which part caused the failure. Improved diagnostics/BIT also can help to reduce "cannot-duplicate" and "retest-ok" actions that contribute to unfailed items being removed and replaced inappropriately.

WHY THIS TECHNOLOGY IS HIGH PRIORITY—
AVIONICS PACKAGING AND MAINTENANCE-FREE PROCESSOR AVIONICS

Program Objective Addressed

- **Reduce production and support costs through the application of advanced packaging technologies and the application of techniques leading to maintenance-free avionics**

Technical Approach

- **Develop advanced packaging roadmap trading off multi-chip module approaches and chip-on-board technology with air-flow-through and liquid-flow-through module cooling**
- **Perform cost effectiveness analysis to quantify production and support costs of packaging options**
- **Identify reliability drivers and approaches to achieve maintenance-free processing solutions**
- **Identify key drivers and risk reduction areas**

Demonstration Elements

- **Trade studies and COEAs**
- **Risk reduction demonstrations**
- **Refine EMD baseline**
- **Prototyping**

System Payoff

Affordability
- **Reduced production cost through advanced packaging**
- **Reduced support cost through advanced packaging and reduced maintenance**

Capability
- **Increased per-module throughput and memory**
- **Reduced/eliminated logistic support training and equipment**
- **Increased "availability" (i.e., mean time between critical failures)**

The development and manufacture of any embedded military avionics processor can be thought of as starting with purely commercial products and through non-commercial processes, packaging, and design features, turning them into something with value in the peculiar avionics domain.

For the application domain, special packaging is the most evident and costly attribute distinguishing applications from commercial products. There is no industry revolution in packaging. Packaging is at the core of the military avionics business. Packaging technology evolves in response to pressures from other aspects of the business.

The common integrated processor (CIP), which expresses the state-of-the-art in packaging, is being developed by the F-22 program, about 10 years ahead of JAST. The Joint Program Office has established the F-22 as the point of departure for its avionics, the benchmark reference point from which excursions may be made into new technology. F-22's missions and needs have strongly driven the CIP packaging design. Liquid flow through cooling is justified by high availability and reliability requirements. Module connector selection was influenced by the need for line-maintenance at the module level. Other hardware and software characteristics were driven by F-22's two-level maintenance concept. Weight, volume, and reliability constraints justified common use of dense multi-chip modules.

While it seems likely JAST will have processor needs similar to F-22, as packaging technology evolves, means will become available to make further gains in weight, volume, and reliability, beyond F-22's initial CIP implementation. Further, the modular design and packaging of CIP hardware, below the module level, invites repackaging to address different needs of non-F-22 platforms. For instance, where conventional maintenance is acceptable and blown air, but not liquid, is available for cooling, JAST processors may be repackaged on air-flow-through cores with (relatively) inexpensive connectors. A packaging design for low-cost, reasonably reliable replaceable components may enable one-level maintenance. Ultimately, a JAST platform may seek maintenance-free avionics by packaging its CIP using chip-on-board methods (eliminating multi-chip modules), high-capacity liquid cooling provisions, and CIP's inherent fault tolerance.

System payoffs for packaging improvements will be greater functionality and availability per weight, volume, and cost and, if the maintenance-free threshold can be crossed, a singularity in logistic support, training, and equipment costs.

WHY THIS TECHNOLOGY IS HIGH PRIORITY—
LOW MAINTENANCE LO MATERIALS AND COATINGS

Program Objective Addressed	***Technical Approach***
• **Develop LO materials and components that minimize the impact on system maintenance costs** • **Increase durability and reliability of LO materials characterisitics**	• **Develop environmentally safe coatings and components that are durable and easily repaired in the field** • **Develop simple and robust designs for seals, access panels, and apertures that require no special treatment following maintenance** • **Develop verification test equipment, procedures, and repair kits to assure signature maintenance**
Demonstration Elements	***System Payoff***
• **Identify high payoff technology enhancements through simulation and laboratory demonstrations** • **Ground test appropriate component models for accelerated life testing of environment and/or handling cycles** • **Flight test JAST prototypes with enhanced maintenance features**	• **Reduced cost of ownership for systems with LO features** • **Reduced mobility airlift** • **Improved system availability** • **Assured signature maintenance**

The perception is that stealth designs are fragile and expensive to maintain. The past decade has seen significant progress in creating more durable, environmentally friendly materials. Similarly, enhanced designs have been developed to reduce the maintenance of openings and apertures in LO systems.

Limited resources have not allowed any significant updates to the F-117 to reduce the supportability cost due to LO. The B-2 was designed to further reduce the cost of LO maintenance, and its performance is just beginning to emerge as the system gains operational experience. The F-22 is being designed to even further reduce the LO maintenance cost while significantly reducing the overall supportability burden.

The JAST should support demonstrations in both laboratory and operational environments that will validate the robustness of today's most promising LO materials and designs.

WHY THIS TECHNOLOGY IS HIGH PRIORITY—
SIMULATION OF USER REQUIREMENTS

Program Objective Addressed	**Technical Approach**
• Develop simulation techniques to perform the trades between requirements and system cost impacts early in the development cycle	• Employ distributed interactive simulation network technology for simulation integration • Integrate existing models for simulating the warfighting environment for requirements vs. cost analysis • Interface with training environments
Demonstration Elements	**System Payoff**
• Conduct demonstrations in a virtual ground-based environment • Demonstrate addition of in-flight aircraft in a virtual environment • Integration of live interaction	• Simulation of user requirements will allow detailed cost vs. performance trades early in the design cycle, which will reduce development costs resulting from having well defined and affordable requirements • Early identification of on-board/off-board sensor requirements

Program Objective
The objective is to integrate present simulation technologies into a system that can be used as a tool to define, analyze, trade, and refine aircraft requirements in a warfighting scenario environment. This system will include simulations of hardware, targets, threats, cooperative assets, the warfighting environment and could include actual algorithms, databases, and real flying assets as the situation or fidelity demand.

Technical Approach
Many of the simulations and models that presently exist can be integrated into a simulation requirement test bed system using distributed interactive simulation (DIS). The DIS architecture and protocol allows for real-time interaction between simulations, hardware-in-the-loop systems (either ground-based or in-flight) via direct land- and satellite-link systems. The DIS also provides an open architecture for high fidelity simulations and test of requirements in varying configurations and environments. Changes in requirements can be rapidly made to conduct performance and cost trades using the simulated environment.

Demonstration Elements
The demonstration plan uses a building block approach. Existing simulation models will be incrementally integrated (i.e., sensors, threats, targets, aircraft environment, etc.) across several hardware resources and interconnected through a ground-based network. Data transfer and interaction among the simulation models will then be demonstrated. Actual hardware, software algorithms, and a man-in-the-loop will be added and a complete simulated mission scenario will be demonstrated showing the performance and cost analysis for various user requirements.

System Payoff

Development of well-defined performance, quality, cost, reliability, maintainability, and supportability requirements early in the design cycle will reduce overall development costs and improve quality. Requirements for new concepts, such as utilizing off-board assets for situation awareness and targeting, can be identified, analyzed, and refined prior to design. Well-defined performance and cost requirements can reduce costs in the development cycle by eliminating the many design changes and modifications resulting from not having requirements well-defined early in the development process.

WHY THIS TECHNOLOGY IS HIGH PRIORITY—
INTEGRATING VIRTUAL AND LIVE TRAINING

Program Objective Addressed	**Technical Approach**
• Give joint-Service commanders the tools needed to train in the environment of anticipated conflict • Reduce training costs through simulation – Develop mobile high fidelity distributed training and evaluation environments – Link interactive virtual to real world participants – Generate training situation from on-board	• Develop robust computer architectures capable of handling thousands of participants • Refine advanced two-way communications links • Integrate real-world, real-time visualization systems • Generate on-board situation data • Interface with participant avionics buses • Integrate GPS with real-world and virtual participants environment
Demonstration Elements	**System Payoff**
• Demonstrate integrated GPS with real and virtual participants environment • Demonstrate advanced two-way data/ communication links • Interface with avionics buses in flying demonstrator • Ensure robust computer architectures • Integrate visualization systems into cockpit and simulator	• Reduced weapon system development costs • Reduced cost of training the "forces" • Warfighters practice worldwide scenario without deployment costs • Validate concepts of operations with advanced aircraft simulations • Provides training for individuals, task forces, C3I, elements, and decision makers

The integration of virtual with live assets will serve two primary cost saving functions for the JAST program. First, during the development of JAST weapons system concepts, the capability will be present to evaluate concepts through simulation in a virtual environment enabling designers to economically zero in on a preferred concept. This can be done before "bending any metal." The direction from DoD in simulation will enhance current capability through improved environments with greater fidelity and increased numbers of participants.

The second cost saver will be in the training area. Flight time, steaming time, and "battlefield" time all can be reduced with a balanced combination of simulation and real world assets participating in training of any nature. The ability to train to a wide variety of scenarios using the combination of assets as determined by the needs of the Commanders is powerful. The major challenge is developing an architecture capable of handling large numbers of participants in real time.

TECHNOLOGY FOR AFFORDABILITY

- Airframe/Systems
  - Advanced Very Low Observables (including Antennas/Apertures)
  - All/More Electrical System Aircraft
  - True Advanced Composite Structure Design
  - Virtual and Rapid Prototyping of Hardware
  - Modular Construction
  - Reduced Tail/Tailless Fighter Configuration
  - Technologies Enabling STOVL
  - Conformal Carriage for LO and Drag
  - High Lethality Payloads
  - Weapons Integration Affordability
- Propulsion
  - Enhanced Thrust/Weight and Durability
  - Reduced IR Design
  - Thrust Vectoring Nozzle Design/Integrated Flight-Propulsion Control
- Avionics (including Software)
  - Digital Communications Links from On- and Off-Board Sensors
  - Integrated RF Sensors
  - Integrated EO Sensor Architecture
  - Multi-Function Apertures
  - Anti-Jam GPS
  - Advanced Avionics Architecture—Hardware and Software
  - Open Avionics Architectures to Accommodate Commercial Components
  - Common Integrated Processing and Processors
  - Virtual and Rapid Prototyping of Software
  - Reusable Software (Modular Software)
  - Sensor Fusion/Decision Aids
  - Information Fusion
- Manufacturing Methods and Tools
  - Paperless Design to Manufacturing
  - Leveraging Composites for Manufacturing
  - Reduced Parts Count Through Design
  - Common Subsystems/Components
  - Virtual Factory
- Operations/Training (including Supportability)
  - Paperless Integrated Technical Data and Smart Diagnostics/BIT
  - Avionics Packaging and Maintenance-Free Avionics
  - Low Maintenance LO Materials and Coatings
  - Simulation of User Requirements
  - Integrated Virtual and Live Training

Technologies considered priority by the Task Force are covered in JAST or elsewhere