Collaborative Virtual Prototyping Sector Study

An Assessment of CVP Technology Integration, and Implementation

May 1996

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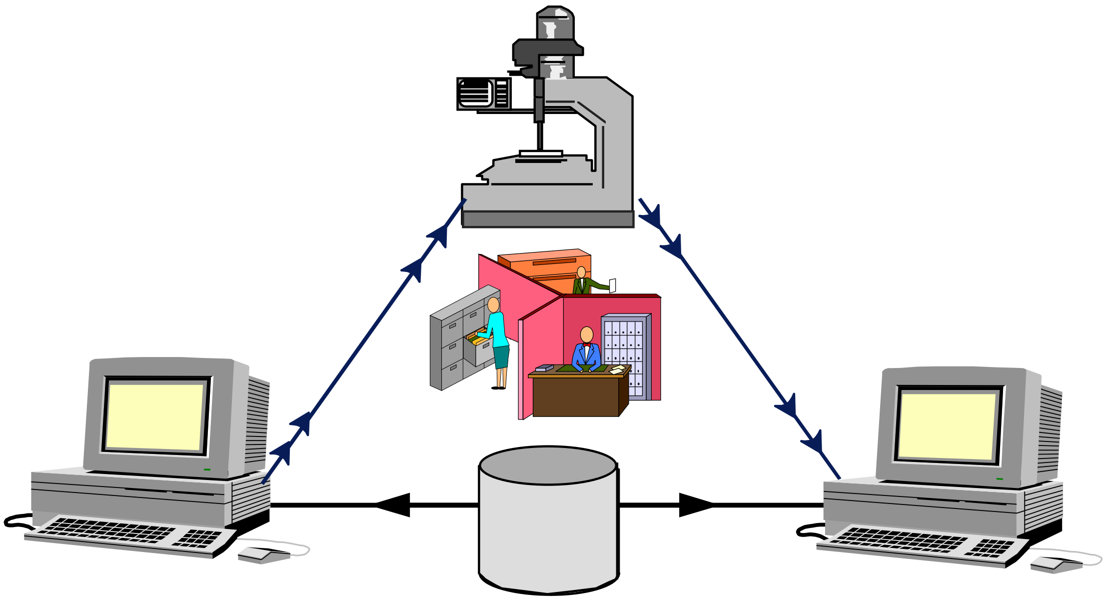
NORTH AMERICAN TECHNOLOGY AND INDUSTRIAL BASE ORGANIZATION

Collaborative Virtual Prototyping Sector Study



Prepared for the North American Technology and Industrial Base Organization (NATIBO)

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FOREWORD

This report provides the results of an assessment of Collaborative Virtual Prototyping (CVP) technology integration and implementation. It highlights the current state of the technology, examines facilitators and barriers to implementation, and recommends cultural conditions that need to be fostered and steps that need to be taken to ensure effective widespread use of this technology in support of the military.

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EXECUTIVE SUMMARY

Study Purpose and Scope

The purpose of this study is to assess the maturity, level of use, utility, and viability of Collaborative Virtual Prototyping (CVP) technology and its application to the industrial base. CVP represents a collection of technologies that enable the establishment of an integrated and simulated acquisition environment. Integrated and Simulated Acquisition (ISA) enables:

- system developers, customers, and end users to work as a distributed team.
- system developers to fully evaluate design concepts and conduct trade offs among design concepts prior to production.

Despite the apparent potential of CVP technologies to support improvements in the weapon system process, numerous questions remain regarding the viability of this technology, namely:

- existence of technological barriers to implementation of CVP in weapon system acquisition programs,
- integration of CVP into the weapon system acquisition process,
- existence of cultural and policy barriers associated with CVP technologies and related new processes,
- economics of implementing CVP and how these economics affect the Government’s ability to use small businesses at the prime and subtier level,
- measurement of the benefits of CVP,
- transition of industrial practices employing CVP to weapon system development programs, and
- acceptance of CVP technologies and practices within the defense development community.

These issues are at the heart of this report, which encompasses the collection and analysis of technical, business, and policy information related to CVP research efforts and industrial capabilities in both the U.S. and Canada. Particular focus is placed on the challenges faced by small and medium sized organizations in applying these emerging technologies.

CVP Technology Overview

The CVP Taxonomy presented in Figure ES-1 depicts the technologies supporting collaborative virtual prototyping (CVP). This taxonomy is divided into two sections: services that directly interact with users (developers) and infrastructures that operate behind the scenes.

Services	**Integration**	**Interaction**	**Applications**	**Data Creation**
Infrastructure	**Product and Process Data**			
	Object Management and Information Sharing			
	Computing and Computer Networks			

Figure ES-1. CVP Technology Taxonomy.

Figure ES-2 provides an overview of the current status of the various technology categories within the CVP Taxonomy.

Processes, Practices and Policies

CVP practices are being implemented in private industry. The commercial state of practice is to move away from hierarchical structures and top-down decisions and place more emphasis on team building and empowerment at the lowest levels. Rather than serial design steps and scheduled milestone reviews, concurrent engineering is being employed with the focus on integration of multi-disciplinary teams, emphasis on conducting more design tradeoffs over a broader trade space, and continuous design review and oversight.

Taxonomy Category	Comments	Status	Rating
Services			
Integration	• Entails tools that enable team integration and tool integration • Major investments being made in developing and commercializing the technology	• Technology is maturing • Limited use • Team integration tools are available and more are being developed • Improvements are coming but more work is required	Emerging
Interaction	• Allow designers to interact and evaluate designs (real-time analyses) - virtual reality • Major investments being made in developing the technology - some commercialization	• Technology is developing • Limited use • Some specific tools exist - visualization • Accuracy is a problem	Emerging
Applications	• Allow designers to evaluate designs (non real-time analyses) • Cost modeling is the biggest challenge • Focused tool development for specific applications still required and ongoing	• Technology is mature • Significant use • New tools being developed	Mature
Data Creation	• CAD and CAM systems develop/create data • Major advances include parametrics, associativity and CAD/CAM integration	• Technology mature • Significant use • Advances continue	Mature
Infrastructure			
Product and Process Data	• Data definitions and storage - the smart product model for a project • STEP is emerging as the standard that will define data requirements • Object oriented databases are emerging as the database of choice	• Technology is being developed and becoming available • Use is in the prototype/ demonstration phase	Emerging
Object Management and Information Sharing	• Artificial Intelligence and Intelligent agents - logical infrastructure • Mostly university work is this area • ARPA SBD program working in this area	• Technology is in R&D • Limited demonstration and prototyping	Immature
Computing and Computer Networks	• Represents the enabling technologies for CVP - physical infrastructure • Technology exists today but significant advances continue	• Technology is mature • Significant use • Advances continue	Mature

Figure ES-2. Technology Status Overview.

Competitive issues currently are impeding full collaboration and hence full realization of the potential benefits of CVP. Small and medium sized businesses in particular are affected because prime contractors often establish "captive subcontractor" relationships by providing CVP technologies to subcontractors in exchange for exclusive business agreements.

The government is lagging behind private industry in the implementation of CVP practices. Though there are ongoing activities to develop procedures for effectively implementing Integrated Product and Process Development (IPPD), few actual development programs are using this concept.

However, emerging government policies are compatible with and supportive of CVP. CVP could prove key to:

- achieving DoD's and DND's new strategic direction,
- reducing the costs of military products,
- improving manufacturing processes,
- capitalizing on commercial technologies, and
- streamlining the acquisition process.

CVP is vital to helping the two governments accomplish their goals of integrating teams and empowering them and revolutionizing the design process. CVP can enhance the acquisition process from "cradle to grave", and hence, enable the governments to acquire a better design in less time and with fewer procurement dollars. Therefore, future government transition to an operational environment is possible.

CVP Investments and Payoffs

For a company, organization, or group of organizations to establish a CVP capability, several investments are required. Investments fall into two broad categories: short term investments which enable implementation of an immediate CVP capability, and long-term investments which will move CVP technology forward and improve capabilities in the future.

In the short-term category, investments can be further divided into computer-related investment and procedure-related investment. A significant amount of computer-related investment is necessary, including:

- buying and installing hardware and software,
- buying and implementing local area networks (LANs) that enable computer systems and people to communicate,
- buying and installing wide area networks (WANs) that enable the creation and operation of virtual organizations,
- maintenance and operation of new computer systems and networks, and
- security of the system.

Procedure-related investment includes training associated with these new computer systems and networks and transitioning from old business processes to modified or new processes.

The major long-term investment consideration is in development of standards that enable interaction among CVP tools, and thus the development of open system architectures. The driving cost factor here is the investment of people's time in developing these standards and implementing them.

While the investment required to implement and maintain a CVP capability can be substantial, several alternatives exist to make CVP technologies available to companies of all sizes. Considerations that come into play when determining the level of investment that is right for the user include:

- required complexity and interoperability of the system,
- level of fidelity required for the application,
- nature of the working relationship with the other organizations, and
- size of the company and its ability to make an investment.

In lieu of establishing a high powered and complete CVP environment companies could opt for a lower cost/limited performance model. Another investment option is the establishment of a physical infrastructure that enables an organization (often in this instance a Government organization) access and oversight of a contractor. In some cases a prime contractor may finance a supplier or subcontractor's investment in CVP. An emerging practice is the practice of leasing software on a pay-per-use basis.

The payoffs associated with using CVP are only beginning to be quantified, but initial predictions indicate significant cost savings throughout the system life cycle. These payoffs include:

- improved manufacturing processes,
- reduced time to market,
- more productive work environment through enhanced communication,
- reduced risks,
- reduced lifecycle costs,
- improved quality,
- enhanced customer satisfaction,
- competitive advantage, and
- dual use technology considerations.

Many of the potential payoffs, such as increased quality, are qualitative but are important to a company's position in the marketplace.

Facilitators and Barriers

Facilitators and barriers can be grouped into four categories: technical, financial, procedural and cultural, and policy. The facilitators and barriers determined in this study are presented in Figure ES-3.

Conclusions and Recommendations

Based on the data gathered and analyzed in this study, Figure ES-4 presents the conclusions that were drawn and the associated recommendations for DoD and DND actions that were developed.

	Facilitators	Barriers
Technical	• Significant commercial and Government tool development and standardization efforts are underway. • Enabling technologies are available and improving.	• No common or standard CVP infrastructure definition exists. • Commercial standards are immature and slowly developing. • Specific technical challenges remain: ⇒ Cost modeling, security, human factor elements, distributed interactive simulation (DIS), ergonomics, bandwidth, and, verification, validation and accreditation (VV&A) of tools. • Rate of change of technology is a challenge.
Financial	• CVP provides a competitive advantage. ⇒ Enables dollar savings during development and manufacturing. ⇒ Results in increased market share. ⇒ Reduces life-cycle costs. ⇒ Reduces risks. ⇒ Enhances communication within the work environment. ⇒ Enables a more productive design and production environment. ⇒ Demonstrates product utility early in the design phase. • Cost of CVP tools is decreasing.	• High investment is required to implement and maintain CVP capability. • Cost benefits of CVP have not been quantified. • Standards and infrastructure development require cooperation in investment.
Procedural/ Cultural	• Engineers gaining confidence in CVP results. • IPT/IPPD concepts are being inserted into academic curriculum.	• Security and proprietary data concerns remain. • Government culture has not caught up with policies endorsing CVP. • Companies keeps CVP use as competitive edge. • Government lacks confidence in CVP results.
Policy	• CVP supports current policies and future DoD direction. • Use of commercial standards is encouraged and M&S standards are being developed.	• Aperture card delivery still a requirement. • No policy in place defining design data ownership. • Verification, validation and accreditation of systems time consuming and expensive.

Figure ES-3. CVP Facilitators and Barriers

Conclusions	Recommendations
11.1.1 Industry Recognizes Opportunities Offered by CVP	11.2.8 Target Government Investments on CVP Integration Technologies
11.1.2 CVP Technologies Exist and Are Advancing	11.2.2 Sponsor Integration and Demonstration Projects 11.2.8 Target Government Investments on CVP Integration Technologies
11.1.3 No True CVP Environment Currently Exists	11.2.2 Sponsor Integration and Demonstration Projects 11.2.8 Target Government Investments on CVP Integration Technologies 11.2.1 Establish Central Government Office for CVP
11.1.4 No Metrics Are in Place for Measuring CVP Benefits	11.2.2 Sponsor Integration and Demonstration Projects 11.2.3 Implement Policy to Develop Standardized Metrics for Evaluating CVP Payoffs in Programs
11.1.5 Proprietary Data Rights and Protection of Competitive Advantage are Industry Concerns	11.2.7 Address Data Security/Proprietary Data Concerns and Formalize Policy Regarding These Issues 11.2.5 Reevaluate How Developers Deliver Data to Government Clients
11.1.6 No Government Guidelines for CVP Use Have Been Set	11.2.2 Sponsor Integration and Demonstration Projects 11.2.1 Establish Central Government Office for CVP 11.2.3 Implement Policy to Develop Standardized Metrics for Evaluating CVP Payoffs in Programs 11.2.6 Coordinate CVP Requirements With Acquisition Reform Initiatives
11.1.7 Current Government Acquisition Procedures Do Not Promote CVP	11.2.5 Reevaluate How Developers Deliver Data to Government Clients 11.2.3 Implement Policy to Develop Standardized Metrics for Evaluating CVP Payoffs in Programs 11.2.6 Coordinate CVP Requirements With Acquisition Reform Initiatives 11.2.4 Implement RFP Language and Contracting Approaches That Encourage CVP Use
11.1.8 CVP Standards and Better Integration of Tools are Needed	11.2.2 Sponsor Integration and Demonstration Projects Target Government Investments on CVP Integration Technologies 11.2.8 Target Government Investments on CVP Integration Technologies
11.1.9 Financial Investment Considerable for Small Companies	11.2.10 Educate Small Business on Less Expensive Options to Acquiring CVP Technologies
11.1.10 No Central Repository of CVP Information	11.2.1 Establish Central Government Office for CVP
11.1.11 Model Validation Process Takes Too Long	11.2.9 Streamline the Validation Process for Models

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1.0 PURPOSE

The purpose of this study is to assess the maturity, level of use, utility, and viability of Collaborative Virtual Prototyping (CVP) technology and its application to the industrial base, including small and medium sized companies. CVP is the application of distributed modeling and simulation in an integrated environment to support tradeoff analyses affecting performance during the entire life cycle of developmental systems. CVP enables:

- all members of a design team to continuously interact through electronic modeling and data exchange,
- performance measurement without building the system,
- increased insight into life cycle concerns,
- testing through virtual proving grounds, and
- accelerated production through the creation of virtual factories.

This report investigates CVP from technological, cultural, policy, financial, and effectiveness points of view and develops conclusions regarding the status of CVP from each of these perspectives. Recommendations regarding actions that the defense community should take in response to these conclusions also are presented.

2.0 BACKGROUND

The North American Technology and Industrial Base Organization (NATIBO) is chartered to facilitate cooperative technology and industrial base planning and program development among and between the U.S. Military Services and Canada. To further this mission, the NATIBO has spearheaded an effort to address the challenges of advancing and maintaining technological superiority in light of reduced government research and development funding. The criteria used for selecting technologies to study through this program are:

- the candidate is a key technology area of high interest,
- there is potential for both military and commercial application,
- development and/or production exists in both the U.S. and Canada, and
- there is a good window of opportunity for investment and application.

Through this initiative, common areas of interest are assessed jointly, allowing participating organizations to capture the information they need cost effectively, avoid duplication of effort, and capitalize on scarce resources.

The NATIBO selected CVP to study under this program because of the many potential benefits offered by this emerging and fast evolving technology. Previous studies have concluded that CVP may enable a 25 percent reduction in cost while simultaneously reducing development time. Several technology demonstrations have yielded impressive results. CVP may affect all phases of the acquisition cycle and certainly will change the way DoD and DND partner with industry. CVP is a key technology enabling integrated product teams across industry and government. Increased use of CVP in the acquisition process also has far reaching implications for the management of technical data, proprietary information, electronic contracting, cost and operational effectiveness analyses, and milestone reviews.

CVP can play a central role in integrating the defense and commercial industrial bases and in implementing the new policies being put forth to achieve acquisition reform. Current policy calls for a national defense force that derives its strength and technical superiority from a unified commercial/military industrial base. DoD's and DND's declining procurement budgets can no longer sustain a defense-unique industrial base to supply its needs. The governments are faced with the challenge of reducing the cost of military products, related manufacturing processes, and the infrastructures that have to be maintained. Meeting this challenge necessitates not only reducing the time required to realize products while still applying the latest technologies, but also improving the predictability of process attributes, product performance, cost, schedule and quality.

Without fundamental acquisition reform, DoD will be unable to tap into the civilian manufacturing base to replace the capabilities lost as defense firms are downsized, converted, or eliminated. Without access to a broader national manufacturing and technology base, defense downsizing could jeopardize basic national security goals. DoD's acquisition processes are being reexamined to help unify the industrial base by applying the most modern industrial products, processes, practices, and standards of management and manufacturing. CVP can help the government realize these goals by enhancing the tradeoff analyses that are conducted throughout the acquisition process. This will require that CVP be practiced and promulgated beyond the major primes to sub-tier levels.

CVP's potential for reducing the cost and time-to-market for complex systems in both commercial and military environments is large. CVP increases the probability of first article acceptance. It enables all members of the team to interact continuously through electronic modeling of user requirements and testing through virtual proving grounds; gives increased insight into life cycle concerns (affordability, supportability, maintainability); and accelerates the transition to production through the creation of virtual factories. Simulations using integrated product and process models permit detailed knowledge to be obtained earlier in the conceptual and preliminary design phases where it can have the most influence on life cycle cost. Payoffs from the use of CVP in development programs include improved product quality, reduced cost/increased value, continuous process improvement, reduced time to market, improved competitiveness, increased design integrity, increased user/market acceptance, and improved supportability.

Despite the apparent potential of CVP as a technology to support improvements in the weapon system acquisition process, numerous questions remain regarding the viability of this technology. These questions are at the heart of this report and include the following:

- What are the principal technological barriers, if any, to the widespread implementation of CVP in weapon system acquisition programs?

- How will CVP be integrated into the weapon system acquisition process? What are the principal cultural barriers? What are the principal policy barriers?

- What are the economics of implementing CVP? How do these economics affect the Government's ability to use small businesses at the prime and subtier levels?

- Have the benefits of CVP been realized in practice? If so, have they met expectations? If not, why not?

- Can industrial practices employing CVP be applied successfully to weapon system development programs? Will CVP technologies and practices be accepted by the defense development community?

3.0 OBJECTIVES AND REPORT STRUCTURE

3.1 Objectives

This study identifies and assesses the maturity and applicability of CVP technologies to the national industrial base, focusing on how small and medium sized companies can be electronically integrated with the large defense and commercial firms.

The objectives of the study are to:

- Identify the status of CVP development and use and trends for the future,
- Identify the potential benefits of CVP,
- Identify new business process opportunities leveraging CVP,
- Identify current government and commercial activities related to CVP development and use,
- Identify facilitators and barriers to CVP use, and
- Recommend actions for government and industry to promote the widespread use of CVP.

This report describes the status of CVP technology and trends, particularly in the areas of current and emerging tools, architecture and interfaces, requirements for supporting hardware, standards and protocols, and accessibility and applicability to small and medium-sized firms. It explores the application of this technology and its impact on weapon system developmental and operational cost, time to market, and performance. The report describes acquisition and business policies and procedures affecting or that are affected by CVP and highlights case studies of previous developments using CVP.

The report discusses investments necessary to implement CVP and cites proven payoffs that this technology currently offers and potential payoffs that could be realized as this technology evolves. Facilitators and barriers affecting the implementation of this technology are outlined. From this analysis, conclusions regarding the state of CVP and a roadmap of recommendations addressing these conclusions are provided.

3.2 Report Structure

Section 3.0 of the report defines the scope of the study. Section 4.0 provides the background for this assessment, with Section 5.0 describing the methodology that was used to conduct the study.

Section 6.0 provides a technology overview and assessment, detailing the status of CVP-related technologies, on-going development activities, and projected advancements. It presents a CVP taxonomy for infrastructure and service technologies that support system development activities. For each area within the taxonomy, technology requirements and the tools that are available and under development to support these requirements are presented.

Section 7.0 discusses system development and acquisition processes using CVP. It presents current industry practices and process/practice changes that are foreseen as CVP becomes more widely used. Government use of CVP in the acquisition process is then discussed. This section includes an assessment of how the use of CVP will affect client, prime and subtier relationships. Current government policies that affect or are affected by CVP are also reviewed.

Section 8.0 presents case studies that demonstrate the use of CVP in current practice. It illustrates how CVP can be used, what problems have been encountered, what solutions have been developed, and what issues remain that affect the effective use of CVP.

Section 9.0 presents investments required to implement CVP and payoffs that have been observed or can be expected as a result of implementing CVP. It describes required CVP investment elements, including hardware, software, networking, training, maintenance, and process improvement/reengineering. It discusses the ability of large and small companies to make these investments and outlines investment alternatives. Expected CVP payoffs are then described. These payoffs are substantiated by direct experience or are reported as the expectation of companies who have made the investment.

Section 10.0 addresses facilitators and barriers to CVP use. Section 11.0 summarizes the information gathered in the previous sections and presents conclusions and recommends actions to be undertaken by the defense community in response to these conclusions.

4.0 SCOPE

This study encompasses the collection and analysis of technical, business, and policy information related to CVP research efforts and industrial capabilities in both the U.S. and Canada. Particular focus is placed on the challenges faced by small and medium sized organizations in applying this emerging technology.

5.0 METHODOLOGY

The CVP study required a clear, concise, and well-defined methodology to survey industry effectively and compile military, commercial, political and academic perspectives. The data collected and analyzed for this study were drawn from previously published reports, conference proceedings, journal articles, Internet home pages, and discussions with US and Canadian representatives from industry, government and academia. The methodology employed is depicted in Figure 5-1.

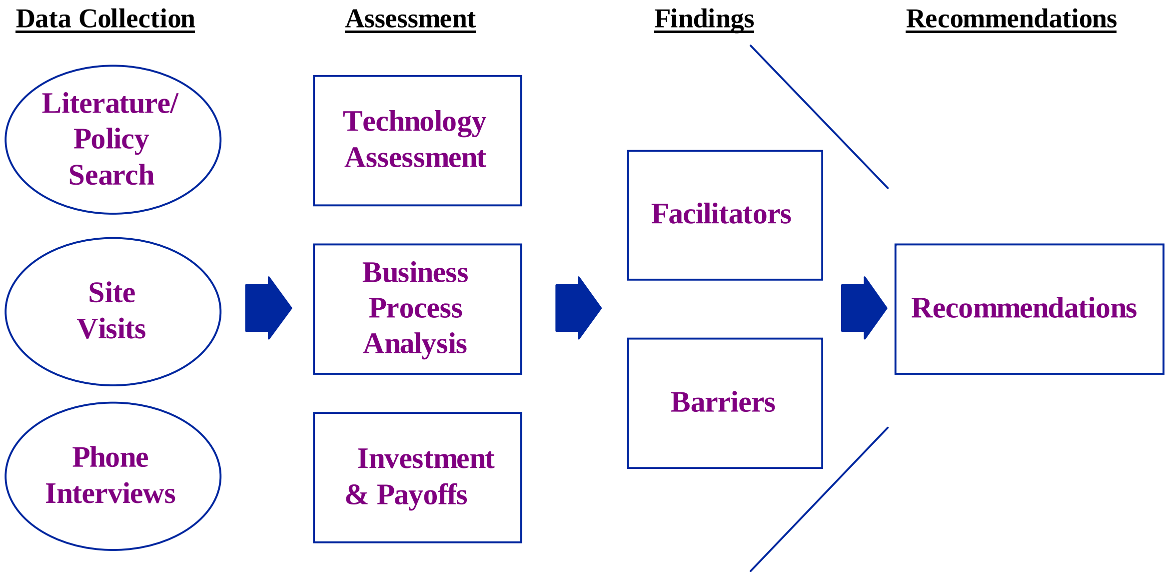

Figure 5-1. CVP Study Methodology.

The study group's goal was to meet with a representative sample of tool developers, users (both government and private industry), policy makers and academia across a broad range of industrial sectors. Factors taken into consideration in selecting sites to visit included volume and business with the individual Military Services and with industry, industrial sector involved, products and service, market niche, state of the technology, applications, new technology development, level of team integration, complexity of system/infrastructure, and effect on system development. Sites then were organized geographically so that trips could be scheduled efficiently. Site visits were conducted in seven regional trips: West Coast, Texas, Detroit, Canada, Midwest, Florida, and Northeast. Appendix B contains a list of the sites visited through the course of this study.

When it was determined that an industry, university, or government site would not be visited, an extensive phone interview was conducted. Data collection guidelines were developed and used to facilitate obtaining data from all points of contact either through telephone interviews and/or site visits. Four different packages were prepared to strategically target the specific audience being interviewed – manufacturers, tool developers, government personnel, and academia.

Data collected from relevant documents, World Wide Web sites, site visits, and phone interviews were analyzed and incorporated into key sections of this report: technology overview and assessment; processes, practices and policies; CVP demonstrations and implementations; CVP investments and payoffs; and facilitators and barriers to CVP use. This report functioned as a working document throughout the data collection phase of this study.

6.0 TECHNOLOGY OVERVIEW AND ASSESSMENT

CVP is a new design/development paradigm, based on an integrated product and process development (IPPD) approach, that requires a variety of different technologies to implement. This section scopes the CVP environment in terms of the processes affected and provides an overview of the technology areas that support CVP. For each technology area discussed, the following are provided: a description of the area, its status in terms of availability and use of the technologies, ongoing development, testing and implementation activities, and projected and required advancements. In addition to the technology areas, this section discusses the importance of an open systems architecture, security implications of CVP, and standards that support the establishment of an open systems environment.

6.1 CVP Scope

As previously defined, CVP is the application of modeling and simulation (M&S) in a distributed integrated environment to support tradeoff analyses throughout the entire life cycle of developmental systems. Central to CVP is the use of integrated product teams (IPTs). IPTs contain representatives from all aspects of a product's life cycle, including the various design agents (mechanical, electrical, major subcontractors and suppliers), manufacturing, logisticians, maintenance, users (operators), and customers (funding source). The premise behind the CVP concept is to eliminate the need for collocation of IPTs through the application of electronic collaboration tools and to provide the IPTs the computer tools necessary to conduct analyses and tradeoffs of various design concepts. Many of the computer tools used to conduct these analyses and tradeoffs are considered modeling and simulation tools. Figure 6-1 provides a graphical representation of the relationships between M&S tools and the CVP tools considered within this study.

Traditionally, M&S supported training through the development and use of flight and driving simulators. The evolution of Distributed Interactive Simulation (DIS) has expanded its use to operational, man-in-the-loop simulations for combat training and planning. More recently, M&S has supported the user and acquisition community in conducting performance and operational analyses of new weapon system concepts. CVP extends M&S to support the entire acquisition process (concept exploration, operational analysis, preliminary design, detailed design, manufacturability, production planning, and production).

In addition to M&S, CVP adds electronic collaboration. Electronic collaboration is the integration of people through multimedia applications, video conferencing, E-Mail, and other like technologies as well as the integration of tools that support computer aided design (CAD), M&S, visualization, product analysis, and virtual reality. These tools can be organized in a CVP taxonomy that outlines all of the technologies that support a CVP environment.

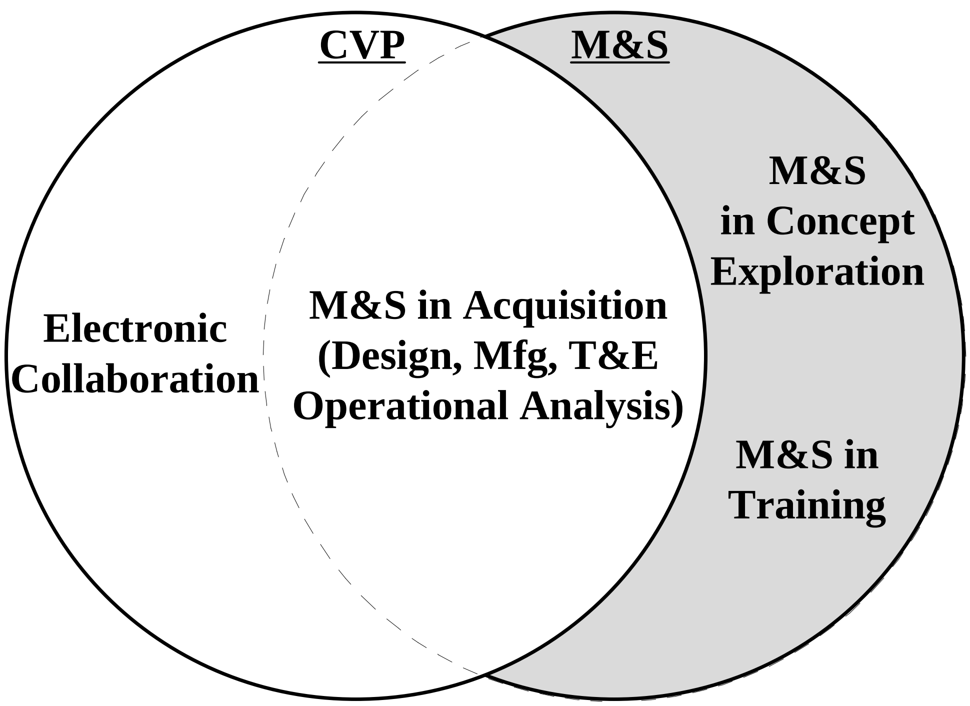

Figure 6-1. Relationship Between M&S and CVP.

6.2 CVP Technology Taxonomy

The CVP taxonomy categorizes the technologies that support the CVP concept into two areas: services that interact with users (IPTs) and the infrastructure that operates behind the scenes and enables the services to function and interact. In Figure 6-2, the services are represented by the top row which includes four categories of tools: integration, interaction, applications, and data creation. The infrastructure contains three categories that are represented in the bottom three rows of the taxonomy: product and process data, object management and information sharing, and computing and computer networks.

The taxonomy presented in Figure 6-2 provides a representative categorization of the tools required to support a CVP environment. The taxonomy was developed to provide organization to the presentation and discussion of tools within this report. The remainder of this section provides information regarding each of these categories. Appendix E contains a listing of the tools analyzed in the course of this study. Each tool is referenced by its associated category within the taxonomy, a list of users, its developer, and a description of the tool.

6.2.1 Integration

The integration category includes tools and technologies that enable collaboration within a distributed integrated product and process development environment. This category includes two types of integration tools: tools that enable team integration and tools that enable tool integration. Team integration tools are used by IPTs to facilitate communication and information sharing. Tool integration addresses the ability for analysis tools to work together. In general, the integration category represents the tool set required for electronic collaboration by an IPT. This tool set depends upon the infrastructure categories; they represent the more generic lower level functionality necessary for the operation of the integration tools.

Team integration tools are well advanced and many are available within the commercial marketplace. Commonly known as “groupware,” these tools include video conferencing, E-Mail, and workflow automation that improve communications among team members and support virtual collocation of teams. Other team integration tools include application conferencing tools that allow users

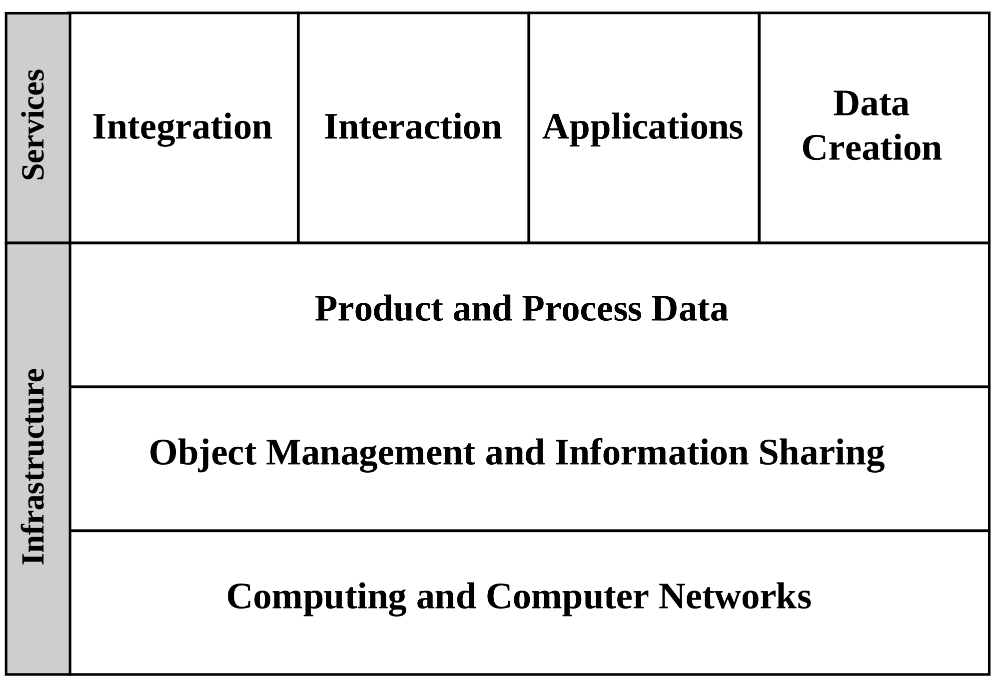

Figure 6-2. CVP Technology Taxonomy.

that are not collocated to simultaneously view a single application and data file across a network and see, discuss, and make changes to the data file in real time.

Specific examples of team integration tools include Lotus Notes for workflow management/automation, CAD conferencing options such as those provided by Intergraph and ComputerVision, and desktop video conferencing. Because of improvements in computing power, desktop video conferencing is becoming more prevalent throughout industry. Under ARPA's DICE and SBD programs, a tool called Multimedia Engineering Collaboration Environment (MECE) was developed. MECE provides an electronic notebook to support the capture of a design team's decisions and associated rationale. MECE is currently operated and maintained over a local area network (LAN). Under the SBD program, Lockheed and EIT are working to upgrade MECE to support operation over a wide area network (WAN) via the Internet. Also as part of ARPA's SBD program, General Dynamics Electric Boat (GDEB) developed electronic visualization rooms (EVRs) which support electronic collocation of IPTs. These rooms support video conferencing, application conferencing, and real-time information sharing for virtually collocated IPTs. The EVRs are currently in use by GDEB and NAVSEA in support of the next generation submarine program.

Team interaction tools are used to support many areas outside the design and manufacturing process. As a result, development of these tools is expected to continue to progress.

Tools that enable tool (interaction, application, and data creation tools) integration are less advanced than the team integration tools. Standard integration tools are primarily within the R&D phase of their development with some testing and prototyping activity occurring. A typical approach used today is for companies to build custom interfaces to enable specific interactions between specific team interaction, application, and data creation tools.

As part of the SBD program, Lockheed is working on two tools to support tool interoperability through the creation of megaprograms: Simbuilder and Netbuilder. Simbuilder enables event and time synchronized engineering simulation through the development of simulation megaprograms. Netbuilder assembles data-driven engineering and warfare analysis simulation megaprograms. Application wrappers based on the Common Object Request Broker Architecture (CORBA) are being developed and tested in a variety of environments to enable interoperability between object oriented applications. These wrappers are somewhat labor intensive to develop, though it appears they are the only mechanism available for integrating legacy applications.

Computing power appears to be the primary barrier to more wide spread use of team integration tools. As the computing power of desktop computers continues to increase, more multimedia applications using higher fidelity video and virtual reality tools will be available for everyday use supporting team integration. These types of tools are available and in use today though they are generally not used in desktop applications. Rather they are used in specialized video conference rooms and EVRs such as those used by GDEB. Other team integration tools such as workflow management tools and application conferencing tools will become more prevalent with time. These are fairly new to the marketplace and are emerging as commercial off the shelf (COTS) packages. MECE and similar tools should start to become available as COTS packages in the next year or two. The combination of improvements in desktop computing power and the availability of tools as COTS packages should lead to wide spread use of team integration tools within the next one to two years.

Tools enabling tool interoperability require more development. ARPA's SBD program is working on these tools (Simbuilder and Netbuilder) and will act as an excellent testing environment for these and similar tools. In addition to ARPA's SBD work, standardization efforts such as STEP and CORBA will help to improve tool integration by standardizing data formats and application architectures. Data standardization should enable tools to operate on a single set of data stored in a single logical database, eliminating the need for the data exchange and translation that is currently required for tools to interoperate. The development of ontology libraries which define common terms for describing products may form the basis for a future technological breakthrough in tool interoperability.

6.2.2 Interaction

The interaction category addresses the use of tools that interact with a product or process. These tools generally require real-time or near-real-time execution. Included in this category are tools such as virtual reality/simulations and immersion technologies that allow a user to interact with a product or process design. The most common application for interaction tools is when user interaction or involvement is required to assess a product's performance or operation.

Virtual reality tools that simulate a product or system based on a digital design are available today. These tools are in use today in applications such as training and interference checks where detailed accuracy is not required. In cases where high detail and accuracy is required, very high powered computers (such as those offered by Silicon Graphics) are needed for virtual reality applications to run effectively.

Accuracy remains a problem in many virtual reality applications, especially when representing dynamic changes to an environment in real time. For example, terrain changes in battle field simulations, dynamic changes to environmental elements such as water, and relationships between objects and the ground are all difficult to model accurately because of the complexity of their properties and the randomness of interactions. The main challenge regarding accuracy is the development of new algorithms that enable these tools to represent various environmental characteristics, dynamic events, and interactions more accurately within a virtual environment. Advances in computing power will provide some improvement in the accuracy of virtual reality applications.

A critical requirement of interaction tools is the need for powerful computing systems to support the display and updating of complex graphic information. Advances in computing power will also help make many of these tools available on a user's desktop PC.

Silicon Graphics is recognized as the leading supplier of high end graphic computing and display systems supporting virtual reality applications and environments. They currently offer desktop and server computer products that can support most virtual reality applications. They have made projections of significant and rapid increases in computing and display capabilities that should be able to support future virtual reality applications.

CAD vendors, who provide computer tools used for the creation of digital models/designs of products, are beginning to offer visualization tools that enable dynamic representation of their CAD models. In addition to those offered by the CAD vendors, Wavefront and Gemini are two commercial visualization tools available today.

The DoD is a major sponsor of the development of man-in-the-loop simulations for training applications. In addition, the US Army Simulation, Training and Instrumentation Command's (STRICOM's) efforts in the area of distributed interactive simulation (DIS) have resulted in major advances in developing interactive tools. In Canada there are several ongoing tool development initiatives that are supporting improved Naval ship design through the use of interaction tools that allow designers to better understand human factor elements during design.

Advances in computing power will continue to enable interaction tools to produce the real-time execution and high fidelity virtual reality required by CVP. As mentioned, CAD vendors are beginning to link CAD applications and environments with visualization environments. This link is essential to enable the real-time analysis of changes to CAD models.

Anthropomorphic modeling , is an area within virtual reality that requires additional effort. Anthropomorphic modeling utilizes a digital model of a human being within a virtual environment to evaluate the effects of a human beings interaction with a potential design. Anthropomorphic modeling is an essential capability to support human factors analyses. More realistic models of humans and human motions are needed to help anthropomorphic modeling to be an effective interaction technology. Improved accuracy and dynamic representation are required to enable virtual reality and other interaction tools to better support an IPT in making design trade off decisions. These areas are being addressed today.

6.2.3 Application

The application category addresses analysis tools that allow a designer to understand better the characteristics and functionality of a design. These tools are primarily computer automated engineering (CAE) and simulation tools that generally do not require real-time execution. These tools model and simulate a product's characteristics, design functionality, and manufacturing processes.

In the past, large manufacturing firms developed and maintained their own custom applications. However, today, CAE tools and manufacturing modeling and simulation tools are available through many of the CAD vendors as well as independent vendors who specialize in these areas. For example, Deneb Robotics, an independent manufacturing simulation tool vendor, is the market leader in providing manufacturing simulation tools. The trend is for manufacturing firms to purchase these commercial tools rather than to fund in-house application tool development and maintenance. Although manufacturers admit that the commercial tools do not meet their specific needs as well as the in-house tools, the cost savings realized far outweigh the slight performance differences.

Commercial companies and the DoD sponsor the development of specialized analysis tools as needs are identified. DoD efforts are focused on developing tools that satisfy the DoD's specific requirements, such as the evaluation of advanced material properties.

Tools within the application category are fairly well advanced. In particular, CAE tools are available for a variety of analysis activities. Requirements remain for specialized tools to support the analysis of new and emerging products and processes such as composites. Manufacturing simulation tools such as shop floor simulations and machine tool path simulations are also well advanced and available. The primary challenge remaining in this category is to understand better new products and processes and to capture this information in application tools that can model the behavior of products and processes accurately.

Two technological advances are required in the applications category: application integration and specific tool development. Application integration is required to allow the different application tools to share data and support design tradeoff analyses. Related to this is the integration of application tools with data creation tools (CAD and CAM). The interoperability tools discussed in the integration category play a critical role in making this happen.

The specific tool development required is related to new and emerging technologies. As new technologies advance, application tools need to be developed to support the analysis and evaluation of these technologies in new designs.

6.2.4 Data Creation

The data creation category addresses tools that enable a designer to create data that is used by the interaction and application tools and is shared via the integration tools. The primary tools that fall into this category are CAD systems for creating product data and Computer Aided Manufacturing (CAM) systems for creating process data.

These tools are well developed and established as COTS packages. There is significant integration between CAD and CAM tools, especially in cases where a traditional CAD vendor has expanded their product to include CAM tools. CAD systems have and are in the process of shifting from the traditional geometric based modeling to feature/object based modeling, which is a more powerful representation of a design. Another recent advance in the CAD market is the addition of associativity within CAD systems. Associativity establishes relationships among different elements or portions of a design model to support improved flowdown of changes within a design. Another emerging area is knowledge-based CAD/CAM systems, which integrate knowledge engineering with CAD/CAM methods and provide intelligent tools for the conceptualization, synthesis, analysis, and verification of design concepts and manufacturing processes.

The main area requiring further work in this area is improving the sharing of data among different CAD and CAM systems.

Some of the major CAD/CAM vendors include Intergraph, CATIA from IBM, ComputerVision, Pro Engineer from Parametric Technologies, AutoCAD and Unigraphics from EDS. While there are many others, these appear to be the most prevalent in the marketplace. Each package has specialties and support certain markets and hardware platforms. For example, CATIA is the CAD system most used to handle the complexities associated with aircraft and ship design, while AutoCAD is the most common low cost PC based CAD system for supporting small businesses.

The development and incorporation of Standard for the Exchange of Product Model Data (STEP) Application Protocols (APs) by the CAD vendors is critical to enabling interaction among the various CAD systems. STEP is the emerging technology identified to enable the sharing of data among data creation, applications, interaction and integration tools.

6.2.5 Product and Process Data

The product and process data category addresses the tools and technologies that support the storage, management, and maintenance of data that defines a design. This category includes databases and product data management (PDM) systems that store and manage data as well as define what data should be stored and managed (for example, geometry, features, processes, part lists, versions). Lockheed's Smart Product Model (SPM) concept developed under the ARPA SBD program is an example of what the product and process category addresses. The SPM concept provides a complete description of a product and its associated processes. The SPM is accessed and used by analysis tools to evaluate the product's manufacturability, operability, maintainability, affordability, and other life cycle concerns.

Data storage tools such as databases are well established. There is a current trend in the market away from relational databases to object oriented databases. This trend is motivated by the idea that object oriented databases allow more flexibility and interaction between databases and tools that use the data within the databases.

Data management tools such as PDM systems are becoming available. PDM systems handle a wider variety of data elements than captured by traditional product databases provided with CAD systems. The PDM systems support capturing all of the data needed to fully define a product and its associated processes. Very few PDM systems are available today that can support the life cycle data requirements of a CVP environment, though they are being developed. Data definitions, which define what data elements should be stored and the format they should be stored in, are beginning to become available. STEP APs provide standard data definitions for specific applications. For example, AP 203 defines the data elements necessary for 3D product models and configuration management. Future APs will identify the data elements necessary to define electronic components and other products.

Traditional relational database developers, such as Oracle, are offering object oriented databases. New vendors such as The Object Store are specializing in object oriented databases. The major CAD vendors such as EDS (Unigraphics) and IBM (CATIA) are beginning to offer PDM systems. The SPM concept being developed under Lockheed's ARPA SBD program demonstrates an implementation of the tools and technologies that define the Product and Process Data category. The SPM is being developed based on STEP's AP 203.

Projected technology advancements within this category will come in the form of new STEP APs being developed and approved as ISO standards. Even if more STEP APs become available, the CAD and CAM vendors as well as the PDM vendors must embrace the standards and begin to incorporate the APs into their products. PDM systems will continue to be developed and expanded to ensure their ability to handle all product and process data required to fully define a design. Technology advances are being driven by logistics needs as well as by CVP-related requirements.

6.2.6 Object Management and Information Sharing

Object management and information sharing describes the logical computer and software infrastructure that enables the sharing of information and data among the tools within the service category of the taxonomy. Object management and information sharing tools are in the research and development and prototyping stage of their development. These tools have not been stabilized in an operational or production environment. Since object management is the trend for nearly all computer applications, most of the tools that support object/data management are further along in development than the tools that support information sharing.

Object management technology provides the framework to achieve interoperability in a distributed computing environment and has widespread acceptance and support throughout the computer industry. Technologies in this area are evolving rapidly. Object management technologies include the object management architecture (OMA) and the Common Object Request Broker Architecture (CORBA), which provide a description of the interfaces and services that must be provided by compliant object request brokers (ORB) which make up the OMA. With the development and stabilization of CORBA, tool developers will become CORBA compliant to support object management across applications. For legacy applications, CORBA wrappers will be developed to enable the same type of tool integration. Lockheed is basing their Simulation Based Design (SBD) on object management technology.

Information sharing is the application of knowledge engineering and artificial reasoning in support of extracting, integrating, and abstracting information across distributed databases. Information sharing technologies support the services tools by determining where information is located, automatically retrieving information using appropriate formats, and notifying interested users when information has changed. Technologies in this area include intelligent agents and brokers, mediators, matchmaking, and subscription and notification services.

Lockheed's SBD program is one of the leading efforts evaluating and developing information sharing technologies. Much of their work is in the area of matchmaking event notification. Matchmaking event notification helps to manage changes to objects and coordinate those changes with other applications and areas that may be affected by the change. In addition, Lockheed is looking at the use of mediators and intelligent agents to support information sharing. The work Lockheed is pursuing as part of the ARPA SBD program will help to validate many of the concepts associated with mediators, intelligent agents, and matchmaking event notification. Significant research work is also ongoing within many universities.

6.2.7 Computing and Computer Networks

The computing and computer networks category describes the physical infrastructure that enables the sharing of information and data among application, interaction, and data creation tools and across the integrated design team. This category also addresses the computing power requirements needed to run a CVP environment and all of its associated tools and operations.

The computing and computer networks category is well developed and the tools associated with it are mature. While the technologies in this category are established, they continue to improve rapidly. Computing power and networking capabilities are improving at incredible rates.

Faster networking capability is a critical element associated with the physical infrastructure for CVP. Networking speed is normally described in terms of bandwidth. Bandwidth is a term used to describe how much information can be sent with a particular method. For example, in typing classes, bandwidth can be measured in words per minute and on the highway, as miles per hour. If you have two people typing, or two cars going down the highway, you double the bandwidth if they are going the same speed. Analogously, in computing terms, bandwidth is the capacity of a network, usually expressed in storage volume divided by time such as bytes per second or megabytes per second.

Many people believe that the wires and optical cables now in use for most computing networks have a bandwidth on the order of gigabytes per second. These claims, though, are usually based upon the results of controlled laboratory experiments with only one or a few nodes of the network active. In actual practice, with many nodes of the network active and each node performing a separate function, the maximum bandwidth of this media is usually on the order of a few megabytes per second. In addition, much of the bandwidth of a network is taken by header and routing information needed by computers and networks to properly act on the files and messages.

Silicon Graphics is the market leader in providing high end networks of computer and graphics workstations. SGI predicts faster networking capabilities will be available in the near future through the use of Asynchronous Transfer Mode (ATM) networks. ATM OC48 is predicted to improve network speed to over 300 megabytes per second in the year 2000. SGI is predicting that computing power (MIPS) will increase at a rate of 10x every five years. In addition, SGI believes that the resulting 10x increase in the number of polygons that a computer can produce will result in more realistic graphics representation capabilities and faster graphics presentation capabilities.

6.3 Open Systems and Standards

One of the primary requirements of computing systems used for CVP is that the systems be "open" or conform to open system standards. In short, an open system standard is an interface specification – a specification that describes services provided by a software product – to which any vendor can build products. There are two important points. First, the specification must be available to any vendor and evolve through a consensus process that is open to the entire industry. Second, the specification must define only an interface, so different vendors can provide the standard interface on their proprietary operating systems.

There are two important aspects to open systems: interoperability and portability. Interoperability is the capability for applications running on different computers to exchange information and operate cooperatively using this information. Portability is the capability for software to run on different types of hardware. Portability can be further broken down into binary portability and source code portability. Binary portability makes it possible to move an executable copy of a program from one machine to another. Source code portability requires a program to be recompiled when moving from one machine to another. The development of portable application software depends on portability standards. Interoperability standards are necessary but not sufficient for a complete open systems environment.

Open systems are becoming the norm for many applications beyond the CVP environment. For example, the Assistant Secretary of Defense issued a policy in May 1995 requiring an open computer architecture for all shared databases throughout DoD.

Standards that define communication protocols, data formats, and information system architecture requirements help to enable interoperability among organizations. Standards that affect CVP include IGES, STEP, CORBA, and the TAFIM. Several organizations, both commercial and federal, are involved in developing these standards. The National Institute of Standards and Technology (NIST) within the Department of Commerce is responsible for Federal Information Processing Standards (FIPS) which support open systems environments. NIST was involved in the development of IGES and is involved in the development of STEP. Various consortia such as PDES Inc. and OMG are supporting the development of STEP and CORBA, respectively. The Defense Information Systems Agency (DISA) is the proponent for the Technical Architecture Framework for Information Management (TAFIM).

6.3.1 Initial Graphics Exchange Specification (IGES)

IGES is an American National Standards Institute (ANSI) standard for the exchange of product drawings. IGES provides a neutral file format for moving computer-based engineering drawings between various engineering design packages. The IGES standard was intended as a means of exchanging CAD drawings. It is consequently very limited because it focuses only on graphical data and does not address all product information or the full product life-cycle.

IGES is the most commonly used standard for exchanging CAD information today. Though IGES generally does not allow the transfer of all data required, it is the best exchange mechanism currently available.

Direct translators are another approach to exchanging CAD information. Many one to one translators have been developed to allow various CAD systems to share information. The problem with the translators is that they are limited to two CAD systems and very often are dependent upon the version of the CAD system being used.

6.3.2 Standard for the Exchange of Product Model Data (STEP)

STEP (also ISO 10300) is an international data standard for product model data. STEP is implemented through application protocols (APs) which provide detailed definitions of data (in terms of what data and the storage format for the data) that help define a product for a specific application, such as configuration management or 2D drawings. Only two APs have been approved as international standards. Several others are in the ISO approval process and should be approved in the near future. Current STEP implementations are enabling data exchange by translating from a native CAD format such as CATIA to a STEP neutral file format based on an AP. In the future, STEP implementations should support the storage of data in STEP's neutral file format. By storing data in STEP compliant format, all STEP compliant applications will be able to use the data without translation.

STEP has the potential to replace IGES and direct translators that are in use today. As STEP matures and more APs become available, application developers such as the CAD, CAM, and CAE vendors and PDM vendors will have to make their products STEP compliant to enable data integration. The major barriers to this are time and money for the development and implementation of the STEP APs.

6.3.3 Common Object Request Broker Architecture (CORBA)

The CORBA specification is a description of the interfaces and services that must be provided by object request brokers (ORBs) to facilitate distributed object oriented computing. Basically, CORBA provides a standard definition for how objects are to interact. The Object Management Group (OMG), which is developing CORBA, solicits ideas for new technologies to be incorporated into ORBs. The ORB represents a portion of an Object Request Architecture which includes object services, common facilities, and application objects.

CORBA is emerging as the commercial standard for ORBs, which provide the infrastructure for objects to communicate in distributed object oriented applications. CORBA provides a definition for how legacy systems can be modified and new systems can be developed to allow all object oriented applications to operate seamlessly, independent of the systems they run on and the languages used to implement them.

The latest version of CORBA is a draft release of CORBA 2.0. Current activities include enhancements to the general CORBA definition as well as continuing resolution of interoperability issues with other object management techniques, primarily centered on Microsoft's Object Linking and Embedding (OLE).

6.3.4 Distributed Interactive Simulation (DIS)

The creation of large virtual worlds by electronically linking individual simulations is known as Advanced Distributed Simulation (ADS). To make ADS a reality, a standard infrastructure to permit individual simulations to interoperate is required. In an effort led by the DoD, Distributed Interactive Simulation (DIS) has been developing the standards needed for ADS.

DIS is in use today by the military to support training, battlefield tactical analyses, battle preparation, and concept evaluation for new weapon systems. Significant work continues in further developing the standards and improving the accuracy and ability of DIS to provide a realistic representation of the battlefield.

The DIS environment is modeled as a set of entities that interact with each other by means of events they cause. The heart of DIS is a set of protocols that convey messages about entities and events, via a network, among various simulation nodes that are responsible for maintaining the status of the entities in the virtual world.

6.3.5 Technical Architecture Framework for Information Management (TAFIM)

The TAFIM, which is mandated for use within the DoD, provides guidance for the evolution of the DoD technical architecture; it does not provide a specific system architecture. The TAFIM provides the services, standards, design concepts, components, and configurations that can be used to guide the development of technical architectures that meet specific mission requirements.

The purpose of the TAFIM is to introduce and promote interoperability, portability, and scalability of DoD information systems. The TAFIM is a DoD enterprise-level guide for developing technical architectures. Over time, the TAFIM should promote integration, interoperability, modularity, and flexibility; guide acquisition and reuse; and speed delivery and lower the cost of information technology to the DoD.

6.4 Security

The CVP environment includes large computer networks with multiple avenues for network access. This wide access raises the potential for security compromises such as industrial espionage or introduction of malicious viruses. Two common methods of dealing with these problems in a CVP-like environment are firewalls and encryption. These methods and their limitations are discussed in the sections that follow.

6.4.1 Firewalls

As the name implies, a firewall is a protection device to shield vulnerable areas from some form of danger. In the context of a computing network used in a CVP-like environment, a firewall is a system (e.g., a router, a personal computer, a host, or a collection of hosts) set up specifically to shield a site or subnet from unwanted activity initiated externally. A firewall system is usually located at a higher-level gateway, such as a site's connection to the Internet. However, firewalls can be located at lower-level gateways to provide protection for some smaller collection of hosts or subnets.

The general reasoning behind firewall usage is that without a firewall, a subnet's systems are more exposed to inherently insecure services and to probes and attacks from hosts elsewhere on the network. In a firewall-less environment, network security is totally a function of each host on the network and all hosts must, in a sense, cooperate to achieve a uniformly high level of security. The larger the subnet, the less manageable it is to maintain all hosts at the same level of security. As mistakes and lapses in security become more common, break-ins can occur not as the result of complex attacks, but because of simple errors in configuration and inadequate passwords.

A firewall can greatly improve network security and reduce risks to hosts on the subnet by filtering inherently insecure services and by providing the capability to restrict the types of access to subnet hosts. As a result, the subnet network environment poses fewer risks to hosts, since only selected protocols will be able to pass through the firewall and only selected systems will be able to be accessed from the rest of the network. Eventual errors and configuration problems that reduce host security are better tolerated, as well as the internal use of less secure protocols.

Firewalls, though, do have some inherent disadvantages that would affect their usage in a CVP environment. The most obvious disadvantage is that certain types of network access may be hampered or even blocked for some hosts. In order for a seamless CVP-like environment to exist, all of the collaborating parties must agree on the details of network access policies and protocols that will govern the CVP environment. This can also be seen as an advantage, however, since firewalls can easily act to block access of specific portions of a CVP environment that members of the collaboration are not required to access. A second disadvantage with a firewall system is that it concentrates security in one spot, as opposed to distributing it among systems. Thus a compromise of the firewall could be disastrous to other less-protected systems on the subnet. This weakness can be countered, however, with the argument that lapses and weaknesses in security are more likely to be found as the number of systems in a subnet increase, thereby multiplying the ways in which subnets can be exploited.

6.4.2 Encryption

Whereas firewalls can protect the integrity of a CVP-like environment by blocking specific functions, encryption can provide security for individual file transactions by mapping a readable file into an unreadable format via a sequence of mathematical computations. The computations affect the appearance of the data, without changing its meaning. Only persons or machines with a decryption "key" are able to translate the file back to its original readable format. If the file is intercepted, an intruder only has access to the unintelligible cipher-text.

Encryption algorithms need not be kept secret. The success of encryption is attributed to the difficulty of inverting an algorithm. In other words, the number of mappings from which plain text can be transformed into cipher-text is so great that it is impractical to find the correct mapping without the key. For example, the NIST DES (Data Encryption Standard) uses a 56-bit key. A user with the correct key can easily decrypt a message, whereas a user without the key would need to attempt random keys from a set of over 72 quadrillion possible values.

Encryption is used to provide the following services: authentication, integrity, non repudiation, and secrecy. Two approaches have been developed to provide these services: conventional or symmetric key cryptography and public or asymmetric key cryptography. The NIST DES mentioned above is an example of a conventional crypto-system. This system was adopted as a federal standard in 1976 and became the de facto US government approved crypto-system. The "Clipper" chip with the "Skipjack" algorithm designed by the National Security Agency (NSA) and the public domain "PGP" (Pretty Good Privacy) are examples of public key crypto systems. The Clinton administration's proponency of the Skipjack algorithm as a new standard has put the government at odds with encryption system developers who potentially could develop these systems for CVP environments. The controversy arises because the NSA won't release details of the algorithm and, more importantly, because the government has proposed that they control and possess all of the private keys for the system, allowing the government to decode all transmissions. The government has also placed export restrictions on any encryption device that does not use the Clipper chip, which means that they are restricted to US markets. Developers of crypto systems are fighting the administration on all three points and the situation has not yet been resolved.

6.5 CVP Technology Summary

The technologies required to enable a CVP environment are advancing well, and improvements are expected in the future. Technology development efforts are being sponsored by both government and private industry. Many of the enabling technologies are required for applications outside the CVP arena, and CVP users will benefit from advances driven by these other applications. The major CVP shortfalls are in information sharing technology, tool integration technology, product interaction technology, and product and process data standardization. Ongoing research and development activities are addressing these shortfalls.

7.0 PROCESSES, PRACTICES, AND POLICIES

7.1 Commercial Use of CVP

CVP is becoming a key technology for commercial firms nationwide. Companies beginning to recognize the competitive advantage of CVP are making major investments to implement the technologies to enable collaborative design in a distributed environment. Along with the new technologies comes the need for new business processes and practices to reap the full benefit of the technology. This section addresses the current state-of-practice in commercial CVP business processes. Specific commercial CVP practices are proprietary; therefore, the following discussion addresses general trends in design and development business practices.

The practices described below typically require changes to program organization structures. Since these changes affect internal and external corporate relationships, organizational issues are addressed in section 7.3.

7.1.1 Previous Development Approaches

In the traditional approach, each step in the development process was executed in sequence: requirements development, preliminary design, detailed design, prototyping, test, manufacturing process development, and production. Little feedback occurred between the steps in the process, and each step was conducted by engineers with specific expertise. Each engineering discipline had its own tools and its own language, and little coordination occurred except during major design reviews. The results of this process included expensive design corrections after testing, manufacturing difficulties, poor integration, and potential performance compromises.

7.1.2 Integrated Product and Process Development (IPPD)

The traditional development approach was acceptable when the defense threats were severe and defense spending was high. However, as defense budgets began to decline, new ways of doing business were needed. In addition, as design complexity increased, it became more difficult for engineers to have broad knowledge to understand the entire design process. In the 1980s, concurrent engineering concepts were implemented where multi-disciplinary teams collaborated to address many design issues together to improve the overall product design.

IPPD is an application of concurrent engineering principles. IPPD involves more than the integration of engineering disciplines (as implied by the term "concurrent engineering"). It includes integration of project management with the engineering team, and encompasses all aspects of a product's life cycle, including requirements definition, design, analysis, cost, quality, manufacture, operation, support, and disposal. In addition, effective IPPD includes extensive user involvement throughout the process. CVP tools enable improved product visualization so that the user can evaluate the evolving design and provide the design team with better feedback about how well the design meets user needs.

In addition to the use of multi-disciplinary teams, IPPD involves two major changes to design and development business practices: continuous design review and expanded tradeoff analysis. These are described in the following paragraphs.

7.1.2.1 Continuous Design Review and Oversight

Corporations using IPPD methods have transitioned from a sequential design approach to a continuous design approach. This means that the design is reviewed and evaluated by all engineering disciplines continuously, rather than at fixed intervals (such as at major design reviews). Frequent informal reviews and meetings are held at the project level, beginning at design inception and continuing through design finalization. Interactions involve the whole team, to include management, users, and suppliers. Through this continuous interaction, design issues are discovered and resolved in a more timely manner than was the case in the traditional approach.

A key feature of successful IPPD implementations is empowerment of the integrated product team (IPT). Decisions are made at the lowest level possible. Since program management is an integrated part of the IPT, management also has continuous insight into the design evolution, and can oversee the design process more effectively. Management intervention, when needed, can be provided as soon as problems arise. Timely corrective action enables design fixes to be implemented while the cost of corrective action is low.

The continuous interaction also changes the approach to design release. With IPPD, product and process designs often are released as an integrated package.

7.1.2.2 Expanded Tradeoff Analysis

IPPD typically requires the design team to broaden its view of tradeoff analysis. While design tradeoffs have always been a part of the development process, the increased number and variety of tradeoffs performed in an IPPD environment requires a cultural change for the design team. In the traditional design process, most tradeoffs were performed to optimize a design within a single engineering discipline (e.g., the mechanical engineering team would select the optimum materials based on the tradeoff between weight and strength). With IPPD, tradeoffs are performed over a variety of parameters affecting the entire product (e.g., the performance may be traded off against reduced production, operation, and/or maintenance costs).

7.2 Government Use of CVP

Although the government is sponsoring many initiatives to develop CVP technologies and procedures (see section 8.0), government implementation of CVP practices in programs is in its infancy. This section addresses the state of practice in government CVP procedure implementation. Section 7.4 addresses the potential government practices for the future as CVP-related policies are implemented.

7.2.1 The Traditional Acquisition Process

The current DoD acquisition process is defined in DoDI 5000.2. This instruction defines a sequential, event-oriented management process. Five milestone decision points are defined to enable progressive decision making based on increasingly better information available as the program matures. At the milestone decision points, the Program Manager prepares required program/design status documents to demonstrate program accomplishments and risk levels. Technology development and prototyping (including hardware and software system, critical subsystem, and manufacturing process prototypes) are typical methods used to reduce program risk. Additional design reviews may be conducted between milestone decision points. Design reviews are the primary means for government multi-disciplinary teams to review and provide input to the design and development process.

7.2.2 Government CVP Practices

DoD and DND are striving to reform business processes to be more efficient and reduce costs. In DoD, efforts are underway to consolidate financial accounting, corporate information management and other common functions. The consolidation and streamlining are consistent with the business practices used in a CVP environment. However, real changes in business practices are slow in coming. Emphasis is placed on developing the automated tools required to execute the functions, rather than on revising processes and procedures.

7.2.2.1 Government Multi-disciplinary Teams

The government is only beginning to incorporate CVP into the acquisition process. In some programs, government multi-disciplinary teams have had opportunities to work concurrently to review and modify designs, cutting down on the time to come to consensus on the required changes. However, these concurrent efforts often occur only at discrete events (such as a major design review) rather than continuously through the design and development process.

A key CVP-related practice common in the government today is frequent interaction between the program office and the user. CVP technologies have made it possible for the government developer to communicate requirements and design approaches more effectively with the user, resulting in better feedback into the design process.

7.2.2.2 Service Development of CVP Procedures for Program Management

The Military Services have recognized the benefits realized in the few CVP implementations effected to date. As a result, each Military Service is pursuing the development of detailed processes and procedures to enable them to work in a CVP environment. The Army's processes and procedures are described in the following paragraphs as representative of the Military Services' efforts.

The Army is implementing integrated product and process management (IPPM) as its business process for acquisition management. While implementation of IPPM in actual programs is limited, the principles and procedures are well defined, and the Army Materiel Command has issued specific guidance on how the Army should apply IPPM business practices in acquisition efforts. The Army guidance stresses that IPPM practices are inserted early in the life cycle, and that the team must establish communication techniques to enable rapid and effective exchange of ideas. The use of IPTs is identified in the master planning for the product and is specified in contractual documents. Financial needs and training are planned well ahead to assure that IPPM is supportable throughout the life cycle.

In the Army model, forming and training the IPT is the first step in establishing a program. In fact, the IPT transitions into the Program Management Office (PMO). Once formed, the IPT develops an "integrated" request for proposals (RFP). AMC distinguishes an integrated RFP as one in which each functional area requirement is evaluated critically for its value, cost, risk, and potential for alternative methods to achieve the same goal. Proposals to the Army are evaluated not only for their design approaches, but for their processes for system engineering, testing, production planning, logistics support planning, and configuration management. Upon contract award, the government and contractor IPTs "merge" to enable program execution.

Integrated Army/contractor IPTs change the manner in which design reviews are conducted.

Rather than formal design reviews at fixed points in time, the IPT uses multiple, successive performance reviews that occur continuously. And performance reviews are commodity oriented rather than functional specialty oriented. Only significant concerns that cannot be resolved at the IPT level are surfaced to upper management at program progress reviews. The program progress reviews also are a forum for the Army to provide feedback to the contractor its IPPD approach, and to recommend process changes that make the IPT more effective.

7.2.2.3 Paperless Programs

Another area where the government is moving toward CVP-related practices is the push for "paperless" programs. This includes both electronic transmission of documents, and reducing document deliverable requirements to a minimum.

Electronic commerce for release of requests for proposals (RFPs) and submission of proposals is becoming common. In addition, many programs require that deliverable documents be submitted in electronic formats. The JAST program is a prime example of the government's new direction in this area.

7.3 Client/Prime/Subtier Relationships

In the current defense environment, many programs are performed by contractor teams. Contractors are focusing internal resources on their unique and specialized capabilities, and subcontracting or teaming with other organizations to supplement the in-house capabilities. While CVP is not a driving force for the use of contractor teams, it provides enabling technologies and practices that enable such teams to work more effectively. The use of CVP in the design and development process has led to new program organization structures, roles and responsibilities, and interfaces. The following sections address these organizational issues.

7.3.1 Organization Structure

With IPPD, programs are moving away from hierarchical organizations where decisions are handed down from the top. The team is the dominant entity, but enough hierarchy is retained to ensure adequate oversight. Management delegates decision-making authority to the lowest level possible.

Programs are organized by product rather than by functional specialty as was the case previously. This organization reinforces the concept the that overall product is optimized, not just the mechanical or electrical design. The product-oriented organization cuts across corporate boundaries. Thus, for an aircraft development, the program organization may consist of an integration team led by company X, an airframe design team also led by company X, an avionics team lead by company Y, an engine team led by company Z, and a user evaluation team led by the government.

These new organization structures present challenges for communication within the team. New terminology must be learned to enable different engineering disciplines to talk to each other, and new "people skills" are needed to reach consensus in a collaborative environment. Currently, the multi-disciplinary teams executing IPPD often are collocated to facilitate communication and break down organizational barriers.

7.3.2 Exchange of Design Information

The current trend for development of complex systems, is for large teams with many subcontractors to participate in the design process. Effective IPPD implies early and comprehensive involvement of subcontractors in the design process, allowing lower tier contractors to influence the design to fit their process capabilities.

However, fear of disclosure of proprietary data currently inhibits this level of design information exchange. The typical scenario today is for prime contractors to require disclosure of subcontractor design information, while retaining their own design information as proprietary. This one-way collaboration dilutes the effectiveness of the IPT, but may continue to be the case until procedures and policies are developed to protect proprietary data rights.

7.3.3 Delegating Integration Responsibility

One organizational practice that may change if proprietary data issues are resolved is responsibility for component integration into the system. When the prime contractor passes detailed specification and interface data to the subcontractor, the subcontractor can assume the responsibility for ensuring that the component integrates physically and functionally with the product. Thus the prime contractor can reduce its integration efforts to an oversight role. This practice is consistent with the IPPD philosophy of assigning decision-making to the lowest level possible. Lockheed-Martin Tactical Air Systems has established such arrangements with its subcontractors with much success. However, substantial cultural changes will be required before this practice becomes standard throughout the defense industrial base.

7.3.4 Facilitizing Subcontractors

Finally, the need for special analysis and communication tools to operate in a CVP environment has implications for the relationship between prime contractors and some smaller subcontractors. Many small and medium sized business cannot afford the extensive investment required to establish and maintain a CVP capability. Therefore, prime contractors have negotiated arrangements where the prime buys the necessary tools for the subcontractor. In exchange, the subcontractor may be prohibited from using the CVP tools to support efforts for other prime contractors, or from working with other prime contractors at all. As a result, these “captive” subcontractors business opportunities can be substantially reduced.

7.4 Current Policies Affecting CVP

CVP can play an integral role in achieving the new course of action set forth by both US and Canadian governments. This section addresses DoD’s and DND’s new strategic direction, with particular emphasis on the two nations’ goals to reduce the costs of military products, improve the related manufacturing processes, capitalize on commercial technologies, and streamline the acquisition process. The importance being placed on integrating teams and empowering them is discussed, as well as the strides being made to revolutionize the design process. The ways that CVP can support these initiatives and enhance current procedures are explored.

7.4.1 DoD’s and DND’s New Strategic Direction

With the end of the Cold War, and the subsequent downsizing throughout the defense community, significant changes are being implemented in the way the DoD and DND conduct business. The reduced threat and limited defense dollars have caused the two governments to examine ways to reduce costs of military products, related manufacturing processes, and the infrastructures that have to be maintained. Main strategic goals are to improve the predictability of process attributes, product performance, cost, schedule and quality, while reducing the time required to realize products through application of the latest technologies.

Rapid advances in commercial technology coupled with declining defense budgets have caused both DoD and DND to reexamine their traditional, defense-unique approach to technology development and procurement. No longer can the two governments afford to maintain a defense unique industrial base for their requirements. More affordable and effective approaches to meeting their needs and taking advantage of state-of-the-art technologies is needed. The DoD and DND realize that it is critical that defense programs take advantage of cost-conscious, market-driven commercial production and leverage the huge investments in leading-edge process technologies made by private industry. According to the DoD Defense Science and Technology Strategy, DoD emphasis is on capitalizing on “commercial or commercially derived products” for the military’s needs. Concentrating on dual use technologies and products will allow the DoD to take advantage of both economies of scale and cutting edge technologies that are now increasingly found in the commercial sector.

A major shift from the classic acquisition approach to tailored, innovative streamlined programs is essential to fulfilling these goals. In “Acquisition Reform: A Mandate for Change”, Secretary of Defense Perry outlines the need for dramatic changes in DoD’s acquisition process. The DoD acquisition process has been criticized for being overly burdensome, costly, and lengthy, with such unique accounting practices and specifications to preclude the government from capitalizing on commercial products and technologies. The Canadian acquisition process has been criticized for many of the same reasons, though their accounting practices are not considered as onerous. Mr. Perry stated that, with the production of weapon systems being dramatically curtailed, the DoD should focus on reducing cost and cycle time, applying efficient business practices, and simplifying acquisition procedures to make them more streamlined, flexible, agile, efficient, timely, and effective.

Ms. Colleen Preston, Deputy Under Secretary of Defense (Acquisition Reform), stated that "improvements in technology now predominantly occur in the commercial sector – at a pace our [DoD] acquisition system cannot keep up with. If we [DoD] are to have access to this advanced technology, we must be able to buy from commercial suppliers, who are, more often than not, unwilling to change their business practices to comply with government unique requirements for actions and activities." She also noted that the length of the DoD acquisition process is such that the technology is often outdated by the time DoD can acquire it. "The key to winning the technology war is to be the first to integrate."

CVP can provide the impetus for making these objectives become a reality, especially in translating operational needs into stable, affordable programs, streamlining the acquisition management structure to increase efficiency and effectiveness, and acquiring quality products. It can expand the range of technical, operational, and system alternatives evaluated, including commercial products; accelerate manufacturing; and reduce costs. Ms. Preston noted that "simulation and modeling technology can be applied to every major DoD weapon development program to reduce design and production cost, improve performance, improve diagnostics and maintenance, assist in better and faster training of personnel, and improve command and control on the battlefield." CVP is a critical element of the Science and Technology Program and its goal of minimizing and working in a smaller force structure, improving joint operations, and maintaining the technological edge.

7.4.2 Emphasis on Integrating Teams and Empowering Them

DoD is moving away from stovepiped program phases to agile Integrated Product and Process Development (IPPD) teams, another avenue to help zero in on cost reduction and front end requirements and planning. Canada is following DoD's lead by placing emphasis on integration of teams across functional specialties. DoD initiatives in this area will enable simultaneous integration of essential acquisition activities through the use of multi-disciplinary teams to optimize design, manufacturing, and supportability processes. Processes should be developed concurrently with the products they support. Some key tenets of this setup are to:

- Maximize flexibility for optimized use of contractor-unique processes and commercial specifications, standards, and practices,
- Encourage robust design and improved process capability using advanced design and manufacturing techniques that promote quality,
- Employ multi-disciplinary teamwork relying on the combined input of the entire team, and
- Ensure proactive identification and management of risk.

The DoD is also transitioning from stovepiped oversight to vertically Integrated Product Teams (IPTs). IPTs are vital to making IPPD work. IPTs facilitate decisions based on timely input from the entire team – program management, engineering, manufacturing, test, logistics, financial management, contracting personnel, and contract administration, as well as with users and suppliers. This shift entails moving away from Pentagon decisions and organizational isolation to integrated cross functional team action through an institutionalized IPT approach. It releases decision makers from a hierarchical decision making process to a process where decisions are made across organizational structures, thus allowing more sound and timely decisions. Rather than checking the work of the program office beginning six months prior to a milestone decision point, the OSD and component staffs can participate early and on an ongoing basis with the program office teams, resolving issues as they arise rather than during the final decision review. This streamlined acquisition management structure is aimed to increase efficiency and effectiveness and to enable flexible tailored approaches to oversight and review.

The teams are encouraged to pursue modern manufacturing processes and methods to obtain cost reduction and shorter cycle times for emerging and ongoing programs. The shift is from product focus to emphasis on front-end manufacturing technology, manufacturability, and supportability.

When a team is fully integrated, it is able to match requirements and technical/cost/schedule risks against capabilities. IPTs also include the user and key suppliers so that their knowledge can be shared to create the best possible strategies and decisions for fulfilling requirements.

Reengineering the acquisition oversight and review process into this team structure requires flexibility. One key objective of this new approach is to reduce the number of documents required to only those absolutely necessary to manage and oversee programs. Milestone review dates and the documents required at a specific milestone checkpoint are now determined individually for each program and approved by the Milestone Decision Authority. Program plans (not required by statute) are considered PM and IPT working tools and do not need to be submitted to the Office of the Secretary of Defense.

This new way of thinking requires a tremendous cultural change throughout the DoD community, transforming oftentimes adversarial relationships between headquarters staff organizations and program office teams, into productive partnerships. New emphasis is on cooperation and empowerment. The teams are directed to have full and open discussions with no secrets. They are empowered to speak for their superiors in the decision-making process, with Program Element Officers and Program Managers acting as the key implementors. Incentives are being offered instead of regulation/enforcement.

One initiative that will aid in this transition and allow better integration is new DoD policy underscoring the importance of moving towards an open networked computing architecture for developing DoD systems. This will enable every DoD computer to interconnect with all other DoD computers, and allow databases, regardless of their ownership, to be shared throughout DoD by authorized users. A challenge to be surmounted is to ensure that the high level of security required for defense communications is maintained.

CVP can provide the interconnecting mechanisms to ensure that all team players are kept informed and up-to-date, and have the ability to provide their inputs in a timely and effective manner. The visual display of the prototype in its projected environment helps foster better communication and understanding of the system being designed so that the right decision can be made the first time.

7.4.3 Revolutionizing the Design Process

The current serial design process is slow and costly. Because it deals with fixed requirements, manufacturing processes that are not developed, and designs that are not constrained by cost, it results in unique DoD and/or DND solutions, special components, changes/rework, reporting oversight, specialized support, and a costly support infrastructure.

The DoD and the DND are exploring how they can design defense systems more effectively and efficiently. The DND is focused on the use of CVP for use in modifying existing designs. The DoD's focus is on involving the operational military user earlier and more often in technology development to hasten the fielding of useful systems and shorten the time it takes to develop doctrine for their use. It entails directing technological innovation not only to improve system performance but also to reduce cost and improve production. The new process proposed is cost driven, has tailored review and oversight, and encourages modern manufacturing. The focus is on front-end integration, and the process:

- uses performance driven requirements,
- employs demonstrated manufacturing processes,
- capitalizes on commercial processes,
- employs an integrated team, and
- ensures an S&T focus on processes and costs.

Because of the team integration, reduced reporting and oversight is required.

CVP plays a central role in ensuring the success of this new process. It is the technology needed to link diverse groups into one cohesive integrated team so that key decisions can be made expeditiously. CVP provides a common framework for all functional disciplines.

7.4.4 How CVP Fits Into this Changing World

The number of reasonably priced, high powered computer systems and enabling design software, coupled with the push for a streamlined acquisition strategy, has dramatically increased the importance and emphasis being placed on CVP. CVP can greatly enhance the acquisition process from "cradle to grave" – from identifying requirements early on to determining where manufacturing capabilities can support dual use initiatives. The use of virtual prototypes provides the ability to explore several competing concepts without the expense of building a complete system. They allow requirements generators to explore various combinations of tactics, techniques, procedures, and technology alternatives to help ensure that the correct solution is developed to fulfill a given need. This enables DoD and DND to develop a better design for a defense system in less time and with fewer procurement dollars.

The ability to pass information, data, and models seamlessly among and between the government's offices and their contractors will be instrumental in achieving the new acquisition vision. By providing the team players with the technology to carry out their work concurrently, rather than sequentially, the amount of time needed to conduct all required action is reduced. It allows the players to communicate in real time and enables substantially improved and faster analysis of design. With the free flow of information, barriers are removed, and enhanced coordination is realized.

CVP can be an asset throughout the entire acquisition process. Among the tangible benefits that this technology offers are:

- Improved upfront analysis and definition of requirements,
- Early simulation of weapon system performance and manufacturability (design, test, manufacture, and support),
- More timely design information to the PMO, thereby allowing the PMO to lower the decision-making authority on day-to-day issues,
- More timely interaction between the contractor and the government through common shared databases,
- Strengthening of the IPPD team and enhancing concurrent engineering,
- Less paper required for design review,
- Fewer test hours needed and a more specific test plan developed.
- Reduced contractor/government time preparing for and conducting major reviews, lessening the need for some of the reviews built into the acquisition process,
- Reduced number of engineering design changes,
- Contractor retention of engineering data, since government can access the information electronically when needed (this is compatible with the new technical data policies that have been issued and those that are being developed), and
- Faster realization of modifications, P3I, and processes, which could foster multi-Service buy in to systems.

CVP can be employed throughout the acquisition process phases outlined in DoDI 5000.2 and DND's Defense Program Management System (DPMS). CVP can enhance the analyses that are conducted and prove out the design concepts that are generated. Specific areas where this technology can be beneficial in the acquisition arena include:

- **Concept Exploration and Definition:** Allowing user/developer/tester/evaluator to concurrently evaluate requirement impact on cost and performance and the battlefield impact of the new system.
- **Campaign Analysis:** Resolving discrepancies in assumptions, employment logic, and assessment routines used in the individual Military Services' campaign models by enabling these models to be enfolded into a single platform. This provides a tool for budget deliberations relating individual system effectiveness to the predicted outcome of military campaigns.
- **Force Structure Assessment:** Allowing DoD to gauge the impact of changing the weapon systems and operator workload numbers and support structures used for a

specific conflict scenario, and inserting new capabilities within the process to judge the impact.

- **System Advocacy:** Justifying the importance of the specific program and the costs that will be incurred by such a system.
- **Design Changes:** Providing the capability to incorporate design changes and evaluate alternate options rapidly.
- **System Configuration:** Permitting near-real-time evaluation of multiple changes/ modifications while maintaining necessary information to produce required drawings for the new configuration within the new dimensions.
- **System Tradeoff Analyses:** Aiding in realistically evaluating in real time options to fulfill the desired objective, using key variables which are required and determining pricing differences for each alternative (which system or mix of systems is the optimal solution for the prescribed scenario and the value added of new systems to the conflict).
- **Cost Analysis:** Reducing the amount of time needed to determine the resource implications of different variables, while improving the accuracy of such an analysis through a visual interactive display.
- **Research and Development:** Reducing the time needed to define requirements, accurately and expeditiously assessing risks of alternatives to determine the most viable, and transitioning to physical prototypes.
- **Test and Evaluation:** Providing flexibility in changing the fields and environment required to be tested for a particular design to determine the impact, thus reducing the need to develop physical prototypes to be run through the actual test.
- **Manufacturing Setup:** Allowing for actual manufacturing processes to be engineered in parallel with the design process and providing for the real-time incorporation of design changes into the manufacturing process.

7.4.5 Government M&S Infrastructure and Supporting Policy Initiatives

M&S and CVP tools have taken such a predominant role that the DoD and the US Military Services have established oversight offices and developed policies for use of M&S. The following subsections describe the infrastructure and policies DoD, DND, and the Military Services have established in this arena.

7.4.5.1 DoD

DoD currently is establishing policies and procedures to enable CVP to be more universally implemented throughout the defense community. In 1991, the Deputy Secretary of Defense approved a plan to strengthen the use of modeling and simulation. He designated the Under Secretary of Defense for Acquisition and Technology (USD(A&T)) as responsible for implementing this plan. The plan established the Executive Council on Modeling and Simulation (EXCIMS) and the Defense Modeling and Simulation Office (DMSO). EXCIMS is an advisory group to USD(A&T) on M&S policy, initiatives, standards and investments. DMSO is the central focus for M&S activities, and promotes cooperation of M&S activities among DoD components to maximize efficiency and effectiveness.

One of the main policy documents guiding the course of M&S programs within DoD is DoDD 5000.59, DoD Modeling and Simulation Management. It establishes DoD policy, assigns responsibilities, and outlines procedures for the management of M&S, including verification, validation, and accreditation of models and simulations. It also provides for the formal organization of EXCIMS and DMSO. This directive requires that a coordinated DoD M&S Master Plan and Investment Plan be developed and an M&S Information and Analysis Center be established. It calls for DoD components to implement an M&S management system for oversight of their M&S activities, and for coordinating and communicating DoD M&S issues. On October 17, 1995, OSD issued the Modeling and Simulation Master Plan, which provides the framework for each individual Military Service's M&S plan and investment strategy.

M&S is a central focus of all of the Military Services, and M&S plans are being implemented to ensure widespread adoption of this technology. A main push has been on intra-functional integration of M&S applications within particular areas. For instance, the Manufacturing Automation and Design Engineering and ARPA Initiative on Concurrent

Engineering are both aimed at integrating manufacturing enterprise disciplines. The Military Services have also developed some joint standards, applications, architectures, utilities, and protocols, and several laboratories are focusing on vertically integrating model hierarchies. In addition, more acquisition programs are using M&S technologies to prove out system and subsystem performance and perform tradeoff analyses. A brief synopsis of some of the Military Services' policies and procedures are described in the ensuing paragraphs.

7.4.5.1.1 Army

Though the Army has used computer simulations and simulators for more than four decades, the use of fully integrated M&S is a new trend. They are committed to and actively engaged in the use of M&S to improve and shorten the weapon system acquisition process.

The Army manages its M&S activities through the Army Model and Simulation Management Office with policy put forth in AR 5-11. The Army has made great headway at institutionalizing modeling and simulation through policy memos/existing regulations, the Distributed Interactive Simulation (DIS) master plans, the DIS modernization plan, and the Army M&S master plan.

Army policy guidance for M&S is included in policy memorandums from the Deputy Assistant Secretary of the Army for Research and Technology (28 June 93) and the Military Deputy to the Assistant Secretary of the Army (Research, Development, and Acquisition) (24 May 93). The Deputy Assistant Secretary of the Army for Research and Technology outlined requirements for all Army Advanced Technology Demonstrations (ATDs) and Top Level Demonstrations to prepare Simulation Support Plans and a Simulation Support Plan outline. The Military Deputy to the Assistant Secretary of the Army (Research, Development and Acquisition) established the requirements for all ACAT I and II programs to prepare a Simulation Support Plan. This plan is to prescribe the functional requirements for M&S to support the program, and outline the M&S acquisition strategy and funding support for M&S initiatives. DA Pam 70-XX, which is under development, will further clarify the importance of M&S by putting forth guidance for the use of simulation to support acquisition.

The Army DIS plan and DIS modernization plan are moving towards a single set of technologies and environments to fulfill many of the Army's needs. These plans focus on the use of virtual prototypes to enhance user/developer interaction during the M&S requirements evaluation process.

The Army M&S master plan builds upon these same premises and asserts the central role for M&S within the Army. It promotes the adoption of standards, common tools, and common processes in building and populating M&S for use in all applications throughout the Army. It proposes that Army M&S applications address requirements within one or more of three M&S domains: advanced concepts and requirements; research, development and acquisition; and training, exercises, and military operations. The Army currently is drafting an M&S Modernization Plan that will lay out the infrastructure requirements, resources, and investments strategy necessary to develop M&S standards identified in the Army M&S Master Plan.

The Army Materiel Command (AMC) has stressed the vital role of virtual prototyping/ simulation in their Business Planning Strategies, FY 1996-2000. It states that AMC should revolutionize the way it does business by transferring RDT&E from the physical world to the virtual world, moving away from development of hardware prototypes. AMC has also undertaken a weapons systems acquisition cycle improvement program through integration of modeling and simulation.

Their implementation plan provides several recommendations for furthering this effort, including:

- Replacing serial with concurrent activities,
- Building credible M&S tools,
- Developing a new acquisition process,
- Educating and training the RDA community, and
- Expanding Army M&S policies.

7.4.5.1.2 Navy

The Department of the Navy views modeling and simulation as one of the major focus areas for the future of the Navy and Marine Corps acquisition. The Navy's M&S vision is to apply the science and technologies of M&S to support the Navy's capability to plan, train, operate, and fight from the same platform in support of single Military Service or joint operations. Through application of M&S, they are striving to achieve a unified and integrated Navy acquisition program, encompassing research, development, test, evaluation, and procurement. The Navy's goal in DIS is for units and platforms to "come as they are" with the capacity to "plug and play" into a distributed simulation environment enabling near real-time mission planning, rehearsal and training.

The Navy's Modeling and Simulation Advisory Council guides the development of policy, coordination, and technical support and advises on the Navy's M&S vision, which is then implemented by the Department of the Navy Modeling and Simulation Management Office. The Navy and Marine Corps Policy and Coordination Offices are responsible for developing the Military Service and Simulation Master Plans and Investment Strategies and for coordinating plans, programs, policies and procedures across functional areas. The Navy has prepared SECNAVINST 5200.38: Department of the Navy Modeling and Simulation Program, to assign responsibilities and prescribe policy and guidance for the execution of the M&S program, and SECNAVINST 5200.XX: Verification, Validation and Accreditation of Models and Simulations, to prescribe a common VV&A process.

The Navy has put forth policy to expand the use of modeling and simulation to support all phases and milestone decisions of the acquisition cycle. A goal of each Acquisition Coordination Team is to strive for consensus on models and simulations used; those selected should have the ability to interface with common architecture and standards developed by DoD.

7.4.5.1.3 Marine Corps

The Marine Corps also is committed to exploiting interoperable M&S and incorporating the many advantages of advanced distributed simulation. The Marine Corps Modeling and Simulation Office serves as the focal point for M&S activities within the Marine Corps and is responsible for managing the Marine Corps M&S Master Plan and Investment Strategy and supporting development of VV&A policies and procedures. The USMC M&S Master Plan asserts that they will participate in improving the DoD acquisition process by simulating before "we buy, build or fight". They are striving to support every major weapon system in the Marine Corps with a simulator that can be networked into a common synthetic environment. The plan outlines 14 policy and management objectives for achieving their vision, including:

- promote the use of virtual prototyping in the combat development process,
- establish centralized coordination/control and decentralized execution of M&S, and
- establish procedures and guidelines for M&S information management and requirements and resource management.

Special emphasis is placed on leveraging the efforts of other DoD components, other government agencies, industry, and academia.

7.4.5.1.4 Air Force

The Air Force has designated the Directorate of Modeling, Simulation, and Analysis as the single POC in the Air Force for policy on modeling, simulation, and analysis activity. This office provides support to the Major Commands and HQ USAF in modeling, simulation and analysis. AFPD 16-10 Modeling and Simulation Management (Draft), implements DoDD 5000.59, provides general Air Force M&S policy, and assigns responsibilities.

7.4.5.2 Canada

Canada is committed to reducing project costs and acquisition time and believes modeling and simulation can help them to fulfill their objectives. Because the Canadian Government recognizes that simulation can provide more effective training, reduce cost or wear and tear on operational equipment, compensate for safety or financial limitations, facilitate skill transfer, and attenuate damage to the equipment, the DND has put forth policy that the use of simulation must be considered in any new capital project.

The defense research and development program, under the direction of the Chief Research and Development, plays a key supporting role in the planning, use and acquisition of simulation technology. The Government has mapped out simulation requirements for maritime, land, air, and other simulator/training initiatives and have shared these emerging application and implementation opportunities with industry.

A working group, entitled the Simulation Permanent Working Group, was established to pool simulation knowledge and coordinate efforts among National Defence Headquarters groups.

7.5 CVP Practices, Procedures, and Policies Summary

CVP practices are being implemented in private industry. Competitive issues currently are impeding full collaboration and hence full realization of the potential benefits of CVP. Small and medium sized business in particular are affected because prime contractors often establish "captive subcontractor" relationships by providing the CVP and technologies to subcontractors in exchange for exclusive business agreements.

The government is lagging behind private industry in the implementation of CVP practices. However, emerging government policies are compatible with and supportive of CVP. Therefore, future government transition to an operational environment is possible.

8.0 CVP DEMONSTRATIONS AND IMPLEMENTATIONS

Section 6.0 provided an overview of the status of CVP technologies. Section 7.0 provided an overview of the processes, practices and policies associated with a CVP environment. This section presents several real scenarios where organizations have and/or are putting CVP technologies to use and demonstrating how the technologies can be implemented with associated processes, practices and policies.

Each of the following sections discuss how particular organizations are implementing CVP technologies and how they are incorporating these technologies into existing or new business practices. Problems encountered, how the problems have been or are being addressed, and what issues remain are discussed. In addition, a discussion of any preliminary or projected benefits is provided for each discussion. Appendix F contains a listing and description of all of the CVP implementation scenarios encountered during this study.

8.1 Tank Automotive Research, Development, and Engineering Center (TARDEC)

The Tank Automotive Research, Development, and Engineering Center (TARDEC) is the research and development component of the Army's Tank Automotive Command (TACOM). In addition to its support of TACOM, TARDEC works very closely with some of the program management offices operated out of TACOM, namely PM Abrams and PM Bradley.

TARDEC has projects that address the use of virtual prototyping technologies at every stage of the development process (concept, preliminary design, survivability, wargaming, operator interface, and producibility). At this time, TARDEC has no underlying integration operation or data management structure that seamlessly links these areas together. Changes made in one area must be manually changed in related areas.

TARDEC has supported PM Bradley in the area of virtual prototyping. This work included creating a complete 3D digital solid model representation of the Bradley from the paper-based design specifications for the vehicle. TARDEC hopes that PM Bradley will use the model to support the evaluation of future design changes to the vehicle. TARDEC and PM Bradley realized as a result of this effort that it is essential to have virtual prototyping involved early in the design and development process to experience the full benefits it has to offer.

TARDEC has also executed an IPPD development of a fire extinguisher bracket in conjunction with PM Bradley. The entire process was conducted electronically and was completed in 60 days. The bracket design was provided electronically to the General Dynamics

Land Systems (GDLS) LIMA plant for production. TARDEC estimated a savings of $1.35 per part (approximately 4-6%). In addition to the cost savings, the lead time associated with acquiring the bracket was greatly reduced.

Based on TARDEC's experience working with PM Bradley, TARDEC is attempting to get involved early with PM Abrams on the follow-on to the M1A2, known as Tank 1080. TARDEC is exploring a partnership with the GDLS LIMA plant for the M1A2 follow-on program. This partnering would have TARDEC working side-by-side with GDLS in a collaborative design environment to do the entire design of Tank 1080 digitally. One of the objectives of this effort is to create a virtual demonstration/validation step within the acquisition process. If such a partnership were established, a major impact would be providing the government (TARDEC in this case) with a portion of the design responsibility for the M1A2 follow-on effort. GDLS would still be involved in the design process, though they would not be solely responsible for creating the design. If TARDEC is successful, this effort could demonstrate participation by the government within a CVP environment, potential impacts on the DoD acquisition process, and potential benefits of CVP in an acquisition program.

8.2 Advanced Research Projects Agency (ARPA) Simulation Based Design (SBD)

Lockheed Martin's Research and Development Division (R&DD) supports ARPA's Simulation Based Design (SBD) program. The object of the SBD program is to develop a design system/environment that will lower the cost, reduce the schedule, and identify and lower the risk associated with the design and development of new systems. Lockheed Martin was one of two prime contractors during Phase I of the SBD program and is the only prime contractor in Phase II of the SBD program. Phase I of the SBD program, which is complete, demonstrated that an SBD environment could be created. Phase II, which began in the latter half of FY 95, will further develop the SBD architecture which supported the proof of concept during Phase I.

The SBD architecture developed by Lockheed during Phase I is not product independent. The applications that are placed within the architecture provide the specific product design and analysis applications required. Lockheed's goal is to create a generic SBD environment which would provide the basic architecture for future development projects. Lockheed believes they are at least five years away from being able to do this.

In Phase I, Lockheed used a notional baseline ship (NBS) design to support their proof of concept effort. Seven major components/areas of Lockheed's SBD environment were demonstrated using this NBS design.

1. Mission Analysis
2. Propulsion Plant Selection
3. Collaborative Design
4. DIS Interactions
5. Multi-Disciplinary Analysis
6. Manufacturing Analysis
7. Cost/Risk Analysis

To support these areas, Lockheed developed (in some cases) and implemented technologies as part of the SBD architecture. The following is a list of the technologies included within the SBD environment. Detailed write-ups on these technologies can be found in Appendix E.

- **Virtual Design Environment (VDE) Viewer:** a visualization tool.
- **Smart Product Model (SPM):** an active (invoked by machine software not by a user) object oriented database which captures product characteristics as well as process characteristics.
- **PartNet:** a catalog of SPMs containing a common object representation of parts accessible through the Internet/WWW.
- **Multimedia Engineering Collaboration Environment (MECE):** an electronic design notebook used to document design decision, rationale, and intentions.
- **Distributed Interactive Simulation (DIS):** an tool used to evaluate interface problems between a tank and the NBS.
- **Netbuilder:** a tool to provide a mechanism for developing megaprograms and wrappers which allow application interoperability.
- **Simbuilder:** a tool to provide an event and time driven synchronous engineering simulation.
- **Manufacturing Analysis Tools:** tools to evaluate shop floor operations and conduct what-if scenarios.

- **IDEAS:** a COTS CAD Package.
- **Vivid:** a Proprietary CAD Package developed by Newport News.

As part of the Phase I effort, Lockheed was able to demonstrate the ability to perform the activities or functions associated with the seven areas listed above using the previously mentioned tools in an integrated SBD environment. The heart of this demonstration was the SPM, which contained and controlled the data that was used and updated by the technologies listed above.

As part of the Phase II effort, Lockheed Martin plans to continue to develop and enhance the SBD architecture to be a generic (domain independent) product development framework. In addition they plan to develop domain-dependent applications in several areas for demonstration within the generic SBD product development framework.

8.3 Electric Boat Corporation (EB) New Attack Submarine Program

The Electric Boat Corporation (also known as General Dynamics Electric Boat (GDEB)) is a designer and builder of nuclear submarines for the US Navy. EB performs overhaul and repair work on submarines as well as a broad range of engineering work, including advanced research and technology development, systems and component evaluation, prototype development, and logistics support to the operating fleet. EB was one of the two prime contractors on the Advanced Research and Projects Agency's (ARPA's) original Simulation Based Design (SBD) program. EB is also involved in Phase II of the SBD program being led by Lockheed Martin. EB is using the technologies and concepts they developed and demonstrated under the SBD program to support NAVSEA's new attack submarine (NSSN) program (many of the technologies demonstrated under the SBD program were originally developed through internal research and development (IRAD)).

The focus of EB's efforts in the area of CVP has been on the creation and use of Electronic Visualization Rooms (EVRs). The EVRs were designed specifically to support the operations of IPTs. EB is using these EVRs to support their NSSN project with NAVSEA. EB has four EVRs at their New London facility and one has been purchased by NAVSEA for use at the NSSN program office. All of the rooms are identically configured and are connected with high speed lines, enabling video and voice communications as well as the real time exchange and sharing of design data. The EVRs provide access to all computer systems including CAE tools, ComputerVision for CAD, Deneb Robotics tools, and graphics engines for visualization. The room at NAVSEA is being used to enable the program office to participate in IPPD team meetings. The EVR at NAVSEA is configured to support only design review and view functions. This configuration was selected because NAVSEA did not require other design functions and it was less expensive to configure the NAVSEA EVR as described.

EB estimated that 85% of the work performed under their ARPA SBD program is currently in use today in support of the NSSN project. EB feels that the manufacturing area will realize the biggest improvement from applying the SBD technologies. They project at least a 25% reduction in the cost of manufacturing based on the use of these technologies.

8.4 Sikorsky (Comanche and S-92)

Sikorsky Aircraft is part of the Flight Systems Division of United Technologies Corporation. Sikorsky designs, develops, produces, markets and supports medium and large helicopters for military and commercial requirements. Sikorsky and Boeing made extensive use of virtual prototyping technologies in executing the Army's newest and largest aviation program – Comanche. Sikorsky also is using virtual prototyping and collaboration technologies to support their multinational commercial venture in developing the S-92, a 19-passenger helicopter.

Sikorsky recognized the potential value of virtual prototyping when developing the Blackhawk. Sikorsky required 300 flight test hours to fully integrate the avionics, which were developed outside of Sikorsky, and eliminate all bugs from the system. On the Comanche program, Sikorsky realized there was no room or flexibility for this type of integration problem. Sikorsky employed CVP technologies on the Comanche program to ensure the integration problems experienced on the Blackhawk program would not occur.

Comanche employed IPT and CVP technologies. CAD tools were used for the design, CAE tools were used to evaluate design options, and various analysis tools (including Deneb Robotics products) were used to evaluate manufacturability. As a result of the use of IPT and CVP technologies, the manufacturing process was a first time fit. Only minor adjustments were required.

Sikorsky estimates that the average unit cost of the Comanche will be reduced by 20-30% based on benefits from using CVP technologies. In addition, the prototyping cost of the forward fuselage for Comanche was about 67% of the cost based on history.

However, the Comanche development contractors have had difficulty gaining DoD level acceptance of the cost projections. The Cost Analysis Improvement Group (CAIG) production cost estimates prepared to support the Defense Acquisition Board (DAB) process are somewhat higher than the Sikorsky and Boeing estimates. This is because the CAIG uses historical data from other similar systems to derive cost projections for new systems. Since DoD has no historical production data for systems designed and built in a CVP environment, the CAIG estimates reflect what the product would cost if it had been developed in a traditional design environment. As more data become available, DoD will have a better basis for estimating production costs for products developed using CVP.

Sikorsky's S-92 program is a commercial, multinational initiative to develop a 19 passenger helicopter. The multinational team assembled for this program makes physical collocation for this project unrealistic; therefore virtual collocation is a necessity. Sikorsky is working to establish a UNIX based 3D collaboration environment to enable virtual collocation and collaboration in the area of production engineering. Sikorsky is looking at other collaboration technologies to support this effort.

8.5 Joint Advanced Strike Technology (JAST)

The JAST program is a joint Services team creating the building blocks for affordable, successful development of the next generation strike aircraft weapon systems. The JAST mission is to:

- facilitate development of fully validated and affordable operational requirements,
- facilitate maturation of leveraging technologies,
- demonstrate leveraging technologies and operational concepts, and
- develop and deliver products and processes to initiate follow-on EMD program(s).

The JAST program completed its concept exploration phase in December 1994. The key conclusion of this phase was that a family of aircraft can meet tri-Service needs with overall potential life cycle cost savings of 33 to 55%. The cost benefits come from a common depot, commonly supported logistics trail, and increased joint Service interoperability. The program entered the concept development phase in December 1994 with the electronic award of 24 contracts worth $130 million. The primary emphasis of this phase is to develop aircraft system designs that take advantage of the "family of aircraft" concept and to define necessary leveraging technology demonstrations and an integrated plan for conducting the follow-on concept demonstration phase.

The JAST program has become a leader in acquisition streamlining and reform. It pioneered a paperless acquisition process, employing electronic procedures from solicitation through contract award, saving over 300,000 pieces of paper and over a year in time for the three major solicitations to date. The JAST program is also exploiting the Internet for real-time paperless dissemination of program information.

To achieve its affordability goal, the JAST program is dependent upon many of the same technologies that are associated with CVP. The Simulation Assessment Validation Environment (SAVE) project, which is sponsored by JAST, is integrating technology and conducting demonstrations to optimize the manufacturing processes associated with JAST. The objectives of SAVE are to integrate and mature a set of computer based modeling and simulation tools that predict manufacturing cost/risk, evaluate alternative designs and processes, and provide for decision support during product development.

Another JAST project which supports its affordability objective is the Avionics Systems Engineering and Prototyping (AVSEP) project. AVSEP will define and demonstrate architecture and avionics concepts which best achieve the lowest cost/performance ratio and ensure readiness for low risk transition to EMD. AVSEP provides a collaborative environment for integrating aircraft avionics with the airframe structure through associate contract agreements with the prime weapon systems contractors. Virtual avionics prototypes are used to validate these concepts within AVSEP.

8.6 F-22

Lockheed Martin Aeronautical Systems and Boeing Defense and Space Group teamed to develop the F-22 as the replacement for the F-15. The Lockheed-Boeing team was selected by the U.S. Air Force in April 1991.

The F-22 is being developed to counter the increasing sophistication of weapon systems being proliferated worldwide. The primary mission of the F-22 is air superiority. Its predecessor, the F-15, entered the Air Force inventory in 1975 and will have reached the end of its service life when the F-22 becomes operational.

The teaming of Boeing and Lockheed Martin, two major prime contractors, introduces new challenges in team integration. Integrating these prime contractors, their business processes, and the many suppliers and smaller partners has been an enormous challenge.

The F-22 program has more than 1100 suppliers. Approximately 200 of these are first tier suppliers. A dedicated network for the top suppliers (less than ten companies) has been established. This network is used for passing files electronically. IGES is being used to support data exchange requirements among the different CAD systems. Only geometry is being exchanged. The companies have had reasonable success using IGES, though it does require considerable verbal coordination to ensure a clean exchange.

Lockheed Martin has looked at using STEP and is considering it. CATIA has a STEP AP 203 translator in Version 4. Some experiments or testing may be conducted but it will not replace IGES yet. Lockheed Martin believes STEP needs 3-4 years till the standard is fully accepted.

On the F-22 program, standardizing business practices between the team members has been very challenging. Every one of the major players has unique business practices, for example, a Bill of Materials. Each was different and standardizing on one took considerable coordination and effort.

8.7 Haley Industries

Haley Industries Limited (Haley) is a sand foundry located in Ontario, Canada. Haley's primary customers are within the aerospace industry. Pratt & Whitney Canada (PWC) is their largest customer. In 1992, Haley was approached by Pratt and Whitney Canada to jointly explore the benefits of applying CATIA CAD data to the construction of complex aerospace foundry tooling. Benchmark testing demonstrated that lead time and cost savings could be achieved.

In 1993, CATIA workstations were installed at Haley and Gudgeon Brothers. Gudgeon Brothers is a major tooling supplier to Haley and is very dependent upon the workload Haley provides them. The CATIA workstations were linked via modem to PWC. The modem link allowed CAD data to be transferred without translation to IGES and allowed PWC to access the workstations and provide technical support.

Haley and Gudgeon Brothers each invested approximately $100,000 per workstation to establish their CATIA partnership. PWC provided training and technical support to Haley and Gudgeon Brothers to help educate them on the use of the new CAD product. The investments made in the CATIA partnership have resulted in significant lead time reductions on a number of new development programs with PWC. Haley estimated that they have been able to reduce lead times by as much as 50%.

8.8 CVP Demonstrations and Implementations Summary

Industry implementations of CVP exist and are in use. While these implementations individually may not address all elements of CVP they do demonstrate that it is possible to execute and implement CVP, to some degree, today. Most of the governments efforts in CVP have been focused on technology demonstrations, such as TARDEC's work and ARPA's SBD program. While these programs develop and advance important technology, they lack the integration required to make CVP use a reality.

9.0 CVP INVESTMENTS AND PAYOFFS

To reap the potential benefits of CVP, investment in the technology and associated processes is required. This section discusses the investment required to establish and maintain a CVP environment and compares investment requirements and alternatives based on company size and position (prime, subcontractor, or supplier). This section also discusses the payoffs that a company can expect as a result of these investments. Because of the immaturity of the CVP concept, the payoffs associated with CVP are discussed in general terms with specific examples provided when available.

9.1 Investment Requirements

For a company, organization, or group of organizations to establish a CVP capability, several investments are required. Investments fall into two broad categories: short-term investments which enable implementation of an immediate CVP capability, and long-term investments which will move CVP technology forward and improve capabilities in the future.

In the short-term category, investments can be further divided into computer-related investment and procedure-related investment. A significant amount of computer-related investment is necessary, including:

- buying and installing hardware and software,
- buying and implementing local area networks (LANs) that enable the computer systems and people to communicate,
- buying and installing wide area networks (WANs) that enable the creation and operation of virtual organizations, and
- maintenance and operation of new computer systems and networks.

Procedure-related investment includes training associated with these new computer systems and networks and transitioning from old business processes to modified or new processes.

Any organization or group of organizations considering investing in the creation of a CVP environment must evaluate different investment options and alternatives. There are a wide range of alternatives to choose from, depending on the required complexity and interoperability of the system, the level of fidelity required for the application, the nature of the working relationship with the other organizations, and the size of the company and its ability to make an investment. The sections below describe CVP investment requirements and alternatives in greater detail.

9.1.1 Computer Investments

Computer-related investments fall into several categories: hardware, software, networking, maintenance, operation, and security. The remainder of this section discusses the various investment elements within each of these categories, why these investments are required and the potential investment costs.

Figures 9-1 and 9-2 provide representative costs for establishing a CVP environment. Figure 9-1 presents the investment necessary to establish a high performance 10 user CVP development environment. This scenario is typical of the investment a prime contractor or major subcontractor may be required to make. Figure 9-2 presents the investment required to establish a basic five user CVP capability. This scenario is typical for a small business or supplier. Both of these scenarios present only the initial computer-related investment. They do not include training costs and continuing software and hardware maintenance costs. Local and wide area network connections are not included.

Investment Requirements	Sample Tool	Approximate Cost (based on a 10 user license)
Integration Tools	Lotus Notes	$3,000
Interaction Tools	EDS Unigraphics FEA (1 copy)	$15,000
Application Tools	Deneb's IGRIP (1 copy)	$60,000
	Deneb's ENVISION (1 copy)	$50,000

	Deneb's Virtual NC (1 copy)	$45,000
	Deneb's QUEST (1 copy)	$45,000
Data Creation Tools	EDS Unigraphics CAD/CAM	$200,000
	EDS Unigraphics PDM	$200,000
Database Management Tools	Oracle OODBMS	$33,000
	Oracle Dev Tool Kit (2 Users)	$8,000
Network Server	SGI Challenger Server	$35,000
Workstations	SGI Indy Workstations	$375,000
Sample Total Investment Cost		**$1,069,000**

Figure 9-1. High Performance CVP Investment

Investment Requirements	Sample Tool	Approximate Cost (based on a 5 user license)
Integration Tools and Database Management Tools	Microsoft Office Professional (Word, Excel, Access, Mail, PowerPoint)	$2,500
Data Creation Tools	AutoCAD	$3,100
Network Server	Pentium PC	$5,000
Workstations	Pentium PCs	$20,000
Sample Total Investment Cost		**$30,500**

Figure 9-2. Basic Low Performance CVP Investment

9.1.1.1 Hardware

The computer hardware associated with establishing a CVP environment includes:

- the computer and its processing capabilities,
- storage media to capture and physically store data,
- input media such as keyboards, 2D and 3D mice, cameras, and microphones, and
- output media such as monitors, display stations, and helmet-mounted displays.

The computer and its processing capabilities represent the engine of a CVP environment. This engine allows the software to operate, accepts and processes inputs, and processes and displays outputs. From a user's perspective, these activities are completed behind the scenes. The highly graphical and complex nature of the data associated with CVP requires high performance computing systems to process and display information.

9.1.1.2 Software

The software investment needed to establish a CVP environment requires the acquisition of tools associated with the CVP taxonomy discussed in Section 6.0. The required investment can vary significantly based on the type of tool, the level of maturity of the tool, the level of fidelity required, and integration requirements. The cost of data creation tools can vary significantly. For example, AutoCAD, which is a simple PC-based CAD system, is considerably less costly than Unigraphics, which is a powerful CAD system capable of handling large, complex designs and supporting solid modeling. Within the data creation area, ideally a single organization would only need to buy one data creation system to support their CAD and CAM operations. The variety of tools within the three other taxonomy areas makes it difficult to generalize costs. In many cases an organization may require three application tools, two interaction tools and three integration tools to satisfy their development requirements.

9.1.1.3 Networks

Networking is the central capability that enables collaboration among a virtually collocated IPT. There are two levels of networking: LANs and WANs. LANs provide connectivity within a certain geographical and organizational area. For example, a large company X with a particular office located in a building in Washington, DC, may have a LAN to integrate all of the computers located within that particular building. A WAN combines organizations that are not necessarily geographically close or related through an organizational or corporate structure. For example, another office of Company X located in Los Angeles, CA, may be connected to the DC office via a WAN. In addition, if both the DC and LA offices of Company X are working with Company Y located in Miami, FL, all three organizations may be connected through a WAN.

Most organizations today are establishing LANs and access to the Internet which provides access to a WAN. Networking investments are becoming mandatory for any company that wants to survive in the future. Therefore, networking investments were not examined in detail.

The investments required to set up LANs and WANs include the network cards for computers to be placed on the network, network servers and software to manage network applications and operations, local network wiring connections, and wide area network connections (hardwired or satellite). In addition to these investment costs, there are significant costs associated with operating and maintaining a network. These include software and hardware upgrades, communications costs and operation and support personnel costs.

9.1.1.4 Maintenance and Operation

Maintenance and operation expenses must be considered when implementing a CVP capability. Maintenance and operation expenses include the cost of software and hardware upgrades (or maintenance contracts), software and hardware support contracts, and internal expenses such as the personnel who monitor and maintain the hardware and software. These costs can be considerable. For example, when Boeing commercial converted from CATIA version 3 to version 4, 500,000 labor hours were required for the upgrade (including analysis and modification of applications and data to operate with the new version). These expenses should be considered and defined during the investment decision process.

9.1.1.5 Security

Security is an essential capability needed for establishing a CVP environment. Security investments affect the day-to-day operations of CVP systems as well as the long term operation and success of individual organizations and the virtual organization. The critical and proprietary nature of much of the data associated with a CVP environment make security a vital CVP investment.

Investments in security include purchasing needed hardware and software, and establishing and implementing the necessary business practices. Hardware investments entail the actual physical security of computers and operation areas as well as encryption devices to ensure data security during transmission. Software security investments include the creation of firewalls to protect data integrity, encryption software, and access control systems to control user access to certain data. Investments in new processes need to ensure a secure data environment as well as procedures for protecting data and access and control operations.

9.1.2 Procedure Investments

The procedure-related investments associated with CVP can be substantial. These investments can include the following.

- **Software Training:** This includes not only training employees on new software packages such as CAD systems, but also training employees on new versions of software packages. Software training also includes training new employees on software packages related to their jobs and educating them on how these packages are used in an organization's environment.

- **Security Training:** Training on security procedures and proprietary data issues is a very important component of the investment required for CVP. The openness and availability of information used in the CVP operating environment requires organizations to retrain employees on the importance of and procedures for securing proprietary and controlled data/information. This training includes the identification of controlled and proprietary data. Many individuals are not cognizant of what is and what is not proprietary data. This training also includes the process of securing this data both electronically and physically. The collaborative nature and the electronic connectivity of a CVP environment make controlling access to data more challenging.

- **Process Improvement:** Process improvement development, implementation, and training are required to take full advantage of CVP technologies. CVP technologies can offer considerable payoffs, though these payoffs cannot be truly realized unless applied to a streamlined and integrated design process. Training in IPPD is needed to teach employees how to take advantage of the tools. Training in collaborative working environments such as IPTs is essential to teach employees to remove the barriers that traditionally exist between organizations.

9.1.3 Long-Term Investments

Organizations need to invest in the development and industry-wide adoption of standards that enable interaction among CVP tools. Because of their ability to fund these activities, the larger, prime contractor organizations and government organizations are driving this investment. While standards are important to smaller companies, the larger organizations have the resources required and the leverage needed to control the direction of the standards.

Investments in standards affect three types of organizations: standards developers, standards implementors, and standards users. Developers include government and international organizations, such as NIST and ISO, and consortia such as PDES Inc. and the Object Management Group (OMG) which operate with participation from major commercial corporations. Developers are responsible for defining and developing standards. Implementors of standards are primarily software vendors such as Intergraph, ComputerVision, IBM, Oracle, Object Store and others. These organizations must embrace standards and incorporate them as part of their software packages. Standard users are the end users who benefit from the development of applications based on standards. Standard users also include organizations which develop focused applications for specific purposes. These focused applications must be compliant with available standards to ensure interoperability with other applications.

The primary cost factor associated with standards development for commercial organizations is the people investment. The “big three” automotive manufacturers and most of the aerospace companies provide people to participate in the consortia activities that are developing the standards. The standards implementors’ investments are associated with upgrading their software packages to incorporate new standards. This again requires people investment to update the software code. The users investment associated with new standards primarily is based on purchasing new software packages that support the standards and training their users on these new packages.

9.1.4 Investment Alternatives

As demonstrated in the previous section, the investment required to establish a CVP environment is considerable in terms of both cost and commitment. As with any investment, there are alternative scenarios for the level and approach taken in making the investment. The scenario selected depends on the size of a company, level of commitment to CVP, position of a company within a virtual organization, among other factors. The following provides a description of several different investment scenarios companies may employ and the types of companies or organizations that would be more likely to employ the scenario.

- **High Performance:** The high performance investment scenario reflects an aggressive investment strategy. Those organizations selecting this alternative believe CVP is the future and their competitive position within an industry is dependent upon the success of this CVP investment. A good example of this is Boeing’s investment in developing the 777, which was designed in a completely digital environment. Boeing has stated that they bet the future of the company on the success of this capability and the benefits they expected to reap from the 777 development approach. General Dynamics Electric Boat is another organization that has made enormous investments in CVP assuming that it was a necessary investment to remain competitive. This alternative would typically be selected by large prime contractors or industry leaders. Figure 9-1 provides a representative investment scenario for this alternative.

- **Low Cost/Limited Performance:** Because of the high cost and potential risk related to making an investment in CVP, some organizations may decide to begin by establishing a low cost, limited performance CVP environment. This environment can be characterized by low performance equipment that may be slow and have limited functionality across all areas and/or by a limited scope environment that only addresses one of the four taxonomy service categories and offers limited connectivity outside an organization. Small companies that cannot afford to create a high performance CVP environment may select one of these options out of necessity. Some organizations may choose to establish a limited performance CVP environment initially to prove the concept to management, with plans to upgrade and expand the environment at a later point. This alternative typically would be selected by small to medium sized businesses. Figure 9-2 provides a representative investment scenario for this alternative.

- **Customer Oversight:** This scenario is unique to the government. Customer oversight investment typically would be made by a government program office to provide access to and oversight of a contractor. The government organization involved in this scenario would not require a system equipped with the ability to manipulate data and information, but rather one that offers them the ability to access and view data and information. This alternative would entail an investment in the physical infrastructure but only a limited investment in the logical infrastructure. They would not need all of the data creation and analysis tools associated with the services component of the taxonomy.

- **Prime Investment in Supplier/Sub-Contractor:** In many cases a prime contractor or a large company that is dependent upon suppliers and subcontractors will finance a supplier or subcontractor investment in CVP technologies. The larger companies are willing to make this investment based on the expected benefit of operating in a CVP environment beyond their corporate boundaries. This has happened in the auto industry as well as with some prime contractors for government contracts. These investments have included the purchase of compatible CAD systems and EC/EDI capabilities to enable the electronic exchange of data.

- **Software Leasing (Pay-Per-Use):** A fairly new concept making software available to organizations on a pay-per-use basis is emerging within the software industry. Since many of the high priced software packages are not affordable for small and medium sized businesses and are a costly consideration for large organizations, this concept is being examined closely by high priced specialty software vendors. This concept would make a wider variety of software products available to more users, benefiting both the users and vendors.

9.2 CVP Payoffs

CVP offers wide ranging benefits in a variety of areas. The direct cost benefits provided by CVP use are only beginning to be measured and predicted. The following paragraphs describe some of the payoffs that can be realized through an investment in CVP.

9.2.1 Reduced Design and Development Costs

CVP provides a common platform from which design, logistics, and manufacturing engineers can work, thus enhancing integrated product and process development. It allows the team to conduct tradeoff analysis of alternatives expeditiously in a controlled, repeatable setting to prove out assumptions. These design iterations are accomplished using fewer people and labor hours. Designs can be modified, the effects of the change analyzed, and the design refined repeatedly prior to building a hardware prototype. In other words, the team can determine in short order if what is proposed is feasible and visualize it in a realistic, three dimensional representation of the system. Since CVP is used to evaluate and quantify system performance, less testing of hardware prototypes is necessary. Less time needed to develop, assess, verify, test, and manufacture the system translates to a reduction in overall costs. Costs will continue to decrease as the capabilities of the current tools are expanded and advanced. McDonnell-Douglas has stated that it anticipates a 50% reduction in acquisition costs due to cycle time/personnel savings resulting from their virtual prototyping initiative.

The use of CVP enhances component integration and evaluation of component interaction. This increases the effectiveness of the team, and reduces the likelihood of errors and/or rework. The Comanche program is a good illustration of this payoff. The manufacturing process was a first time fit; only minor adjustments were required. The team estimated that the average unit cost of the Comanche was reduced by 20-30 percent through the use of CVP.

CVP enables better design decisions to be made earlier in the design process, so that expensive late-cycle design changes are not required. Approximately 80% of affordability decisions are made prior to detailed design; however nearly all development costs occur during detailed design. CVP enables better system knowledge earlier in the design process, so that rational design decisions can be made. Boeing has demonstrated the effectiveness of CVP-based design decisions in the development and production of the 777, where production phase change activity currently is only 30% of the change activity experienced in the 767 case.

CVP also can be used to ensure that design decisions support cost reduction strategies. CVP applications can be constructed to evaluate designs based on specific strategies, such as lean manufacturing, reduced parts count, part interchangeability, and minimized hand tooling.

Finally, CVP can enable a more effective use of subcontractors during the design process. With CVP, prime contractors can pass more detailed and accurate specification and interface data to subcontractors, so that components and subsystems designed by subcontractors will integrate better into the product. Primes can then pass the burden for integration to the subcontractors, and save manpower costs. Lockheed-Martin Tactical Air Systems has used this approach in dealing with subcontractors and has been able to reduce manpower by 56%.

9.2.2 Improved Manufacturing Processes

CVP can be used to identify the manufacturing processes, facilities, and tooling and material handling requirements. The team can perform analysis of the design and manufacturing processes and compare the operating loads and manufacturing constraints to the strength of the structure. If the manufacturing of a certain part is determined to be not viable, the design and/or the manufacturing process can be changed prior to production. Having the capability to incorporate detailed considerations of the manufacturing process and capabilities into the design phase, the team can match the requirement more effectively with what can be manufactured. And, since designs are electronically transmitted to the shop floor, fewer manufacturing errors are incurred. All of this translates into overall reduced production costs.

In addition, CVP can support tradeoffs to optimize manufacturing processes. Many manufacturers are pursuing lean manufacturing initiatives – eliminating non value added manufacturing processes. CVP manufacturing process applications enable identification of processes that can be eliminated or reworked to achieve lean manufacturing. Interaction between manufacturing process applications and design applications can feed information back to the design team to identify design features that are difficult or expensive to manufacture (such as part that require substantial touch labor), so that the designer can modify the design to reduce manufacturing costs.

The Joint Advanced Strike Technology (JAST) Program Office, in conjunction with the Wright Laboratory Manufacturing Technology Directorate, recently completed a highly successful short term, high impact program to quantify the cost benefits of a Virtual Manufacturing (VM) approach in aircraft airframe design. McDonnell Douglas Aerospace was contracted for a six-month effort to conduct a side by side production design change comparison and to demonstrate VM techniques to induce cost savings during the design and manufacture process. The JAST VM Fast Track program successfully reduced design time and costs in the redesign effort. The benefits attributed to the VM approach were 33% reduction in design release time, 27% reduction in design cost, 19% reduction in manufacturing cycle time, and 20% reduction in factory floor space utilization.

9.2.3 Reduced Time to Market

CVP allows visualization of and immersion into the environment being simulated. Multiple designers working in different areas using different tools can tap into the CVP database concurrently to interface with the same design. Hence, designs can be produced in a fraction of the time it would take if the designers were using manual or isolated tools to develop a product.

Reduced development time enables producers to respond quickly to changing consumer needs. Companies that use CVP can get their products to market more quickly and “get a jump” on the competition. Reducing time to market is the driving factor behind why the aircraft division of Raytheon is actively employing IPPD and related CVP tools and techniques. Raytheon believes they can reduce their time to market by 30 percent based on applying these concepts and tools.

9.2.4 More Productive Work Environment and Enhanced Communication

CVP provides a common frame of reference to support activities across the system life cycle. It fosters project team interaction through increased communication between disciplines and allows the group to work in parallel and share product and simulation data simultaneously. This enhances cross functional areas of cooperation and creates a more productive work environment.

Lockheed Martin, Orlando, has shown commitment to utilizing CVP to enhance productivity through a pilot project it has undertaken to design an Advanced Fire Control System. This program is an Art-to-Part concept which requires no paper drawings to be delivered. As part of Phase I, Lockheed Martin developed an Internet access architecture which enables all companies involved to communicate and exchange information electronically. Currently a direct access/dedicated network architecture has been established between three companies to support the exchange of CAD data. The current architecture and the Internet architecture support design collaboration among the companies involved.

9.2.5 Reduced Risks

CVP is instrumental in evaluating system performance and effectiveness. It helps to ascertain cost, schedule and performance impacts and alternatives to assess better the risks involved and to facilitate determining the best solution based on the information available. The increased knowledge obtained from these evaluations reduces development risk and therefore the financial risk to the developer.

In the commercial world, less development risk leads to higher profits. The defense industrial base also reaps a financial benefit from reduced risks. Lower program risk means better contractor cost and schedule performance, reducing or eliminating program overruns. The money saved can be used by DoD/DND to fund further system development and production efforts.

9.2.6 Reduced Life cycle Costs

In conducting trade off analyses using CVP, many life-cycle considerations (e.g., fuel efficiency and maintenance operations) can be incorporated. These can be weighed against cost, performance, and manufacturing objectives. In this way, the team can examine a host of possibilities to ensure that the life cycle cost of the system is minimized.

CVP can also have an indirect impact on life-cycle costs. Products designed using CVP require fewer design fixes during production and integration. Therefore, the intent of the original design remains intact and design features such as aerodynamics and ease of maintenance are preserved so that life-cycle costs are not adversely affected. For example, airplanes designed traditionally can require thousands of fixes during integration because of parts that do not fit together properly. With these fixes, the airplane does not line up exactly straight; for the first plane produced, deviations of up to half an inch off the center line are common. These deviations affect aerodynamics and reduce fuel efficiency. The first Boeing 777 produced was only 0.023 inches off center.

In the commercial world, reductions in product operation and maintenance cost result in better sales and profits. For the defense industrial base, the financial benefit of reduced costs enables the government to procure more systems and equipment, which in turn brings more business to defense contractors.

ARPA's Tri-Service RASSP initiative is a good example of how CVP technologies can be used to reduce life cycle costs. This program changes the process by which embedded signal processors are designed, manufactured, upgraded, and supported to obtain a four fold improvement in the life cycle cost and a four fold speedup in development time.

9.2.7 Improved Quality and Higher Customer Satisfaction

Customers want a high quality system that will fulfill their needs. CVP enables users to visualize and "test drive" a product early in the development process to ensure that performance is acceptable. Weapon system product models can be played in battle simulations to verify that the system will contribute to the mission as anticipated. Early user feedback gives the design team better information for design decisions.

CVP enables manufacture of higher quality products. With CVP, developers can perform more design tradeoffs for the same (or less) development dollars. The result is a higher quality product which is more suited to consumer needs, but which does not cost more.

CVP also can facilitate “mass customization.” As defense budgets shrink, the Military Services are moving toward more joint programs, with product versions tailored to meet specific Military Service organization requirements. CVP enables more comprehensive analysis of tailoring requirements and their impact on design and production processes and costs. With CVP, product designs can be optimized for small lots of tailored products, enabling more customers to purchase products that meet their specific needs.

9.2.8 Competitive Advantage

CVP enables companies to gain a competitive edge. Because reduced cycle times can be achieved as a result of CVP, companies can produce products more quickly and emerge as the marketplace leader. CVP also is an effective marketing tool because of its capability to provide a realistic visual presentation of the capabilities of the system. This capability only enhances the competitive stature of the company.

9.2.9 Incorporation of Dual Use Technologies

With CVP, numerous factors can be considered during the design phase. Instead of designing a system from scratch, the team can build on existing commercial technologies, using performance based specifications vice military specifications. For instance, an IPT can plug into the design equation the performance specifications of a commercially available component, e.g., a battery, to ensure the government is thoroughly examining the potential of commercially available products. In this way, the team is able to capitalize on dual use technologies and move away from a dependency on a military-unique product.

9.3 Investments and Payoffs Summary

While the investment required to implement and maintain a CVP capability can be substantial, several alternatives exist to make CVP technologies available to companies of all sizes. The payoffs associated with using CVP are only beginning to be quantified, but initial predictions indicate significant cost savings throughout the system life cycle. Many of the potential payoffs, such as increased quality and larger market share, are qualitative but are important to a company’s position in the marketplace.

10.0 FACILITATORS AND BARRIERS

10.1 Technical Facilitators and Barriers

Section 6.0, Technology Overview and Assessment, provided a discussion of the maturity level of technologies associated with CVP. The maturity levels represent the readiness of the technologies for use as well as their actual use within industry and the government. In general highly mature technologies such as those within the computing and computer networks category can be considered technical facilitators to CVP. Immature technologies, such as those within the object management and information sharing category, can be considered technical barriers. This section does not address the specific technologies that represent facilitators and barriers to CVP. Rather, it discusses in general terms technical facilitators and barriers associated with the advancement and use of CVP technologies. Where technologies are critical to the success of CVP, specific technological facilitators and barriers are discussed.

10.1.1 Technical Facilitators

Technical facilitators address the existence of technologies that support CVP and the investments being made in technologies that support CVP. This section discusses technical facilitators in terms of three areas: commercial tool development and standardization efforts, DoD tool development and standardization efforts, and the availability and rapid improvement of enabling technologies.

There are no distinctions in terms of technical facilitators between the United States and Canada. The primary focus of efforts in Canada has been on the development and commercialization of simulation tools to support training and operational environments such as air traffic control. While these tools are not directly applicable to a CVP acquisition environment, they do provide a foundation for developing new and modifying existing tools to support CVP functions.

10.1.1.1 Significant Commercial Tool Development and Standardization Efforts Are Underway

Commercial-off-the-shelf (COTS) software packages exist today in many areas of the CVP taxonomy. These tools include:

- CAD/CAM products from a variety of vendors,
- CAE products to support various engineering analyses,
- 3D manufacturing analysis tools (such as those offered by Deneb Robotics),
- groupware technologies that support team integration (such as Lotus Notes), and
- object oriented programming languages (such as C++) and object oriented databases (such as Oracle and MS Access) support the creation of object based environments.

The variety and quantity of these tools facilitate the rapid creation of CVP environments. Software vendors continue to make significant advances in these areas as well. For example, CAD vendors are incorporating object oriented features and capabilities into their products.

In addition to the commercial effort in the development of software packages, industry consortia are working on improving standardization to facilitate interoperability among these systems. Some of these consortia efforts are:

- PDES Inc. is supporting the advancement of STEP to support data exchange between CAD systems,
- the OMG is supporting the advancement of CORBA, which enables interoperability among analysis tools, and
- the CAD Interoperability Association (CIA) is working to improve interoperability among CAD systems.

Interoperability is a critical element associated with CVP. The efforts by these consortia help to advance and improve interoperability among all the tools that support CVP.

10.1.1.2 Significant DoD Tool Development and Standardization Efforts Exist

The DoD has several major programs underway that are researching and developing tools that support CVP. The previous (D)ARPA Initiative in Concurrent Engineering (DICE) program demonstrated tools that support team integration. These tools are being enhanced under ARPA's SBD program. The SBD program also is researching and developing tools associated with the infrastructure elements of a CVP environment and examining integration issues.

The DoD also is involved in application standardization efforts within the Corporate Information Management (CIM) initiative. While application standardization is not the ideal solution for interoperability, it is an acceptable solution especially within an organization as large and diverse as the DoD. The CIM initiative is developing standard business practices and tools to support those practices. Included in this standardization effort is the development of Joint Computer Aided Acquisition and Logistics Support (JCALS) and Joint Engineering Data Management and Information Control System (JEDMICS), which represent preliminary efforts to standardize DoD technical data management operations. The Joint Logistics Systems Center (JLSC) is in the process of developing standard systems to support material management and depot maintenance functions. Standardization will lead to improved interaction and integration among organizations.

The DoD has invested significant time and money in the DIS environment. DIS provides the critical link between a development program and the user community to evaluate a system's performance in a simulated operational scenario. The focus of the government's efforts related to DIS has been on the development of standards for the development of simulation tools and the integration of simulation tools to support demonstrations, training, wargaming, and new concept evaluation. While DIS was not developed specifically to support an acquisition environment, elements can be modified and enhanced to support a CVP acquisition environment.

The DoD has been actively involved in many commercial standards development efforts. Many DoD organizations participate within the PDES Inc. consortia and many DoD organizations have participated in demonstrations of the STEP standard.

The final area related to standardization where the DoD is working is in the development and implementation of the TAFIM. The TAFIM provides a definition for how government organizations should set up information technology architectures.

10.1.1.3 Enabling Technologies are Available and Improving

An essential element to the success of CVP is the availability of the enabling technologies associated with creating the physical infrastructure. The physical CVP infrastructure is defined in the CVP taxonomy as the computing and computer networks category. The enabling technologies exist today and are advancing in capability at a tremendous rate. Silicon Graphics, Inc., believes that computing power (CPU performance) is growing by a factor of 10 every five years and networking speed is expected to be at 2500 Mbits per second by the year 2000.

With the explosion of networking and distributed environments, network and data security is emerging as a critical technology. This area is receiving a significant level of attention and major investments are being made in developing multi-level secure systems. Just like physical security, no computer system or network will be completely safe. Industry is grappling with the question of what constitutes a secure system. The technical challenges associated with this are being addressed and security technologies are available today.

10.1.2 Technical Barriers

Technical barriers to CVP fall into four major categories: lack of a common or standard CVP infrastructure definition, immature and slowly developing commercial standards critical to the success of CVP, some unique/specific technical challenges in developing CVP tools, and the rapid rate of change in technology which prevents users from keeping pace with the state-of-the-art. The remainder of this section discusses each of these areas in more detail.

10.1.2.1 No Common or Standard CVP Infrastructure Definition Exists

The biggest technical barrier to advancing CVP is the absence of a standard architecture or infrastructure definition that provides guidance and direction on establishing a CVP environment. Such guidance would support any organization interested in establishing a CVP capability by providing the underlying infrastructure definitions and the interface requirements needed to ensure interoperability.

By establishing a common or standard environment, integration and synchronization across architectures could be achieved. Such a capability also would help to lessen the risk associated with establishing a CVP capability. In addition, a common infrastructure based on commercial standards would facilitate the integration of both tools and people.

A common infrastructure would facilitate the creation of a centralized source of information related to CVP. The lack of a single focal point for CVP related information is a barrier to advancing CVP. By establishing a centralized CVP information center, software reuse and access can be improved. A central repository or library of CVP and M&S tools would lessen the duplication of effort that exists today in tool development. Also, by limiting duplicate tools, the tools that are available would receive more use and could reach a mature and validated state faster.

10.1.2.2 Commercial Standards Are Immature and Slowly Developing

The lack of standardization is a critical barrier to enabling interaction between multiple organizations as well as within a single organization. Industry and government are investing in the development of commercial standards, such as STEP and CORBA, that support tool integration within a CVP environment, but the current capability does not exist and is developing slowly.

STEP is emerging as the commercial/ international standard for exchanging product model data. While the basic structure of the standard has been approved by the International Standards Organization (ISO), the application protocols (APs) that are used to implement the standard are developing at a slow pace.

Two major challenges remain for STEP. The first is to develop the APs that support all elements of a design effort including mechanical components, electrical components, assembly processes, design intent, and many other areas. This requires a significant investment to develop and approve these APs. The second challenge is the integration of the STEP APs into software products. The CAD software vendors are beginning to incorporate available APs but this is a slow process.

CORBA is emerging as the commercial standard for developing object request brokers (ORBs) which allow applications to interact. However, it is still in the developmental phase. Like STEP, application developers need to embrace this standard and incorporate it into their products. Until this happens the standard will not be effective in enabling application interoperability. The larger problem for CORBA is the application of the standard to legacy applications. For legacy applications, wrappers need to be developed based on the CORBA standard to allow them to interact with other applications. The development of wrappers is a costly and lengthy process.

10.1.2.3 Specific Technical Challenges Remain

Though the tools and systems used in the CVP arena are evolving rapidly, there are currently shortcomings and limitations to the current systems. These shortcomings are due to remaining technical challenges as well as areas which have not received the necessary investment. Many of these areas are presented below.

- Traditional cost models are based on parametrics such as weight, size, and structure. These models generally cannot provide the detail and accuracy required to support design tradeoff decisions during a development program. The cost models that exist today are not based on input from the product models; they are based on separate parameters that are input to the cost models. By not linking a cost model to the product model within the CAD system, the ability to support design tradeoff decisions rapidly and accurately is hindered. In addition, existing models generally do not support life cycle cost analyses which include production costs, support and maintenance costs, and operation costs. New cost models that address some of these concerns are beginning to emerge. The barrier at this time is a lack of confidence in the validity of the models.

- Security technologies represent a potential barrier to CVP. While multi-level security systems, firewalls, and encryption techniques are available today, there is a significant level of distrust in these technologies' ability to ensure security of proprietary and classified data. Technical challenges remain in terms of improving the technologies to ensure data is secure or at a minimum to know when data integrity has been compromised. The major challenge remaining is to overcome the cultural barrier and invoke user confidence in the technologies that exist today.

- A current barrier to creating virtual work environments and virtual reality evaluation environments is the human factor elements of the input and interface technologies. These technologies include helmet-mounted displays and booms which allow a user to look into a virtual environment, and tactile feedback mechanisms such as gloves to allow a user a more realistic interaction with virtual environments. Currently these technologies are bulky and uncomfortable to use over any extended period of time. Fatigue and discomfort make it impractical for a user to operate for any extended period in a virtual environment. In the near term weight and size reductions of these devices are needed. In the long run new approaches to enabling user immersion in virtual environments are needed. For example, the creation of immersion rooms that allow a user to interact in a virtual environment using miniature sensors mounted on a user's body could eliminate many of the current problems associated with helmet-mounted displays, gloves, and other immersive techniques.

- The government has made and continues to make significant investments in developing Distributed Interactive Simulation (DIS). Even with these investments, the DIS infrastructure still requires a significant amount of work, especially to support a CVP environment. Areas such as simulating dynamic terrain environments to reflect changes caused during an operational scenario, the simulation of environmental conditions, the development of reconfigurable simulators to support low cost and rapid development of various simulators, and the seamless integration and synchronization of live, virtual, and constructive simulations all remain challenges to DIS.

- Ergonomics is increasingly used to evaluate human factor concerns during design. More accurate and realistic animation of human behavior is required for this technology. A considerable amount of research and development is ongoing at universities. However, application of this technology in development programs is very limited and significant technical challenges remain. One such challenge is providing the capability to measure stress on a body over an extended period of time.

- Bandwidth is potentially a major technical problem for the further implementation of CVP. Given the heavy graphic requirement of CVP, industry experts have indicated that a bandwidth on the order of a two hundred to three hundred megabytes per second is desirable. This bandwidth requirement would be impossible to satisfy by any data network now in daily commercial operation. The technology exists to enable networks to support such a bandwidth requirement, though the physical networks must be upgraded.

- A serious barrier to the use of modeling and simulation tools within an acquisition environment is the verification, validation and accreditation (VV&A) of these tools. Acquisition and design decisions based on the results from modeling and simulation, requires a significant level of confidence in the tools being used. Currently, most decision makers do not have the necessary confidence in the tools that are available. Many technical challenges need to be overcome. A number of the tools associated with operational analysis were not originally designed to support acquisition decisions; they were developed for training and wargaming purposes. They do not have the detail and accuracy required to support acquisition decisions. In addition, the time and money required to achieve full accreditation of these tools is considerable.

10.1.2.4 Rate of Change in Technology is Difficult to Handle

While the high rate of change and advancement in technology can be considered an advantage to CVP, it is also a challenge. Users need to become acclimated to these new technologies. The high rate of change in technology causes several other problems: the cost associated with upgrading technology and with training employees on new technologies, compatibility between old and new technologies, and the creation of a stable working environment within an organization.

Cost is the biggest barrier to rapid technology advancements, even when organizations want the latest and greatest tools available. Controlling and managing upgrades in technology can be a considerable challenge. By baselining on a particular set of technologies, organizations can control the costs of upgrades and training as well as stabilize the interaction and integration operations among technologies. To ensure a stable working environment, organizations will often take this approach to managing advancements in technology.

10.2 Financial Facilitators and Barriers

Financial facilitators and barriers are critical in the commercial sector where market forces drive companies' decisions. In the commercial sector, if the financial benefits of CVP are believed to outweigh the required investment, then companies will trend toward implementing a CVP capability.

Financial issues also affect the defense industrial base because of shrinking defense budgets and resulting reduced hardware buys. Defense contractors can no longer count on large fixed-price production contracts to offset the relatively small profits made during design and development. Therefore, if CVP makes a positive impact on the cost of design, development, and production, organizations using CVP can leverage scarce defense dollars to enable more systems to be produced.

10.2.1 Financial Facilitators

10.2.1.1 CVP Provides a Competitive Advantage

CVP can provide a market advantage because the products developed in a CVP environment are more responsive to customer needs. Many companies are implementing CVP to gain this market advantage. Others are implementing CVP so as not to lose the market share they currently command.

CVP enables companies to produce better products with fewer design, development, and manufacturing dollars. CVP enables more efficient procedures and shortens design and development cycle times, so that fewer engineering hours are expended during the design process. It also reduces the need for extensive engineering testing.

CVP also can help reduce operation and maintenance costs. Life-cycle cost reductions result in higher customer satisfaction, motivating the developer to invest in CVP technologies to gain a larger market share. For the defense industrial base, the financial benefit of reduced costs enables the government to procure more systems and equipment, which in turn brings more business to defense contractors.

CVP enables more design tradeoffs to be performed more quickly than with traditional design approaches. Thus, with CVP, manufacturers can design and produce high quality products quickly to satisfy the specific needs of a variety of customers. This capability can results in a larger share of the market for companies using CVP.

With CVP, manufacturers can evaluate the cost-performance tradeoffs of design alternatives beginning early in the design process and reduce development risk., and therefore the financial risk to the developer.

10.2.1.2 Cost of CVP Tools Is Decreasing

Although the investment required to establish and maintain a CVP capability is high, the cost of CVP tools is decreasing. Computers and networks are becoming less expensive and public networks are available. Commercial-off-the-shelf applications are becoming more common, minimizing the need for in-house development and maintenance of these tools. Application vendors are seeking ways to make tools affordable to a broader segment of the industry, such as the emerging pay-per-use concept. The cost reductions are enabling more companies, including small and medium sized firms, to take advantage of CVP.

10.2.2 Financial Barriers

10.2.2.1 High Investment Is Required to Implement and Maintain a CVP Capability

Although potential cost savings and the resulting competitive advantage afforded by CVP are key facilitators to CVP use, the high investment required to implement a CVP capability is one of the primary barriers.

While the level of investment required to implement a high performance CVP capability is substantial for a large company, many companies believe that the potential payoffs are worth the required level of investment. However, this costs may be prohibitive for small and medium sized businesses. As indicated in Section 9.0, the cost of a basic low performance CVP capability is about $30k. Based on an ECRC survey, small businesses are willing to invest between $1,000 and $5,000 for computer resources.

CVP also requires a large continuing investment to maintain. For large prime companies, continuous upgrades to hardware and software are required, as well as ongoing training for the design and development staff.

In addition, maintenance costs affect prime contractors who establish CVP capabilities for their subcontractors. Arrangements must be made to upgrade established contractor capabilities to may require more investment when new subs are brought into the fold, or when primes pay for subcontractors CVP capitalization.

10.2.2.2 The Cost Benefits of CVP Have Not Been Quantified

Corporate decisions to commit to the large investments typically require substantiation of anticipated return on investment (ROI). However, data are just becoming available to hint at the quantified ROI due to CVP. In addition, companies that have data often are reluctant to make the data available to the public because it may jeopardize their competitive advantage.

Many of the potential cost benefits of CVP may not be quantifiable. For example, additional profits due to increased market share for the higher quality products developed in a CVP environment are anticipated, but measurement of CVP's contribution to improved market position is difficult.

10.2.2.3 Standards and Infrastructure Development Require Cooperation in Investment

One of the biggest technical barriers is shortfall in standards and infrastructure. However, this shortfall can only be addressed by investment by many parties, including the government. In addition, since major investments are required, only the large prime companies in the private sector are able to contribute to the standard and infrastructure development efforts.

Cooperative investment in technologies that are believed to provide a competitive advantage is difficult to achieve. However, this barrier is mitigated because the cost of maintaining a CVP environment without standards and an established infrastructure can be excessive.

10.3 Procedural and Cultural Facilitators and Barriers

10.3.1 Procedural and Cultural Facilitators

The use of CVP requires a major change to the design and development process. Multi-disciplinary teams must learn to work cooperatively and learn how to "speak the same language" to be effective. CVP expands the ability to perform tradeoffs (e.g., easing performance requirements slightly to achieve large cost savings in the manufacturing process), requiring the development team to take a broader view of the interactions between requirements, product design, manufacturing process design, and supportability. This new way of doing business requires radical changes in development culture and procedures. Two facilitators to achieving the procedure and culture changes are described below.

10.3.1.1 Universities Are Beginning to Include IPT/IPPD Concepts into Curriculum.

Many universities, especially those involved in research and development of CVP technologies and procedures, are beginning to incorporate CVP concepts into their course curriculum. Thus, the next generation of engineers will be trained in the interactions between the various engineering disciplines. They will be able to communicate more effectively within a multi-disciplinary team, and will have academic experience in performing the wider range of analysis made possible by CVP.

The CVP curricula also enable engineering students to gain experience with emerging CVP technologies and processes. This experience will facilitate training on and implementation of CVP procedures as these engineers enter the workforce.

10.3.1.2 Engineers Are Gaining Confidence in CVP Results

While managers and decision makers may remain skeptical about the contribution CVP can make in the design process, engineers are gaining confidence in the results of using CVP tools and technologies. This grass roots acceptance of the advantages provided by CVP will enable continued improvements in development productivity and product quality to facilitate use of CVP in the future.

10.3.2 Procedural and Cultural Barriers

Although some strides are being made in changing the development culture to take full advantage of CVP, some serious cultural barriers remain. These barriers exist for two reasons: competition and collaboration are inherently opposing forces, and the government is behind industry in embracing CVP. Specific procedural and cultural barriers are described in the following sections.

10.3.2.1 Each Company Views CVP Use as Competitive Edge

CVP is viewed by industry to be a key technology in obtaining an advantage over the competition. Because of this, companies are reluctant to share specific information about procedures, costs, and benefits. The lack of information exchange inhibits rapid development of CVP technologies and procedures. "Lessons learned" are not disseminated to enable industry wide corrective action. In addition, upper level management in companies considering implementing CVP have little concrete data on which to base an investment decision.

10.3.2.2 Security and Proprietary Data Are Viewed as Vulnerable

Concern over broader access to proprietary data is a major barrier to CVP use. At a minimum, access controls implemented within IPTs can inhibit collaboration so that the full benefits of CVP are not realized. This happens when prime contractors receive design data from the lower tiers, but do not grant subcontractors access to the prime contractor design data. As a worst case, the fear of disclosure of proprietary data can prevent some companies from establishing a CVP capability.

10.3.2.3 Government Culture Has Not Caught Up With Policies Endorsing CVP

At the highest government levels, IPTs and IPPD have been established as the new way of doing business. However, as yet procedures and technologies have not been implemented widely at the operational level. The lack of a DoD/DND-wide CVP infrastructure and established procedures deters individual program offices from implementing a CVP capability because the effort and expense to establish the capability at the program level are prohibitive. Moreover, there is a risk that a program-level CVP capability established now will not be compatible with the DoD/DND-wide direction that will emerge in the future. In the current budget environment, such risky investments are not feasible. Therefore, aside from a few exceptions, government program offices are not implementing CVP.

There is also reluctance on the part of program offices to implement a new development process because of program risk. The bigger the program, the greater the risk, and hence the more the program manager is likely to stay within the structured program process because they trust the procedures. But, the bigger the program, the greater the return on investment that could be realized by streamlining the process. A balance needs to be struck between taking risks and streamlining the DoD acquisition process. Government delays implementing CVP also impact private industry. Many defense contractors are implementing only limited CVP capabilities because of the risk of incompatibility with the future government CVP capability.

10.3.2.4 Government Lacks Confidence in CVP Results

Although industry is claiming substantial benefits from the use of CVP, many key government decision makers remain skeptical. Issues with model verification and validation and lack of concrete cost data create a lack of confidence in predicted cost savings. Therefore, acquisition decisions are being made using old paradigms to the disadvantage of the contractor and government organizations who have invested in CVP. For example, some programs are suffering from absorbing the cost of implementing CVP while having to document, review, and test designs using the old criteria. Thus the full cost benefits of CVP are not realized, and contractors and program offices are discouraged from implementing CVP.

10.4 Policy Facilitators and Barriers

10.4.1 Policy Facilitators

10.4.1.1 CVP Supports Current Policies and Future DoD Direction

CVP supports current DoD/DND policies and is vital to fulfilling the future vision of both governments. CVP can be used to more effectively fulfill some of the requirements specified in DoDI 5000.2 and DND DPMS.

This technology area has been rated of high importance and potential by both governments. Advanced modeling and simulation is one of four DoD dual use R&D focus areas as well as one of the major Science and Technology program thrusts.

CVP is key to reducing costs of military products and the manufacturing processes that support them. It provides the mechanisms for capitalizing on dual use technologies and streamlining the acquisition process, while ensuring high quality and a quicker time to market. A central goal throughout both governments is to streamline procedures, advance innovative processes, reduce oversight, reporting, and unique requirements, and employ risk taking for cost reduction.

CVP plays a central role in electronically connecting IPTs and fulfilling the goals set forth in IPPD, both concepts of which are being emphasized throughout the DoD and DND communities. It supports some of the major tenets of IPPD, including:

- Encouraging the use of advanced design and manufacturing techniques to achieve robust design and improved process capability.
- Establishing seamless management tools that relate requirements, planning, resource allocation, execution and program tracking over the product's life cycle, thereby enhancing team decision making at all levels. Capabilities should be improved to share technical and business information throughout the product life cycle through the use of acquisition and support databases and software tools for accessing, exchanging, and viewing information.
- Proactive identification and management of risk.

M&S has taken such a predominant role that the DoD and the US Military Services have established M&S oversight offices and developed policies for use of M&S. Program offices have greatly increased their use of M&S due to budget cuts, availability of M&S tools, and need for information. Engineers are starting to develop confidence in the use of virtual prototypes and are beginning to transition away from physical prototypes. They are using M&S to respond to a broader range of questions and to reduce the costs of system development.

10.4.1.2 Use of Commercial Standards is Encouraged and Modeling and Simulation Standards Are Being Developed

DoD and DND are striving to reduce the number of government unique requirements and capitalize on performance and commercial specifications and standards. Performance specifications are to be used when purchasing new systems, major modifications, upgrades, and non developmental and commercial items, for programs in any acquisition category. Contractors are encouraged to propose non government standards and industry-wide practices that meet the intent of the military specs and standards. DoD has issued a memo calling for the continual review of existing directives to eliminate standards that constrain activity, creativity, and progress. The Department's goal is to only authorize centrally mandated standards that assure interoperability, connectivity, and the appropriate level of security.

Regarding DIS standards, the government is working with industry to develop commercial standards. DIS top level standards are making good progress. IEEE 1278 and others have widespread support from both government and industry, as well as internationally. The user community, though, has expressed a need for more emphasis on standards regarding algorithms, data, and environmental representations. Guidelines, training programs and materials, and documented procedures will need to be put in place to ensure maximum interoperability.

10.4.2 Policy Barriers

10.4.2.1 Aperture Card Delivery Is Still a Requirement

Current contracting language requires that aperture cards be delivered to the government client. There is no provision for providing the government with the design data electronically or allowing them access to the design data in lieu of this procedure. The government does not use aperture cards to produce the components. Instead, they contact the source of the data for the needed design details. Aperture cards are expensive to prepare and add no value other than serving as a concrete deliverable that the government can check as being received.

10.4.2.2 No Policy Exists for Defining Ownership of Design Data

At present, there is no policy that definitively defines what constitutes design data. Design data can be defined in a broad sense as anything a designer uses to develop or analyze a design, ranging from aperture cards, raster data, solid models, and manufacturing process models to product simulations. Much of the information is considered proprietary and there is a lot of confusion as to who rightfully owns this data. At present, the government only requires aperture cards. Industry questions whether the government is entitled to receive all design data or if the Government should only have access rights to the data when needed. This needs to be clarified.

10.4.2.3 Verification, Validation, And Accreditation of Systems Is Time-Consuming and Expensive

The process involved in getting a CVP system verified, validated and accredited is lengthy, costly, and onerous. People are distrustful of the virtual world and lack confidence in the validity of the simulations being demonstrated. Hence, the amount of rigorous testing and trials that a system must be put through before the government will make acquisition decisions based on the model is extensive. Currently, users base a system's validation on the number of people who have used the system and the degree to which it is being used. The assumption is that if a lot of people have used the system, then it is a valid representation of reality regardless of whether it has gone through the VV&A process.

11.0 CONCLUSIONS AND RECOMMENDATIONS

This section presents conclusions based on information gathered throughout this study effort and based upon the facilitators and barriers presented in Section 10.0. The conclusions are observations of the current technical, business, and political environment associated with CVP. Based on the conclusions that are presented, recommendations are provided. The recommendations define specific actions that should be undertaken to foster the advancement and successful incorporation of CVP within a unified national industrial base. The roadmap provided at the end of this section summarizes the recommended actions and identifies interdependencies and action officers for execution of the recommended actions.

11.1 Conclusions

11.1.1 Industry Recognizes Opportunities Offered by CVP

There is general, widespread agreement that CVP provides significant benefits, especially in the areas of design, development, and production process improvements. Industry recognizes the competitive advantage that can be realized by employing CVP effectively; some have touted that this technology has become a requirement to remain competitive in the marketplace.

11.1.2 CVP Technologies Exist and Are Advancing

Many elements of the CVP technologies exist and are available for use. Substantial progress has been made in technology development (both commercial and defense) and more advances are on the horizon.

11.1.3 No True CVP Environment Currently Exists

To date, there has been only limited and partial implementation of a true CVP environment. In many cases, the prime contractors exert control over the subcontractors in an IPT setting, in terms of the tools they use, the procedures they need to follow, the data that is required and the formats for this data. The information flow is up the chain to the prime contractor. The prime generally does not share its data with the subs, so only one-way collaboration is achieved. A cultural chasm needs to be overcome to enable true collaboration to occur.

11.1.4 No Metrics Are in Place for Measuring CVP Benefits

Although certain industrial sectors have been able to roughly gauge the savings they have realized through the use of CVP technologies, there are no adequately baselined, universally recognized metrics captured in the application of CVP for measuring the benefits of CVP. Hence, it is difficult to quantify the specific financial savings of this technology at this date.

11.1.5 Proprietary Data Rights and Protection of Competitive Advantage Are Key Industry Concerns

Companies recognize the importance of working in a collaborative environment. However, concerns remain about jeopardizing or compromising their proprietary data and, thus, their competitive position. Companies are reluctant to release data to their teammates (which could improve their teammates' ability to enhance the design) because they are afraid that this will allow the teammates insight into their competitive edge. The teammates' contribution to the design process is not believed to be able to compensate for this exposure of proprietary data (risk does not justify the expected return). And companies are not comfortable that they can ensure that teammates have access to only the data the company wants to release. Security products are strongest on a site basis – not on an individual data item or data domain basis. This precludes fully implementing CVP technologies across company lines and with the Government offices because of the perceived risks that could be incurred.

11.1.6 No Government Guidelines for CVP Use Have Been Set

The government has not defined how it will work in a CVP environment. No guidelines have been established for the use of CVP within the government, hindering the government from reaping the full benefits of this technology. Hard choices remain for the government in terms of determining who they want to interact with (the prime level or down to lower level subs), what kind of data and level of detail they want access to, and what level of approval authority is necessary for design changes, keeping in mind the criticality of these changes and the frequency with which these changes need to be reviewed. As noted previously, CVP will enable designs to evolve faster and allow the government to be an interactive part of this process. There have been some unique cases demonstrating how CVP could work (program by program).

11.1.7 Current Government Acquisition Procedures Do Not Promote CVP

The nature of the current DoD acquisition environment does not promote the application of CVP technologies, especially in the high cost and high risk programs. The risk of employing a new technique/approach such as CVP keeps PMs from using it, even though the benefit that could be reaped from its use on a high cost program could be substantial. High level policy makers support implementation of CVP technologies in IPTs and through the course of IPPD. They are tackling CVP policy issues and beginning to put forth policy guidelines. However, this initiative has not trickled down to the PM and PEO level for implementation. The modeling and simulation communities and the acquisition communities are disjointed. There is a question regarding how the required up-front investment in infrastructure will be paid for on a program by program basis. More effective technology transfer mechanisms need to be established between these communities.

11.1.8 CVP Standards and Better Integration of Tools are Needed

Integration and standardization of these technologies are major issues. The lack of currently available and mature standards results in a higher investment cost required for small businesses and reduces the level and ease of interoperability among organizations. It also makes companies reluctant to invest because they don't know what to spend their money on. Standardization would cut down on the number of unique tools needed for different virtual relationships.

Integration is a critical element to sub-tier companies who support multiple primes. The ability of a company to interact between different tools enhances the benefits they can gain from these technologies. Better integration of tools is needed.

11.1.9 Financial Investment Is Considerable for Small Companies

One significant challenge facing small businesses wishing to use CVP technologies is the financial investment that they will need to incur and the continuing costs that they must bear for maintaining and upgrading CVP technologies. In particular, many of these companies work with multiple customers and must, under today's constraints, buy unique systems for each to ensure compatibility for data exchange.

In some instances, the primes purchase the tools for the subs so that they can more effectively work together. However, the subs are then precluded from working with other companies using this tool set.

11.1.10 No Central Repository of CVP Information Currently Exists

Currently there is no central organization responsible for coordinating CVP related activities and maintaining CVP related material. There is a need for a single point of contact that can provide information regarding available tools, lessons learned, standards, ongoing efforts and other pertinent information. This central information source could also help to identify available modeling and simulation tools that are accepted and validated for use.

11.1.11 Model Validation Process Takes Too Long

The current process for validating models for use is too long. A more rapid and flexible approach to validating models is required to better support developers. New models that are developed need to be validated and accepted for use rapidly. In addition, a single list of available models and their validation status is required. This listing would help increase model reuse, reduce duplication of efforts in model development, and could shorten the model validation process by increasing the amount of use and experience a model receives.

11.2 Recommendations

Ten recommendations address the study conclusions. Figure 11-1 provides a mapping between the conclusions presented in section 11.1 and the recommendations presented in the remainder of this section.

Conclusions	Recommendations
11.1.1 Industry Recognizes Opportunities Offered by CVP	11.2.8 Target Government Investments on CVP Integration Technologies
11.1.2 CVP Technologies Exist and Are Advancing	11.2.2 Sponsor Integration and Demonstration Projects 11.2.8 Target Government Investments on CVP Integration Technologies
11.1.3 No True CVP Environment Currently Exists	11.2.2 Sponsor Integration and Demonstration Projects 11.2.8 Target Government Investments on CVP Integration Technologies 11.2.1 Establish Central Government Office for CVP
11.1.4 No Metrics Are in Place for Measuring CVP Benefits	11.2.2 Sponsor Integration and Demonstration Projects 11.2.3 Implement Policy to Develop Standardized Metrics for Evaluating CVP Payoffs in Programs
11.1.5 Proprietary Data Rights and Protection of Competitive Advantage are Industry Concerns	11.2.7 Address Data Security/Proprietary Data Concerns and Formalize Policy Regarding These Issues 11.2.5 Reevaluate How Developers Deliver Data to Government Clients
11.1.6 No Government Guidelines for CVP Use Have Been Set	11.2.2 Sponsor Integration and Demonstration Projects 11.2.1 Establish Central Government Office for CVP 11.2.3 Implement Policy to Develop Standardized Metrics for Evaluating CVP Payoffs in Programs 11.2.6 Coordinate CVP Requirements With Acquisition Reform Initiatives
11.1.7 Current Government Acquisition Procedures Do Not Promote CVP	11.2.5 Reevaluate How Developers Deliver Data to Government Clients 11.2.3 Implement Policy to Develop Standardized Metrics for Evaluating CVP Payoffs in Programs 11.2.6 Coordinate CVP Requirements With Acquisition Reform Initiatives 11.2.4 Implement RFP Language and Contracting Approaches That Encourage CVP Use
11.1.8 CVP Standards and Better Integration of Tools are Needed	11.2.2 Sponsor Integration and Demonstration Projects Target Government Investments on CVP Integration Technologies 11.2.8 Target Government Investments on CVP Integration Technologies
11.1.9 Financial Investment Considerable for Small Companies	11.2.10 Educate Small Business on Less Expensive Options to Acquiring CVP Technologies
11.1.10 No Central Repository of CVP Information	11.2.1 Establish Central Government Office for CVP
11.1.11 Model Validation Process Takes Too Long	11.2.9 Streamline the Validation Process for Models

Figure 11-1. Mapping of Conclusions to Recommendations.

11.2.1 Establish Central Government Office for CVP

Establish a central government department where industry can seek out opportunities for their new CVP related technologies and government personnel can go to learn about available commercial practices and technologies from which they could benefit. This office could be responsible for policy issues central to implementing CVP technologies. It could also provide a significant technology transfer function to better promote the government laboratory tool advances to the private sector and to ensure the government's adoption of best commercial practices and technologies. The office could be instrumental in establishing industry/government/academia consortia across laboratory lines, and directly involve in MS&T programs, particularly in the Advanced Industrial Practices and Manufacturing and Engineering Systems sub-areas.

The office would be responsible for establishing a CVP/M&S information repository to promote communication and reuse of software, models, and simulations related to CVP. The focus of this central repository should be on reducing duplication of effort in model development, making valid models and simulations easily available, and providing the CVP community one stop shopping for information related to CVP.

These initiatives could potentially be incorporated into the Defense Modeling and Simulation Office's charter.

11.2.2 Sponsor Integration and Demonstration Projects

Sponsor integration and demonstration activities to illustrate how CVP can be used effectively in government programs (include all elements from requirements, manufacturability, operational effectiveness, maintainability, and human interaction and team integration of users, customer, suppliers, sub-tiers, and prime contractor). Develop standard procedures for the government's use of CVP, define metrics and quantify the benefits of CVP, and support the advancement of the integration of CVP technologies. Potential programs to support such a demonstration include AAAV, PM Abrams, and CSA.

By Government sponsorship of such initiatives, PMs have incentives to undertake a CVP approach to design. Since this type of project is regarded as a test case for the technology, the PM is alleviated of the risks that he would normally incur as a natural course of weapon system development. And, funding for the infrastructure that would need to be put in place to accomplish this program is also provided.

Such a program would help to instill the confidence in CVP technologies that is currently lacking within Government offices. It would help facilitate the establishment of Government guidelines for CVP and alter attitudes towards a streamlined acquisition process predominant throughout the defense culture. Through this course of action, a standardized, validated technique for capturing and analyzing metrics affected by CVP against an established baseline could be demonstrated and a model CVP infrastructure put in place. The payoffs of CVP could be authenticated and the program could serve as an example of the promise that CVP holds.

11.2.3 Implement Policy to Develop Standardized Metrics for Evaluating CVP Payoffs in Programs

The government should incorporate in policy the requirement for development of a standardized, validated technique for capturing and analyzing metrics to compare CVP payoffs against an acceptable baseline for defense weapon systems. By mandating this action, procedures will be put in place to effectively gauge what benefits have been derived from using CVP technologies, quantifying cost and time savings among other variables, and thereby establishing credibility for this process.

11.2.4 Implement RFP Language and Contracting Approaches That Encourage CVP Use

The government should promote in the Statement of Work and the proposal evaluation criteria of solicitations that part of the evaluation of the proposals will be based on the contractor's ability and willingness to use cost saving CVP techniques. Spelled out in the RFP is what the government will provide. The RFP should also request insight into the team structure, subcontractor arrangements, and the technologies they will be employing to communicate. In addition, the government should advocate contracting approaches that encourage programs to adopt new and emerging CVP related technologies. Examples include front loading programs financially to support a high initial investment profile as required by CVP or using cost plus incentive award contracts to encourage contractors to save contractual time and money.

11.2.5 Reevaluate How Developers Deliver Data to Government Clients

The government needs to reevaluate the procedures currently in place for developers to deliver data to their government clients. At present, an archaic procedure is used involving the delivery of aperture cards. This is not effective and does not give the government the data it needs. The 1996 draft version of DoDI 5000.2 partially addresses this issue by calling for the delivery of digital data. Further policy is needed that defines what data, if any, is to be delivered to the Government and the format for the data, as well as what data, if any, is to be maintained by the customer and procedures for accessing this data (including format).

In addressing this issue it is important to examine the role of the Commerce At Light Speed (CALS) program and in particular the Contractor Integrated Technical Information Services (CITIS). CITIS provides a strategy and specifications for Government access to a contractor maintained product data base. Currently CITIS addresses only Contract Data Requirements List (CDRL) data. CITIS will need to be examined for potential expansion to include CVP related data.

11.2.6 Coordinate CVP Requirements with Acquisition Reform Initiatives

Ensure coordination with acquisition reform activities on CVP requirements. Document CVP acquisition reform requirements (such as ascertaining when and how often the Government requires access to the data and insights into the stages of the design process) and communicate these requirements to the Acquisition Reform office within OSD. This could be part of the mandate for the central CVP office, which could provide examples of enhancements offered by the use of CVP in implementing policies resulting from current and proposed acquisition reform design and development activities.

11.2.7 Address Data Security/Proprietary Data Concerns and Formalize Policy Regarding These Issues

Industry is concerned about incorporating CVP because of their worries regarding the security of their proprietary data, their unwillingness to share this data with their competitors who are teammates on this particular project, and the potential that this data could leak to organizations outside of the team. The issue of who has ownership rights to the data also needs clarification. The government should formally address industry concerns regarding data security and proprietary data. The government needs to outline policy on data ownership and define product data in terms of ownership rights.

11.2.8 Target Government Investments on CVP Integration Technologies

Focus future DoD investments in CVP on integration technologies. Significant commercial and Government tool development efforts have occurred and are currently underway. These efforts have resulted in a decrease in the cost of the tools. However, integration tools to enhance the physical connections between systems and the necessary software to enable different tools to communicate easily with one another are vital to ensuring that the benefits of incorporating CVP in the design process are maximized.

11.2.9 Streamline the Validation Process for Models

The process to verify, validate and accredit new models is time consuming and expensive. The government should reevaluate the validation process for new models and develop an approach to shorten the time required to validate a model.

11.2.10 Educate Small Businesses on Less Expensive Options to Acquiring CVP Technologies

The government should educate small businesses on less costly alternatives for acquiring CVP technology. CVP technologies require that a major upfront expense be shouldered by the purchaser, which has significant impact on the cash flow of smaller companies. Other less expensive options are now being offered by the software industry for gaining access to their technologies. These include pay-per-use software practices for high cost and specialized tools.

11.3 CVP Evolution Roadmap

The first step in implementation of recommendations is to establish the Central Government Office for CVP. This office should play a key role in all other recommendations. DMSO is a potential organization to operate this function.

With the establishment of the CVP office, the focus should be on setting up the CVP Integration Demonstrations. As part of these demonstrations several of the other recommendations should be considered. Need to evaluate how developers deliver data which should result in defining CVP requirements for acquisition reform and identifying data security and proprietary data concerns and communicating these issue to the Acquisition Reform effort and developing new policy and regulations that address these issues. In coordination with the demonstration program, new policy defining standard metrics for evaluating CVP payoffs and new RFP language and contracting approaches that encourage CVP should be promoted.

As part of the new CVP offices charter, language regarding future CVP investment strategies should be focused on targeting investments towards CVP integration technologies. Also as part of the CVP office's operation, they should establish a repository and listing of CVP related models and technologies. Within this listing the office should develop and promote a new streamlined approach to validating models.

The final element of the recommendations addresses the small business concerns. Here the focus is on the financial investment required. The new CVP office should work with the Small Business Administration to establish a mechanism for communicating to these companies the various options associated with investing in CVP and projections for the costs associated with making these investments.

APPENDIX A
ACRONYMS

AAAV	Advanced Amphibious Assault Vehicle
ACAT	Acquisition Category
AM3	Affordable Multi Missile Manufacture
AMC	Army Materiel Command
AMRI	Agile Manufacturing Research Institute
AP	Application Protocol
ARPA	Advanced Research Projects Agency
ATD	Advanced Technology Demonstration
ATM	Asynchronous Transfer Mode
AVSEP	Avionics Systems Engineering and Prototyping
BLRSIM	Battle Lab Reconfigurable Simulator
CAD	Computer Aided Design
CAE	Computer Aided Engineering
CALS	Commerce At Light Speed
CAM	Computer Aided Manufacturing
CDRL	Contract Data Requirements List
CIM	Corporate Information Management
CITIS	Contractor Integrated Technical Information Services
CNC	Computer Numeric Code
CORBA	Common Object Request Broker
CSA	Common Support Aircraft
CVP	Collaborative Virtual Prototyping
DAB	Defense Acquisition Board
DARPA	Defense Advanced Research Projects Agency
DICE	DARPA Initiative in Concurrent Engineering
DIS	Distributive Interactive Simulation
DISA	Defense Information Systems Agency
DMSO	Defense Modeling and Simulation Office
DMSS	Depot Maintenance Standard System
DND	Department of National Defence
DoD	Department of Defense
DoDD	Department of Defense Directive
DoDI	Department of Defense Instruction
DPMS	Defence Program Management System
EB	Electric Boat Corporation
EC	Electronic Commerce
ECRC	Electronic Commerce Resource Center
EDI	Electronic Data Interchange
EFOG-M	Enhanced Fiber Optic Guided Missile
EIT	Enterprise Integration Technologies
EVR	Electronic Visualization Room
EXCIMS	Executive Council on Modeling and Simulation
FEA	Finite Element Analysis
FIPS	Federal Information Processing Standards
GDEB	General Dynamics Electric Boat
GDLS	General Dynamics Land Systems
HTML	Hyper Text markup Language
HTTP	Hyper Text Transfer Protocol
ICM	Interdisciplinary Communications Medium
IGES	Initial Graphics Exchange Standard
IPDE	Integrated Product Data Environment
IPPD	Integrated Product and Process Development
IPPM	Integrated Product and Process Management
IPT	Integrated Product Teams
IRAD	Internal Research and Development
IST	Institute for Simulation and Training
JAST	Joint Advanced Strike Technology
JCALS	Joint Computer Aided Acquisition and Logistics Support
JCALS	Joint Continuous Acquisition and Lifecycle Support
JEDMICS	Joint Engineering Data Management Information Control System
JLSC	Joint Logistics Systems Center
LAN	Local Area Network
M&S	Modeling and Simulation
MECE	Multimedia Engineering Collaboration Environment
MIPS	Mega Instructions Per Second
MMSS	Material Management Standard System
MS&T	Manufacturing Science and Technology
NAC	National Automotive Center
NATIBO	North American Technology and Industrial Base Organization
NAVAIR	Naval Air Systems Command
NAVSEA	Naval Sea Systems Command

NAWC	Naval Air Warfare Center
NBS	Notional Baseline Ship
NCSA	National Center for Supercomputing Applications
NIIIP	National Industrial Information Infrastructure Program
NIST	National Institute of Standards and Technology
NREN	National Research and Education Network
NSA	National Security Agency
NSF	National Science Foundation
NSIA	National Security Industrial Association
NSSN	New Attack Submarine
OLE	Object Linking and Embedding
OMA	Object Management Architecture
OMG	Object Management Group
OODBMS	Object Oriented Data Base Management Systems
ORB	Object Request Brokers
OSD	Office of the Secretary of Defense
PC	Personal Computer
PDES	Product Data Exchange using STEP
PDM	Product Data Management
PEO	Program Executive Office
PGP	"Pretty Good Privacy"
PM	Program Manager
PMO	Program Management Office
POC	Point Of Contact
PWC	Pratt & Whitney Canada
R&DD	Research and Development Division
RASSP	Rapid-Prototyping of Application Specific Signal Processor
RDT&E	Research and Development Test and Evaluation
RFP	Request For Proposal
ROI	Return On Investment
S&T	Science and Technology
SALC	Sacramento Air Logistics Center
SBD	Simulation Based Design
SGI	Silicon Graphics Incorporated
SPM	Smart Product Model
STEP	STandard for the Exchange of Product model data
STRICOM	Simulation, Training, and Instrumentation Command
TACOM	Tank-Automotive and Armament Command
TAFIM	Technical Architecture for Information Management
TARDEC	Tank-Automotive Research, Development, and Engineering Center
TRP	Technology Reinvestment Program
UCF-IST	University of Central Florida - Institute for Simulation and Training
USAF	United States Air Force
USDA&T	Under Secretary of Defense for Acquisition and Technology
USMC	United States Marine Corps
VCE	Virtual Collaborative Engineering
VDE	Virtual Design Environment
VHDL	VHSIC Hardware Description Language
VM	Virtual Manufacturing
VV&A	Verification, Validation, and Accreditation
WAN	Wide Area Networks
WWW	World Wide Web

APPENDIX B
LIST OF SITES VISITED

West Coast* - March 8-10 (B-2 to B-12)
- Stanford Knowledge Systems Center (KSC)
- Lockheed SBD Program
- Enterprise Integration Technologies

Texas* - April 10-14 (B-13 to B-36)
- ECRC San Antonio, TX
- Microelectronics and Computer Technology Corporation (MCC), Austin, TX
- Meneaco /Aerosystems Division, Austin, TX
- Northrop Grumman Vought, Commercial Aircraft, Dallas, TX
- University of Texas/Automation & Robotics Research Institute, Arlington, TX
- Loral Vought Systems, Grand Prairie, TX
- Texas Instruments, Plano, TX
- Knowledge Based Systems Inc. (KBSI), College Station, TX

Detroit - April 19-21 (B-37 to B-46)
- TARDEC/NAC
- Laserform
- 3-Dimensional Services
- Deneb Robotics, Auburn Hills, MI

Canada - May 15-19 (B-47 to B-76)
- ATS Aerospace, Inc.
- CAE Electronics
- Virtual Prototypes, Inc.
- Object Form Software, Inc. (formerly Famic Technologies, Inc.)
- Simdev
- Prior Data Sciences
- Atlantis Aerospace
- DCIEM

Midwest - May 30 to June 2 (B-77 to B-90)
- John Deere
- University of Iowa
- Caterpillar
- NCSA
- Purdue University

Southeast - June 26-30 (B-90 to B-110)
- Univ. of Central Florida
- JSIMS
- Lockheed/Martin (Orlando)
- STRICOM
- NAWC Training Systems Division
- Georgia Tech
- Lockheed/Martin (Atlanta)

JAST* August 7-11 (B-111 to B-122)
- McDonnell Douglas
- Northrop/Grumman
- Lockheed Martin
- Boeing

Northeast - August 14-18 (B-123 to B-141)
- Northrop/Grumman
- Sikorsky
- Pratt & Whitney
- GD/Electric Boat
- Lockheed Sanders
- Raytheon
- STEP Tools Inc.

NOTE: Copies of selected trip reports are available upon request. Please contact Michael Slack at 613-945-7106.

*** NAVAIR CVP Study Trips**

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APPENDIX C
LIST OF DOCUMENTS

Title	Source	Type	Date
Simulation and Modeling Help Picture the Future			
The Problem - Why Change is Necessary			
Systems Acquisition Manager's Guide for the Use of Models and Simulations	Defense Systems Management College	Book	September 1994
Virtual Prototyping: Concept to Production	Defense Systems Management College	Book	March 1994
Acquisition Reform A Window of Opportunity	Principle Deputy Under Secretary of Defense (Acquisition and Technology) - Noel Longuemare	Briefing	May 2, 1995
Acquisition Task Force on Modeling and Simulation	Acquisition Task Force on Modeling and Simulation	Briefing	
Acquisition Task Force on Modeling and Simulation - Brief to NADIBO	Acquisition Task Force on Modeling and Simulation	Briefing	
Defense Manufacturing Council Priorities and Integrated Approach to OSD/Service Oversight	Noel Longuemare	Briefing	March 7, 1995
Federal Acquisition Streamlining Act 1994, Public Law 103-355	Defense Acquisition University	Briefing	
Joint Directors of Labs Manufacturing Science and Technology - Manufacturing and Engineering Systems Sub-Panel DDR&E Summer Review	Joint Directors of Labs	Briefing	July 27, 1995
Modeling and Simulation - An Overview at General Dynamics Land Systems Division	General Dynamics Land Systems Division	Briefing	
Technology for Acquisition Reform - Preliminary Report		Briefing	May 1993
US Army Simulation , Training and Instrumentation Command - Command Forecast	STRICOM	Briefing	March 1995
A Briefing for Industry - Multiple Briefings	US Army Training and Doctrine Command	Briefings	March 16, 1995
Briefing to Industry - Multiple Briefings	STRICOM	Briefings	March 15-17, 1995
Oak Ridge - Center for Manufacturing Technology - Information Packet	Oak Ridge National Labs	Information Packet	1992
Engineering a Change in the Design Process An Evolutionary Approach Rocket Engine Development Comanche Airframe Design Developing the MD Explorer CE at General Dynamics Space Station Freedom	Aerospace America Rockwell International Rocketdyne Sikorsky Aircraft Division McDonnell Douglas Helicopter General Dynamics Space Systems McDonnell Douglas Aerospace	Internet Case Study Case Study Case Study Case Study Case Study Case Study	April 1993
A More Perfect Union	Manufacturing Systems	Journal	April 1995

Title	Source	Type	Date
Bentley Systems Joins CAD Industry Alliance	Managing Automation	Journal	December 1995
CAD Vendors Saying “Ole!”	Manufacturing Systems	Journal	July 1995
CORBA As Solution		Journal	
Creating Concurrent Business Processes Across the Supply Chain	Manufacturing Systems - Gartner Group	Journal	June 1995
Do Organizations Achieve Their Objectives from Computer-Based Manufacturing Technologies?	IEEE	Journal	May 1992
EDI... A Free Lunch for Small Businesses?	EDI World	Journal	March 1995
Electronic Commerce: Back to Basics	EDI World	Journal	November 1994
Engineous Explores the Design Space	Mechanical Engineering	Journal	February 1992
Evolution in EDI	Manufacturing Systems	Journal	August 1995
Ford Testing a ‘Private Internet” to Link Suppliers		Journal	
Forging a Global Appliance	CIO	Journal	May 1, 1995
Getting the Most Out of Your Design Data	A/E/C Systems Computer Solutions	Journal	September-October 1995
Groupware and the Virtual Enterprise	Datamation	Journal	March 15, 1995
How Automation Impacts Design Costs	A/E/C Systems Computer Solutions	Journal	September-October 1995
On the Verge of Internet Manufacturing	Managing Automation	Journal	June 1995
Rapid Value	Manufacturing Systems	Journal	May 1995
Rapid Value	Manufacturing Systems	Journal	May 1995
Safety First on the Information Highway - Part 2	EDI World	Journal	December 1995
Sharing Makes Sense	Beyond Computing	Journal	May 1995
Shastra: Multimedia Collaborative Design Environment	IEEE Multimedia	Journal	Summer 1994
Simulation Will Help Define U.S. Army Roles, Missions	Defense News	Journal	October 17-23, 1994
Simulation: Art or Science	Manufacturing Engineering	Journal	February 1995
The Economics of EDI	CIO	Journal	May 1, 1995
The Inside Story: Competing CAD and Integration Standards	A/E/C Systems Computer Solutions	Journal	September-October 1995
The Myth of the Specialized Military Contractor	Technology Review	Journal	April 1995
Updating Your CAD System	Mechanical Engineering	Journal	February 1992
Virtual Prototype Advances Displace Engineering Mockups	Signal	Journal	October 1994
Virtual Prototypes Move Alongside Their Physical Counterparts	Mechanical Engineering	Journal	August 1992
Virtual Prototyping Simulation for Design of Mechanical Systems	The University of Iowa	Journal	June 1995
Virtual Prototyping: Concept to Production	Program Manager	Journal	May-June 1994
War Fighter’s Impact Crucial In Altering Army’s Azimuth	Signal	Journal	June 1993
Why We Need Doctoral Programs in Design	Mechanical Engineering	Journal	February 1992
Approval of the Contract Administration Reform Process Action Team Report		Memo	
Approval of the Procurement Process Reform Process Action Team Report		Memo	
Department of the Navy Modeling and Simulation Program	Department of the Navy	Memo	October, 18, 1994

Title	Source	Type	Date
Elimination of Unnecessary Reviews Related to Procurement	Director of Defense Procurement	Memo	
Good Judgment in the Competitive Procurement Process		Memo	
Memorandum for the Defense Acquisition Community - Update of the DoD 5000 Documents		Memo	October 11, 1995
MOU Between The Advanced Information Technology Systems - Joint Program Office and Defense Simulation Internet Sites	Advanced Information Technology Systems - Joint Program Office	Memo	June 2, 1994
Open Computing Architecture	Deputy Secretary of Defense	Memo	May 5, 1995
Specifications and Standards -- A New Way of Doing Business		Memo	
Reengineering the Acquisition Oversight and Review Process	Under Secretary of Defense	Memo and Report	April 25, 1995
Use of Integrated Product and Process Development and Integrated Product Teams in DoD Acquisition	Secretary of Defense - William Perry	Memo and Report	May 10, 1995
Special Report: 1994 Survey of American Manufacturers	National Center for Manufacturing Sciences (NCMS) Focus	Newsletter	January 1995
Acquisition Integrated Product and Process Management - Volume 1: Concept Implementation	U.S. Army Materiel Command	Report	March 14, 1995
Acquisition Integrated Product and Process Management - Volume 2: Applications	U.S. Army Materiel Command	Report	March 14, 1995
Acquisition Integrated Product and Process Management - Volume 3: Tools and Practices	U.S. Army Materiel Command	Report	March 14, 1995
Army Efforts to Implement Integrated Product and Process Management	Industrial Engineering Activity	Report	June 1995
Army Model and Simulation Master Plan	Department of the Army	Report	May 1994
Army Modeling and Simulation Master Plan	Deputy Undersecretary of the Army	Report	May 18, 1995
Computer Networking Practices in Small Manufacturing Enterprises	Computer and Automated Systems Association of the Society of Manufacturing Engineers	Report	May 1994
Cooperation with Industry - Simulators and Trainers	Canadian DND	Report	June 1994
Critical Issues in the Defense Acquisition Culture - Appendix B	Defense Systems Management College	Report	
Critical Issues in the Defense Acquisition Culture - Government and Industry Views from the Trenches	Defense Systems Management College	Report	December 1994
Defense Science and Technology Strategy	DOD, Director, Defense Research and Engineering	Report	September 1994
Defense Technology Plan	DOD, Director Defense Research and Engineering	Report	September 1994
Department of Defense Instruction Number 5000.2 - DRAFT		Report	October 11, 1995
Department of Defense Instruction Number 5000.2 Appendices - DRAFT		Report	October 11, 1995
Department of Defense Technical Architecture Framework for	Defense Information Systems Agency	Report	June 30, 1994

Title	Source	Type	Date
Information Management (TAFIM)	(DISA) Center for Architecture		
Developmental Manufacturing and Modification Facility - Handbook	ASC/AMF	Report	February 1994
DoD Directive Number 5000.59 - DoD Modeling and Simulation Management		Report	January 4, 1994
Dual Use Technology: A Defense Strategy for Affordable, Leading-Edge Technology	DOD, Under Secretary of Defense for Acquisition and Technology	Report	February 1995
Emerging Technologies - Volume IV Appendix: US Access to Japanese Technology Transfer Services	Forecast International	Report	1991
Engineering in the Manufacturing Process (Defense Science Board Task Force Report)	Office of the Under Secretary of Defense for Acquisition	Report	March 1993
Final Report of the Acquisition Task Force on Modeling and Simulation	DoD, Director for Defense Research and Engineering	Report	June 17, 1994
Guide to Implementation and Management of Integrated Product and Process Development in DoD Acquisition - Part I: Executive Summary		Report	June 15, 1995
Implementation Plan for the Federal Acquisition Streamlining Act of 1994 (Final Version)		Report	
Integrated Process Engineering	Policy Analysis Center at George Mason University	Report	November 1, 1994
JEI: Just-Enough-Information Paradigm for Production Scheduling in a Manufacturing Supply Network	University of Southern California, Information Sciences Institute	Report	May 1995
Modeling and Simulation Study Report	National Security Industrial Association	Report	February 1995
NATO Cooperative Armaments Projects and Pre-Feasibility Studies	International Armaments Cooperation	Report	March 1995
Pricing the Internet	University of Michigan	Report	April 1993
Second to None: Preserving America's Military Advantage Through Dual-Use Technology	Office of Science and Technology - National Economic Council, National Security Council	Report	February 9, 1995
Simplified Acquisition Procedures - Satellite Broadcast Reference Material	Acquisition Reform Communications Center/Federal Acquisition Institute	Report	June 28, 1995
Simulation Based Design - Final Report	ARPA/General Dynamics Electric Boat Division	Report	October 1994
Simulation Based Design - Final Report	ARPA/Lockheed Missiles and Space Company, Inc.	Report	October 1994
Simulation Based Design for Military Systems Supportability and Human Factors - DMSO Project Summary	University of Iowa - Dr. Ed Haug	Report	
Small Business Innovation Research (SBIR) Program Solicitation	National Science Foundation	Report	June 12, 1995
Some Economies of the Internet	University of Michigan	Report	November 1992
Statement by Deputy Under Secretary of Defense on Acquisition	Deputy Under Secretary of Defense -	Report	April 6, 1995

Title	Source	Type	Date
Reform	Mrs. Colleen A. Preston		
Statement by Deputy Under Secretary of Defense on Acquisition Reform	Deputy Under Secretary of Defense - Mrs. Colleen A. Preston	Report	February 21, 1995
Strategic Agenda for National Science and Technology Council (NSTC) Subcommittee on Manufacturing Infrastructure	NSTC	Report	August 1, 1994
Summary Descriptions of Projects - Appendix	Institute for Defense Analysis	Report	June 30, 1995
Technologies Enabling Agile Manufacturing - Relationship to National Agility Initiatives	Technologies Enabling Agile Manufacturing Program Office	Report	July 13, 1994
Technologies Enabling Agile Manufacturing Strategic Plan - Book 1: Business & Management Plan	Technologies Enabling Agile Manufacturing Program Office	Report	July 13, 1994
Technologies Enabling Agile Manufacturing Strategic Plan - Book 2: Technical Plan	Technologies Enabling Agile Manufacturing Program Office	Report	July 13, 1994
Technologies Enabling Agile Manufacturing Technical Plan - Program Statement of Work and Task Schedules	Technologies Enabling Agile Manufacturing Program Office	Report	August 26, 1994
The Defense Acquisition Challenge: Technological Supremacy at an Affordable Cost	Under Secretary of Defense for Acquisition and Technology - The Honorable Paul Kaminski	Report	January 27, 1995
The Role of Distributed Simulation in Defense Acquisition	Institute for Defense Analyses	Report	November 1993
Trip Report - Canada	BDM Federal, Inc.	Report	May 15-19, 1995
Trip Report - Detroit	BDM Federal, Inc.	Report	April 19-21, 1995
Trip Report - JAST/Aircraft Primes	Johns Hopkins University Applied Physics Lab/NSM	Report	August 7-11, 1995
Trip Report - Mid West	BDM Federal, Inc.	Report	May 30 - June 2, 1995
Trip Report - Northeast	BDM Federal, Inc.	Report	August 14-18, 1995
Trip Report - Palo Alto, CA	Johns Hopkins University Applied Physics Lab/NSM	Report	March 8-10, 1995
Trip Report - Southeast	BDM Federal, Inc.	Report	June 26-30, 1995
Trip Report - Texas	Johns Hopkins University Applied Physics Lab/NSM	Report	April 10-14, 1995
Weapon Systems Acquisition Cycle Improvement (through integration of modeling and simulation) - Implementation Plan	US Army Materiel Command Task Force	Report	November 1994
Weapon Systems Acquisition Cycle Improvement (through integration of modeling and simulation) - Final Report	US Army Materiel Command Task Force	Report	June 10, 1994
Integrated Product Teams: One Important Step Forward in Military Acquisition Affairs	Under Secretary of Defense for Acquisition and Technology - The Honorable Paul Kaminski	Speech	July 20, 1995
Integrated Program Management: The Manager's Tool for Success	Dr. Paul Kaminski,, Under Secretary of Defense for Acquisition and Technology	Speech	October 23, 1995

Title	Source	Type	Date
The DoD and Small Business: Synergy for the 21st Century	Dr. Paul Kaminski,, Under Secretary of Defense for Acquisition and Technology	Speech	October 16, 1995
Technology Reinvestment Project (TRP) - Special News Briefing	Dr. Paul Kaminski,, Under Secretary of Defense for Acquisition and Technology, Ken Flam, Special Assistant for Dual-Use Technology, Lee Buchanan, Advanced Research Projects Agency	Speech, Briefing	February 10, 1995
Survey of the Acquisition Community on Applications of Modeling and Simulation - Survey Team Workbook	Defense Modeling and Simulation Office (DMSO)	Workbook	

APPENDIX D
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APPENDIX E
CATALOGUE OF CVP TOOLS

CVP Tools				
Tool	**Developer**	**Users**	**Category**	**Description**
TRAXX	FAMIC Technologies	First release was available in June/July 95	Integration	Provides an integrated synthetic design/development environment infrastructure. TRAXX is a COTS package and costs approximately $30,000. TRAXX does not provide any of the design/development tools, only the infrastructure which allows them to be linked together and be interactive.
I-GRIP/	Deneb Robotics	· GM Cave · TARDEC · ARPA SBD (GD Elec Boat) · Crusader · Comanche · NAWC · SALC · Lockheed · MD · NASA · Caterpillar · John Deere · Others...	Application	3D simulation based interactive multipurpose engineering tool for designing, evaluating and off-line programming robotics workcells.
Virtual NC			Application	3D simulation based engineering tool for visualizing and analyzing the functionality of a machine tool, its CNC controller, and the material removal process.
ENVISION			Application	3D simulation based environment for virtual prototyping and ergonomic analysis including MTM, kilo calories, posture and MIOSH tables.
Quest			Application	Queuing Event Simulation Tool (QUEST) for analyzing production scenarios, production mixes and failure responses for machines and labor; factory layout; throughput; and production costs.
Virtual Collaborative Engineering (VCE)			Integration	This tool is available in the 3.0 release of the Deneb software. Deneb has developing a connection protocol which will enable models and simulations to be run synchronously while communicating over a 2400 baud modem. Each site maintains a copy of the simulation package and separate access to the necessary data. Only changes are communicated over the modem.
CAD	CAD vendors	Designers (Primes, sub-tier, and suppliers)	Data Creation	These tools include all CAD vendors such as Intergraph, Pro Engineer, CATIA, Computer Vision, Unigraphics, Auto Cad, Mentor Graphics and many others. All of these packages support the creation of product data electronically and graphically represent the product designs electronically.
CAM	CAD/CAM vendors	Manufacturers (Primes, sub-tier, and suppliers)	Data Creation	Most CAD vendors offer a CAM product along with their CAD system. In addition there are many vendors who specialize in providing CAM products. The CAM product evaluates a CAD representation and will automatically propose processing requirements to create the design. The system also assists a user in manually creating the processing requirements for a design.
Design Space	Stanford Center for Design Research	None - R&D	Data Creation, Integration	Design Space is a 3D graphical design tool where humans can interact in a virtual environment for collaborative and conceptual design with manual interactions. Using a cyber glove, objects are passed back and forth between designers via networks. Modifications to the objects can be seen in real time by other collaborators.
Design Sheet	Rockwell	· North American Aviation · MADE-	Integration, Application	Design Sheet is a conceptual tool used to examine performance, cost, manufacturability, and reliability options in the design space of a product. Design Sheet utilizes physics equations and constraints in a parametric approach to viewing the options. Design Sheet offers designers an automated tool for conducting design

CVP Tools				
Tool	**Developer**	**Users**	**Category**	**Description**
		FAST		tradeoff studies.
Virtual Design Environment (VDE) Viewer	Lockheed - SBD	None - R&D	Integration	VDE is a tool used in the SBD environment for the visualization of and interaction with product behavior. The product behaviors include visualization, CAD, operation, and analysis. Maintenance, training and other areas and not included.
Smart Product Model (SPM)	Lockheed - SBD	None - R&D	Product and Process Data	The SPM is central to the SBD environment. The SPM is based on object oriented technology and an active object oriented database. The database is defined as active because the database is invoked by software not by a user. The SPM for an item is based on objects rather than functionality. The SPM captures the product characteristics as well as process characteristics. Design intent is not captured in the SPM, but could be captured in the engineers notebook (see MECE).
PartNet	Lockheed - SBD	None - R&D	Product and Process Data	PartNet is a catalog of SPMs. PartNet is run by the University of Utah as part of the ARPA MADE program. PartNet provides a common object representation of parts which allows a designer to download a complete SPM for a part. PartNet is accessible on Internet through the WWW.
Multimedia Engineering Collaboration Environment (MECE)	Lockheed - SBD	None - R&D	Integration	MECE is used to document design decisions, rationale and intentions electronically throughout the design process. MECE supports collaboration among people through an electronic design notebook as well as creates an electronic search capability for a design notebook.
Netbuilder	Lockheed - SBD	None - R&D	Integration	Netbuilder supports multi-disciplinary analyses. It provides a mechanism for developing megaprograms and wrappers which allow application interoperability. The application wrapper controls what information is required by an application. The megaprogram operates as an agent for the applications interacting. Netbuilder provides data driven engineering simulations. Netbuilder supports collaboration between tools through the integration of analysis tools.
Simbuilder	Lockheed - SBD	None - R&D	Integration	Simbuilder provides an event and time driven synchronous engineering simulation.
NREN			Computing and Computer Networks	NREN (National Research and Education Network) is envisioned to be the replacement for the Internet in the future. NREN uses Asynchronous Transfer Mode (ATM). This program is backed by Vice President Al Gore.
STEP APs	PDES Inc. ISO	Designers, Manufacturer and Tool Developers	Standard, Product and Process Data	STEP (Standard for the Exchange of Product Model Data) is a developing international standard which is defining application protocols to enable data exchange and sharing of product data. The STEP APs can help to define the data required to fully define a product and its associated processes. STEP APs can act as the data definition for what should be capture and stored in a project database.
CORBA	OMG	Designers and Tools Developers	Standard	CORBA (Common Object Request Broker) ??????????
DIS Protocols	US Army	DoD and	Standard	Distributed Interactive Simulation (DIS) protocols enable real-time communications

CVP Tools				
Tool	**Developer**	**Users**	**Category**	**Description**
	STRICOM	Prime Contractors		and interactions among simulations (both hardware and software) running synchronously.
IGES		Designers, Manufacturer and Tool Developers	Standard	IGES (Initial Graphics Exchange Specification)
Secure HTTP	EIT	Infrastructure	Computing and Computer Networks	EIT has developed a secure hyper text transfer protocol (HTTP) which is being used by Commerce Net.
WWWeasel	EIT	None - R&D (SBD Program)	Integration	WWWeasel provides a tool which supports developing HTML documents by pulling multimedia information from a variety of sources. the tool supports easy integration of information. WWWeasel provides wide area controls for document control and access. Plans include the addition of read/write access controls over the WAN. Under the ARPA AIMS program, MECE and WWWeasel are to be integrated into one multimedia electronic engineers design notebook which will operate over the WWW in a WAN environment.
WISE (Weight Interactive Sizing)		Northrop Grumman	Interaction	WISE enables a parametric design space analysis. WISE can examine an unlimited number of variables/inputs to identify the optimum design area based on affordability. WISE also supports the execution of sensitivity analyses.
TOPAS Life Cycle Cost Model		Northrop Grumman	Application	TOPAS provides total parametric aircraft costs. Costs are computed based on historical data.
PIX/TOPS Flyaway Cost Model		Northrop Grumman	Application	PIX/TOPS addresses costs from the top level of a design to the component level, providing a parametric information expert/target oriented production solution. Costs are computed based on historical data.
Product Data Management (PDM)	Various - CAD Vendors and others	Designers - Prime Contractors	Product and Process Data	PDM systems are just becoming available. The current focus for PDM systems is on managing design (CAD/CAM) data, though the concept of PDM systems is to manage all data associated with a design. This would include financial data, procurement data, a configuration management functions would be supported by the PDM systems, and more. PDM systems ultimately could support Lockheed's Smart Product Model concept.
OLE	Microsoft	Microsoft	Standard	
SEER		Lockheed Sanders	Application	Parametric cost model being used by LS on the RASSP program.
Visualization Tools	CAD Vendors (starting) and others	Designers and Manufacturers	Interaction	Visualization tools provide dynamic graphical representations of CAD models. The lack of integration and between CAD packages and visualization tools has caused CAD vendors to consider offering visualization tools as additional components of their CAD packages. There are commercial packages currently available and being used, such as Gemini and Wavefront.

CVP Tools				
Tool	**Developer**	**Users**	**Category**	**Description**
CorpsSam		Raytheon	Application	CorpsSam is a distributed test bed for missile systems engineering. The architecture allows for the use of low fidelity models, high fidelity models, or portions of real systems. A user can roam through a virtual world or ride with a specific object in a Stealth mode. CorpsSam is being used to support Raytheon's EFOG-M program.
BLRSIM	US Army STRICOM	will be the Battle Labs	Integration	STRICOM is sponsoring the Battle Lab Reconfigurable Simulator (BLRSIM) program which is developing an easily reconfigurable simulator with man-in-the-loop interaction to support concept evaluation and formulation at the Battle Labs. BLRSIM is in the R&D phase. The technology for BLRSIM exists, the work required involves integrating elements and pulling everything together.
Polyshop	STRICOM/ UCF-IST	None- R&D	Data Creation, Integration	The Institute for Simulation and Training (IST) has been funded by STRICOM to develop Polyshop. Polyshop is to be a networked virtual CAD environment. Polyshop allows a modeler to see and manipulate data in a true 3D perspective. Modelers are able to construct and manipulate a design through a graphical user interface which contains objects with counterparts in the physical world. The networking element allows subject matter experts in other locations to be brought into the world, or multiple modelers to work on creating the same design. Related efforts are ongoing at the University of North Carolina (Isac), at Georgia Tech, Stanford University (Design Space), and the University of Virginia (Worlds in Miniature).
SILMA		Lockheed Martin Electronics, FL	Application	SILMA is a virtual coordinate measuring machine which LM is using to create and prove inspection programs. SILMA creates, simulates and edits programs for CMMs, allows users to create and test programs without tying up CMMs, and identifies and corrects costly errors before they reach the factory floor.
Shastra	Purdue University		Integration	Shastra is a scientific and engineering collaborative design tool. Shastra facilitates geometric design for simulation, visualization, and simulation. With Shastra, Purdue is attempting to develop the next generation design environment, where geographically distributed teams can create , share, manipulate, analyze, simulate, and visualize complex 3D geometric designs over a heterogeneous network of workstations and supercomputers.
ICM	Stanford Center for Design Research		Integration	Interdisiplinary Communications Medium (ICM) is a collaborative design tool being developed by the Stanford Center for Design Research. ICM provides shared graphs in a multimedia environment to allow engineers on a design team to explain their design rational, to propose designs and design changes, to interpret design decisions by other team members and to critique the information which is presented for their review. ICM works across a network by providing notification services to team members as a part of the infrastructure, and providing graphical services to help the engineers interact with the product.

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APPENDIX F
CATALOGUE OF CVP APPLICATIONS, DEMONSTRATIONS AND IMPLEMENTATION
(Includes Related Government Programs/Projects)

CVP Applications, Demonstrations and Implementations	
Site/Organization	**Description**
TARDEC	TARDEC is doing a considerable amount of work in the area of virtual prototyping. They have projects that address the use of virtual prototyping technologies at every stage of the development process (concept, preliminary design, survivability, wargaming, operator interface, and producibility). TARDEC has not addressed the use of collaborative tools or the integration of all of the virtual prototyping activities. At this time there is no underlying data management structure that allows changes to be made in one area to automatically impact related areas; this is all done manually. TARDEC is working with PM Bradley and PM Abrams to apply virtual prototyping technologies to elements of these programs.
Lockheed/ARPA SBD	Under the ARPA Simulation Based Design (SBD) program, Lockheed has demonstrated a collaborative virtual prototyping environment. Lockheed has been funded to expand/improve the SBD environment. The expansion/improvement is focused on developing a generic product development environment which is domain independent and developing domain dependent product development systems. The JAST program is expected to become part of the Lockheed SBD program. The current environment is based on an object oriented database which maintains a smart product/process model for the development product. The smart product model contains the geometric characteristics of the product as well as all of the processing characteristics. Simulation tools are used to evaluate the product design, the manufacturing process associated with the product, the operational performance of the product and system, and interactions of the system with outside elements. Various collaborative tools have also been developed. These include an electronic engineers notebook and tools supporting the linking and integrating of various simulations. The SBD environment developed by Lockheed offers considerable potential in improving future acquisition environments. Currently the SBD system is not robust enough or complete to support a full acquisition program. The cost to develop and use such an environment is considerable. The tools used within the Lockheed SBD environment include MECE (Multi Engineering Collaboration Environment), IDEAS (CAD package), VDE (Virtual Design Environment) Viewer, Simbuilder, Netbuilder, PartNet, and a proprietary object oriented database.
GD Electric Boat/ARPA SBD	As part of ARPA's SBD program as well as through internal efforts, GDEB has developed and implemented Electronic Visualization Rooms (EVR) to support GDEB role as the designer for NAVSEA's New Attack Submarine (NSSN). GDEB has four EVRs at their New London facility and one at NAVSEA. All rooms are connected with high speed lines and configured the same. The rooms are specially designed for IPPD teams. They provide access to all computer systems including CAE tools, Computer Vision, and graphics engines. NAVSEA is using the rooms to participate in IPPD team meetings. The EVR support virtual collocation of IPPD teams.
United Defense/ Bradley A3	Vendors for A3 components are required to obtain SUN workstations with Matrix software. The vendors use these systems to develop models of their components to be given to United Defense. United Defense integrates the models to determine the overall functionality and performance of the A3 system. As components become available they replace the models with hardware-in-the-loop simulations.
SAVE	Lockheed Sander's SAVE program is an initiative out of the JAST program office. The objective of the SAVE program is to pull together tools that benefit the manufacturing design process. The SAVE program is using the RASSP Design Environment to integrate commercial tools into a SAVE Development Environment. LS hopes to commercialize the RASSP Design Environment as a result of the SAVE program.

CVP Applications, Demonstrations and Implementations	
Site/Organization	**Description**
RASSP	As a prime contractor for ARPA's RASSP program, Lockheed Sanders is developing a new approach by which embedded signal processors are designed, manufactured, upgraded, and supported. The purpose of the RASSP program is to deliver a new design process. The objective is for this new design process to result in a four fold improvement in the life cycle cost and a four fold speedup in development time. LS is creating a standardized data environment using a PDM systems. LS is looking at using STEP as the potential format for storing the data in the PDM system. STEP AP 210 will hopefully support LS in this area. LS is using SEER as their cost model. SEER is a parametric cost model. As part of the RASSP effort LS is using VHDL to support the development of virtual prototypes in a collaborative virtually collocated environment. VHDL provides a software (virtual) description of electronic hardware. Source code management over a virtual database was a very challenging aspect of this effort.
Northrop Grumman Virtual Enterprise Integration Infrastructure	NG is moving towards a virtual enterprise concept. They are developing an infrastructure which is focused on establishing virtual collocation services, requirements analysis and tracking, management information systems, and engineering tool integration/product data management. NG is using a modular approach to developing the infrastructure. The modular approach enables the insertion of new technology solutions in the future. Security cultural impacts, and proprietary data issues remain key concerns.
Sikorsky Comanche Program	The Comanche program is a good example of the benefits of IPTs and CVP technologies. The manufacturing process was a first time fit, Sikorsky estimated the average unit cost was reduced by 20-30%, and the prototyping cost of the forward fuselage was about 67% of historical costs.
Sikorsky S-92 Program	Sikorsky's S-92 program is a multinational initiative to develop a commercial 19 passenger helicopter. Sikorsky is working to establish a UNIX based 3-D collaboration environment to enable collaboration in the area of production engineering. Due to the multinational aspect of this program virtual collocation is a requirement.
NIIIP (National Industrial Information Infrastructure Protocols)	The NIIIP Consortium organized to develop open industry software protocols that will make it possible for manufacturers and their suppliers to effectively interoperate as if they were part of the same enterprise. These protocols will enable a new form of collaborative computing is support of highly efficient and globally competitive "Virtual Enterprises". The NIIIP Consortium is a group of 18 companies led by IBM. Each organization provides a unique set of technologies and/or end user experiences needed to define and implement the NIIIP architecture. GDEB is involved with IBM's NIIIP TRP. GDEB is helping to define what capabilities are needed to establish a virtual enterprise. This program will have a demonstration in October 1995.
EFOG-M	Raytheon's Enhanced Fiber Optic Guided Missile program is using virtual prototyping. This effort is prototyping a communications/software environment rather that a physical systems. A major challenge they face is determining the level of fidelity they require in producing the mock-ups of the vehicle and gunner console. The mockups allow a driver to mover through a simulated battlefield and a gunner to guide a missile through the battlefield based on a simulated infrared image from a missile.
Raytheon's Vertical Partnering Facilitation Program	This ManTech sponsored effort is finding an approach to allow subcontractors to access a prime contractor's CAD/CAM tools and associated databases.
AAAV	The Institute for Simulation and Training (IST) is supporting the Advanced Amphibious Assault Vehicle (AAAV) program in applying virtual prototyping in DIS environment to support the assessment of different operational concepts.
Lockheed Martin Electronics Division Advanced Fire Control System Pilot Project	LM has a pilot project to design an Advanced Fire Control Systems. This project is employing an art-to-part concept which requires no paper drawings to be delivered. LM will be developing an Internet access architecture which enables all companies involved to communicate and exchange information electronically. The project is currently using a direct access/dedicated network architecture between the three major organizations involved to support CAD data exchange. LM is using a security systems which only allows outside access to applications which control the access to the data. The data storage areas are protected from access by

CVP Applications, Demonstrations and Implementations	
Site/Organization	**Description**
	outside users. LM's PDM (from IBM) system is being used to manage the data access by the applications. LM is predicting significant benefits to be demonstrated from the pilot project (more than a 50% reduction in design hours).
JAST	The JAST program is a joint Services team creating the building blocks for affordable, successful development of the next generation strike aircraft weapon systems. The JAST mission is to: · Facilitate Development of Fully Validated and Affordable Operational Requirements, · Facilitate Maturation of Leveraging Technologies, · Demonstrate Leveraging Technologies and Operational Concepts, and · Develop and Deliver Products and Processes to Initiate Follow-On EMD Program(s). The JAST program completed its concept exploration phase in December 1994. The key conclusion of this phase was that a family of aircraft can meet tri-Service needs with overall potential life cycle cost savings of 33 to 55%. The cost benefits come from a common depot, commonly supported logistics trail, and increased joint Service interoperability. The program entered the concept development phase in December 1994 with the electronic award of 24 contracts worth $130 million. The primary emphasis of this phase is to develop aircraft system designs that take advantage of the "family of aircraft" concept and to define necessary leveraging technology demonstrations and an integrated plan for conducting the follow-on concept demonstration phase.
DICE	The DARPA Initiative in Concurrent Engineering (DICE) program, which is no longer in existence, developed and demonstrated many of the technologies supporting an IPT. Some of the technologies included the electronic design notebook which is now known as MECE within Lockheed's SBD program, demonstrated the use of application wrappers to enable interoperability among applications, and an IPPD design network. The DICE program was run out of the University of Iowa.
MADE	The Manufacturing Automation and Design Environment (MADE) program will drive the next generation of enabling technologies and CAD tools for design space exploration, design reuse, design knowledge sharing, and design rationale capture. Interoperability of tools and design team collaboration across time and space are key objectives. Development is application-driven, with demos in electro-mechanical assemblies like missile seeker gimbals, where geometry and function are closely intertwined. The MADE research community fosters interaction among universities, defense contractors, and tool vendors.
CALS/IPDE (JCALS and JEDMICS)	CALS is a core strategy to share integrated digital product data through a set of standards to achieve efficiencies in business and operational mission areas. The strategy consists of the following elements: - Business process change - Use of leading edge information technology - A shared information environment - Use of international standards - A structured management approach The DoD is committed to incorporating CALS into functional process improvements. As DoD applies the best technologies, processes, and standards for the development, management, exchange, and use of business and technical information among and within governmental and industrial enterprises, an Integrated Product Data Environment (IPDE) will be generated. The IPDE is defined as the business environment created by the application of existing national and international standards, practices, and technologies to automate the management and exchange of information. The IPDE directly enables Integrated Product and Process Development while increasing the agility and decreasing cycle times of the Defense Enterprise. CALS is founded on the recognition that affordable, readily accessible, and timely technical and business information is a critical element of the acquisition process. The two flagship programs underneath the CALS umbrella are JCALS and JEDMICS.
JLSC (DMSS and	The Joint Logistics Systems Center (JLSC) is chartered to achieve Corporate Information Management (CIM) goals for assigned

CVP Applications, Demonstrations and Implementations	
Site/Organization	**Description**
MMSS)	Department of Defense (DoD) logistics business areas by managing the design, development, implementation, and sustainment engineering of an integrated DoD logistics process system, as well as facilitating development and implementation of improved business practices. Leading this effort are the JLSC programs for development of standardized logistics systems, specifically the Depot Maintenance Standard System (DMSS) and the Materiel Management Standard System (MMSS).
AM3	The Affordable Multi Missile Manufacturing (AM3) program is an ARPA/Tri-Service Advanced Technology Demonstration (ATD) whose objective is to demonstrate advanced missile design and manufacturing enterprise concepts and systems that can substantially reduce the cost of DoD's portfolio of tactical missiles and smart munitions while maintaining product quality and performance and allowing rapid insertion of new technology. The AM3 program will define, validate, implement and demonstrate key changes to missile product architecture and enterprise processes and systems that significantly reduce missile costs. The four AM3 teams include virtually all of the tactical missile prime contractors, key component suppliers, technology vendors, and world class commercial manufacturers.
Agile Manufacturing Program	The deployment of Agile Manufacturing business practices and enabling technologies will create an expanded envelope for made-to-order defense products from commercial enterprises by allowing efficient production in arbitrary quantities of customizable, reconfigurable, and upgradeable products, supportable over the life cycle. The Agile Manufacturing program is developing and demonstrating these agile business practices and enabling technologies to achieve accelerated implementation of next generation manufacturing concepts, practices, and technologies in US industry. Over 25 demonstration programs were initiated in FY 1994-95. The Agility Forum at Lehigh University is the industry forum that will be the deployment mechanism. Recent efforts and the thrust until the end of the program will be to support the efforts of the Agility Forum to create assessment tools and a knowledge base continuing the results of the funded projects. These results will include case examples, best agile practices, legal templates, software tools, and network services. This ARPA program is part of a joint Agile Manufacturing Initiative with the National Science Foundation (NSF). NSF has funded three Agile Manufacturing Research Institutes (AMRIs) in electronics, machine tools and aerospace at Rensselaer, University of Illinois at Urbana-Champagne, and University of Texas-Arlington.
ECRCs	The Electronic Commerce Resource Center (ECRC) Program has been established to assist small and medium-sized manufacturing companies to keep pace with rapidly evolving technologies and business practices. The mission of the ECRC program is to promote awareness and implementation of electronic commerce and related technologies into an integrated civil-military industrial base. This will help manufacturers improve their competitive posture in global markets and subsequently serve to strengthen the U.S. military industrial base.
Haley Industries Limited	Haley Industries (a sand foundry specializing in castings for aerospace applications) along with Gudeon Brothers (a major tooling supplier) and Pratt & Whitney Canada (Haley's largest customer) established a "CATIA partnership" in an effort to reduce the lead time for new development programs with Pratt & Whitney Canada. Haley estimates that this partnership has led to approximately a 50% reduction in lead time. The CATIA partnership allows all three organizations to exchange CAD files without translating to IGES and has improved collaboration among the three organizations during design efforts.

CVP Applications, Demonstrations and Implementations	
Site/Organization	**Description**
MARS Virtual Reality Simulator	The objective of this program is to design, develop and evaluate a low-cost, portable simulator for teaching junior MARS officers the conning skills required of an Officer of the Watch (WOC). The Canadian Navy requires the use of training simulators to avoid the high cost and difficulties of training officers at sea. Other factors, such as fleet reductions and growing reliance upon the reserves, have amplified this requirement. The Chief of Maritime Doctrine and Operations (CMDO) requested the investigation of technologies that would enable the exploratory development of a simulator for training ship-handling skills. A prime requirement of the system was the ability to simulate formation maneuvers. Several emerging technologies provide inexpensive or novel components that can be exploited in the development of training simulators. These technologies, which include virtual reality devices, voice recognition, computer graphics, local and long range networking. expert systems and precision tracking, allow inexpensive, alternative design approaches for training simulators. Further, they permit portability, generic application, objective measurement of performance, and reduction in the number of instructional support staff. However, few practical applications have attempted to reduce the technical uncertainty associated with their use. An exploratory development model (XDM) of the MARS Virtual Reality Simulator (VRS) has been constructed to determine the technical challenges and risks associated with the use of virtual reality technologies and to demonstrate proof-of-concepts. An iterative design approach has been used. Involving subject matter experts from Venture, the Naval Officer Training Center (NOTC) in Victoria, British Columbia. One of the three design reviews included appraisal and testing of the XDM at the Defense and Civil Institute of Environmental Medicine (DCIEM) by four students who were trained in the simulator which it was controlled by Course Training Officers. A more extensive development evaluation and field trial of the XDM began in October 1993 at Venture. The MARS VRS consists of two components: (1) a network of simulators that can be reconfigured to model a variety of ship types for simultaneous training of formation maneuvers, and (2) the means for recording and animating the maneuvers of ships at sea.
Virtual Prototyping of Compartment Arrangements	Background: The complex 3-D geometry's typical of warship compartment arrangements combined with the intensive use of available space to fit equipment and furnishings demand advanced visualization techniques to optimize layouts. The same technologies utilized in the DCIEM MARS VRS project for training purposed could be used as a design tool to forestall costly reengineering and possibly as a replacement for physical mockups. Vision: This project is to provide a rapid dynamic 3-D visualization capability for ship's compartments during the definition and all design phases of new products, refits, mid-life updates and significant engineering changes. Status: This project is to be executed in two tasks. The first will conduct a definition study to consider long term requirements and evaluate alternative strategies to satisfy research issues. The second will select, develop, and trial the most promising COTS alternative

CVP Applications, Demonstrations and Implementations	
Site/Organization	**Description**
Intelligent Computer Aided Drawing and Design (ICADD)	Background: Hardware and software improvements have advanced the state of the art of Computer Aided Design (CAD) to the point where it is used on virtually every ship design and rearrangement problem. To date however, compartment arrangement drawings, which have a tremendous influence on the ultimate level of habitability, human engineering and safety, are still reviewed manually via paper prints. Aside from the costs and inefficiencies induced by converting electronic data into thousands of paper drawings, there are dwindling human resources available to review them. DCIEM and DMSS 2-6 have been investigating the development of computer-based tools to facilitate the application of human factors engineering (including habitability, human engineering, system safety engineering, and ship arrangements) in ship design and changes. Vision: Develop a software shell with intelligent software which would incorporate COTS software modules on a common platform to aid the DMSS 2-6 design development and review process, including engineering change projects. Future design evaluation and development will be done via 2-D and 3-D electronic models incorporating intelligent constraint checkers and case based reasoners. Status: A three year contract was awarded February 1994 under DPAS 0519L for $550K to consortia compromised of Humansystems Inc. (Milton, Ontario), Genicom Consultants Ltd. (Montreal, Quebec) and Protogon Systems Inc. (Ottawa, Ontario). System architecture built around the UNIX based SGI Indigo platform and incorporates 3-D anthrometrically correct mannequin software engine SAFEWORK, Multi-window CAD (Integraph/AutoCad) with “drawing redlining” capability with associated peripheral hardware. Work progressing on automated constraint checkers, contact-dependent checklist look-up module (based on OF/NATO Standards and Specifications), case based reasoner module, and integration with ship establishment modeling tools. Report generator module based on InterNet compatible file formats (*.html).