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Collaborative Virtual Prototyping: An Assessment for the Common Support Aircraft Initiative
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Background and Approach

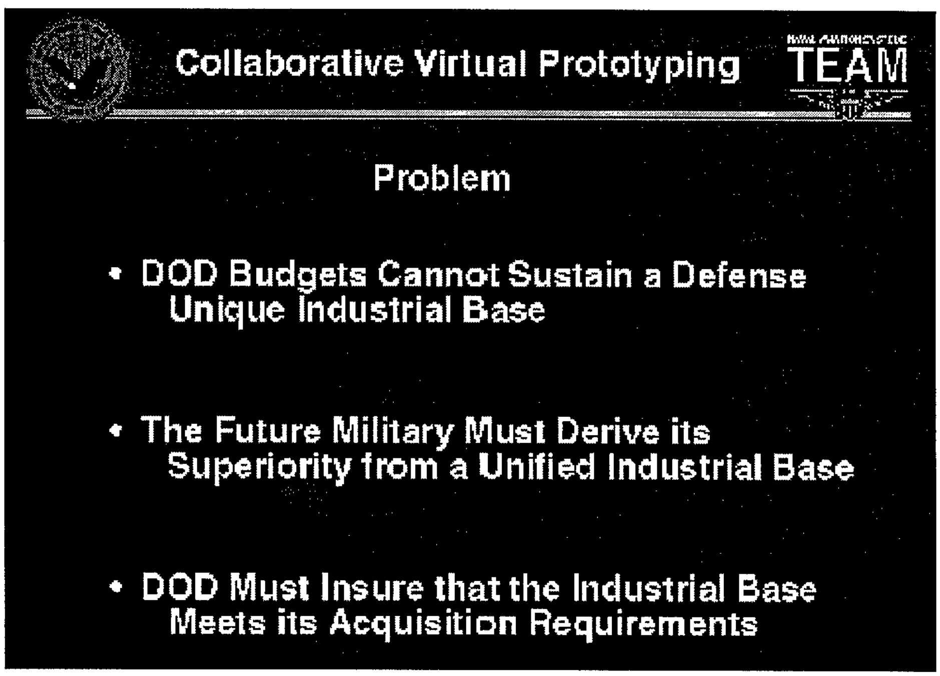
THE PROBLEM

For the last 50 years, the United States has relied for its security on a unique industrial base that has provided superior weapon systems for our warfighters. The sustainment of this unique industrial base has become unaffordable, and the national strategy calls for a "unified national industrial base" to supply our future weapon systems. Title 10 U.S.C. Chapter 148 states Congressional policy and objectives as:

1. Rely, to maximum extent practicable, upon the commercial national technology and industrial base to meet the national security needs.
2. Reduce the reliance of DoD on technology and industrial base sectors that are economically dependent on DoD business.
3. Reduce Federal Government barriers to the use of commercial products, processes, and standards.

To maintain the force structure needed for our security, the traditional relationship between quantity and price must be broken and a means found to drastically alter the cost curves we have been on for the last 30 years. Collaborative Virtual Prototyping (CVP) offers the possibility to do this and enable the acquisition of complex weapon systems at significantly reduced cost.

The Naval Aviation Team is procuring less weaponry than in the past, yet that weaponry must continue to provide our technological edge while meeting new requirements within our affordability goals. The Naval Aviation Team, under the leadership and encouragement of the Assistant Secretary of Navy (Research, Development & Acquisition) is exploring strategies that rely on dual use and commercial technologies to hold down cost and promote innovation. This study examines the potential of CVP to meet these needs for the acquisition of future systems.



INTEGRATED PRODUCT AND PROCESS DEVELOPMENT

TEAMS

CVP is the application of distributed modeling and simulation in an integrated environment to support trade-off analyses throughout the product life cycle. It enables all members of an integrated product and process team to interact continuously through electronic modeling and data exchange; increases the insight into life cycle concerns; permits earlier testing through virtual proving grounds; and accelerates physical production through process optimization using virtual factories. CVP brings the best and the brightest talent from across the unified national industrial base into integrated product and process development teams to concurrently engineer complex systems.

Advances in computer processing and networking have been the enabling technologies for CVP. Until recently, model and simulation fidelity was constrained by the amount of computer processing one could afford locally. Networking technology has removed that constraint, thereby allowing access to the best models and simulations wherever they may be located. This distributed simulation capability will permit detailed knowledge of the system to be obtained earlier in the conceptual and preliminary design phases where it can have the most influence on life cycle cost. These advances have allowed the formation of geographically distributed but electronically integrated product and process development teams.

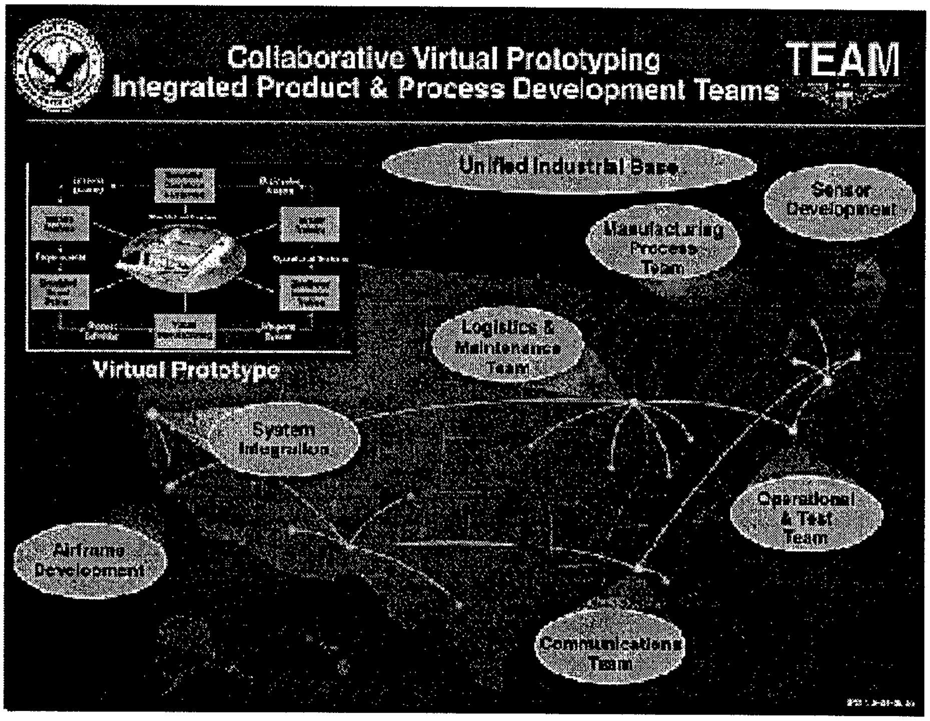
DoD leadership has fostered the development of this technology and its application to the acquisition process. DDR&E commissioned the Acquisition Task Force on Modeling and Simulation that reported out in June 1994, and the DoN tasked the Navy Research Advisory Council to examine the application of modeling and simulation within the Navy in an acquisition context.

The Naval Research Advisory Committee examined how the DoN could train more efficiently, refine new weapon system requirements, and acquire new or modified systems in a less costly manner. In their November 1994 report on Modeling and Simulation, they recommended adopting a new Distributed Simulation-Based Acquisition (DSBA) process that:

- Promotes end-to-end verification of requirements matched to design, manufacturing, and supportability;
- Facilitates cost and performance trades for the complete life cycle.

Further, the study concluded that DSBA if properly implemented:

- Would enable a "try before buy" in a virtual environment using distributed simulation;
- Would solve problems that are usually first evidenced only after hardware has been produced; and
- DoN should begin evolving this technology with existing acquisition projects stating that the technology has been demonstrated and more demonstrations are not needed.



ADVANTAGES PROVIDED BY CVP

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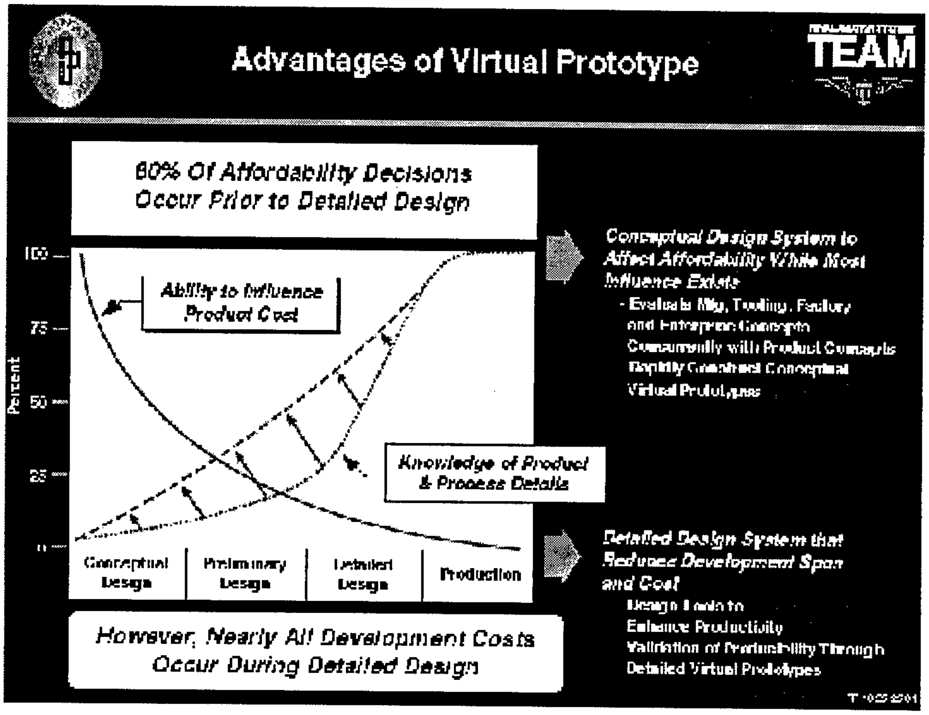
The Systems Realization Laboratory at the Georgia Institute of Technology has studied virtual prototyping and has found that virtual prototyping "drags" the knowledge curve to the left and increases the ratio of hard to soft information that is available in the early stages of design. The improvement in the quality of information should lead to designs that are completed in less time and at less cost. Another important factor is to keep the ability to influence product cost or "design freedom" open as long as possible. This factor would be shown by moving the "ability to influence product cost" curve upward (not shown on this chart). The Systems Realization Laboratory hypothesizes that virtual prototyping enables both curves to shift. It is this shift that enables producers to change the cost curves they have been on for the last thirty years.

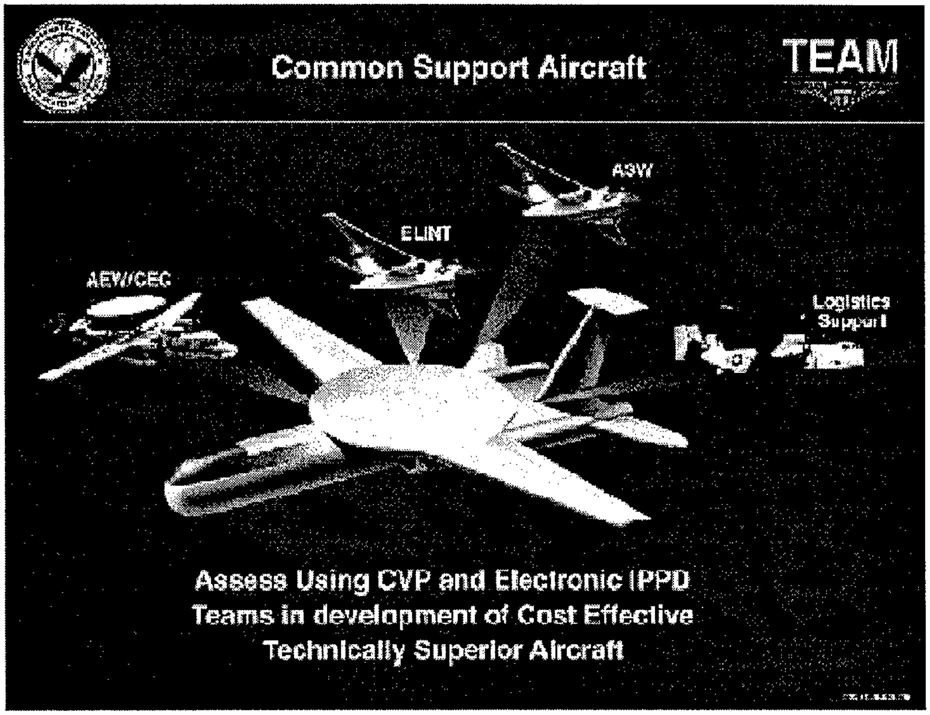


THE COMMON SUPPORT AIRCRAFT

Current carrier-based tactical mission support aircraft (S-3, E-2, ES-3, and C-2) will reach the end of their operational service lives between 2010 and 2015. For many airframes, mission obsolescence may occur sooner. A Naval Aviation Affordability Study, concluded in May 1993, determined that the more restrictive budgets require a "neckdown" in the types of airframes, reduced fly-away unit costs, and reduced life cycle costs.

The Chief of Naval Operations (CNO) plans to initiate a two-year study beginning in FY-96 to determine requirements and feasibility of using a common airframe to support many mission areas now performed by multiple platforms. The Common Support Aircraft (CSA) study will examine the possibility of combining the mission functions shown into a single airframe. The first year of the CSA study is devoted to collecting fleet inputs from the support aircraft communities and to performing unit and mission level analysis on those requirements. The second year is devoted to the development of a notional aircraft concept. The CNO study will develop a Mission Needs Statement (MNS) for the CSA. The MNS will outline the future carrier-based aircraft early warning (AEW), anti-submarine warfare (ASW), anti-surface warfare (ASuW), mine warfare (MIW), maritime and overland surveillance, C41, tactical intelligence, and tanking and logistics missions through the mid-21st century. The MNS will discuss the technical feasibility and economic benefits of a common airframe, and will determine the number of platforms of specific mission configurations to be procured.

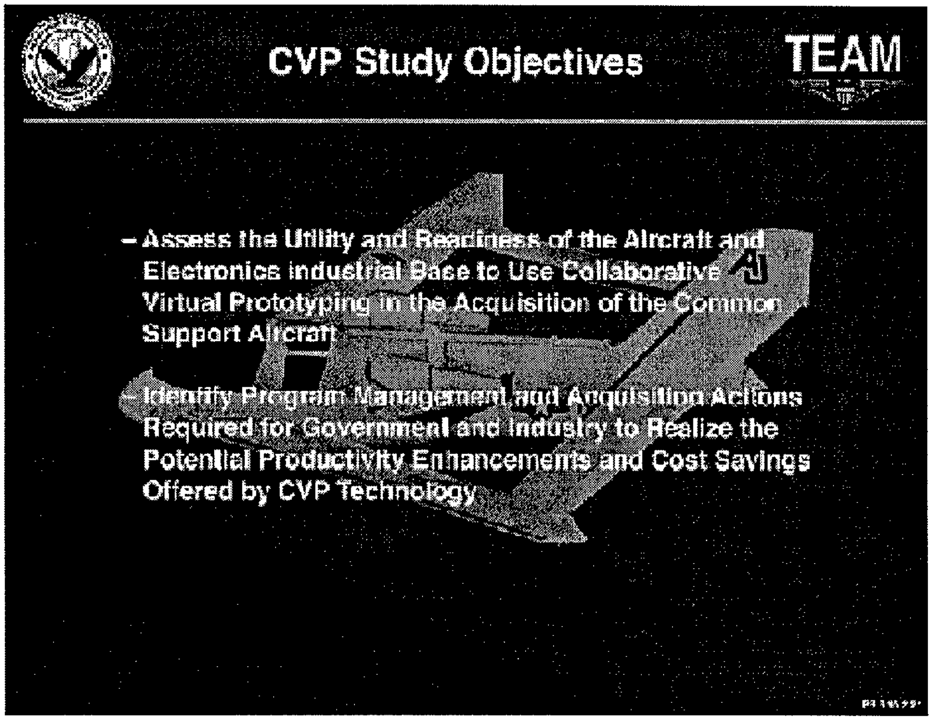
The results of the ongoing CVP study will feed into the CSA initiative. Future initiatives such as CSA should use those CVP technologies that are mature and offer significant cost advantages.



STUDY OBJECTIVES

This report provides the framework and background information needed for applying CVP to the CSA initiative. The study examines the state of CVP technology, forecasts its maturation in the next three to five years, identifies its acceptance by the aircraft and electronics sectors of the industrial base, identifies new business processes that maximize the exploitation of CVP, and provides recommendations for implementing CVP for the acquisition of the CSA. Specific objectives are:

- To assess the utility and readiness of the aircraft and electronics industrial base to use collaborative virtual prototyping technologies in the acquisition of the CSA.
- Identify program management and acquisition actions required for government and industry to realize the potential productivity enhancements and cost savings offered by CVP technology.



STUDY APPROACH

Three major sources of information were accessed to collect the information for the study:

- Government and Industry Development Activities
- Industrial Base Site Visits
- Conferences and Literature Searches

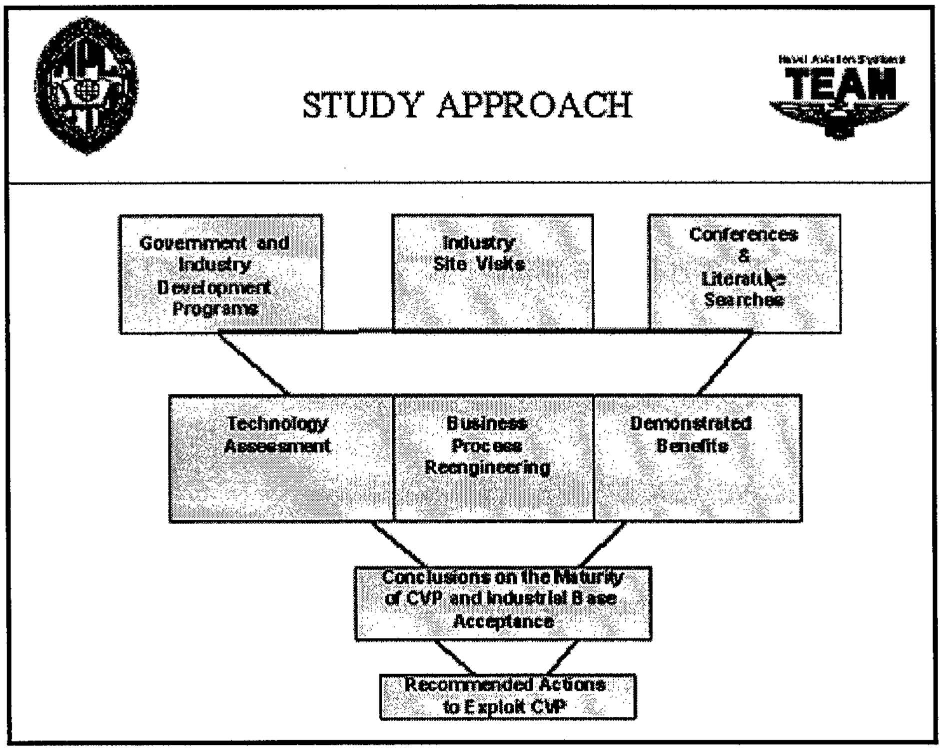
There are a number of government departments and agencies developing CVP tools and technologies. The Departments of Defense (DoD), Commerce (DoC), and Energy (DoE); the National Aeronautical and Space Administration (NASA); and the National Science Foundation (NSF) are all developing tools, integrating tools, developing advanced manufacturing processes, or are conducting pilot programs that can be used in the CVP environment. (Examples of these programs are provided on the next few slides.) Site visits were made to selected aerospace and electronics industrial base contractors and CVP tool developers. Literature searches, news articles, and conferences were also used as sources of information. Conferences that were attended by project personnel were AUTOFACT 94', the Defense Manufacturing Conference, and the National Institute for Standards and Technology (NIST) Advanced Manufacturing Conference.

The study was divided into three main areas:

- Technology Assessment
- Business Process Reengineering
- Demonstrated Benefits

CVP technology development is being sponsored by government and commercial organizations and is taking place largely in the academic community. The state of the art and the state of the practice were examined and enabling CVP technologies requiring additional development were identified. Many new business practices were identified during visits to large corporations and any demonstrated benefits were quantified and documented.

Information in the study areas was used to assess the maturity of CVP in both the commercial and defense components of the industrial base. In all cases, the aircraft and electronic sectors of the industrial base have either invested heavily in CVP or were developing programs to integrate their tools and departments into a CVP environment. Finally, there are a number of actions that NAVAIR and the DoN must take to exploit the benefits of CVP. These recommendations are presented at the end of the document.



GOVERNMENT AND INDUSTRY DEVELOPMENT PROGRAMS

There are numerous federal programs developing tools and technologies that can be leveraged when implementing collaborative virtual prototyping. The Advanced Research Projects Agency (ARPA) is leading DoD in developing technologies that support the distributing computing and collaborative design environment. The Simulation Based Design Program (SBD) is developing and demonstrating technologies to support the distributed, collaborative infrastructure. In addition, ARPA is sponsoring the Affordable Multi Missile Manufacturing (AM3); the Agile Infrastructure for Manufacturing (AIM); and the Manufacturing, Automation, Design, and Engineering (MADE) programs. The Joint Advanced Strike Technology (JAST) Program Office is maturing technologies that can be used for the next generation strike aircraft. Many of these technologies are directly applicable to the development and production of the CSA. Within the Manufacturing Science and Technology (MS&T) Programs of the Army, Navy, and Air Force are efforts in composites structures, high speed machining, and virtual manufacturing. The DoC has the Advanced Technology Program, the Manufacturing Extension Partnerships, the Partnership for the Next Generation of Vehicles, Intelligent Manufacturing Systems, Advanced Manufacturing Testbeds, and many NIST laboratory programs. The DoE is supporting an industrial consortium known as Technology Enabling Agile Manufacturing (TEAM), which is defining a common information infrastructure and conducting demonstrations of pilot projects. The NSF is sponsoring projects in Manufacturing Research including the Agile Aerospace Manufacturing Research Center located within the Automation & Robotics Research Institute (ARRI) at the University of Texas, Arlington. It is one of three institutions to be designated an Agile Manufacturing Research Institute and is the only one dedicated to the Aerospace industry. Industrial consortia are focusing on the development of standards and manufacturing practices to help American industry compete in the world market. Standards are being developed by PDES Inc. and Object Management Group (OMG), while manufacturing practices are being identified by the Agility Forum, the Lean Aircraft Initiative (LAI), and Consortium for Advanced Manufacturing International (CAM-I).

Additional information on these programs is in Appendix C.

Government and Industry Development Programs

Naval Aviation Systems TEAM

DoD

- ARPA
  - Simulation Based Design
  - Mfg. Automation, Design Engineering
  - Affordable Multi Missile Mfg
  - Agile Infrastructure for Mfg
- JAST
  - Virtual Strike Warfare Environment
  - Avionics Sys Eng Prototype
  - Simulation Assessment Validation Environment
  - Adv Lightweight Fuselage
- Continuous Acquisition Life Cycle Support
- Electronic Commerce Resource Center
- Manufacturing Science and Technology
  - ARMY
  - NAVY
  - AIR FORCE

DoC

- Advanced Technology Program
- Mfg Extension Partnerships
- Computer Security
- Intel Mfg Systems
- Adv Mfg Test Bed
- Lab Programs

DoE

- Technology Enabling Agile Mfg
- Lab Prog

NSF

- Engineering Research Center
- Agile Manufacturing Research Institute

INDUSTRY

- Agility Forum
- Prod Data Exch STEP
- Object Mgn Grp
- Object Database Mgn Grp
- Lean Aircraft

INDUSTRY SITE VISITS

Personnel from NAVAIR and the North American Technology Industrial Base Organization (NATIBO) collaborated in the collection of information for the CVP studies. From March 6 to September 14, 57 organizations were visited. The names of the organizations and the dates of the visits are presented in the accompanying slide. The information contained from those site visits is the foundation of this report, and the authors are indebted to the organizations that took their time to host the visit teams.

End of Background and Approach

Continue to Technology Assessment

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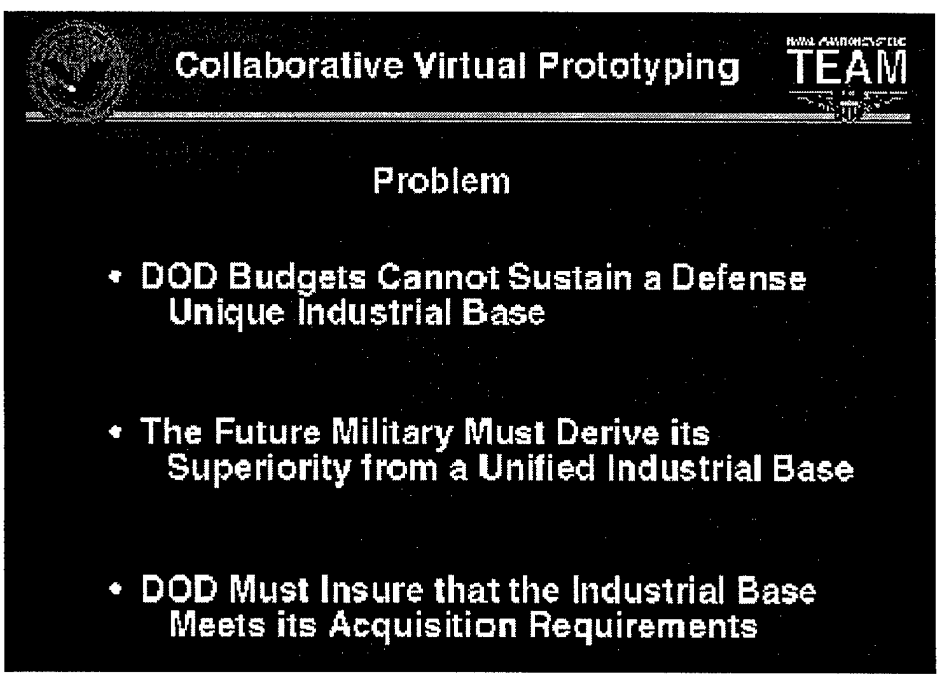

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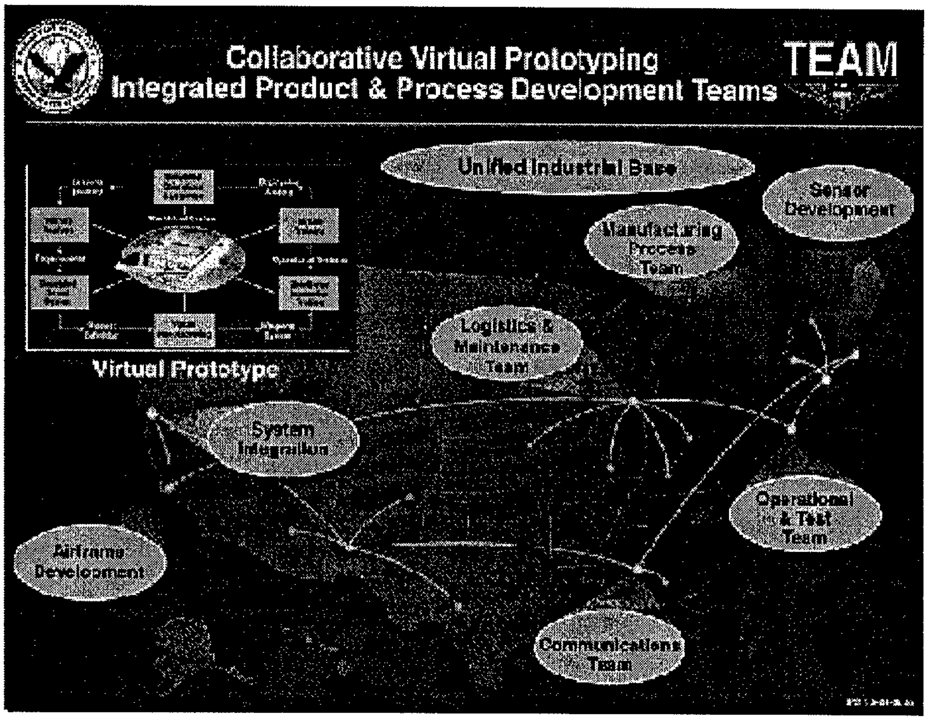

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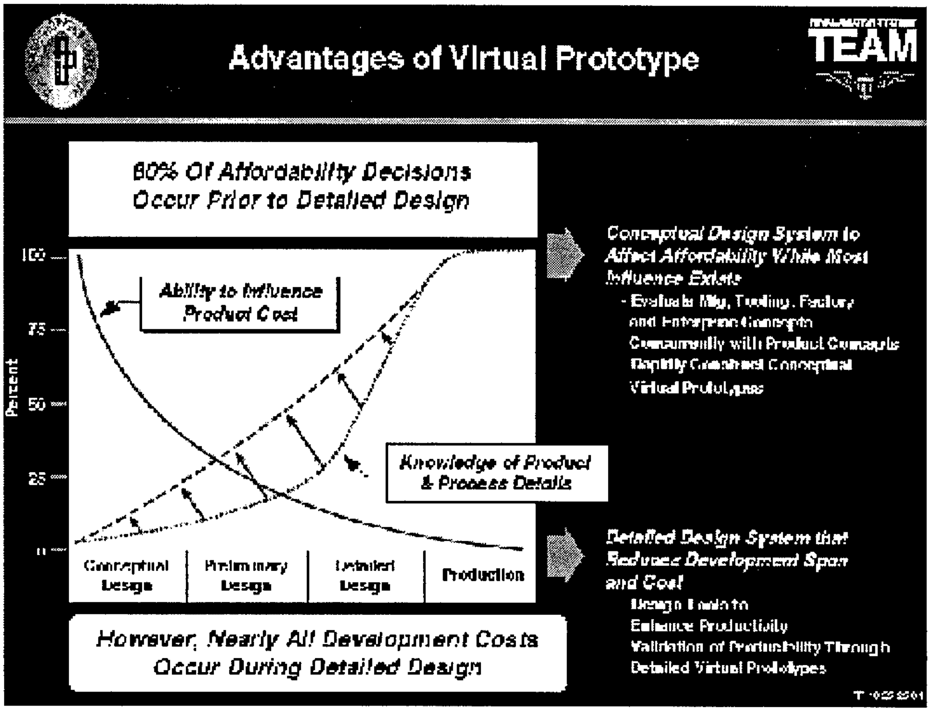

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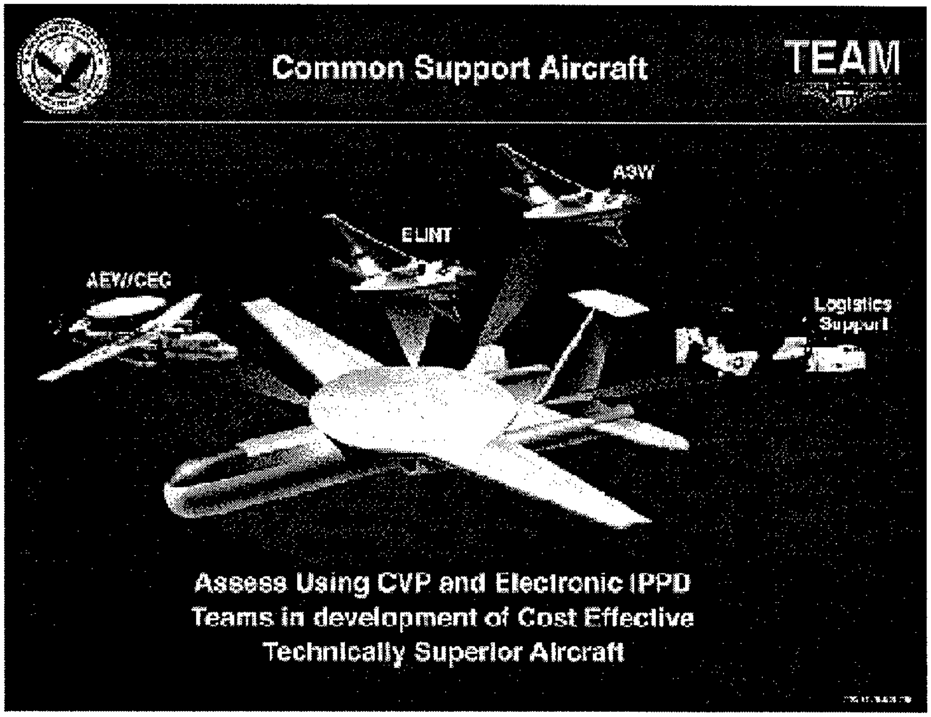

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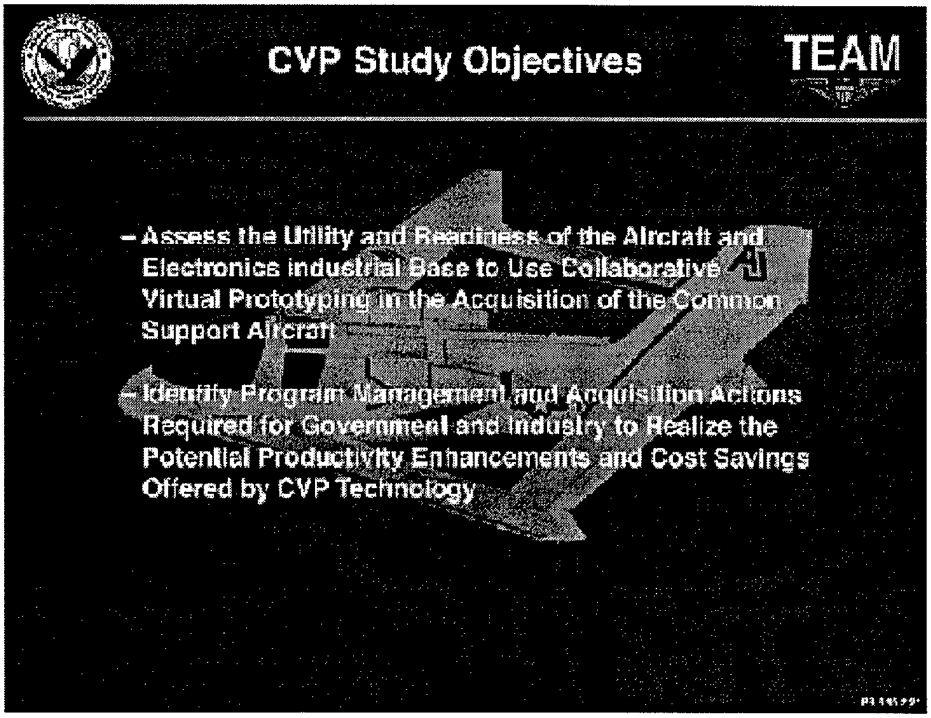

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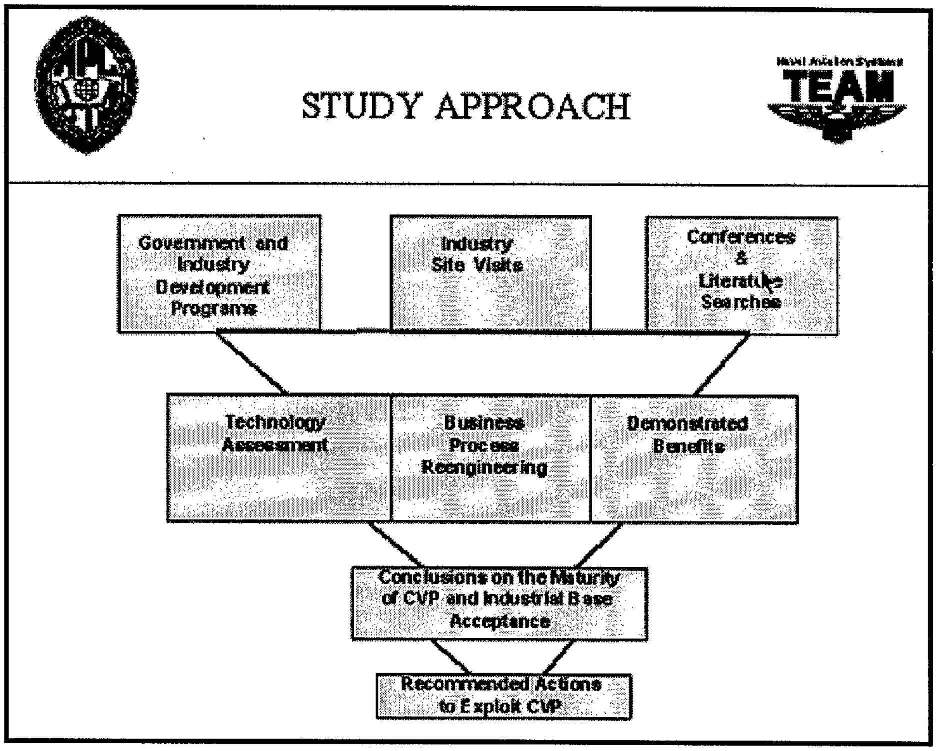

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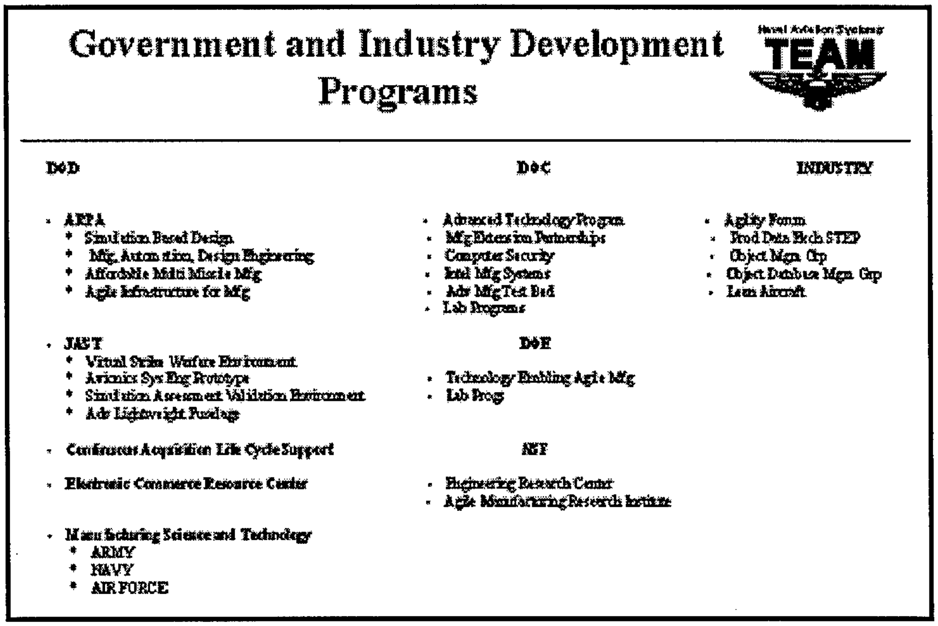

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End of Background and Approach

Continue to Technology Assessment

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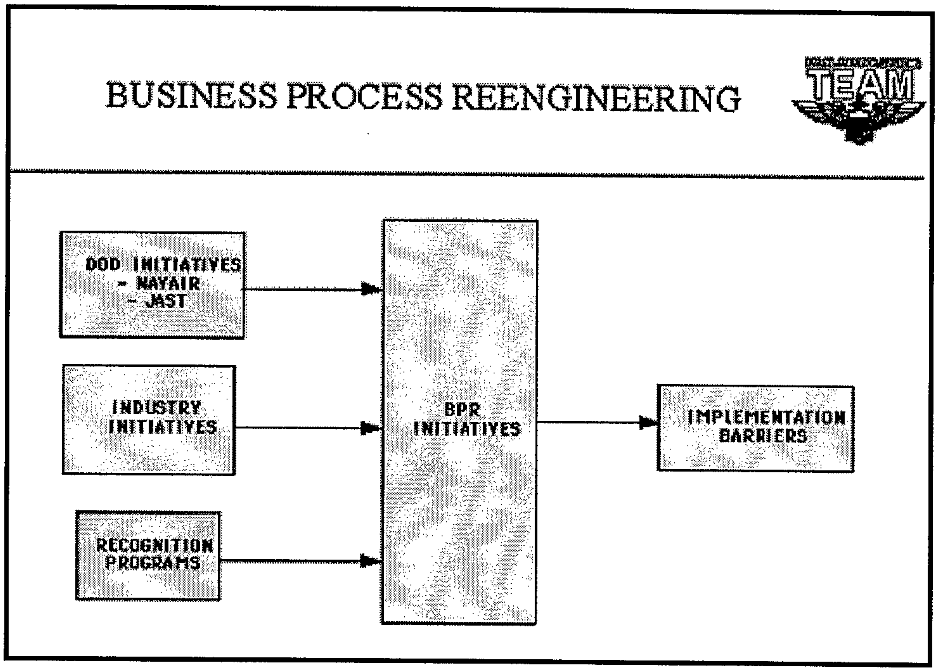
BUSINESS PROCESS REENGINEERING

To effectively implement CVP, many cultural business changes need to be adopted by government and industry. The objective of this component of the study is to identify potential business practices that will maximize the benefits of CVP. The current initiatives that have met with success, and the technical and business barriers in implementing CVP were identified. Information was collected from a variety of resources: a) current NAVAIR initiatives; b) new business practices within the JAST program; c) new business practices being explored in pilot projects within industry; and d) the recognization programs, i.e., quality and performance programs, sponsored by industry and government to overcome the current business practice barriers. Potential business processes that may be useful to NAVAIR and the CSA program in exploiting CVP were identified as a result of the above investigations.

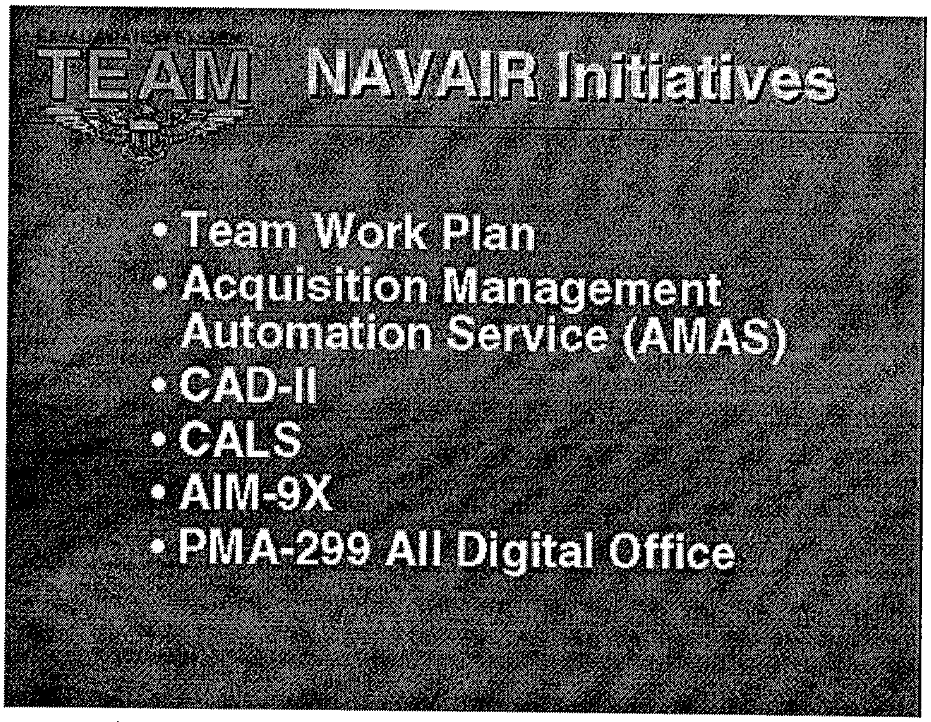
DOD INITIATIVES

Within the Department of Defense, two main areas were examined for their relevance to CVP: NAVAIR initiatives and new business practices within the JAST program. Technologies and work processes potentially valuable to CSA have been identified in the following slides.



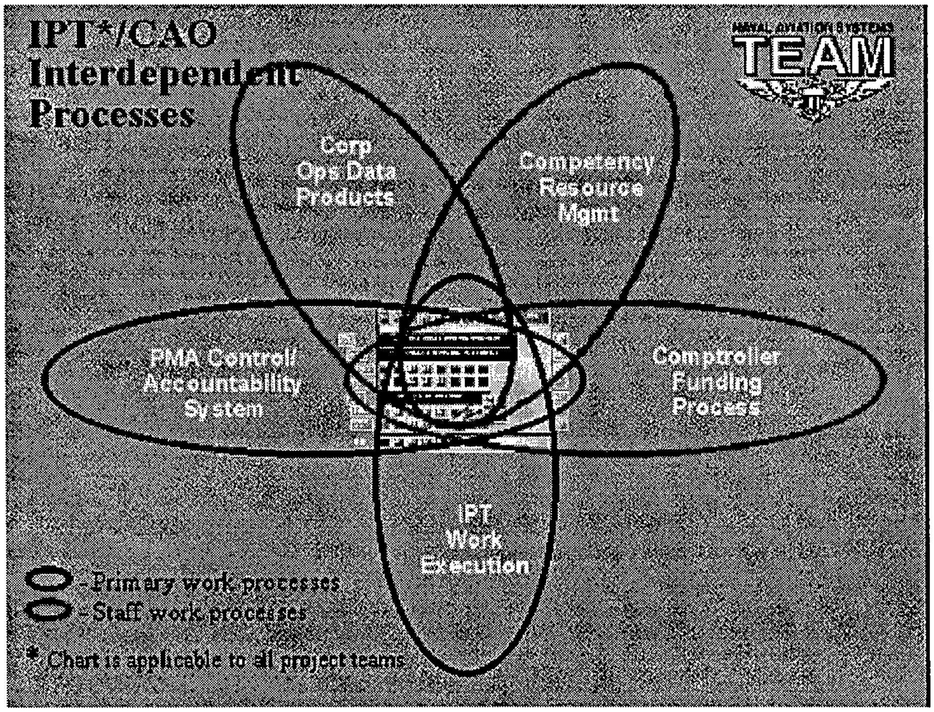
NAVAIR INITIATIVES

NAVAIR initiatives identified are the Team Work Plan, Acquisition Management System, CAD-II, CALS, AIM-9X, and the PMA-299 All Digital Office. These programs are heavily involved in CVP relevant issues such as interoperability; modeling and simulation during system design to reduce program costs; and the electronic Integrated Program Team (IPT) concept for acquisition. The approaches and the lessons learned by these programs can assist the CSA team in establishing its own CVP program.



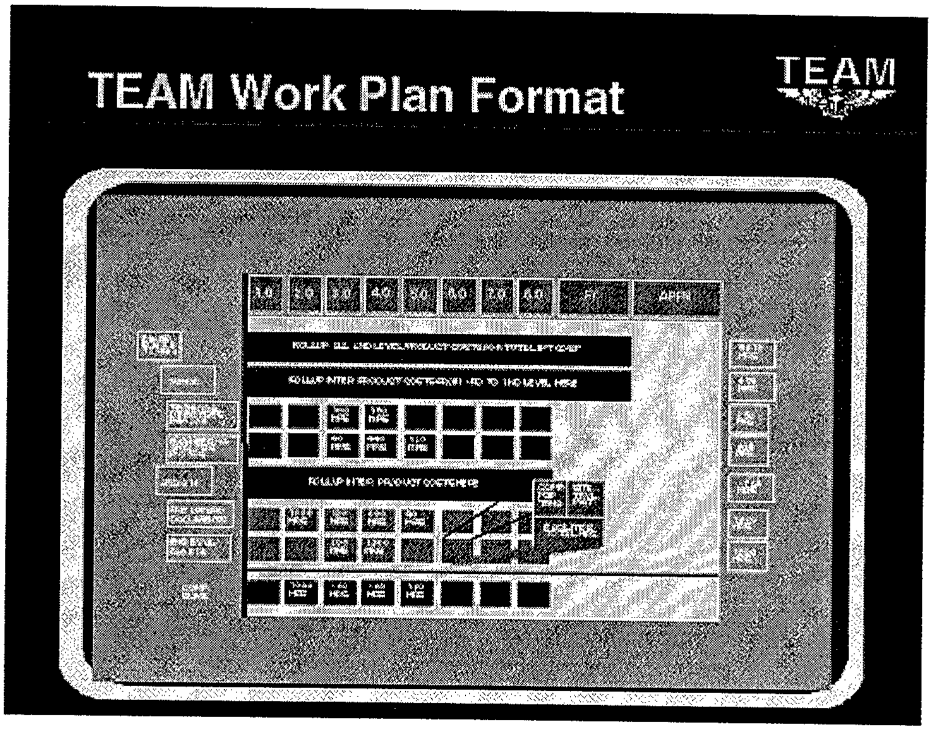
NAVAIR TEAM WORK PLAN

The Naval Air Systems Command has adopted a product-focused life cycle management philosophy that systematically employs integrated program teams, led by program managers, to manage all aspects of a program's product(s) over its entire life cycle. Program teams drew upon the newly established Competency Aligned Organization for human, fiscal, and other program-dedicated resources to accomplish their goals. The TEAM Work Plan (TWP) is the vehicle for defining and documenting requirements for work to be accomplished internally by the Naval Aviation Systems Team. It facilitates integrated, streamlined program management support from engineering, logistics, financial management, contracts, etc.



NAVAIR TEAM WORK PLAN

Initially, TWP will be implemented across the TEAM in FY-96 as a simple collaborative tool. It will use a RDBMS accessible over the NAVAIR network with appropriate access and security controls. The TWP collaborative tool will be the first enterprise-wide collaborative tool that changes an existing business process. Additional business-oriented collaboration functions such as desktop video, "electronic blackboard," sound clips, etc. should be rapidly added to improve usability, functionality, and overall efficiency.



ACQUISITION MANAGEMENT AUTOMATION SYSTEM

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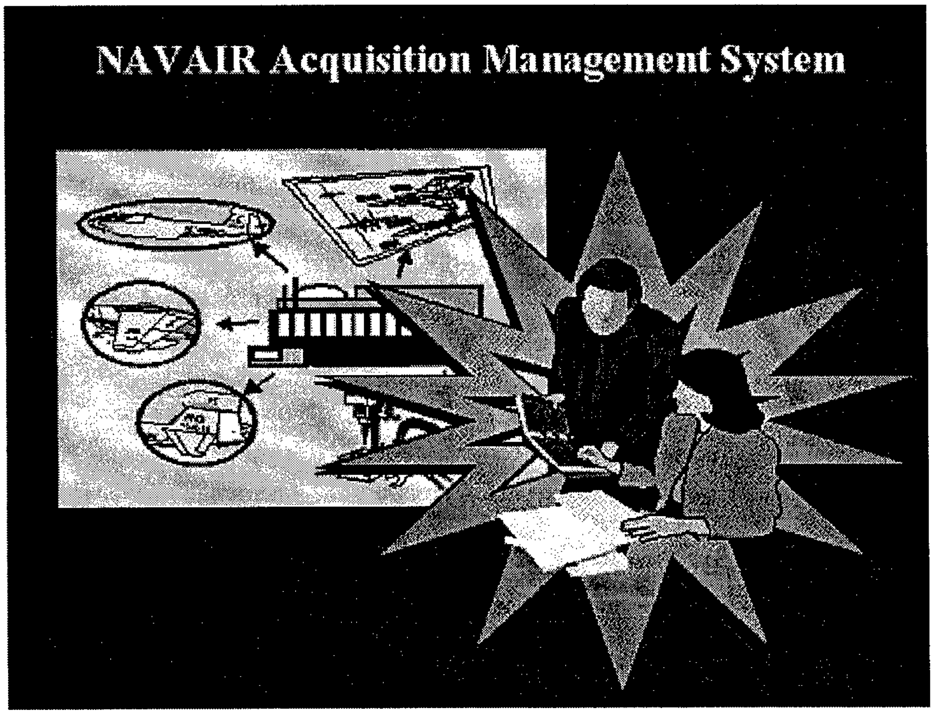

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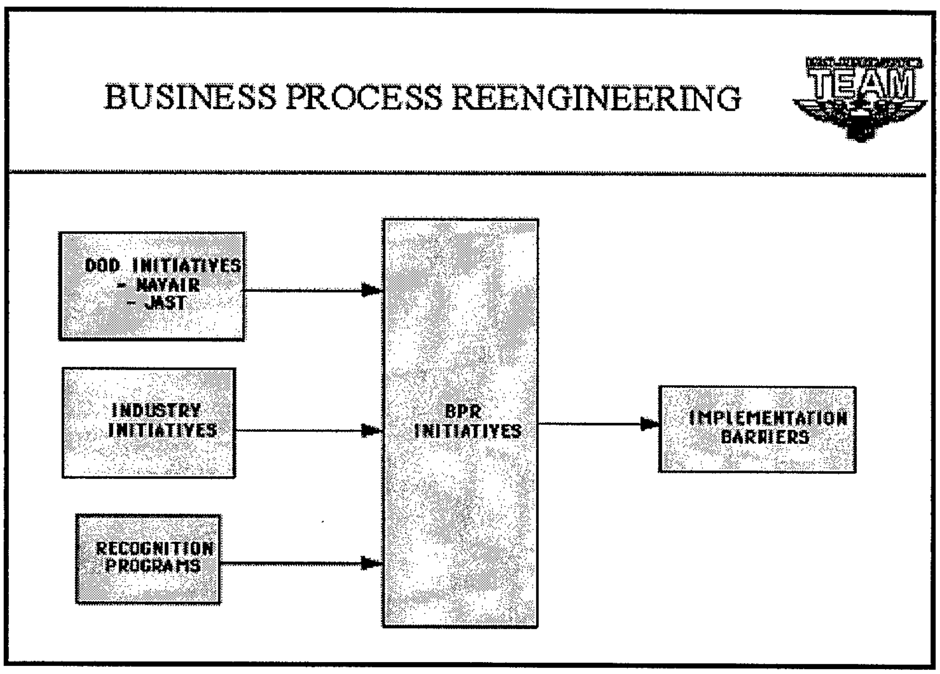

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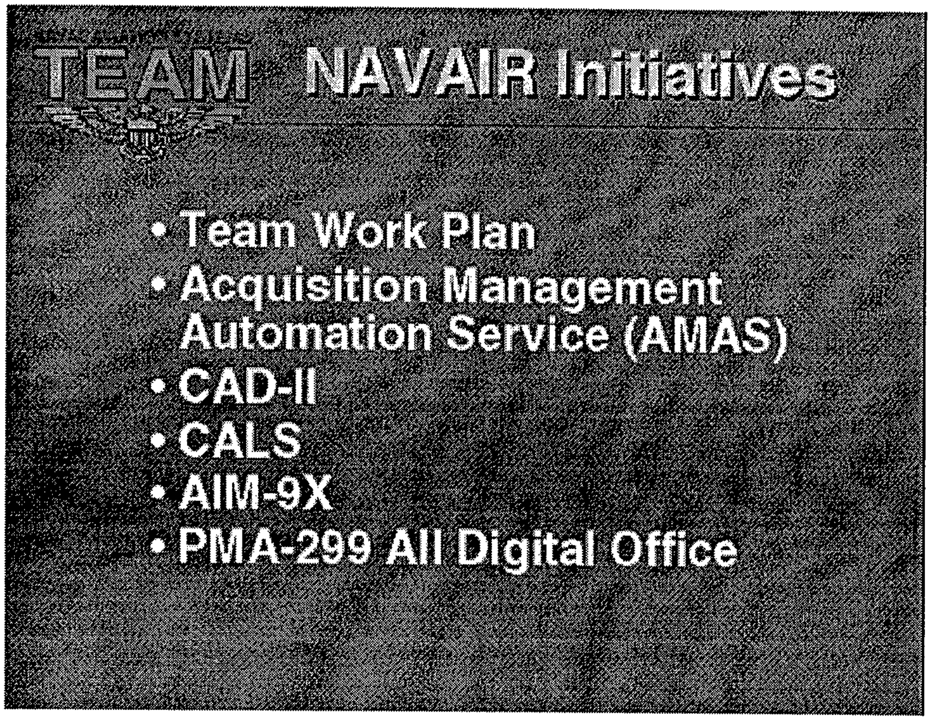

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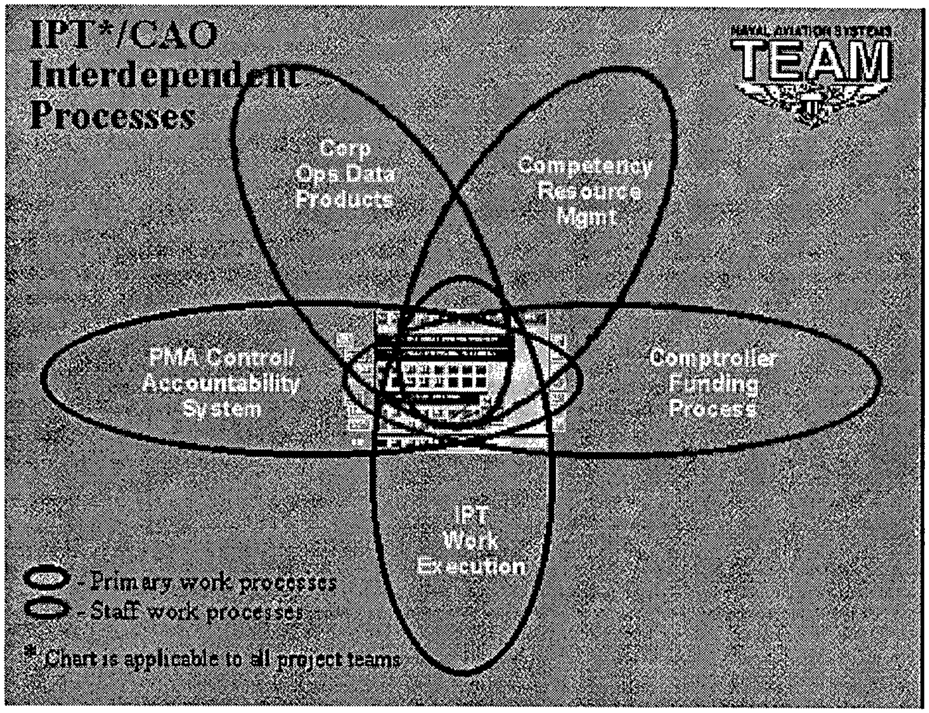

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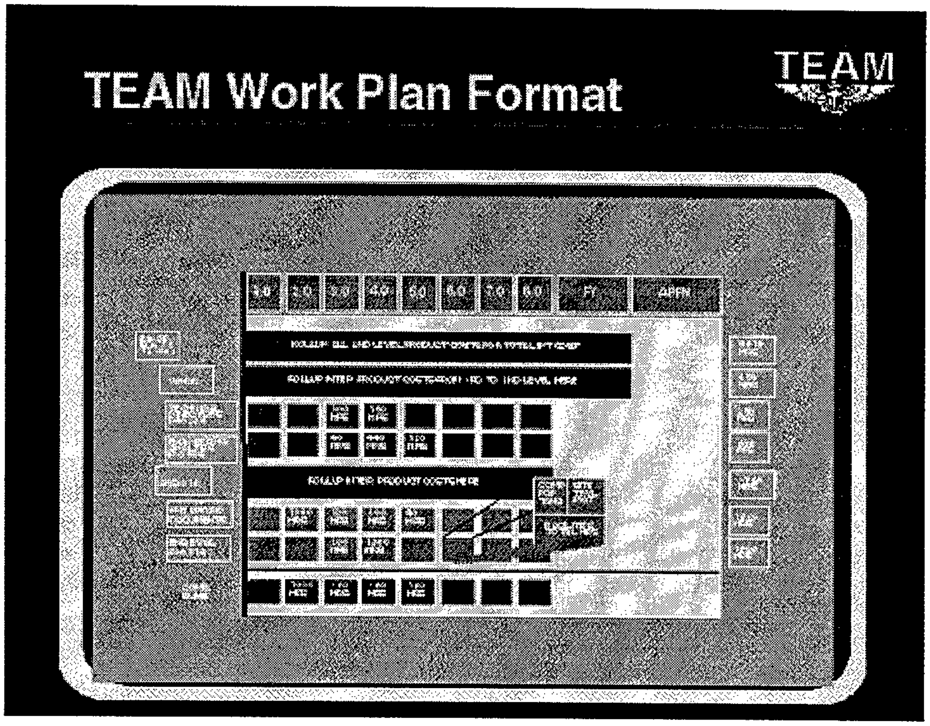

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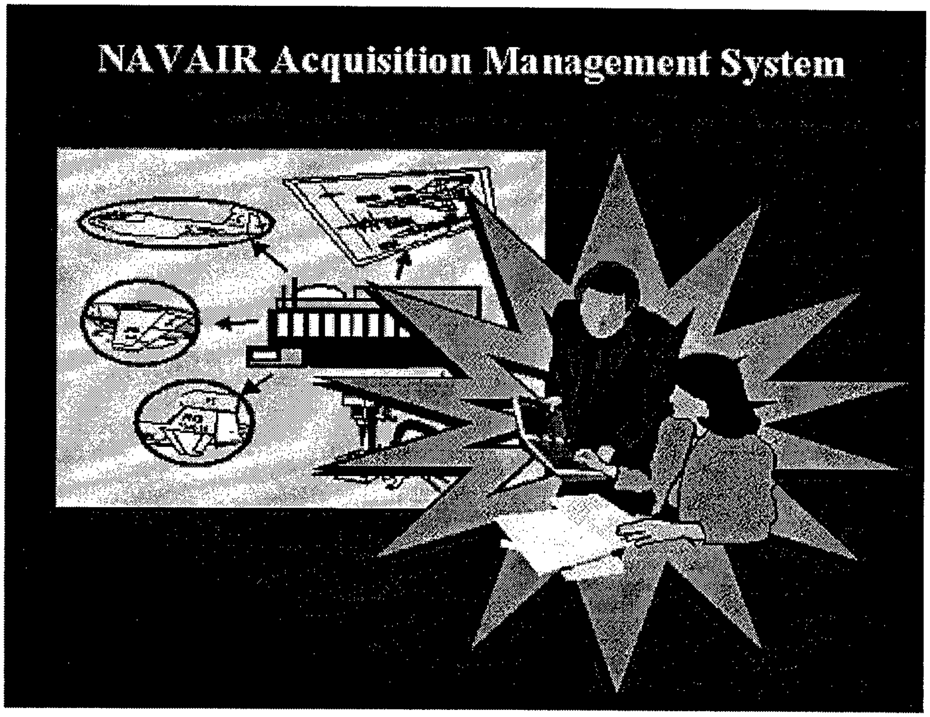

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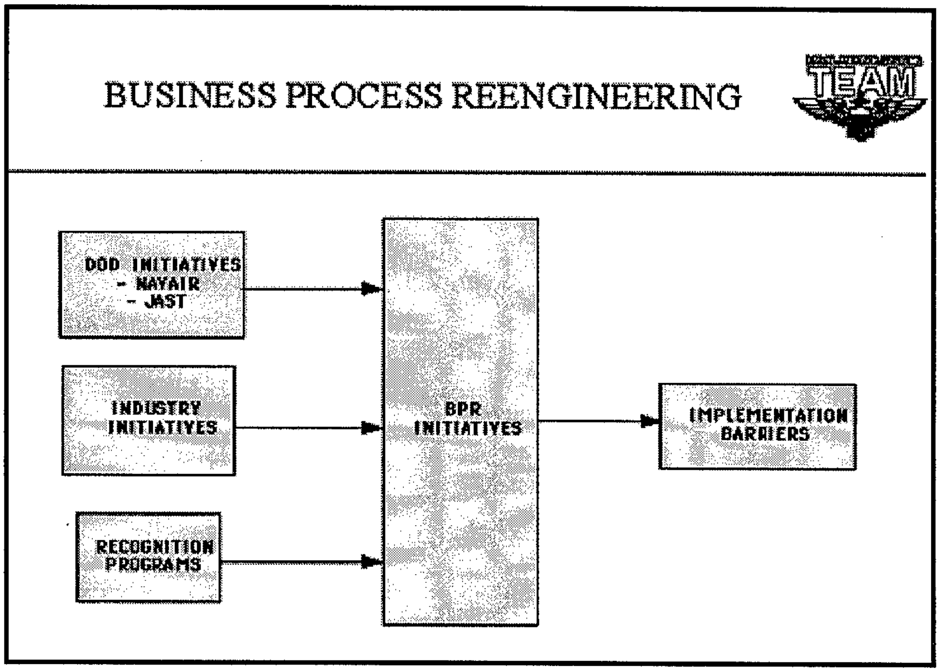

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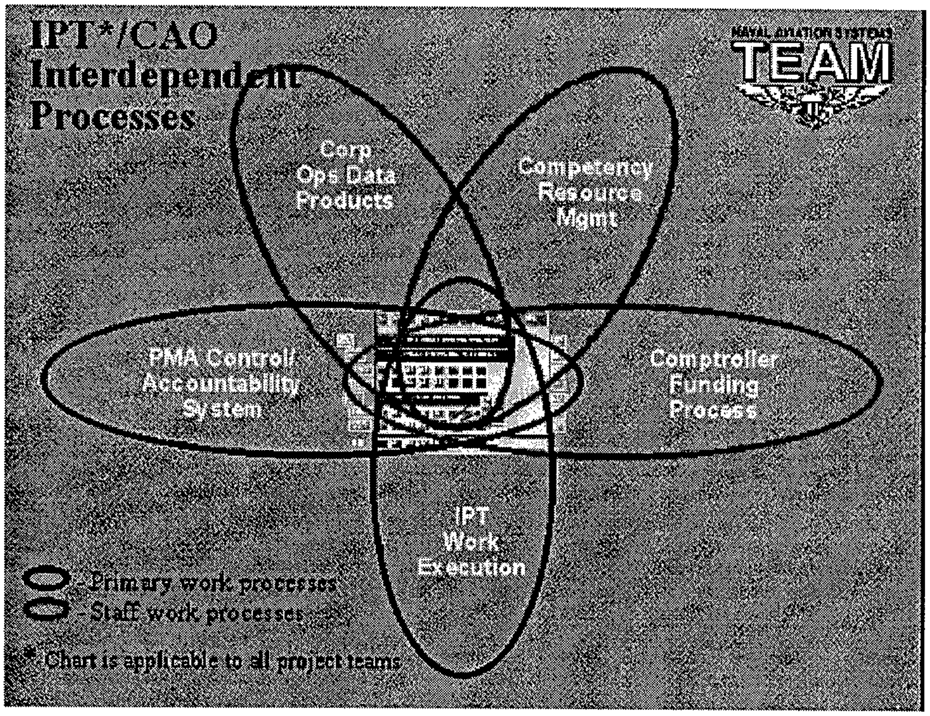

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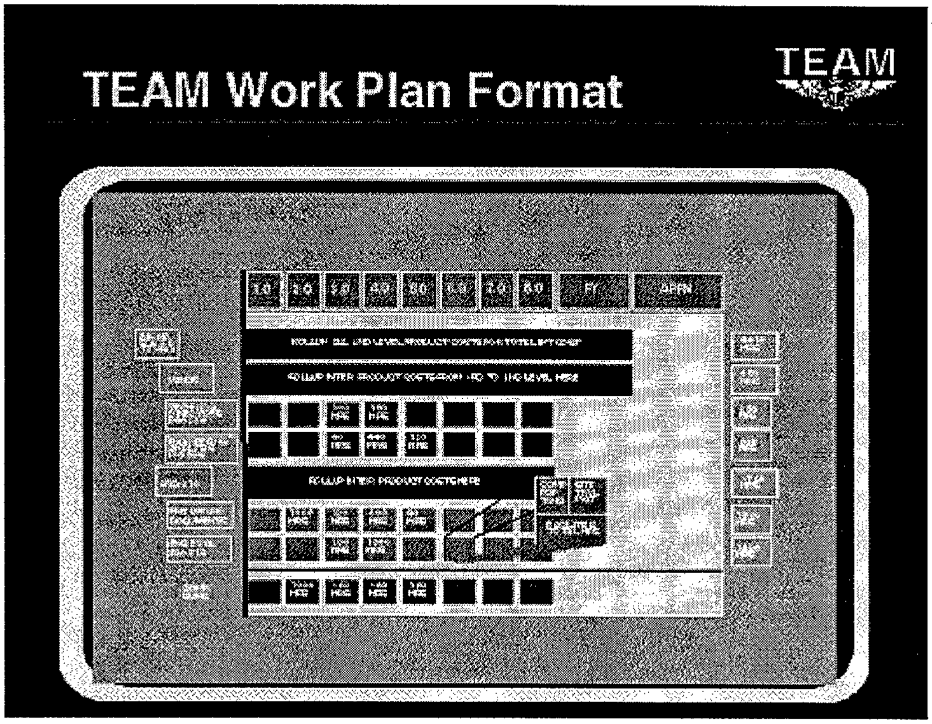

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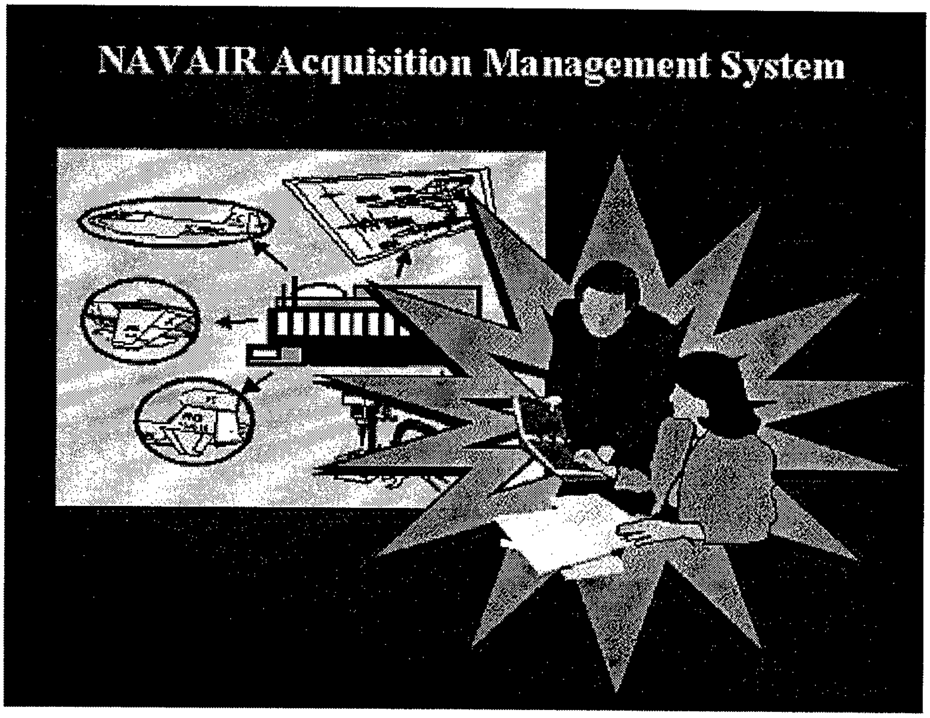

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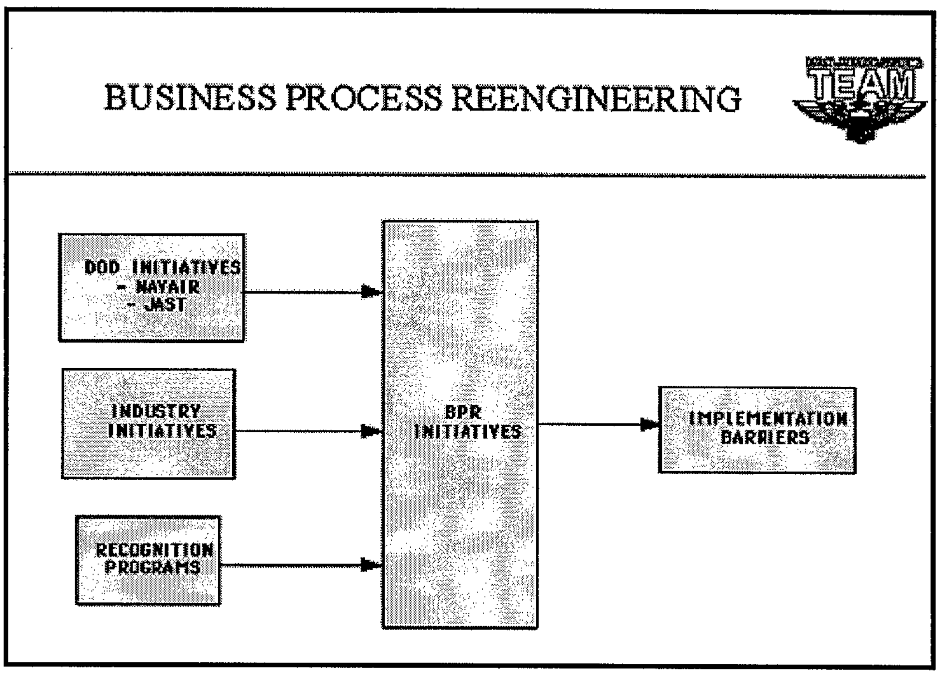

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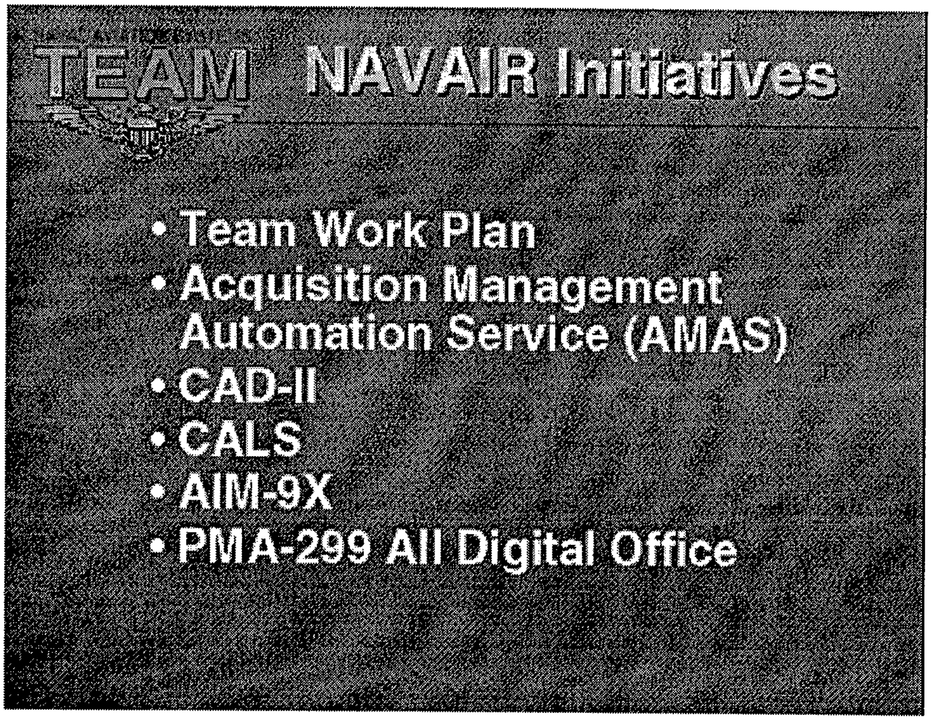

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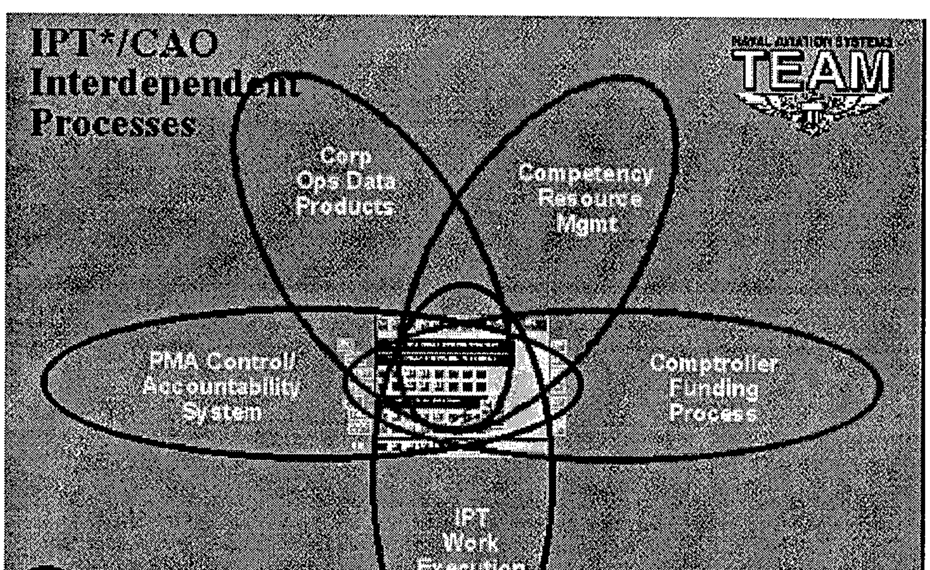

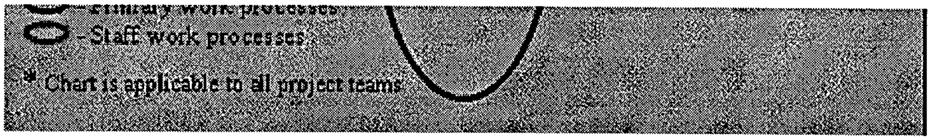

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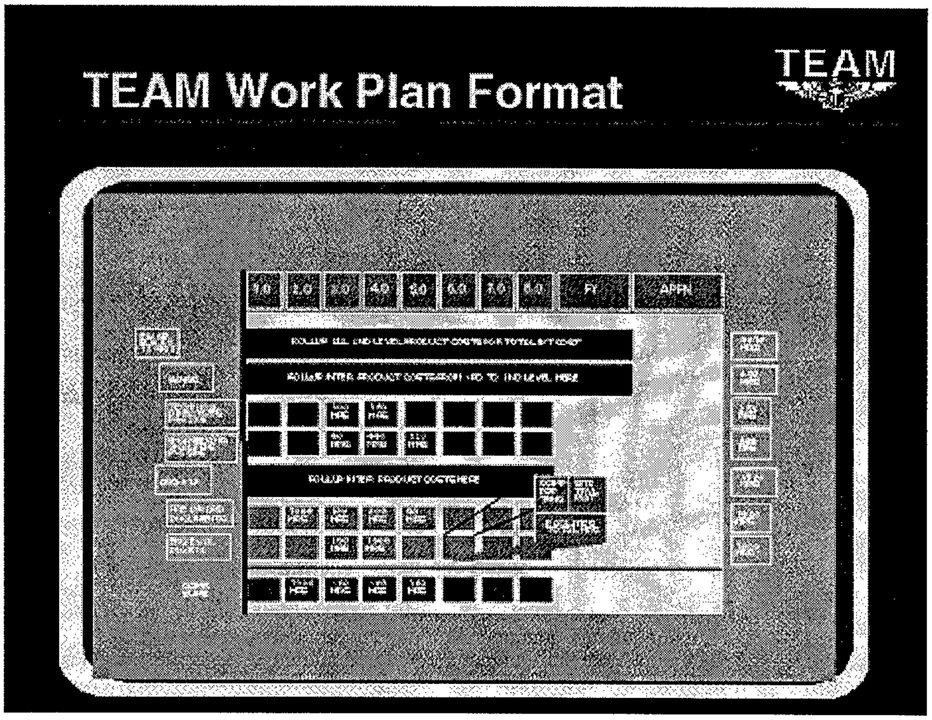

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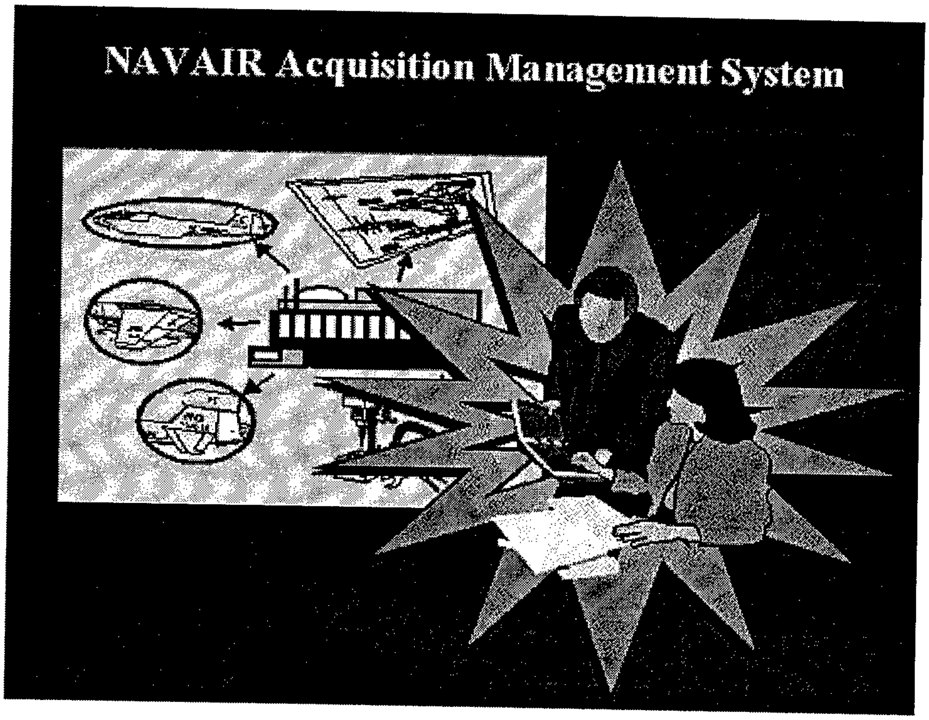

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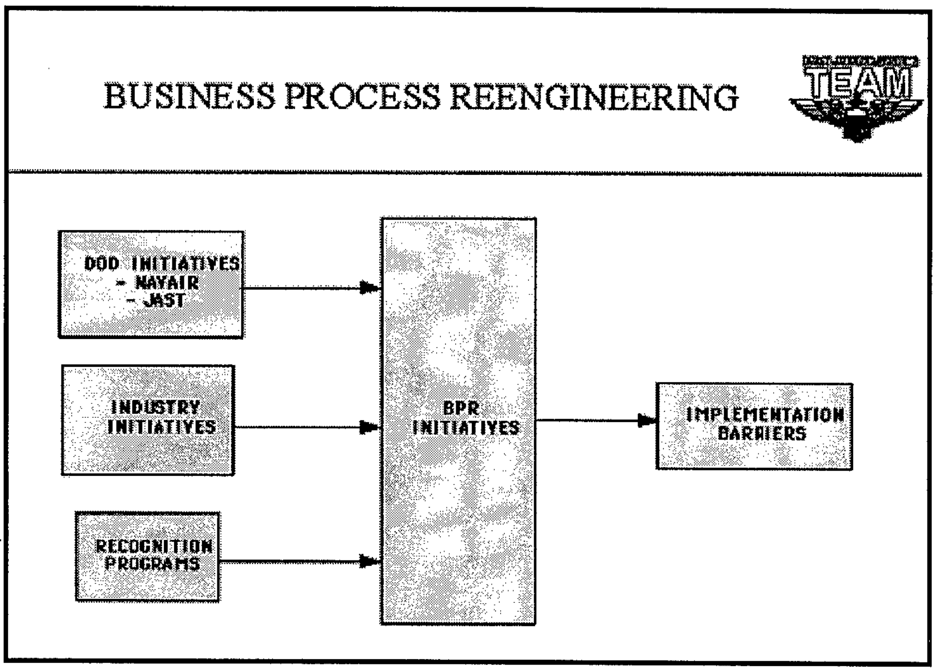

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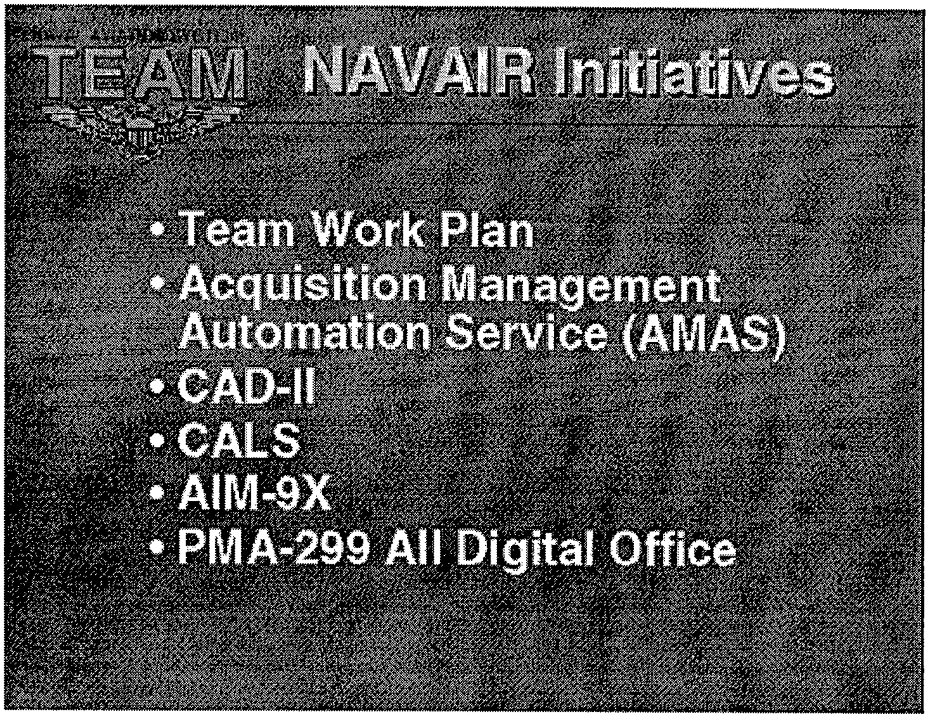

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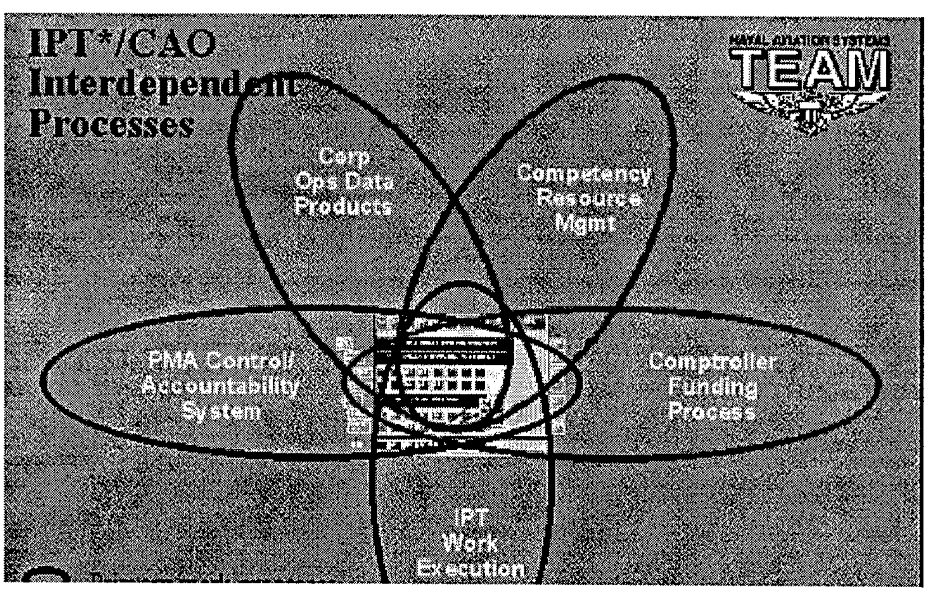

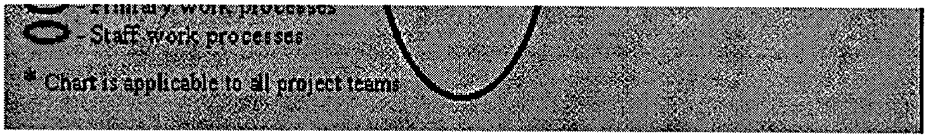

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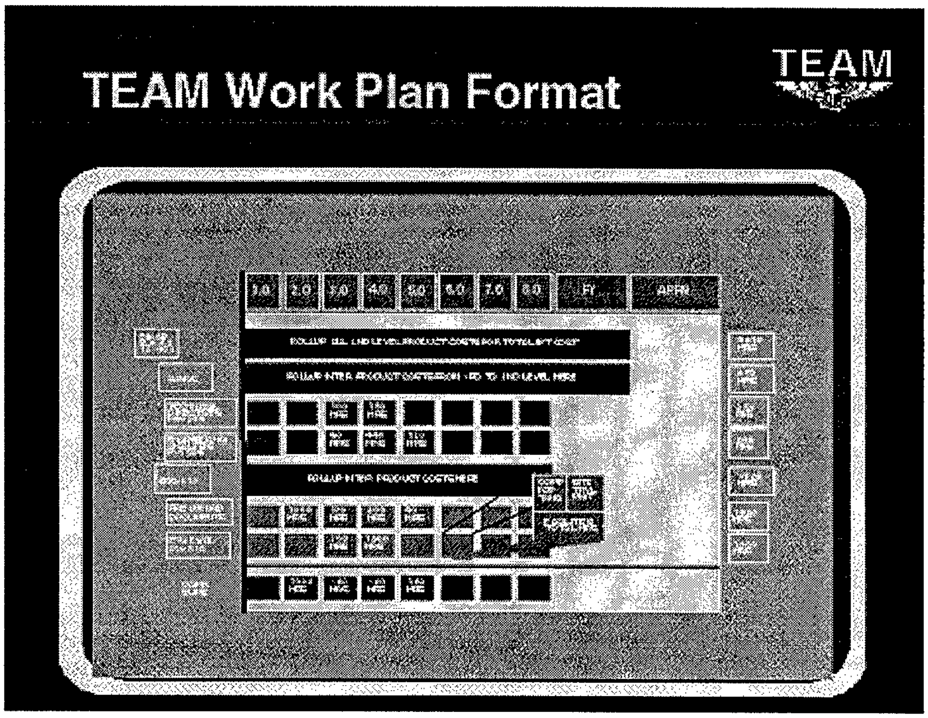

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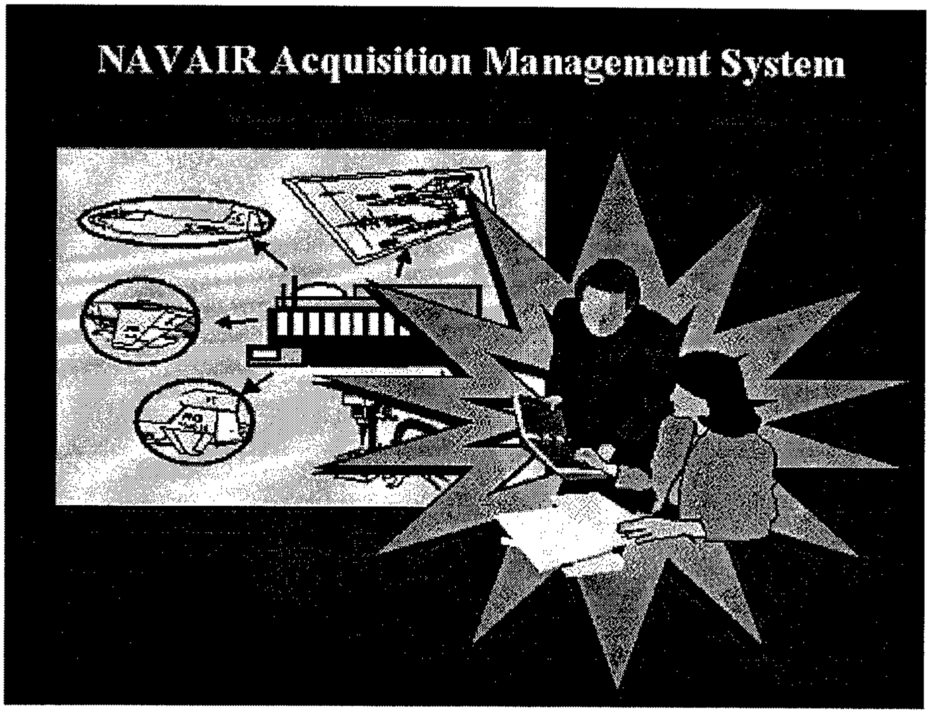

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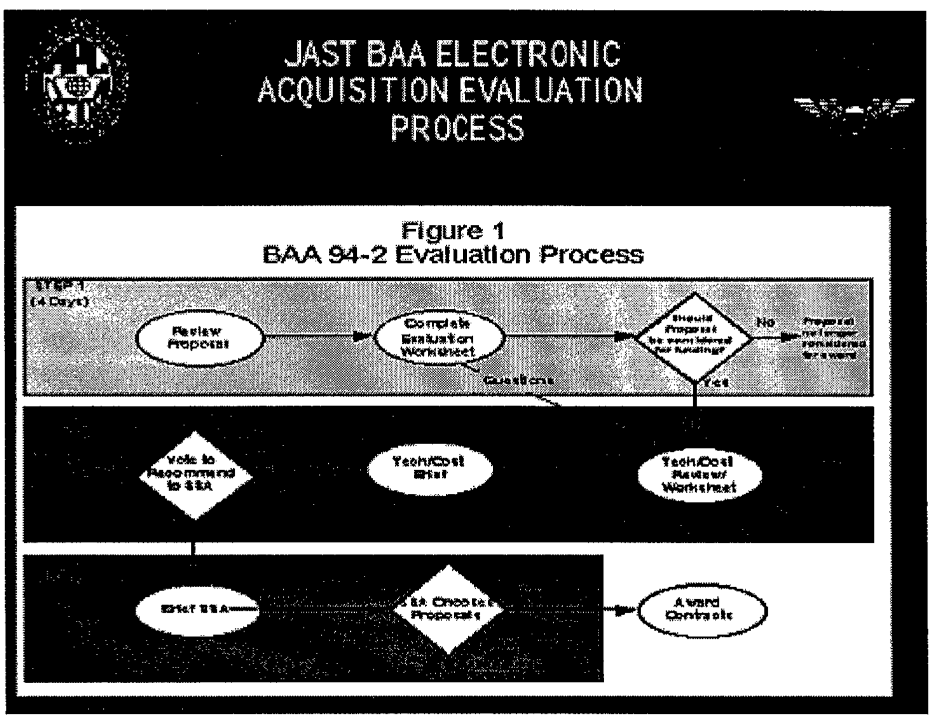
Program Office Points of Contact The final section provides links to obtain information on each of the program office points of contacts. This section gives biographies, phone numbers, and e-mail addresses.

JAST BAA ELECTRONIC ACQUISITION EVALUATION PROCESS

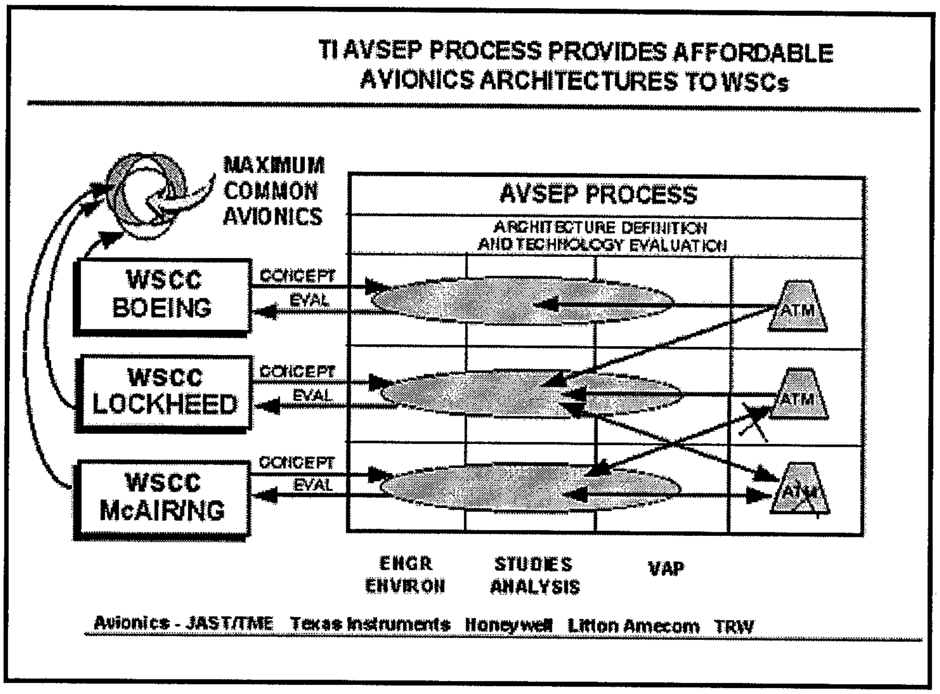
The JAST community has been using electronic source selection techniques for the preparation, evaluation, and awarding of contracts. Using this technology, the source selection process for BAA 94-2 was reduced to 15 weeks. Nine weeks were reserved for proposal preparation, four weeks for proposal evaluation, and two weeks for final negotiation and award. To facilitate this process, limits were placed on the length and format of proposals. Paperless Acquisition software tools such as the Bids Evaluation Support Tool (BEST) and Contracting Officer Support Tool (COST) were employed. BEST provides proposal inputting, worksheets, and other features to collect and evaluate proposals. COST was used to generate procurement and contracting documents. The FoxPro database software was used to store and access proposal and evaluation information. Two features used by the JAST Program include the use of a bulletin board system (BBS) to exchange contracts between the program office and award-winning contractors and the use of electronic signature software. With the AT&T DSA Signature program, the JAST Program Office completed the all electronic contracting process, from solicitation to the signing of electronic contracts.



JAST ASSOCIATE CONTRACTOR AGREEMENTS

Resolving the interfaces between the Weapon System Concept Contractors (WSCC) and the contractors maturing technologies for the JAST aircraft is a collaborative, iterative, and evolutionary process. The JAST Program Office is attempting to simplify the process through the use of Associate Contractor Agreements (ACAs). The ACAs are agreements signed between the technology maturation contractors and the weapon system contractors to exchange information for the purpose of making sure that the technology fits within the conceptual design for the JAST aircraft.

Texas Instruments' AVSEP process integrates the weapon system concepts into the avionics system engineering process. It is a good example of the intent of the ACAs. TI is exchanging data with the three JAST WSCC's to couple TI's avionics system design to the conceptual design of the three weapon system concepts. This process ensures that regardless of the weapon system concept that is finally chosen, the avionics system will fit into that design.



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Business Process Reengineering

CAD II

CAD II is a contracting vehicle for the purchase of advanced state-of-the-art hardware and software for Computer-Aided Design (CAD), Manufacturing (CAM), and Engineering (CAE). CAD II involves computer hardware and software for design, analysis, modeling simulation, documentation, data transfer, and data management, as well as the necessary technical services to maximize utility of these tools to the Navy.

The NAVAIR/SPAWAR CAD-II contract is a fixed-price, competitively awarded twelve-year contract with Intergraph Corporation (IGC) for electrical/electronic and aeronautical/mechanical CAD/CAM/CAE hardware, software, training, maintenance, and support services. The Contract Part Number (CPN) list is available upon request from IGC and is available on the world wide web (http://www.intergraph.com/cad2). IGC has developed a buyer's guide that provides detailed technical descriptions of these items.

Upon acceptance of hardware and software, Configuration Management System (CMS) will be provided for all hardware and software delivered. The CMS database will reside at IGC and dial-up access will be provided to government personnel. IGC will maintain the CMS and updates/changes will occur every fifteen days, after acceptance of application by contractor field service personnel.

NAVAIR CONTINUOUS ACQUISITION AND LIFE-CYCLE SUPPORT (CALS)

CALS Overview

CALS (formerly Computer-Aided Acquisition and Logistics Support) is a DoD strategy for achieving effective creation, exchange, and use of digital data for weapon systems and equipment. CALS specifications and CALS data interchange are generally concerned with four different types of data: character data and document text; raster data (bitmaps); vector data (lines); and CAD data (models). These data types, either by themselves or in various combinations, constitute the major digital deliverables CALS focuses on, e.g., publications, drawings, and engineering models.

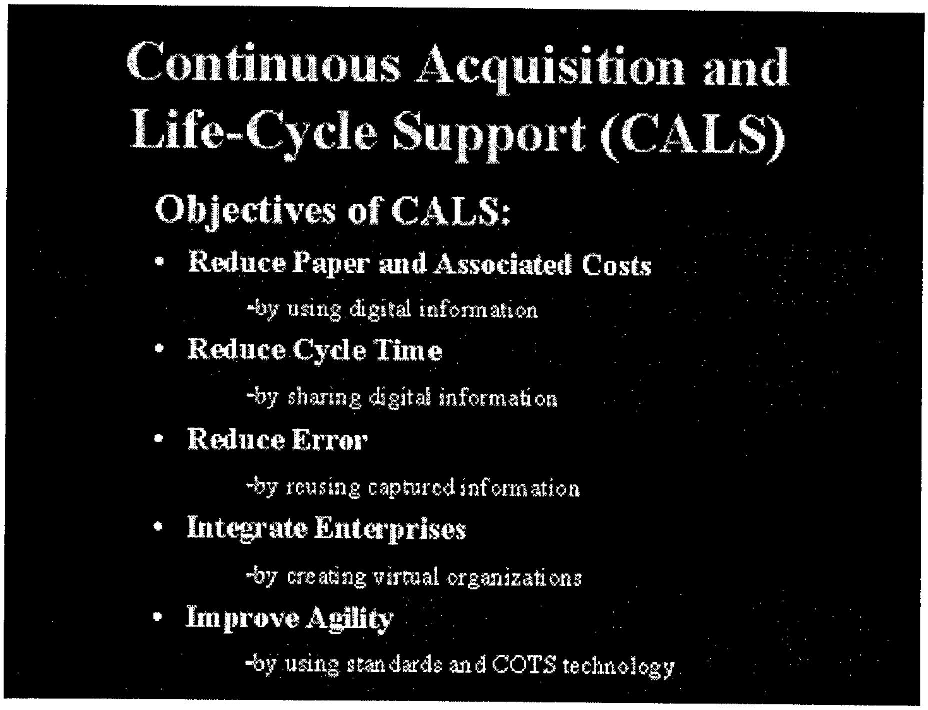
An understanding of these data types, what they are, what they mean, how they differ in complexity, and what meaning and intelligence each conveys is elemental to a good comprehensive and proper application of the CALS Standards. It is important to note that these CALS standards are focused on end products, technical data, that is exchanged between industry and government, or between government activities that are involved in supporting the logistic life cycle for a weapons system. Additional standards may need to be specified for other products and information that needs to be exchanged. The guidance provided in these standards represents a broad base of experience of digital products and data exchange. The FEDWORLD Bulletin Board (www://fedworld.gov/), maintains an FTP archive of CALS Standards. Most of the CALS Standards and some supporting documents can be retrieved from this site. Current CALS Standards include the following: MIL-HDBK-59, MIL-STD-1840B, MIL-D-28000A, MIL-M-28001B, MIL-R-28002, MIL-M-28003, MIL-M-87268, MIL-D-87269, MIL-Q-87270, EC/EDI, STEP, and MIL-STD-974.

Joint CALS (JCALS)

JCALS is a major information system program that was established in 1992 with the Army, as the lead service, the Central Design Agency, for the services, and DLA. The JCALS program will provide infrastructure to give DoD the capability to create, manage, use, transfer, and store acquisition and logistics technical information in digitized format. The JCALS program will identify the joint functional

logistics technical information in digitized format. The JCALS program will identify the joint functional requirements to be implemented, and acquire, implement, and field a CALS-compliant architecture and its interfaces to existing supporting systems.

The JCALS infrastructure will give the APML, PMA, and field activity unprecedented access to technical information across both commodity and weapon systems technical information, which fulfills the CALS intention of purchasing data once, and using it many times. JCALS will fully support the NAVAIR Competency Aligned Organization with a seamless pathway to manage and distribute digital data. On the functional side, it will provide the user an automated workflow system empowering the user to improve current business processes and create a common environment to electronically exchange data with DoD's industry partners. This common environment is essential to the collaborative efforts CSA will entail. NATSF and ASO will be brought on line as a test site to ensure JCALS meets NAVY requirements.



AIM-9X MISSILE PROGRAM

Several NAVAIR programs are currently using modeling and simulation during system design to reduce program costs. The approach and the lessons learned by these programs can be used as an example for the CSA team .

AIM-9X Missile Program

Acquisition Reform Initiatives The AIM-9X Sidewinder program is one of ten NAVAIR ACAT 1D programs being rebaselined under acquisition reform. It is currently in concept development and is scheduled for a Milestone II review in December 1996. An Overarching Integrated Product Team (IPT) has been established to replace the traditional DAB Review Board facilitating greater interaction between the reviewers and the process. The IPT is led by the former DAB Committee Chair, and is composed of the Program Manager (PM), the Program Executive Officer (PEO), and Component and OSD staff principals, or their representatives, involved in oversight and review of the ACAT ID program.

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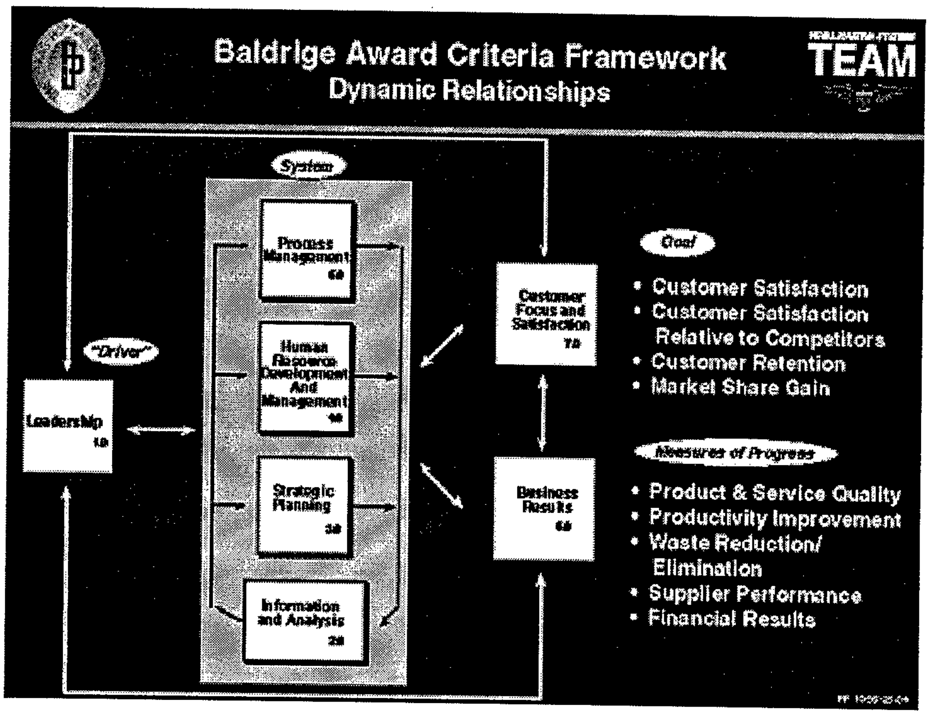

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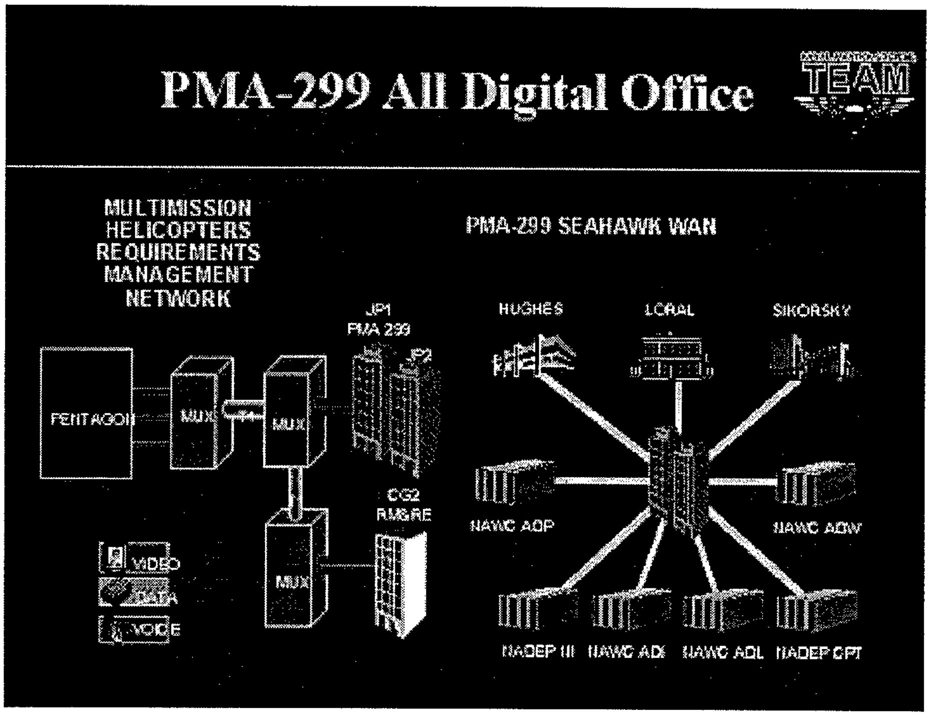

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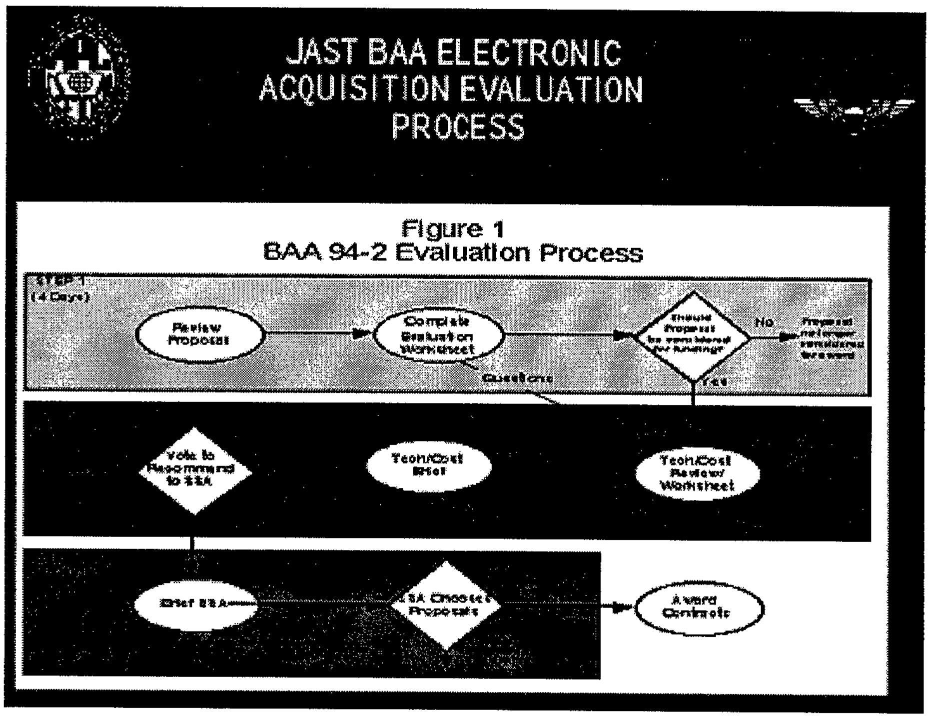

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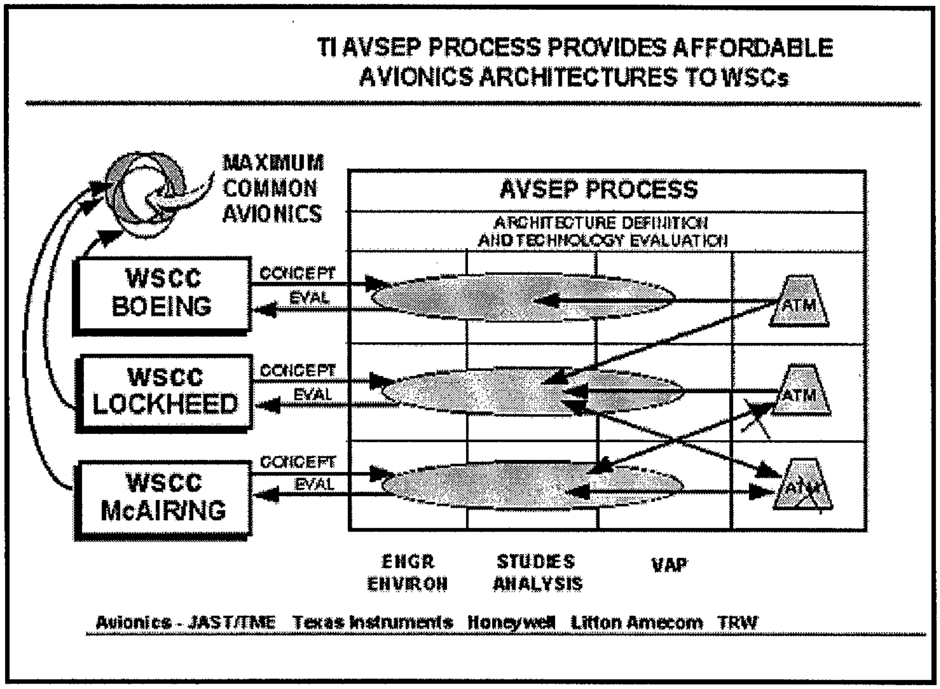

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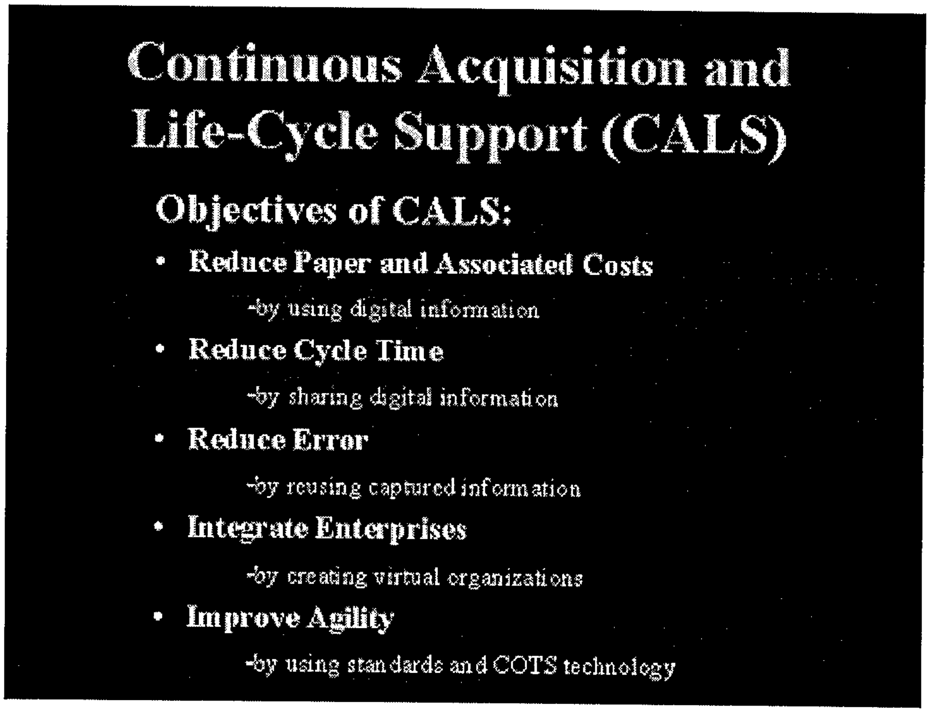

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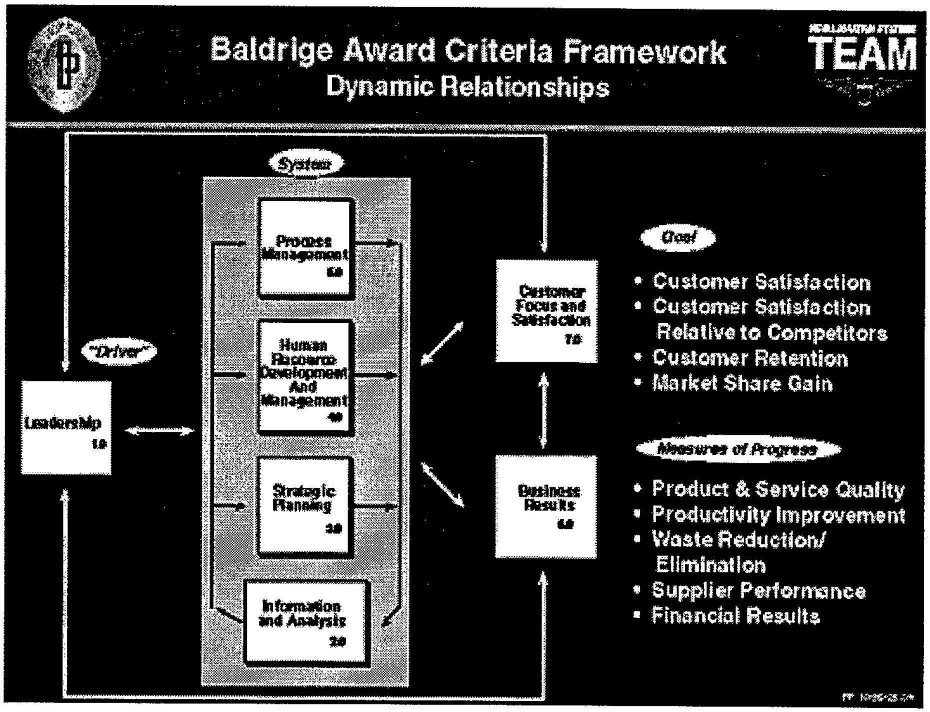

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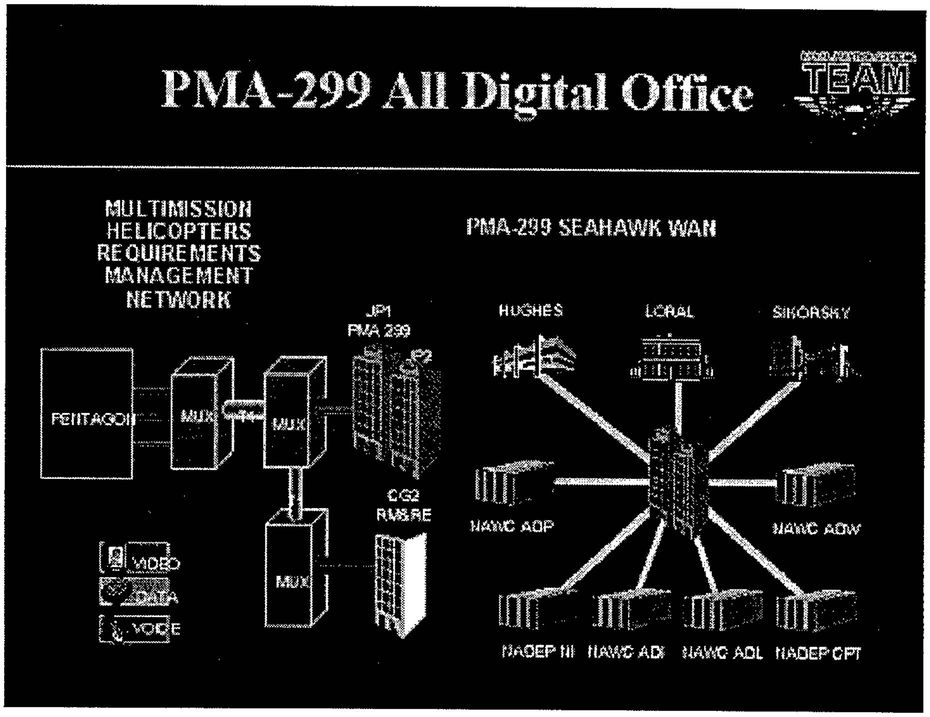

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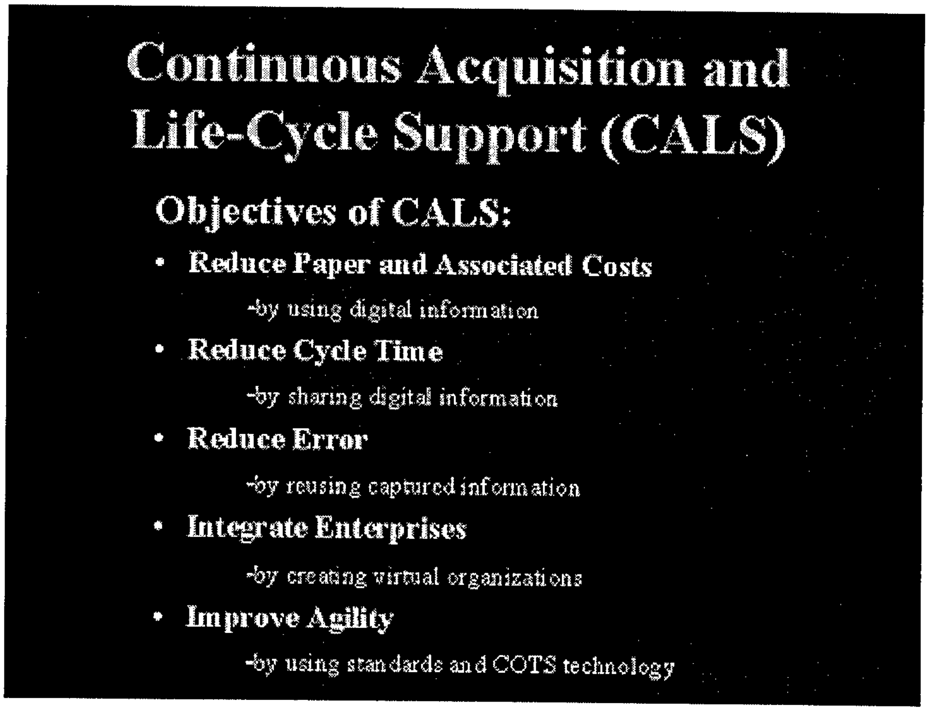

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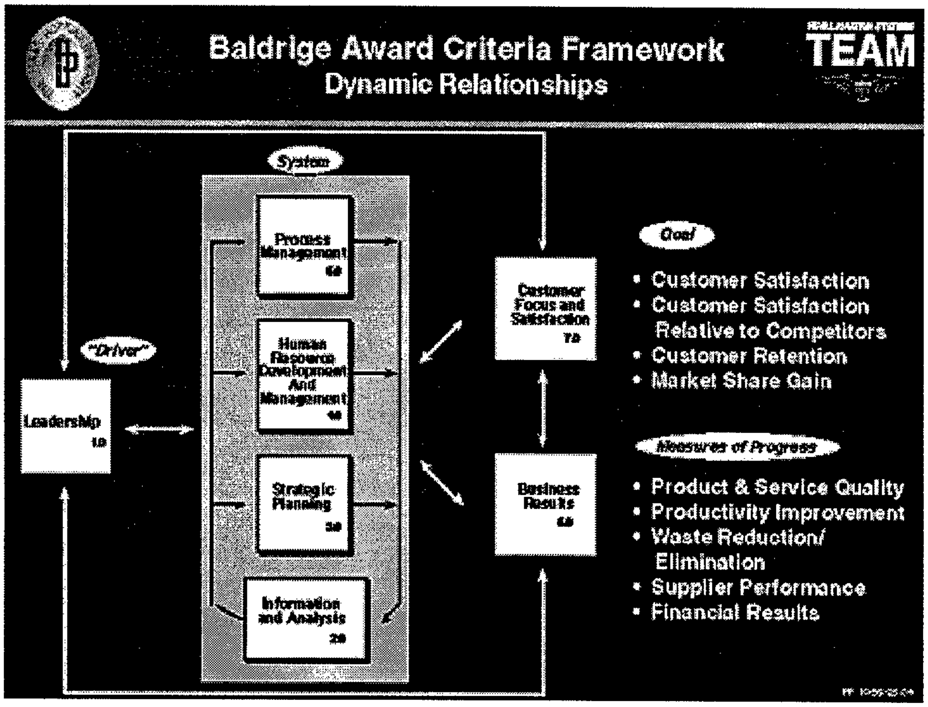

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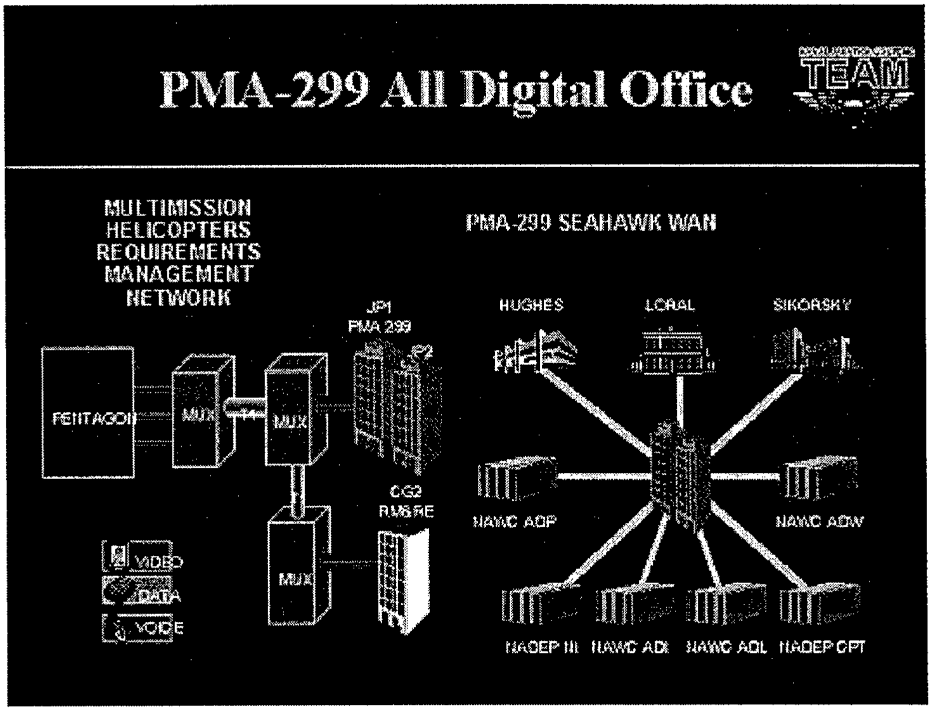

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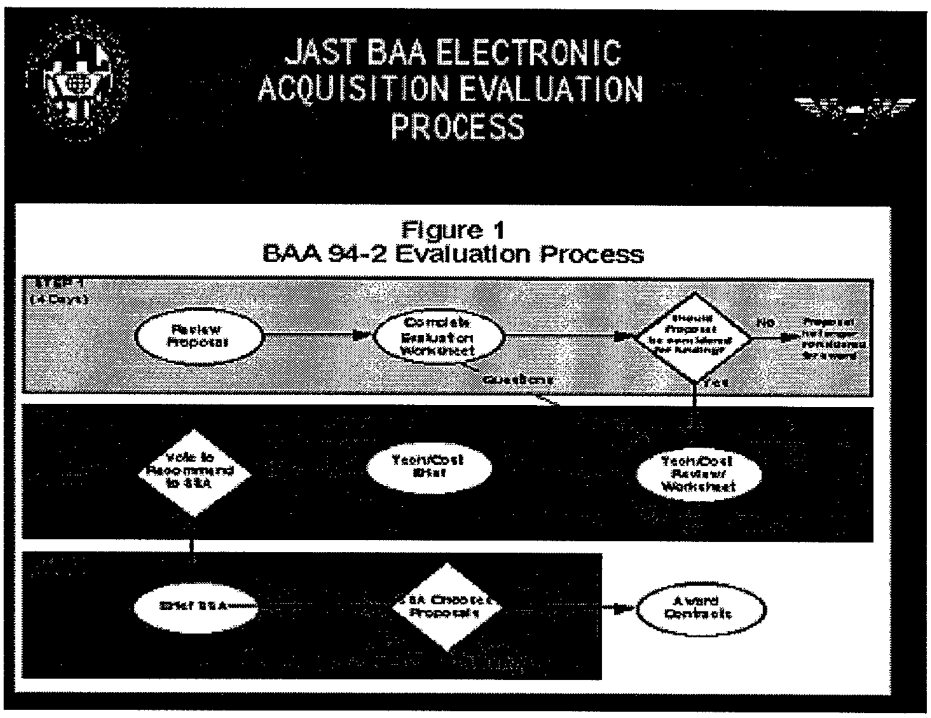

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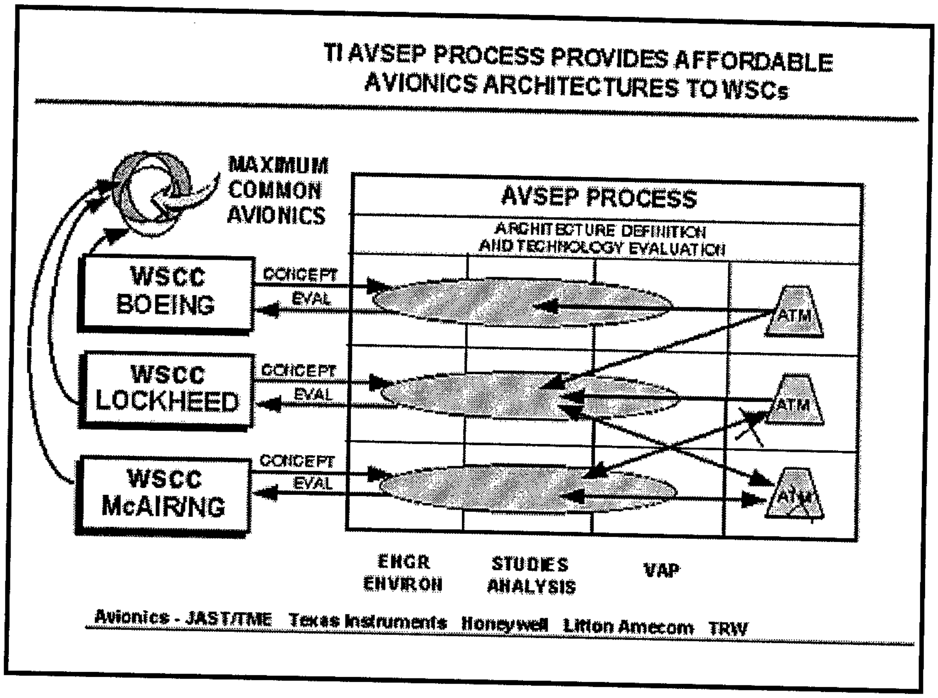

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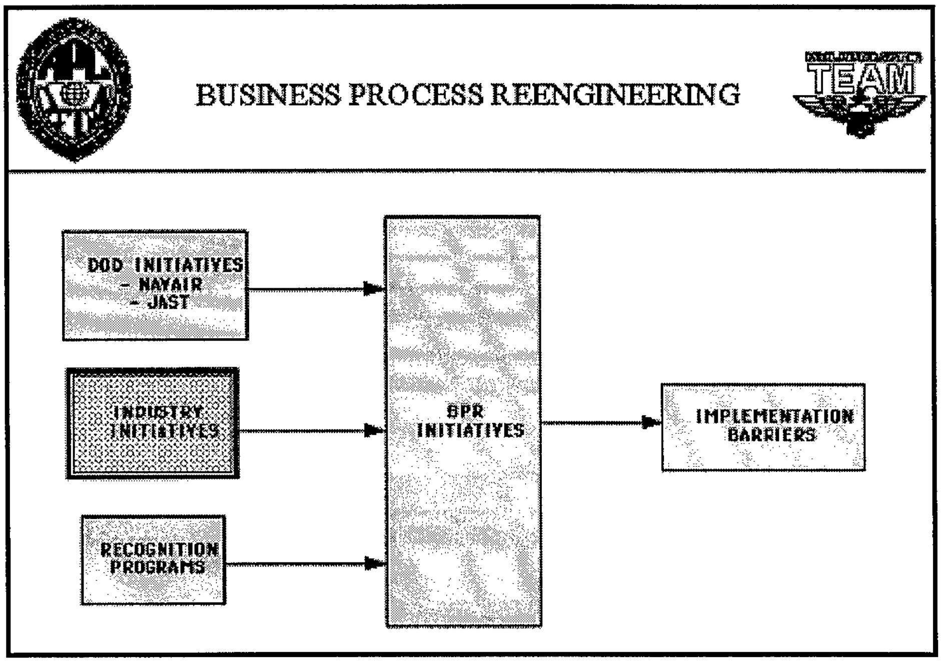


LEAN AIRCRAFT INITIATIVE

The Lean Aircraft Initiative (LAI) is an MIT research project patterned after the highly successful Lean Automotive Initiative used by the automotive industry to recapture the U.S. and world markets. The LMI is a three-year collaborative effort with government and industry that began in 1993. The focus of the effort is on data, analysis, benchmarking, and implementation of lean aircraft principles. The project's resources are derived from industry at a rate of $75K per company per year, and from Government at a rate of $975K per year. The individual participants incur the cost of surveys, workshops, case studies, and implementation.

The following are the five elements of a lean enterprise:

1. Lean Management
2. Lean Customer Relations
3. Lean Supplier Relations
4. Lean Development
5. Lean Factory Operations

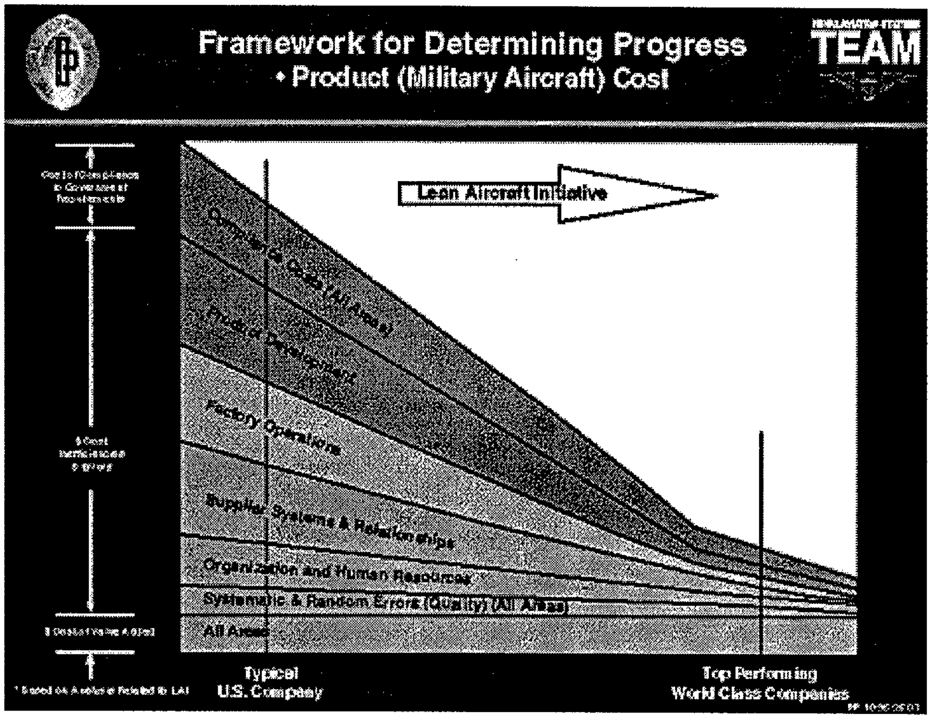
Elements of Lean

- **LEAN DEVELOPMENT PROCESS**
  - Multifunctional Teams
  - IPPD
  - Well-Defined Development Process
  - Supplier Participation
  - Design for Manufacturing
  - Supplier Involvement
  - Prototypes with Production Workers/Processes
  - Production Experienced Design Engineers
- **LEAN FACTORY OPERATIONS**
  - Maximum Tasks Assigned to Workers on Shop Floor Who Add Value to Product
  - Workers Expected to Find/Prevent/Fix Problems
  - Open Information Flow
  - Few Classifications/Multiple Skills
  - Continuous Training Instruction
  - Reciprocal Management Obligation
  - Design Process to Minimize Setup
  - Effective Use of Automation
  - Defects Not Allowed to Continue in Assembly
  - Just-in-Time Inventory
  - Reduced Workspace
  - SPC Widely Used
  - Quality System Not Satisfied with Superficial Answers
  - Aggressive Action to Fix Problems Permanently
- **LEAN SUPPLIER RELATIONS**
  - Shared Development
  - Long-Term Relationships
  - Prime/Supplier Scrub Costs Jointly
  - Joint Cost Reduction/Problem Solving Work During Production
  - Fair Profit Sharing Rules for Cost Reductions
  - Broader Responsibilities for 1st Tier Suppliers
  - Fewer Parts Despite Increasing Complexity
  - Single Source Used Sparingly
- **LEAN MANAGEMENT/ORGANIZATION**
  - Broad Tasking of Direct Employees
  - Fewer Layers of Management
  - Decision Authority Delegated to as Few as Possible
  - General Management has Different Basic Function
  - Employees Viewed as Fixed Cost
  - Management Works to Level Workload
  - Significant Training Investment
  - Few Skill Classifications/Flexible Job Assignments
  - Advancement Mainly in Skills/Challenge-Not Job Title
  - Bonuses Tied to Team/Company Performance
- **LEAN CUSTOMER RELATIONS**
  - Continuing Evaluation of Customer Needs
  - Rapid Changes in Product when Need Identified
  - Customer Interface People Part of Development Teams
  - Fix Anything Other Than Normal Wear/Tear
  - Extensive Training of Customer Interface People

* Source: MIT IMVP Program

LEAN AIRCRAFT FRAMEWORK FOR DETERMINING PROGRESS

The slide shows the framework that the Lean Aircraft Initiative is using to determine progress. This framework is centered around the cost of delivering a quality military aircraft. The costs are divided into the cost of compliance to government requirements, the cost of inefficiencies and errors, and the cost of value added. The cost of inefficiencies and errors are further subdivided into product development, factory operations, supplier system relationships, organization and human resources, and systematic and random errors. Progress is achieved when the cost of government compliance and inefficiencies & errors steadily decrease over time. CVP technology and new business processes are the major contributors to these cost reductions.



INDUSTRY INITIATIVES

Boeing

Boeing is well known for their investment in technology for design and production of their new commercial aircraft the Boeing 777. These same technologies are being employed for their defense business. They are currently employing 3-D solid models and virtual walk-throughs to replace physical mockups. Physics-based models are being used to reduce and tailor testing. Boeing was a leader in the development of the STEP AP203 protocol for the transfer of electronic models with its suppliers which has significantly reduced the time and cost of new designs. Boeing has implemented a worldwide network with its suppliers for the transfer of design data and electronic commerce information and has formed virtual enterprises with Lockheed, Bell, and Sikorsky for the F-22, V-22, and RAH-66 Comanche.

McDonnell Douglas

Phantom Works at McDonnell Douglas St. Louis, MO, is dedicated to change fundamentally the way aerospace systems are designed, developed, and constructed. Technical product data and NC code is sent electronically to suppliers machine shops directly from McDonnell Douglas design teams. Advanced manufacturing techniques like high-speed machining and automatic composite fiber placement are reducing parts count, saving man-hours, and dramatically reducing cost. McDonnell has been visiting firms within this country and abroad to identify the best manufacturing practices. As an example, McDonnell has an agreement with the Russian Design Bureau to examine the utility of low-cost aircraft construction techniques and materials like titanium.

McDonnell Douglas has integrated their electronic design and production tools into a CVP environment called Design Manufacturing and Producibility Simulation (DMAPS). McDonnell Douglas has been conducting electronic commerce with its suppliers for initiating and transacting purchase orders and contact orders. This initiative has resulted in considerable savings in time and man-hours.

Industry Initiatives

Aircraft Industry Initiatives:

Boeing

- CVP technologies and practices applied to the 777, F22, V-22, & RAH-66 Comanche
  - 100% electronic design - solid models
  - Customer involvement in IPTs
  - Form virtual enterprises with suppliers
  - Increased use of modeling and simulation for analysis, fit, form, function, serviceability etc.

McDonnell Douglas

- Phantom Works
  - Solid Models and Neutral file formats
  - Reduced Parts Count (High-Speed Machining, Fiber Placement & Composite molds)
  - McGoin Construction Practices
- Buyers Workstation
- Design Manufacturing and Producibility Simulation

INDUSTRY INITIATIVES

Lockheed Martin

Lockheed Martin, Fort Worth, TX, produces one of the most affordable fighter aircraft, the F-16. They have been able to reduce the per unit cost of the F-16 for smaller buy orders by instituting lean manufacturing principles and removing all non-value-added processes. Lockheed recently made an offer to the Air Force and OSD to commercialize the F-16 plant. Under this agreement future aircraft would be delivered under commercial fixed priced contracts with a 15% reduction in price. To accomplish this reduction, all government regulations and oversight would be removed, and commercial standards and accounting systems would be implemented. The F-16 offer has the potential to be a commercialization benchmark since 3500 F-16s have already been produced and metrics have already been established.

Lockheed is investing in the creation of a CVP environment for integrating all of their product and process tools. The key elements are: a rapid modeling capability, integrated product analysis tools, product and process evaluation tools, product visualization, integrated manufacturing standards and architecture, integrated factory data systems, and an integrated supplier base. LMTAS has made a strategic business decision to invest in conceptual design and analysis tools for examining design, producibility, and trade-offs during the Concept Exploration Phase.

Northrop Grumman Vought

Northrop Grumman Vought facility, Dallas, TX, is integrating suppliers into their planning schedules and giving them total responsibility for supplying raw materials using "Just-In-Time" business practices. In a Just-In-Time inventory pilot with Alcoa, Vought turned over responsibility to Alcoa for delivery of materials, thereby reducing purchasing support, inventory, warehousing, inspection, cutting, and transporting.

Northrop Grumman is also investing in advanced manufacturing processes for automatic NC control of composite tape, age creep forming to reduce machining, and fastening and precision assembly.

Northrop Grumman is teaming with McDonnell Douglas, Wright Labs, and the C-17 Program Office in identifying best commercial and military policies and practices. The project will develop metrics for these practices and transition the benefits analysis to the aerospace community through the Lean Aircraft Initiative. Northrop Grumman facilities have been networked together to form a virtual enterprise for virtual prototyping and process development, virtual manufacturing, and systems integration.

Industry Initiatives

Aircraft Industry Initiatives:

Lockheed Martin
- Commercialization of the F-16 production
- Implementation of Lean Aircraft Production
- Integration of Design and Manufacturing Tools into a Information Technology Environment
- Development of Conceptual Design Tools

Northrop Grumman Vought
- Customer Supplier Integration
- Advanced Manufacturing Process Development
- Military Products using Best Commercial/Military Practices
- Systems Integration Infrastructure
- Prototype & Simulation Center of Excellence

INDUSTRY INITIATIVES

Texas Instruments (Defense Systems and Electronics Group)

The Texas Instruments Defense Systems & Electronics Group (TI-DSEG) has made total quality basic to its business. The Dallas-based maker of precision-guided weapons and other advanced defense technology believes that its full-scale conversion to total quality management (TQM) is making it a stronger competitor in a declining defense industry.

Aiming to achieve a defect rate of 3.4 per million (six sigma) by the end of 1995 and to reduce product development time by 25 percent each year, TI-DSEG is reaping the benefits of accelerating quality-improvement efforts that began in the early 1980s. The reliability of TI-DSEG systems exceeds the specifications of its Defense Department customers, in several instances by four or five times. Effective strategic planning, wide use of concurrent engineering methods, and strong relationships with key suppliers have helped TI-DSEG penetrate new defense markets, while increasing its share in five of the company's six existing markets.

The Malcolm Baldrige award criteria principles have been the foundation of TI-DSEG's strategy. In 1992, TI-DSEG received the Malcolm Baldrige award and they continue to employ Baldrige criteria in application of new business processes.

Texas Instruments is employing the Hammer Business Model to focus its internal business processes. This model incorporates the Hammer Diamond that has been successfully employed in the semiconductor side of the company. This process relies on empowering a team-based organization to focus on processes, quality, increased manufacturing agility, and team leadership.

Industry Initiatives

Electronics Industry Initiatives:

Texas Instruments

- Commitment to the Malcolm Baldrige Process
- Six Sigma, Cycle Time, Affordability
- Hammer Business Process Model
- Increased Employee Training
- Electronic Commerce
- Implementation of Best Manufacturing Practices
- Benchmarking
- Concurrent Engineering & Information Technologies

INDUSTRY INITIATIVES

Westinghouse Electric

Westinghouse Electric is a supplier of aircraft avionics for the F-16, F-22, P-3 improvement, and JAST technology maturation program. Westinghouse is engaged in a three-year program, referred to as "Strategy #3," to integrate engineering and the shop floor with state-of-the-practice tools and information technologies.

Westinghouse is involved in a number of joint ventures to examine future ways to conduct business. A sample of these ventures are:

1. Study to investigate the use of autonomous agents to support optimization of manufacturing processes.
2. A Manufacturing 2005 Pathfinder project with Raytheon to examine security aspects of electronic data exchange.
3. F-16 commercialization with Lockheed.

Westinghouse is conducting joint research with the University of Maryland in a project called the Optimum Selection of Partners for Agile Manufacturing (OSPAM) sponsored by the U.S. Army Tank-Automotive Command (TACOM). This project describes a process for rapidly identifying partners for virtual organizations based on the capabilities of potential partners to perform needed manufacturing processes.

Industry Initiatives

Electronics Industry Initiatives:

Westinghouse
- Optimum Selection of Partners for Agile Mfg
- Strategy #3 (integration of engineering & the shop floor)
- Joint Ventures

INDUSTRY INITIATIVES

Raytheon

Raytheon identified the following new business practices associated with CVP: Vertical Partnering, Electronic IPPD, and Requirement and Design Reuse.
Vertical Partnering The aircraft division of Raytheon has recently completed the Vertical Partnering Facilitation Program, which is sponsored by the ManTech Program Office at Wright Patterson Air Force Base. Raytheon's participation in this program demonstrated an approach that allowed subcontractors access to its CAD/CAM tools and associated databases, while maintaining networks security, confidentiality, easy access, and low cost. The program allowed smaller businesses that typically can't afford CAD/CAM systems to benefit using these systems.

Electronic IPPD Raytheon's time to market is the driving factor behind the use of Integrated Product and Process Development (IPPD) and related CVP tools and techniques. The critical element to the success of IPPD teams is to enable the acquisition environment to embrace a team concept that includes the customer and the user. Raytheon in participating in a Ballistic Missile Defense (BMD) distributed team using T1 lines to create a Wide Area Network (WAN) between themselves and select subcontractors. Object oriented programming techniques are used to facilitate collaborative design efforts over the network in real time.

Requirement and Design Reuse Raytheon along with Loral, Lockheed Martin, and Texas Instruments is a participant in ARPA's affordable multimissile manufacture (AM3) program and will be looking at applying reuse earlier in the requirements process. The AM3 program's goal is to reduce acquisition cost in all existing missile programs by 25% and in all future missile programs by 50%. Savings will be made through the use of CVP technologies linking prime and subcontractors, and through reuse of assembly lines, common tools, and common parts for different missile programs. Raytheon's Enhanced Fiber Optic Guided Missile (EFOGM) program is using virtual prototyping. This effort is prototyping a communications/software environment rather than a physical system. Electronic mock-ups are being developed are for the vehicle, to allow a driver to move through a simulated battlefield and for the gunner console, to enable the gunner to guide the missile through the battlefield based on the IR image. The EFOGM program is Raytheon's first application of CVP technologies and is a good example of how CVP technologies are maturing. The EFOGM program will be conducting an advanced concept technology demonstration (ACTD) in July of 1996. For further information on EFOGM or Raytheon, contact Richard Bolander, Software Engineering Laboratory, Electronic Systems Laboratories (E-FOG-M), 508-858-9170.

Continue with Business Process Reengineering - Industrial Initiatives

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Business Process Reengineering

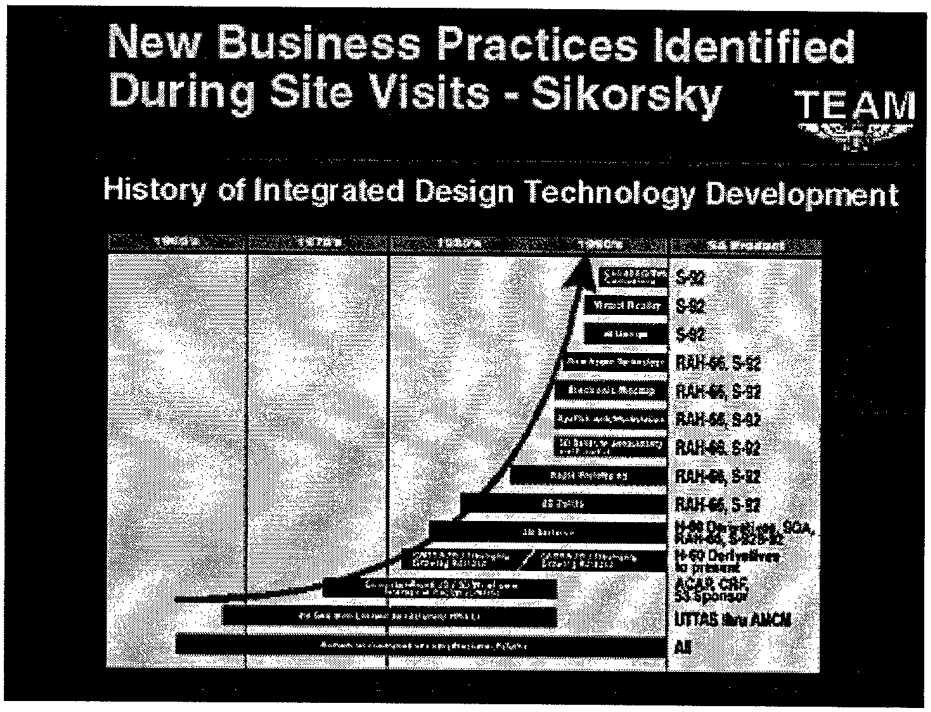
INDUSTRY INITIATIVES

Sikorsky Aircraft Division

As part of United Technologies Corporation (UTC), Sikorsky participates in the UT Engineering Coordination Activities (UTECA). UTECA supports the development and transfer of engineering technologies across all divisions. Sikorsky uses COTS software design and manaufacturing packages and integrates them as required. For example, Sikorsky uses two CAD systems for design: Catia for the overall airframe structure and ProEngineer for component parts.

The Comanche program is an excellent example of the benefits of IPTs and CVP technologies. Sikorsky chose to use CVP technologies to engineer and manage the integration process on the Comanche. The manufacturing process was a first time fit, and Sikorsky estimated that the average unit cost of the Comanche was reduced by 20-30%. Based on historical data, the average unit cost was estimated to be $12M while the average unit cost of the Comanche is now estimated to be less than $10M. Additionally, the prototyping cost of the forward fuselage is 67% of the historical cost estimates.

Sikorsky is also using CVP technologies to facilitate a multinational team for the production of their 19 passenger commercial helicopter, the S-92. An internationally dispersed team is being used in this program making collocation an unrealistic solution and virtual collocation a necessity. Sikorsky is working towards establishing a UNIX-based 3-D collaboration environment and enabling collaboration in the area of production engineering.



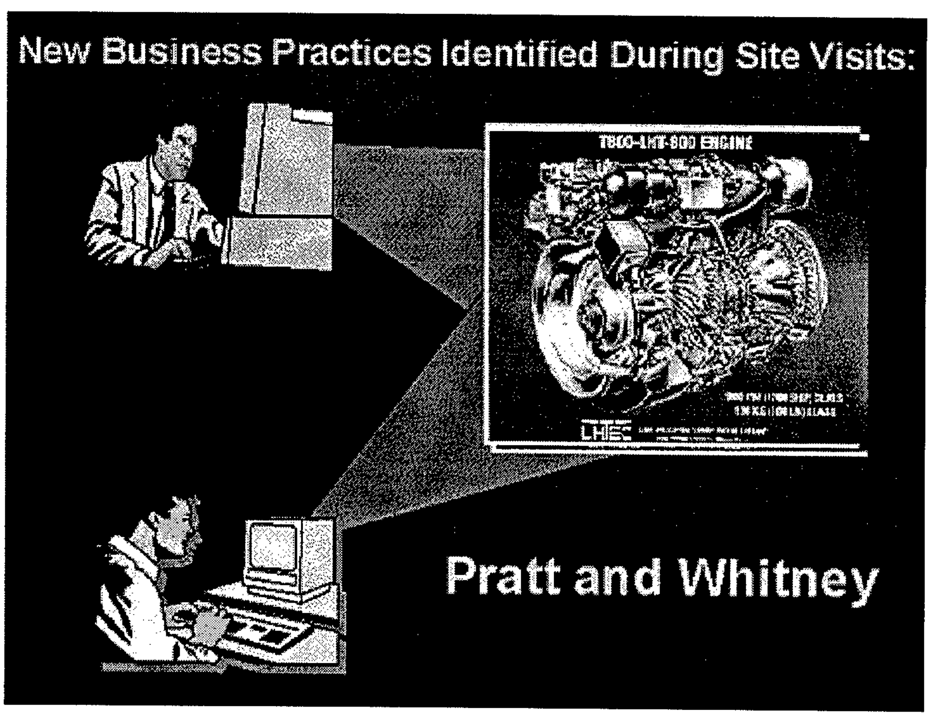
INDUSTRY INITIATIVES

Pratt & Whitney

Pratt and Whitney sees potential applications of virtual reality tools in maintenance and in marketing/requirements analysis - allowing customers to examine sound, airflow, and cooling characteristics of a virtual engine. Currently, Unigraphics is the foundation of Pratt and Whitney's CAD/CAM system. Other systems are used for specialty purposes: ICAD is used for their rule-based design work, and COTS software packages (Nastran, MARC, etc.) and some internally developed packages to support engineering. Developers have been working in the rule-based CAD environment for the last 5 years. Currently, 25% of Pratt and Whitney components are designed using rule-based CAD. This has shortened the design process for these components from 3 months to 2 days. This environment also supports the simulation of manufacturing process to help standardize processes. COTS tools are used for stress analysis and pre/post processors. Pratt and Whitney feels they have developed world class Computational Fluid Dynamics tools.

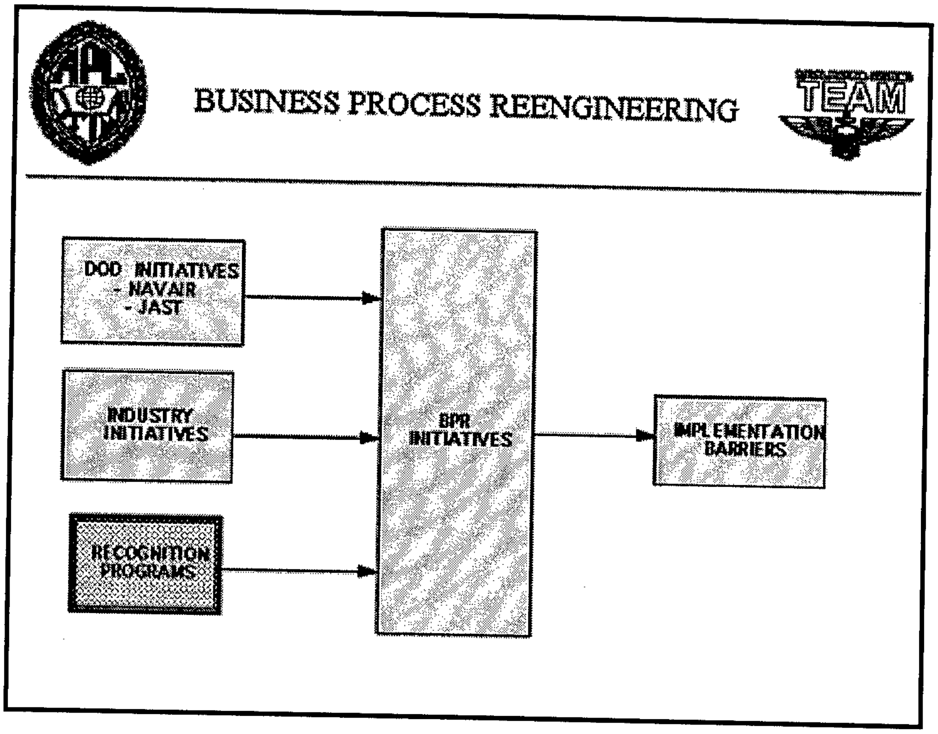
Since 1991, Pratt and Whitney has had a 50% reduction in engine production. Normally, this would result in a unit cost increase, but in response, Pratt and Whitney initiated a redesign of the process flow associated with their shop floor operations required to produce an engine. The redesign effort organized the shop floor into cells to help reduce the distance traveled between stations and reduced the number of stations. The result of this effort was a 7-8% reduction in the unit cost of an engine. Currently, it takes 18 months to produce an engine. Pratt and Whitney's goal is to reduce this to 4 months with continued process improvements. Pratt and Whitney is now taking the next step, i.e., applying information technology to their redesign processes, which is estimated to reduce the production time for an engine to less than 4 months. Additionally, Pratt and Whitney believes the design time of an engine to can be reduced to 36 months, from a clean sheet to a first unit of production with a 50% reduction in the number of physical prototypes. Historically this process has taken 5 years for commercial engines and 10 years for DoD engines.

Pratt and Whitney is looking at smart product models, such as Ingenious/Insight as a tool for optimization of designs; collaboration tools, personnel construct theory and collaborative design demonstrations; and PicTel system to support collaboration. Pratt and Whitney believes engineering collaboration has major benefits but is underdeveloped compared to business collaboration, which is growing fast and is well advanced (for example, Lotus Notes). UTECA is working with Pratt and Whitney to define an integration infrastructure.



RECOGNITION PROGRAMS

Recognition programs are addressed in this study due to the incentive they give industry and government to become more agile, efficient, cost effective, etc. Such incentives promote greater use of and research in CVP technologies. Two programs examined in this section are the Malcolm Baldrige National Quality Award, annually presented by NIST; and the President's Quality Award Program, administered by the Federal Quality Institute.

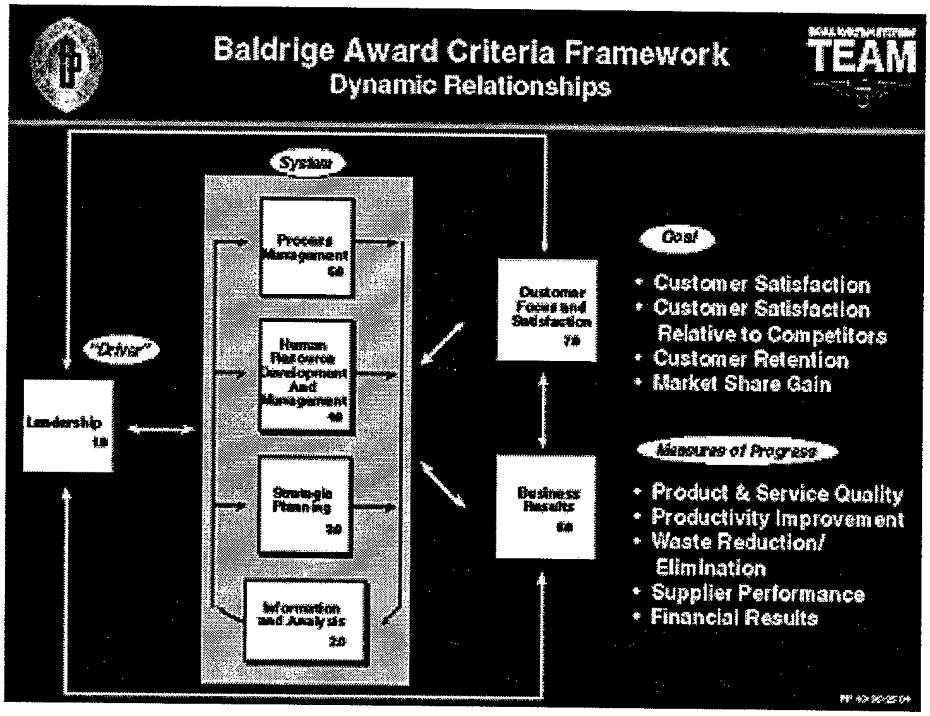


THE MALCOLM BALDRIGE AWARD

The Malcolm Baldrige National Quality Award is given annually by NIST, of the Department of Commerce, to three companies catagorized as manufacturing, service and small business. The Baldrige Award has three central purposes: (1) to promote awareness and understanding of the importance of quality improvement to our nation's economy; (2) to recognize companies for outstanding quality management and achievement; and (3) to share information on successful quality strategies. The Award Program is a public-private partnership. A crucial part of this partnership is the willingness of the Award winners to share information on their successful quality strategies with other U.S. organizations. For purposes of the Award Program, a "successful quality strategy" has three principal features: (1) integration with business strategy; (2) active organizational learning processes tying together all corporate requirements and responsibilities -- customer, employee, supplier, productivity, etc; and (3) multidimensional results that contribute to overall business improvement and competitiveness.

The criteria for the Baldrige Award comprises 28 examination items distributed among the following seven categories: (1) Leadership; (2) Information and Analysis; (3) Strategic Quality Planning; (4) Human Resource Development and Management; (5) Management of Process Quality; (6) Quality and Operational Results; and (7) Customer Focus and Satisfaction. An applicant for the Baldrige Award is required to submit a report summarizing its practices and results, responding to requirements in the examination items.

The criteria are designed to help companies enhance their competitiveness through focus on dual, results-oriented goals: delivery of ever-improving value to customers, resulting in marketplace success; and improvement of overall company performance and capabilities.



THE PRESIDENT'S QUALITY AWARD PROGRAM

The President's Quality Award Program is administered by the Federal Quality Institute. The Program was created in 1988, and includes two awards: the Presidential Award for Quality and the Quality Improvement Prototype (QIP). Both are awarded on an annual basis to federal organizations.

The award criteria are an adaptation of the Malcolm Baldridge National Quality Award criteria, but reflect the unique federal environment and culture. Federal agencies competing for both awards are now evaluated against the same standards of excellence used for private sector companies. This congruence facilitates cooperation and the exchange of information between public and private sector organizations.

These awards are designed for organizations that have mature quality management efforts, well-advanced in the quality transformation process. Winners of both awards provide excellent models of quality management systems that produce impressive results. The Presidential Award is reserved for the best of these outstanding organizations. Applicants must be part of the Executive Branch of the federal government, and have at least 100 federal employees. The Presidential Award may be given to as many as 2 organizations each
year and the QIP Award to as many as 6 organizations each year.

The President's Quality Award Program is intended to:

- Recognize organizations that have implemented quality management in an exemplary manner;
- Result in high quality products and services, and the effective use of taxpayer dollars;
- Promote quality management awareness and implementation throughout the federal government;

and

- Provide a model against which organizations can assess their quality transformation efforts.

The U.S. Army Research and Development Engineering Center (TARDEC) won this years Presidents Quality Award for their use of Concurrent Engineering principles.

IMPLEMENTATION BARRIERS

A variety of barriers or hindrances to CVP have been identified through interviews with personnel involved in Navy acquisition programs and through site visits to prime contractors, subcontractors, and universities. The following is a brief discussion of those barriers frequently identified.

Cultural Issues

Cultural issues were consistently identified as a barrier. Program managers manage risk and generally do not deviate from proven business practices. Consequently, many program managers who must bring their programs in on cost, within performance requirements, and on schedule, see CVP-related technologies as lacking maturity and do not wish to make their programs part of the validation process. Decreasing cost or improving schedule, although commendable, are not generally considered worth the downside risk. Unlike the commercial sector, the program manager and his team are not rewarded for program savings.

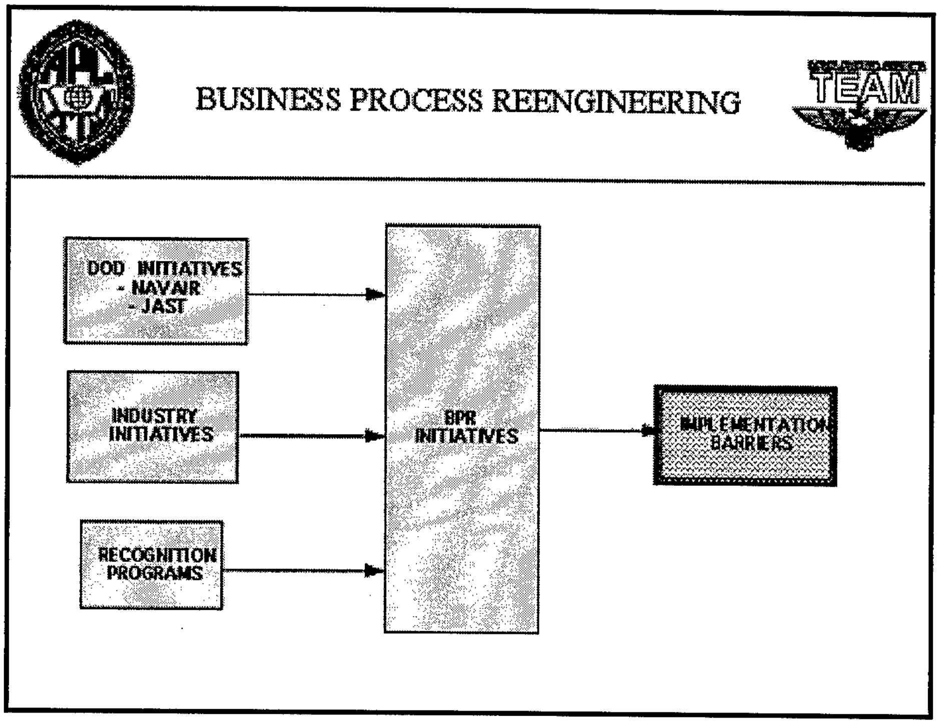
Additionally, CVP technologies impact the workforce, by automating the most people intensive processes. As in most efficiency- type improvements, management expects to see the savings in reduced personnel cost immediately. The potential impact of CVP technology on a workforce can be a significant barrier to acceptance.

Proprietary Issues

Proprietary issues are a large industry concern, making them a hindrance to the full acceptance and implementation of CVP related technology. In today's agile enterprises, subcontractors become associates and add value to the product. In these types of arrangements, information is rapidly and freely exchanged between associates. Who owns what data and intellectual property is often difficult to sort out. In other cases, a subcontractor often supports multiple primes who compete with each other. Ownership of digital information and intellectual property must be clean and unambiguous.

Technology Issues

CVP technology exists at various stages of maturity within industry. Inspite of the technological tools and knowledge available to implement CVP technology; implementing the technology requires an investment in time and money. Additionally, due to the various levels of maturity, there are standardized issues that still need to be resolved. The independent development of the CVP technologies has created problems with compatibility and communication between systems.



End of Business Process Reengineering

Continue to Demonstrated Benefits

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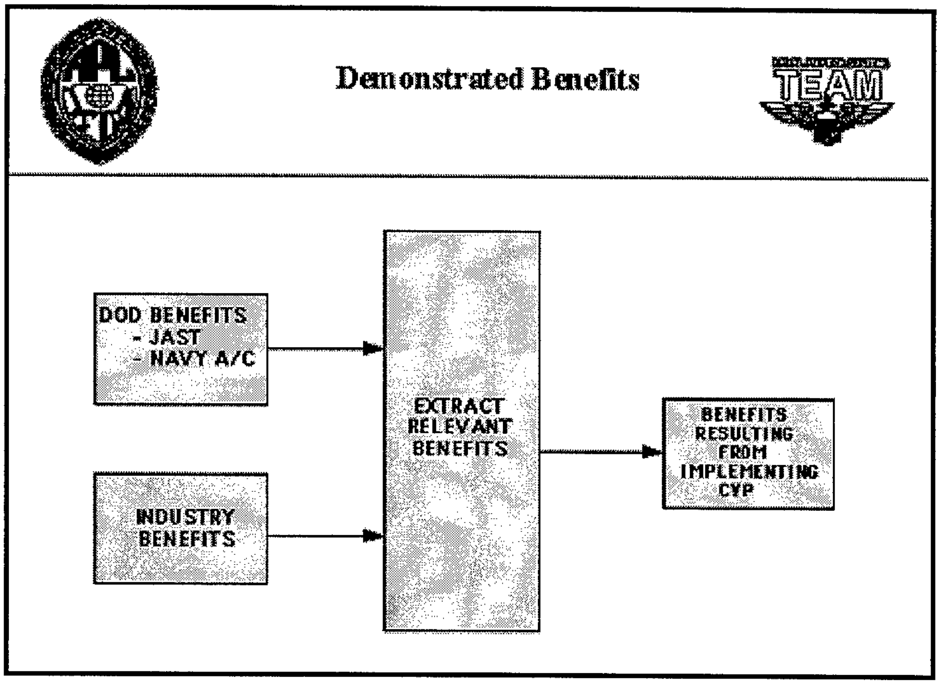
Demonstrated Benefits

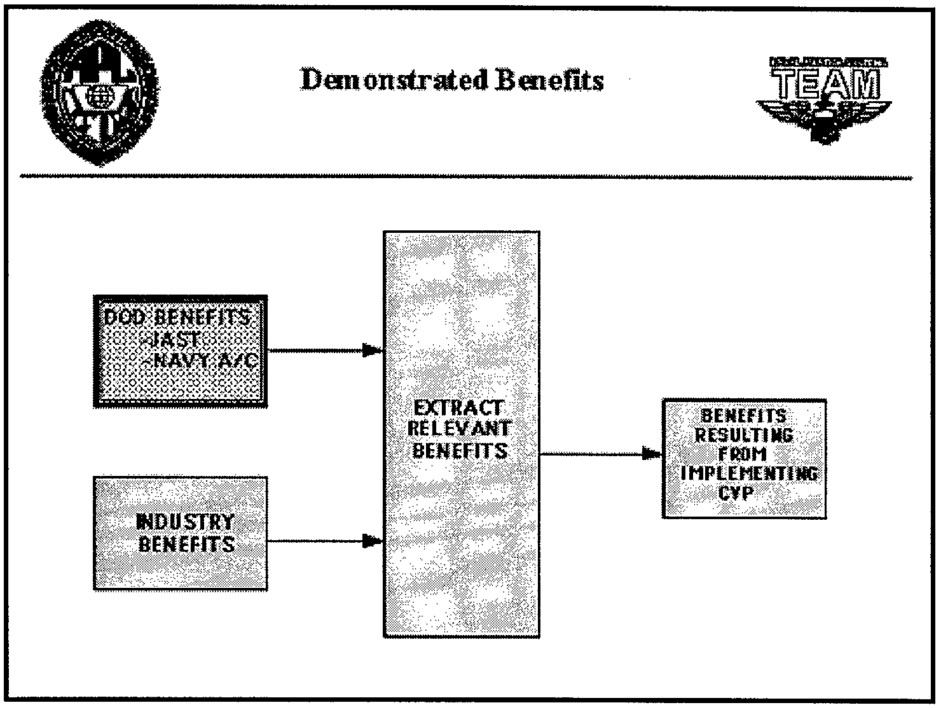
BENEFITS OF IMPLEMENTING CVP TECHNOLOGIES

Reforming or reengineering the acquisition process is a challenging and time-consuming effort. CVP technologies offer the potential for fundamental change within the acquisition community and the real prospects of major cost and time-to-market reductions. However, before major changes are implemented, management generally requires a cost benefit analysis to be performed. Performing such analysis for the Common Support Aircraft at this time is a difficult task since the CSA and its missions have not been defined. The approach used in this study is to identify the benefits that CVP technologies have had for other aircraft and DoD programs.



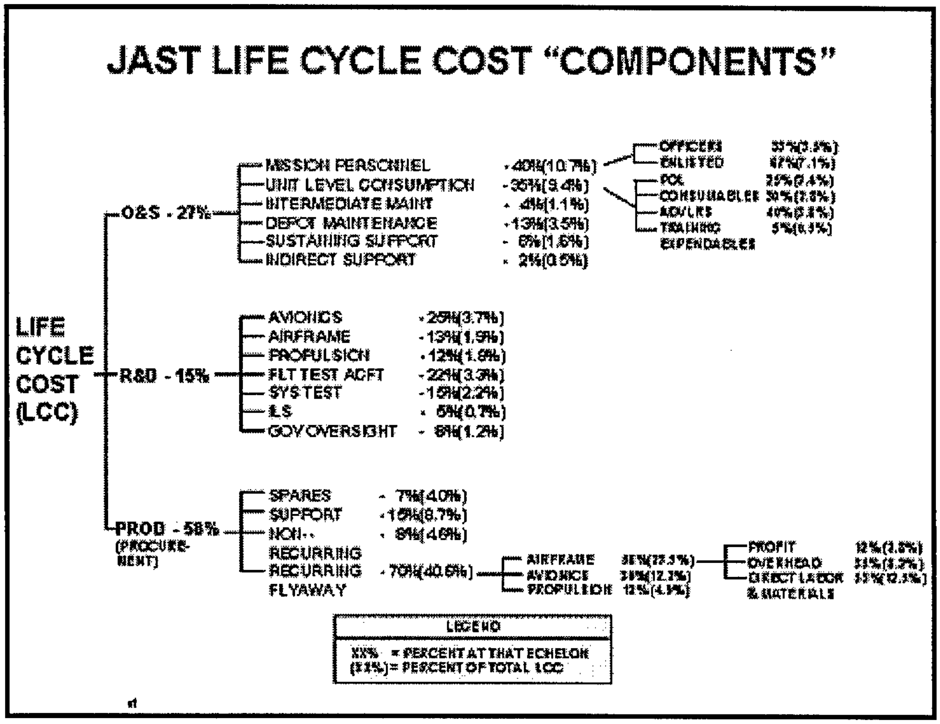
JAST AFFORDABILITY RESULTS

The largest aircraft program maturing technologies for affordability within the DoD is JAST. Life Cycle Cost reduction estimates and the technologies that support these reductions should be directly related to CSA. JAST material relevant to CSA is presented in this section.



JAST LIFE CYCLE COST COMPONENTS

The slide shows the estimated life cycle cost (LCC) breakdown of the JAST aircraft into the three life stages of research and development, production, and operation and service. The three major stages are further broken down into cost categories within those stages. Of the three major stages, production has the highest price tag of 58% of the total life cycle cost. Within production, the recurring flyaway cost accounted for 70% of the cost of production and 40.6% of the total LCC. The flyaway cost can be further broken down into the airframe, avionics, and propulsion. For the JAST aircraft, the airframe accounts for 23.5%, the avionics for 12.2.%, and propulsion for 12% of the total LCC. For the CSA, avionics is expected to dominate the recurring flyaway cost structure. This type of analysis is being used by the JAST office to determine where technology needs to be applied to reduce the cost of the JAST aircraft.



EXAMPLES OF JAST COST SAVINGS ESTIMATES

The following two slides present JAST projects and technology maturation efforts directed at reducing the major life cycle cost drivers.

The most significant cost driver for the CSA is avionics. Although the missions may be different between JAST and CSA aircraft, most of the avionics technology maturation deliverables can be employed to some extent by both aircraft. Architectures, virtual system engineering, virtual environments, and software development tools are directly applicable to CSA development. Using these technologies, JAST estimates an LCC savings of 9 to 17%. For CSA, the savings should be greater since avionics will have a higher percentage of the LCC.

AVIONICS ADVANCED TECHNOLOGY AREAS

AVIONICS ARCHITECTURE DEFINITION
- OPEN SYSTEMS ARCHITECTURE
- REDUCE COST OF AVIONICS UPGRADES
- CAPITALIZE ON JIAWG/F-22 INVESTMENT
- FULLY DEFINED INTERFACE STANDARDS
- INTEGRATED SENSORS

TECH INTEGRATION & PROTOTYPING
- COST/BENEFITS TRADEOFFS
- VIRTUAL SYSTEMS ENGRG PROCESS

TECHNOLOGY DEMOS
- ARCHITECTURE
- CRITICAL TECH COST SAVINGS PROGRAM

SOFTWARE
- COMMERCIAL BASED S/W DEVELOPMENT & SUPPORT ENVIRONMENT
- COMPONENT REUSE

PRODUCTS
- MODULAR RQMTS PRIORITIZED
- OPEN SYSTEMS
- VIRTUAL DEMOS TO ID MILITARY UTILITY
- SYSTEM STUDIES TO QUANTIFY COST EFFECTIVE TECHNOLOGY

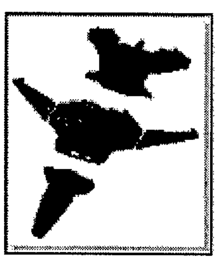
LCC SAVINGS	
R&D	2 - 3%
PROD	6 - 14%
O&S	1 - 3%
TOTAL	9 - 17%

EXAMPLES OF JAST COST SAVINGS ESTIMATES

For the airframe, new materials and construction techniques help to reduce the life cycle cost from 10 to 12%. A large facilitator in new structures concepts and advanced production techniques is the use of virtual prototypes. These prototypes can be employed to perform structural analysis, producibility trade-offs, and for generating NC machine code. For the airframe, JAST has estimated that the new technologies could result in a LCC savings of 10 to 12%.

STRUCTURES & MATERIALS LEVERAGING TECHNOLOGY AREAS

MID FUSELAGE/WING
- UNITIZED CONSTRUCTION
- REDUCE PARTS COUNT
- REDUCE FASTENED ASSYS



AIRFRAME SENSOR INTEGRATION
- CONFORMAL, LOAD BEARING ANTENNAS
- DURABLE/AFFORDABLE EO/IR WINDOWS

AFT FUSELAGE
- HIGH TEMP MAT'LS & PROCESSESS
- DURABILITY
- PRODUCIBILITY

INLET DUCT/EDGES/ FRONT FRAME
- DURABILITY
- AIRFRAME INTEGRATION
- PRODUCIBILITY

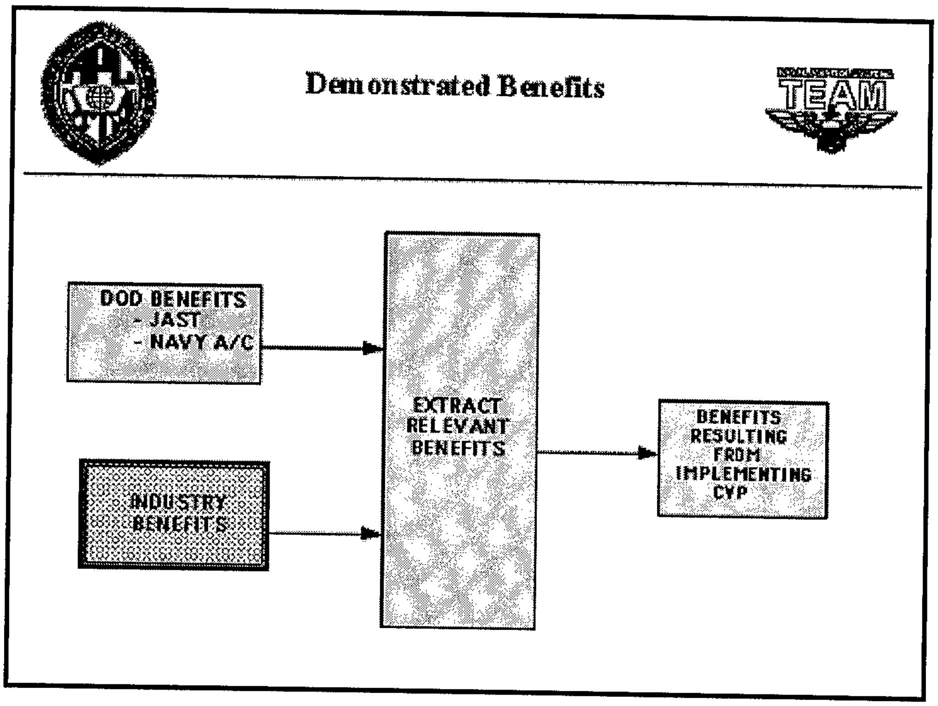
AIRFRAME COMMONALITY
- OPTIMIZE AIRFRAME DESIGN FOR TRI-SERVICE AIRCRAFT
- AIRFRAME COMMONALITY FOR PRODUCTION COSTS & SUPPORTABILITY

LCC SAVINGS	
R & D	1 - 3 %
PROD	15 - 20 %
O & S	10 - 13%
TOTAL	10 - 12 %

INDUSTRY BENEFITS

One of the objectives of the industry site visits was to collect information on the benefits of CVP and related technologies that have already been implemented by industry. Obtaining this information was much more difficult than expected since identification of cost savings usually equates to lost jobs. In cases where staff reductions had already taken place, it was easier to disclose the savings. Some companies were very willing to discuss CVP benefits, whereas; others considered this information proprietary.

Many world class companies have already been implementing CVP technologies. New technologies have given them a competitive edge in the world market. The automobile industry is a leader in implementing virtual prototyping, exchanging 3-D solid model design data with their suppliers, and conducting electronic commerce. Two suppliers to the automobile industry (3-Dimension, Lazerform) and three CVP tool developers (Deneb Robotics, CADSI, Step Tools) were visited. Site visits were also made to John Deere and Caterpiller which are leaders in the heavy land moving equipment industry.



DEMONSTRATED BENEFITS

For FY 95, McDonnell Douglas is producing the majority of the fixed-wing aircraft for the DoD. Included in these procurements are the F/A-18, T-45, AV-8, C-17. McDonnell is also a JAST Weapon Systems Contractor teamed with Northrop Grumman and British Aerospace. The JAST program in conjunction with existing production gives McDonnell the opportunity to conduct pilot programs using current production assets.

Design, Manufacturing, and Producibility Simulation (DMAPS) is a McDonnell program to tie together their product, process, and simulation (CVP-like) tools into a virtual prototyping environment. The objective of DMAPS is to reduce the acquisition costs by 50%. The integration of these tools will permit design time to be reduced by 33%, design personnel to be reduced by 25%, manufacturing cycle time to be reduced by 50%, and manufacturing personnel to be reduced by 50%. DMAPS was employed on the redesign of the tail for the T-45 trainer. The redesign was performed at 30% of the man-months previously estimated. The design included accurate cost estimates for production, verified loads and weights, 3-D solid feature based files for enabling advanced fabrication techniques (composite lay-ups, high-speed machining etc.), and an electronic visualization package for supporting IPT decisions.

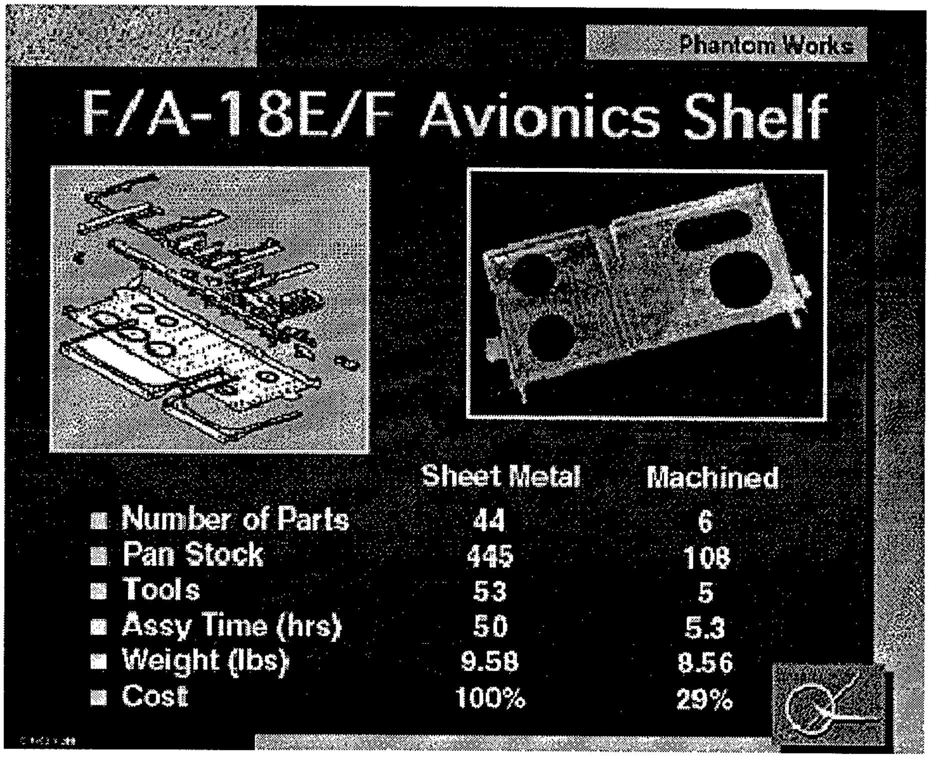
Phantom Works is a McDonnell Douglas effort to change fundamentally the way aerospace systems are designed, developed, and produced. The center of this effort is electronic product data that can be employed in innovative fabrication techniques. These techniques include high-speed machining and composite lay-up to reduce the number of parts, tools, labor, assembly time, and cost. Examples of this are high- speed machining of the F/A-18 E/F avionics shelf and T-45 nose gear door. For the avionics shelf, the parts count was reduced from 44 to 6. Tools were reduced from 53 to 5. Assembly time was reduced from 50 to 5.3 hr, and the cost was reduced by 71%. Similar savings were experienced for the T-45 nose gear door where high-speed machining reduced the cost by 75%. The following slides give Phantom Works examples of pilot projects and achieved savings.

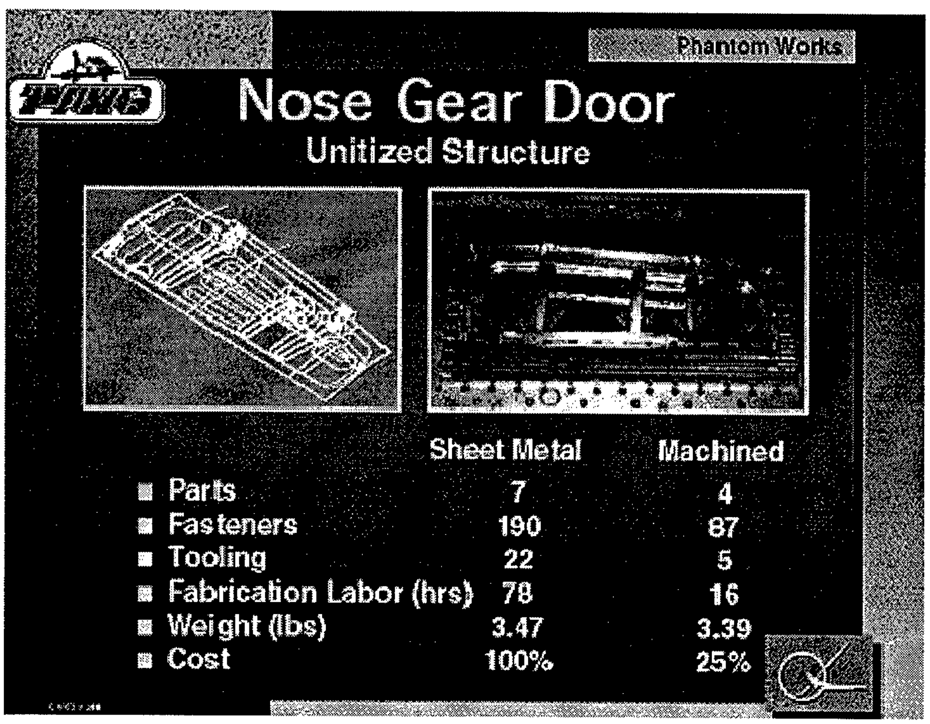
McDonnell Douglas has been achieving savings in supplier electronic commerce. This process makes them think differently about their suppliers. Using tools like a McDonnell-developed Buyer Workstation, they have been able to reduce the purchase order cycle time from 14 days to 3 days, manpower by 33% and the cost of processing purchase orders and contracts by 80%. These techniques are being employed for all orders over $25K and will be used for all orders in the near future. McDonnell has estimated savings through partnering of 33 to 50% on joint electronic procurements due to the larger volumes purchased.

Demonstrated Benefits
McDonnell Douglas

TEAM

Design Manufacturing & Producibility Simulation (DMAPS)
Reduction Goals: Design Cycle Time -33%, Design Personnel -25%
Production Cycle Time -50%, Mfg Personnel -50%
T-45 Tail Redesign: 30% of estimated man months
Accurate Cost Estimation, Verified Weights
Mature Design Enables Advanced Fabrication
Digital Data Supports IPT Decisions
Phantomworks (Fundamental Production Changes Enabled by Exchanging CAD and NC File Formats)
F/A-18E/F Avionics Shelf: 29% of original cost
T-45 Nose Gear Door: 25% of original cost
Supplier Electronic Commerce
Reduce Cost of PO/CO Processing: 80%
Reduce PO Cycle Time: 3 vs 14 days (79%)
Reduce Manpower: 33%
Savings to trading partners joint procurements: 33-50%





Continue with Demonstrated Benefits

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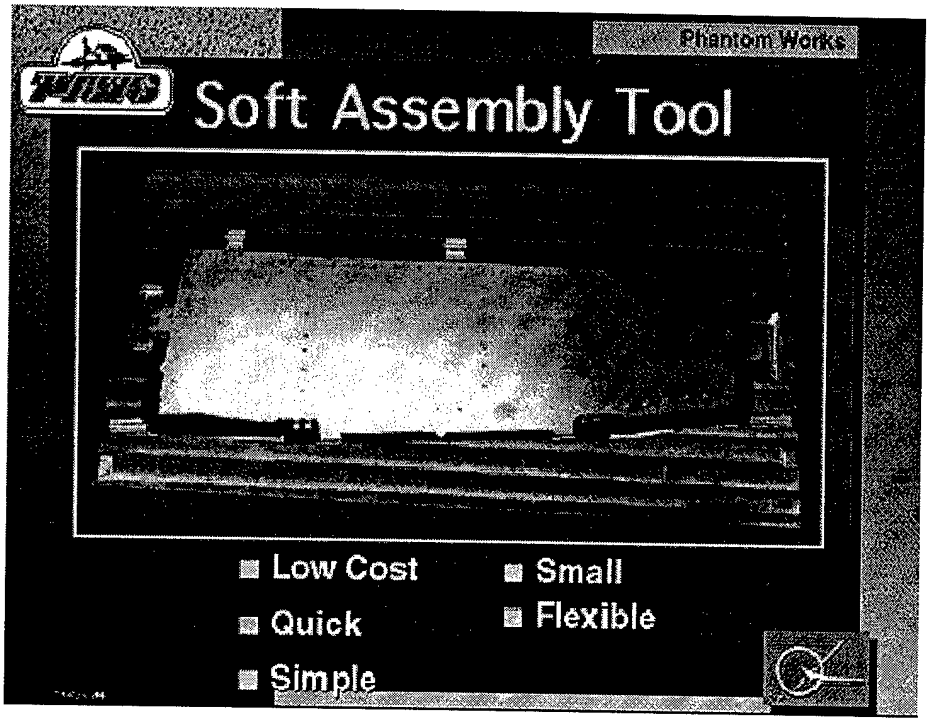
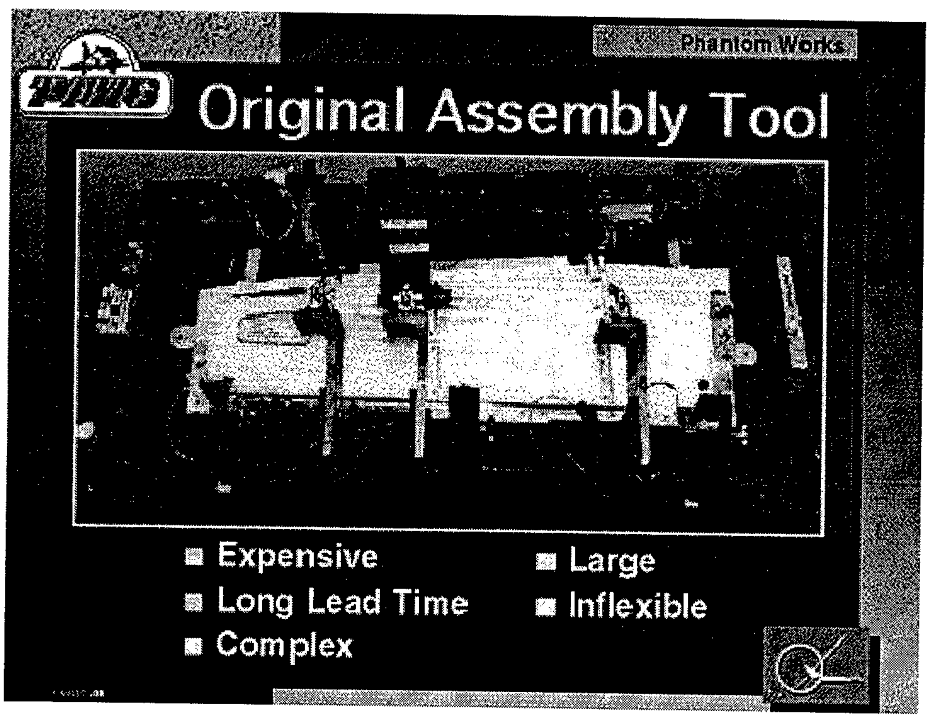
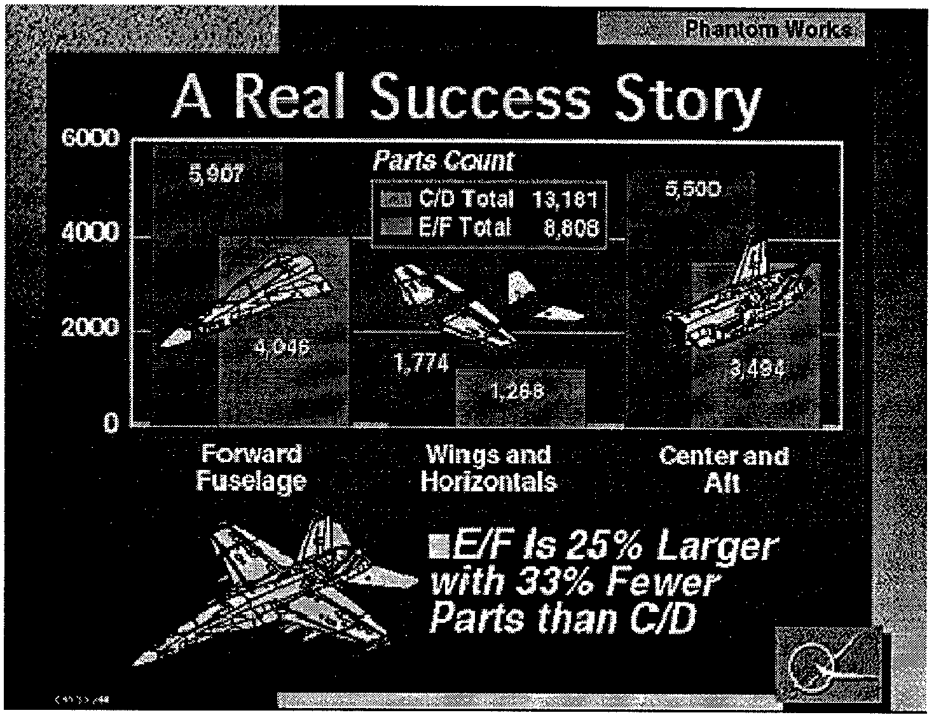
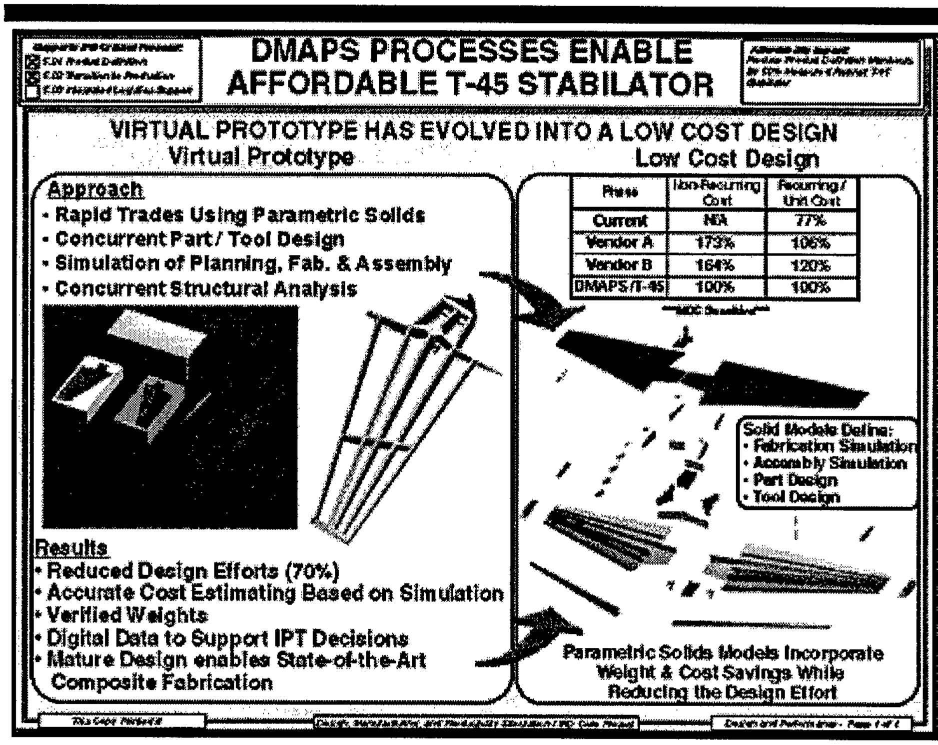

Phantom Works
Soft Assembly Tool
Low Cost
Quick
Simple
Small
Flexible


Phantom Works
Original Assembly Tool
Expensive
Long Lead Time
Complex
Large
Inflexible





DEMONSTRATED BENEFITS

Lockheed Martin Tactical Aircraft Systems (LMTAS) is supporting the JAST Manufacturing Demonstrations (JMD) program. The objective of the program is to assemble tools and conduct pilots demonstrations for integrating design information with manufacturing cost data to develop the most cost-effective production processes. By combining Lockheed's JMD efforts with lean aircraft production techniques and new business practices, they have estimated a $1.2 billion life cycle cost savings for the JAST aircraft, and a $161 million savings for the F-22.

Lockheed (LMTAS) has had an F-16 Improvement program for the last several years. The objective of this effort is to reduce the per unit fly-away cost of the F-16 by implementing new business and manufacturing practices. These practices include outsourcing of parts, increased in-plant quality, lean business practices, and removal of all non-value-added processes. As a result of these initiatives, the LMTAS component of the per unit cost of the F-16 has dropped from $8.7M in 1992 to $7.3M in 1995. During the same time the number of aircraft delivered dropped from 16 to 4. The figure on the next page gives the breakdown of the per unit cost into the major categories.

Lockheed has proposed to the Air Force and Office of the Secretary of Defense that the F-16 plant be turned into a commercial venture. In a recent TASC and Coopers & Lybrand report to the Secretary of Defense, regulatory and statutory procurement practices accounted for 18% of the total procurement cost. If the commercialization of the F-16 program is approved, the venture would be exempt from procurement statutes and regulations. Commercial cost accounting and standards would be implemented, and Lockheed would guarantee a reduction in the fly-away price of 15%.

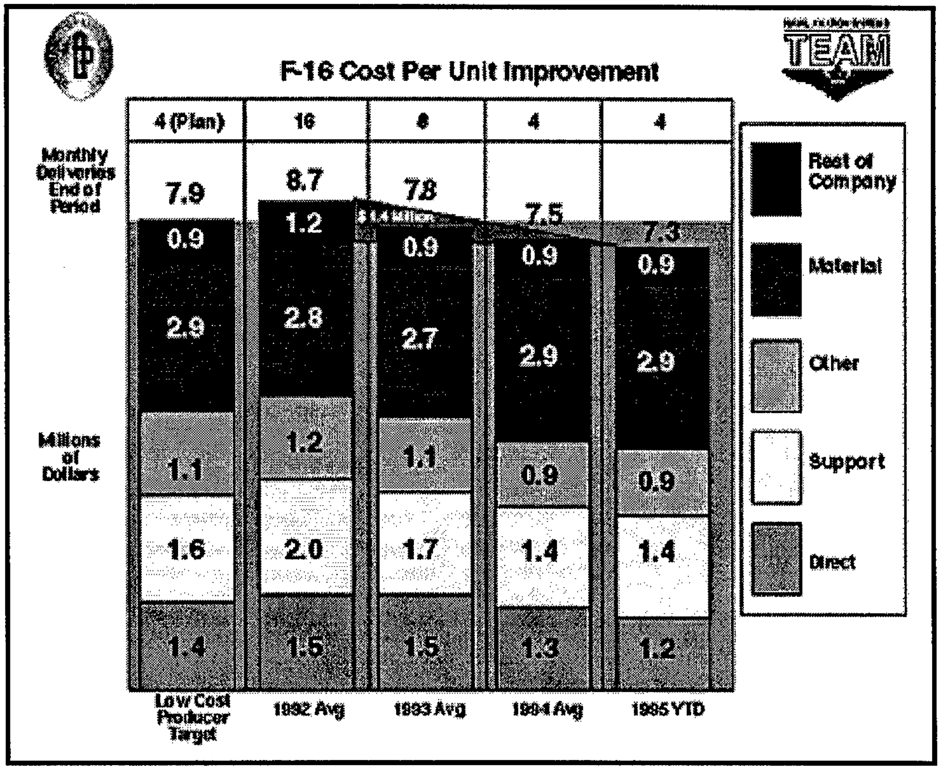
Demonstrated Benefits
Lockheed/ Martin

Tactical Aircraft Systems (LMTAS)

JAST Manufacturing Demonstrations
Estimates for Life Cycle Cost Savings using CVP technologies, Lean Practices, & New Business Practices: **JAST= $1.2B, F22= $161M**

F-16 Improvement
F-16 Per Unit Cost: Reduced from **$8.7M in 1992 to $7.3M in 1995**
with only 1/4 the number of units procured in 95' vs 92 (LEAN Practices)
Supplier/Material: Electronic Commerce supported parts outsourcing,
Improved In-Plant Quality **66% Reduction in Manpower**

F-16 Commercialization
Convert F-16 Plant into a Commercial Venture, Exempt from Statutes, Regulations, Cost Accounting, Mil Specs, etc. Would provide benchmark for acquisition reform due to the maturity of the F-16 program.
Guaranteed Fly-Away Price Reduction of 15%



Lockheed Martin Tactical Aircraft Systems (LMTAS) F-16 Commercialization Initiative: A Vanguard for Sweeping DoD Acquisition Reform

- Unsolicited Offer Provided to DoD to Convert the F-16 Production Program to Commercial Business Practices Under a Pilot Plant Program Concept
  - Guaranteed Price Reductions for Ongoing F-16 Programs and Aircraft Procurements
- Requires DoD Sponsorship and Enabling Legislation
  - Pilot Plan Program Destination
  - Additional Exemptions from Statutes, Such As:
    - ✓ Audit Provisions
    - ✓ Truth In Negotiations Act
    - ✓ Dispute Resolution Provisions
- Allows Sizable Reductions in the Cost of Oversight
- A Quantum Step, Well Beyond Current Pilot Programs and Acquisition Reform Efforts

The F-16 Program Allows Benchmarking of Acquisition Reform and Measurement of True Savings for the Use of Commercial Practices

DEMONSTRATED BENEFITS

LOCKHEED MARTIN

Electronics, Information & Missiles Group

The Electronics, Information, and Missiles Group has an Art-to-Part pilot for an Advanced Fire Control System. As part of the initial effort, Lockheed Martin will be developing an Internet access architecture that enables all companies involved to communicate and exchange information electronically. The architecture will support collaborative design among the companies involved. Data security is being managed by controlling access to the applications. Lockheed believes that a 50% reduction in design time is possible once this system is in place.

Aeronautical Systems

Lockheed Martin Aeronautical Systems found that exchanging design data in 3-D solid file formats resulted in a reduction of development costs of 10%.

The JAST SAVE program at Lockheed Martin estimated that the use of CVP technologies would result in a 15% savings in production costs for the JAST aircraft and an overall 2-3% reduction in life cycle costs.

Demonstrated Benefits
Lockheed/ Martin

TEAM

Electronics, Information & Missiles Group

Advanced Fire Control Systems Pilot
Internet-based architecture for the communication and exchange of electronic CAD files Estimate 50%reduction in design time

Aeronautical Systems

Lockheed Martin Documented Results
Eliminating 2-D paper drawings and just receiving 3-D CAD files from suppliers will reduce Development Costs by 10%

SAVE Program
Estimate for the benefits of CVP technologies 2-3% Reduction in Life Cycle Cost and 15% Reduction in Production Costs

DEMONSTRATED BENEFITS

Sikorsky Aircraft Division

The Comanche program is a good example of the benefits of IPTs and CVP technologies. Sikorsky estimated that the average unit cost of the Comanche was reduced by 20-30% based on benefits from using new CVP technologies. The average unit cost based on historical data was estimated to be $12M. The average unit cost based on historical data is estimated to be $12M. The average unit cost of Comanche is now estimated to be less than $10M. In addition, the prototyping cost of the forward fuselage is 67% of the historical cost.

Pratt & Whitney

Two years ago, PW undertook an initiative to redesign the process flow associated with their shop floor operations required to produce an engine. In addition, PW conducted training to improve the way people operate in the redesigned shop floor environment. The redesign effort organized the shop floor into cells to help reduce the distance traveled between stations and the number of station stops for an engine. The result was a 7-8% reduction in the unit cost of an engine. The time required to produce an engine was reduced from 18 months to an average of 4 months. PW is now taking the next step by applying information technology to their design processes. PW hopes that this will result in the production time for an engine to be less than 4 months. The target for achieving this reduction is the end of 1996.

PW also has a target for design time of an engine to be 36 months from a clean sheet to the completion of production for the first unit. Historically this process has taken 5 years for commercial engines and 10 years for DoD engines. PW also hopes to reduce the number of physical prototypes they develop by 50%.

Demonstrated Benefits

TEAM

Sikorsky Aircraft Division

Comanche

Sikorsky estimates that the cost of the Comanche was reduced 20-30% based on benefits of new technologies. The expected unit price for Comanche is under $10M vs $12M based on earlier cost estimates.

Pratt & Whitney

New Engine Time-to-Market

- Target time to market for new engine design is 36 months
  Historically TOM has been 5 yr for commercial and 10 yr for DoD engine.
- Reduction of physical prototypes by 50%.
- Production of current engines has been reduced from 18 months to 4 months.

DEMONSTRATED BENEFITS

General Dynamics Electric Boat

General Dynamics Electric Boat (GDEB) was one of two team leaders for the ARPA Simulation Based Design Phase I effort. GDEB assembled a team of companies that had developed commercial CVP tools and demonstrated those tools during Phase I. GDEB estimated that 85% of the capability demonstrated during their Phase I effort is now in use on the development of the New Attack Submarine. Using these tools GDEB hopes to eliminate the use of wooden mockups that have cost $200M for a new submarine. GDEB is targeting production as the largest area for savings of CVP technologies. They believe that a 25% reduction in production cost is possible.

Boeing

Boeing Defense has recently been involved in two studies looking at the affordability of new aircraft. The first study was the ARPA Affordable Aircraft Acquisition effort looking at the ASTOVL aircraft. The largest saving potential was identified as object oriented software reuse. The ASTVOL study concluded that a 17% fly-away cost reduction was possible. For the JAST study the manufacturing processes were identified as a cost driver. By including new manufacturing processes, a 12% fly-away cost reduction was projected. Combining the two estimates, Boeing calculated that a 29% cost reduction is possible if the DoD works with the contractor as a team in developing and maintaining production schedules.

Boeing Commercial is noted for employing CVP technologies in the development and production of the 777. Boeing has established a goal to use CVP technologies to reduce the production of a wide-body aircraft from 3 years to 9 months, and the production of a medium body from 2 years to 6 months.

Demonstrated Benefits

General Dynamics Electric Boat

New Attack Submarine
Electric Boat estimates at least a 25% reduction in the production costs using SBD/CVP tools.

Boeing

ASTOVL & JAST Aircraft
Combined studies sponsored by ARPA Affordable Aircraft Acquisition and JAST indicate that there is a 29% savings in aircraft production possible through the use of CVP technologies.

Commercial
Boeing is seeking to reduce production cycle time from a wide body from 3 years to 9 months and the reduction of a medium body from 2 years to 6 months.

NAVAIR ESTIMATES ON THE SAVINGS OF USINGELECTRONIC VS PHYSICAL MOCKUPS FOR THE V-22

The V-22 Action Team recently conducted an investigation of the improvements realized from utilizing electronic mockups in place of physical mockups for the V-22. The improvements are summarized below:

1. Significant monetary savings achieved ($21M) by reducing physical mockups
2. Schedule improvements since time for the construction of physical mockups is eliminated
3. Electronic prototype stays current throughout Product Life Cycle
4. Electronic prototype is available for investigation and design of variants
5. First time fit rates for tubes, wires, and ducting improved from 30-50% to 90%

The figure shows an estimated savings obtained from a eliminating physical mockups. Total man-hours are reduced from 232,926 to 66,518 and costs reduced from $28.7M to $7.0M.

ELECTRONIC VS PHYSICAL MOCKUP
COST COMPARISON

	Cost Element	Class III Mockup
FSD Actuals	Engineering Operations Total Hours	40,915 192,011 232,926
	Total $	$28.7M
EMD Estimate	Engineering CATIA delta* Engineering DPA admin. Total Hours	53,318 13,200 66,518
	Total $	$7.0M

*- CATIA delta yields total 3-D production definition. Other benefits are arrived at from 3-D data, including elimination of master models and gages, utilizing Direct N/C machining, etc. which results in reduction in Error, Change and Rework and Manufacturing costs. Ref Cht A1-CR17.

End of Demonstrated Benefits
Continue to Conclusions and Recommendations

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CONCLUSIONS & RECOMMENDATIONS

APPLICATION OF CVP TECHNOLOGY

There is intense interest within industry in collaborative virtual prototyping. Companies like Ford, Chrysler, Caterpillar, and Boeing have produced products using virtual prototypes in design and analysis and as replacements for physical mockups. There has been much publicity surrounding the development of the Boeing 777. Aircraft firms that previously were not using virtual prototyping now see this as mandatory if they are to remain competitive. The aircraft industry is employing many CVP tools for their applications. The following conclusions and recommendations are a result of visits and discussions with leaders in the computing, aircraft, and electronics sectors of the industrial base.

1. There exists a wealth of commercially available products and services to support immediate implementation of a CVP environment for the development of new products. The tools and infrastructure have been demonstrated in the JAST, MADEFAST, Boeing 777, Chrysler Neon, SBD programs.

2. The DoD, DoC, NSF, and DoE are developing an infrastructure and a host of collaboration tools that should be available to new programs in the next three years.

3. There are aircraft specific applications and technologies being matured by the JAST program. These efforts should be leveraged for the development of the Common Support Aircraft.

4. Standards are the key element to all distributed enterprise activities. Without standards electronic media cannot effectively be exchanged among members of the enterprise. The DoN needs to select information exchange standards to be employed across all programs.

5. The majority of existing models and simulations needed to perform warfare analysis have not been developed to operate in a distributed computing environment. Effective use of these models requires in-depth knowledge of the assumptions and constraints of the models. Procedures must be developed to permit these models and their developers/operators to use these models in a distributed computing environment. Investments must be made to develop and maintain effective DoD Warfare Analysis models. Selection of common models to be used across DoN and DoD will reduce the investment cost and allow more capable models to be available to all users.

6. Producibility is a life cycle cost driver. Approximately 80% of the life cycle cost of a new product is determined during the conceptual design phase. Production process models for advanced manufacturing processes are needed for use in all phases of product development, but specifically conceptual design. There are numerous advanced manufacturing programs within the DoC, DoE, and NASA. The DoN should leverage these programs to provide the processing models needed for its programs.

Conclusions & Recommendations Technology Application

1) Commercially available tools to provide an infrastructure exist.
2) DOD, DOC, NSF, and DoE programs will mature in three years.
3) CSA should leverage JAST technology.
4) Standards are key for effective enterprise integration.
5) Legacy models and simulations must operate in a distributed environment. Use of common models across the Navy needed.
6) Advanced Manufacturing Programs should be leveraged for production process models.

APPLICATION OF NEW BUSINESS PROCESSES

1. The commercial sector is rapidly developing tools for distributed computing and virtual prototyping. World class companies are procuring these tools and developing additional application-specific products. These companies see these technologies as their competitive edge in the world marketplace. In cases where these technologies have been applied to new products, companies have seen significant reductions in time-to-market, improved quality, increased customer participation and satisfaction, and increased employee productivity.

2. Incorporation of the customer as a member of the IPPD team significantly reduces the development time since non-value-added activities can be minimized. Rapid trade-off decisions by the consumer helps to focus the teams activities.

3. New information and distributed computing technologies have spawned the formation of many small innovative companies. These companies not only offer products, but also provide a complete set of solutions and services to assist organizations in becoming proficient with new business processes.

4. ARPA Electronic Commerce Resource Centers are educating small to medium size firms in the use of electronic commerce. State-funded university programs are educating small to medium size firms on advanced manufacturing programs. NAVAIR should leverage these programs by working through primes to assist in modernizing critical suppliers.

5. NAVAIR should investigate the benefits of using commercial business practices in revolutionizing the acquisition process. Forming partnerships with industry as well as understanding and reacting to cost driving procurement actions can significantly reduce procurement costs.

Conclusions & Recommendations
Business Processes

1) The industrial base is rapidly adopting CVP technologies.
2) In cases where the customer has been a member of an IPPD team there hasbeen a significant decrease in the development time.
3) Innovative small companies are becoming more than just suppliers, offering products with information, services, and solutions.
4) Leverage ECRCs and state-funded university programs to modernize critical supplier organizations.
5) Promote commercial business practices and partnering with industry.

CSA RECOMMENDATIONS

1. **The Naval Aviation Team should:**

   Develop a strategy and plan for adopting CVP technologies (SBD) and associated business practices.
   Develop an investment strategy for collaboration, product interaction, and application tools. - Many multimedia collaborative tools will be available during the next 2-3 years for use by the Naval Aviation Team.

2. **The CSA initiative should leverage the newly established NAVAIR M&S Executive Committee to:**

   Survey existing models and simulations that will be applicable to the CSA initiative. The models and simulations should be categorized according to their functional discipline and the best selected for use within a distributed computing environment that enables rapid iterations and evaluation.

   Procedures and policy are needed that address the sharing and accessibility of appropriate models and simulations between government and industry. Electronic access to warfare models and simulations should facilitate the communication of mission and performance requirements while reducing cost.

3. **Developments within the S&T community should be focused to achieve an affordable CSA.**

   ARPA's Simulation Based Design program should demonstrate the viability of the required information technology infrastructure. A follow-on ATD should leverage the SBD infrastructure, continue development of the infrastructure as required, and develop/integrate the necessary tools or applications that are needed by the CSA initiative. Recommended applications include manufacturing process models and associated cost models.

   ARPA and ONR technology efforts should orient their testing/demonstrations to support the CSA initiative.

   S&T investments should be made in process technologies that reduce cost. Specific investments are recommended to speed the development and approval of Application Protocols within the STandard for the Exchange of Product Model Data and a program that demonstrates interoperability of NAVAIR's CAD-2 system with various CAD packages using STEP.

S&T should invest in CSA unique engineering and warfare analysis tools.

4. **CVP technology should be used to facilitate the partnership between government and industry. Specifically:**

   The government should use DISA's "Technical Architecture For Information Management " (TAFIM) to identify those open systems specifications and the architectural framework that will be used for CSA.

   Emerging collaboration tools identified in this report should be used to support business and technical decision making. As a minimum, a WWW home page should be used to communicated the government's intent and to keep industry informed on the CSA.

   Industry should participate in the requirements development process to enable a more responsive and cost-effective design. The report identified many COTS software tools and applications that support the requirements definition and concept development phase.

   Industry should be tasked to identify cost reduction/avoidance initiatives applicable to the CSA. As a partner, industry can assist the CSA government team in identifying and understanding those initiatives that apply to the CSA. When combined with significant changes made by the government to its acquisition and business practices (ECI, IPTs, CIM, CALS, etc.), a highly streamlined acquisition approach may be appropriate for CSA.

5. **The CSA IPT should rapidly adopt and transition the successful technology and business practices from JAST.**

Conclusions & Recommendations
CSA Initiatives

1) Naval Aviation Team
   - Develop implementation strategy for adopting CVP technologies
   - Develop investment plan

2) NAVAIR M&S Committee
   - Survey existing M&S and identify Best of Breed
   - Establish procedures to electronically share M&S

3) NAVAIR S&T
   - Focus on CSA
   - Plan ATD follow-on to ARPA's SBD]
   - Invest in generic manufacturing process models and cost models
   - Develop CSA warfare analysis tools and any unique engineering analysis tools
   - Demonstrate STEP standards with CAD-II
   - Influence ONR and ARPA initiatives

4) CSA IPT
   - Transition successful JAST technology and business practices
   - Initiate partnership with industry
   - Identify open system information system specs and standards that will be used for CSA
   - Keep industry informed using a WWW Home page
   - Invite industry to be a part of the requirements process
   - Task industry to identify cost savings

End of Conclusions and Recommendations

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