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CURRENT STANDARDIZATION AND COOPERATIVE EFFORTS RELATED TO INDUSTRIAL INFORMATION INFRASTRUCTURES

Robert I. Winner, *Task Leader*

May 1993

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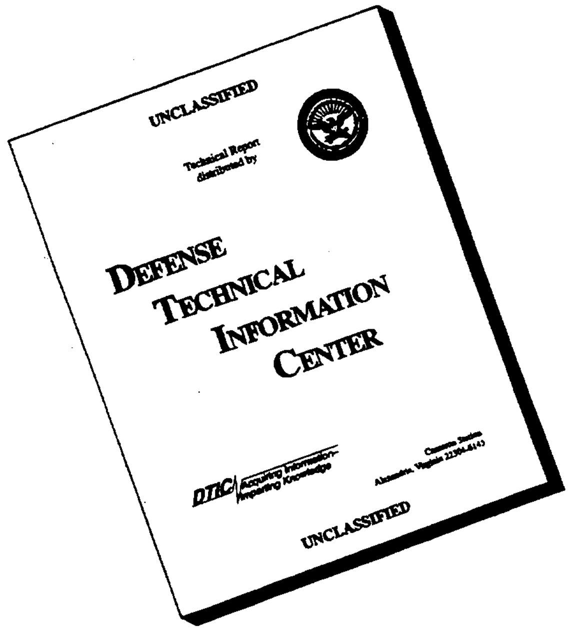

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PREFACE

This document was prepared by the Institute for Defense Analyses (IDA) under the Advanced Research Projects Agency (ARPA) Assignment A-160, DARPA Engineering and Manufacturing, and fulfills an objective of the task, "to assist DARPA in planning its approach to engineering and manufacturing process technology." The work was originally sponsored by the Computer-Aided Acquisition and Logistics Support Directorate of the Office of the Assistant Secretary of Defense (Production & Logistics) in cooperation with the U.S. Air Force Manufacturing Technology Directorate and the Software and Intelligent Systems Technology Office of ARPA, under Task Order T-B5-849, Defense Industrial Information Infrastructures.

This document was prepared as a companion document to IDA Paper P-2664, *Information Infrastructures for Integrated Enterprises*, which contains the information on industry business requirements and rationale for enterprise integration.

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SUMMARY

Purpose

The Institute for Defense Analyses (IDA) was tasked by the Department of Defense (DoD) to study information infrastructures for enterprise integration. Two documents resulted, IDA Paper P-2664, *Information Infrastructures for Integrated Enterprises*, and IDA Document D-1386, *Current Standardization and Cooperative Efforts Related to Industrial Information Infrastructures*. The information presented here in this document provides an assessment and a baseline of 85 key standards and technologies that will be required over the next 10 years to build the necessary components of an information infrastructure. Both public and proprietary standards are reviewed since important contributions to an information infrastructure will come from both sources. A brief description of each standard and technology is provided, and its importance to information integration is assessed along with its current status.

The team set out to accomplish the following objectives:

- Identify, organize, and present available technology components from which a United States information integration strategy can be coalesced. These technology components are derived from current standards and from standardization and pre-standardization efforts.
- Identify specific opportunities to accelerate the development and adoption of components and/or to increase the likelihood of their success.

Scope and Methodology

The analysis of critical standards and technologies depends heavily on the choice of a framework or a reference model for expressing "what the customer wants." The use of requirements derived from business needs can be defended as reflecting the wants and perceptions of those who must ultimately pay the bill for enterprise integration. It also includes the organization, procedural, and personnel aspects of enterprise integration, as well as the technical ones.

The approach also takes a broad view of the importance of standards and technologies in meeting the general needs of an information infrastructure. It does not differentiate between standards and technologies with a broad scope and those addressing a narrow set of requirements.

Using the baseline data, a number of useful questions concerning the status of standards, technologies, organizations, and programs relevant to information infrastructures for enterprise integration can be answered directly. Examples of such questions include the following:

- What organizations and programs are concerned with information modeling?
- What standards and technologies are proposed or in place concerning user interfaces?
- What organizations and programs are involved with POSIX (Portable Operating System Interface for Computer Environments), and what are their interests?

Other questions, such as "Which of the standards and technologies are most critical to success in implementing a National Information Infrastructure, and what is their current status," cannot be answered directly from the baseline data. They require further analysis and often additional data. The specific analytic techniques needed, of course, depend on the question being asked. Consequently, the document presents an example analysis of the question just raised, to demonstrate the types of analyses possible with the baseline data.

Findings and Conclusions

A generic view of manufacturing, adapted from the Advanced Manufacturing Technology (AMT) Standards Reference Model [1], provided a convenient way to categorize activities engaged in by the various organizations and programs and to characterize the activities to which particular standards and technologies pertain. Ten technical categories were used in this study: Integration Frameworks and Architectures, Operating Systems and Distributed Environments, Communications, Data Management Systems, Application Development Tools and Methods, Data Representations, Information Modeling Tools and Methods, User Interfaces, Programming Languages, and Security Tools and Methods.

Integration Frameworks and Architectures and *Operating Systems and Distributed Environments* are critical foundational technologies which must be established. These categories scored the highest across all evaluation frameworks. Several potentially important standards and technologies were identified. Since much of the work in this area is proprietary or consortial, there is still a need to promote standards in these areas. The lack of unifying standards may lead to market fragmentation that will slow the development of an information integration infrastructure.

Data Management, Communications, and Data Representation standards and technologies are next in importance. The information infrastructure requires standards that support highly integrated information management systems across the entire enterprise. The need for standards in these areas has long been recognized as evidenced by the preponderance of standards available. There is still a need to organize these standards into a consistent framework and to ensure that they are compatible.

Application Development Tools and Methods and *Information Modeling Tools and Methods* are scored as equally important for information infrastructures as the group above. However, standards development in these categories is less advanced. This reflects their focus on the broader process of translating requirements into system implementations, rather than on data structures within those implementations.

Other categories such as *User Interface, Programming Languages*, and *Security Tools and Methods* are also important. Standards and technologies in some of these categories are more important in the development of applications. Since this report focused on information infrastructure, they did not score very high.

The importance of integration frameworks supports the necessity of identifying a reference model that can be used to guide the selection of standards and technologies for an integrated information infrastructure. The need for a reference model is widely recognized. Several groups are developing reference models in this area, including proprietary models, vendor models, and standards efforts. *Consensus is needed around a single model (or group of models) from which a coherent set of standards can be developed.* A single reference model, with its benefits for analysis and decision-making, does not imply a single view of information integration. Business needs vary with the corporation, its market sectors, and its strategies. It is unlikely that a single set of standards will emerge to fit all these varying needs. Still, a well-designed reference model can support profiles of standards suited for different needs (such as the use of the Open Systems Interconnection (OSI) reference model for communication standards).

Further, in the context of a National Information Infrastructure, needs derived from education, health care, and scientific research, among other areas, will also be important. Unexpected uses of the infrastructure and resulting changes in the way the nation lives and works will occur. Any reference model must be flexible enough to incorporate this pattern of infrastructure development.

It is important to maintain a sense of timing and evolution about infrastructure development. The U.S. Air Force Enterprise Integration Program is an effort focused on identifying appropriate responses to near-term demands for information integration. Likely, these responses will take the form of finding ways to use existing and near-term standards and technologies more effectively. The needs anticipated 10 years or more in the future appear to require the development of new technologies and architectures leading to systems of autonomous modules. Also the development of strategies and methods for aiding the transition towards these forms of information integration must be planned and pursued.

1. OVERVIEW

The American business environment is facing a significant change in the next 10 years. Individual companies are moving towards greater levels of integration, both internally and with their suppliers and customers. In this century, the nation laid out a long-term plan for a network of national highways that today provide a critical infrastructure for defense mobility and for linking companies to their suppliers and customers. Today we face a similar need for an information infrastructure to enable the integration of information in and among enterprises. One of the biggest challenges facing the development of this infrastructure is the identification and development of the necessary standards and technologies.

Information technologies have matured to the point where they provide sufficient support for today's required "integrating" tasks, and they have great potential for continued development of powerful capabilities. One need only pick up any computing periodical to be overwhelmed by both the multitude of products available and the many advances being achieved.

This baseline report has the following objectives:

- Identify, organize, and present available technology components from which a United States information integration strategy can be coalesced.
- Identify specific opportunities to accelerate the development and adoption of components and/or to increase the likelihood of their success.

In support of these objectives, this report includes the following:

- An overview of programs, standards (both officially sponsored and *de facto*), and standards organizations.
- An analysis of the deployment (development and market building) of a selection of standards and technologies.
- An example analysis identifying critical standards and their status.

This report provides the reader with an assessment of key standards and technologies (STs) that will be required over the next 10 years to build the necessary components of the information infrastructure. It establishes a baseline of STs, documents the organizations and programs (OPs) that support them, classifies each technology's contribution to the total integration picture, and assesses its importance to the needs of enterprise integration and its current status. This assessment provides insight in developing strategies for the most critical STs required to establish a successful information infrastructure.

This report has four sections and five appendices. The first section is this overview. The second section establishes a "baseline" of data documenting a broad array of information-oriented standards and technologies. It summarizes information contained in the profiles of OPs described in Appendix A. These profiles describe the primary OPs that are behind these STs. This section also summarizes the brief synopses of STs pertinent to building an information infrastructure as given in Appendix B. The report looks at both private and public technologies since elements of a total solution may come from either source. Critical elements existing only as proprietary solutions help to identify where new standards efforts may be needed. The second section also references data on the standards deployment activities of OPs as presented in Appendix C. This information, identifying OPs involved in technology development and market building for standards, is useful in promoting appropriate development and transfer strategies.

Standards, technologies, organizations, and programs (STOPs) are defined as broadly as possible in this report. Thus, there may be overlaps in definition or categorization. The categorization is meant as an aid to organizing the vast amount of information on this subject, not as a definitive classification scheme. In this report "organizations" and "programs" refer to the companies and efforts that are behind the development and deployment of STs.

In the third section, example analyses identify critical STs and their current status. The analyses uses a model based on the Quality Function Deployment (QFD) methodology. QFD is a structured technique for articulating needs, relating needs to means for meeting those needs, and detecting complementing and conflicting requirements. The methodology requires scoring the fit of solution features to requirements. The model used here is described in sufficient detail that others could use their own scoring criteria to generate different analyses. The intent is to provide a useful first-cut identification of areas needing work, along with a tractable method for understanding the rationale behind the choices. Data for the analyses is drawn from this report's baseline and from related work such as the on-going Enterprise Integration Program (EIP) and the National Institute of Standards and Technologies (NIST) Application Portability Profile (APP).

The analyses identify potential STs that are critical to building an integrated information infrastructure. Once these STs are identified, the charts and information in Section 2 of this report and supporting appendices will provide further definition of the specific technologies, the organizations behind them, and the potential deployment activities where additional development could significantly leverage the success of those STs.

The final section contains a number of observations, conclusions, and issues that resulted from this effort.

Overall, the report documents an organized perspective on activities to support an information infrastructure. This perspective can be used to help identify key aspects about those activities requiring further development, leading to the realization of an adequate U.S. information infrastructure.

An earlier version of the baseline was reviewed with an external panel of experts. This report incorporates the review panel's advice, given its constraints and timetable. Guidance was given in two directions: the need for identification of business scenarios that drive enterprise integration applications, and the necessity of choosing and applying an architecture or framework to guide the selection of standards and technologies. In response to the first issue, the report uses the results of the EIP Needs and Requirements Analysis, presented in Section 3. In response to the second issue, the report uses technical categories adapted from the Advanced Manufacturing Technology (AMT) Standards Reference Model [1] as a default means of grouping STs in the context of information infrastructures for enterprise integration. The report does not intend to suggest that this grouping meets the long-term need for an adequate framework. Discussion of the need for a standard reference model of enterprise integration appears in Section 4.

2. ESTABLISHING A BASELINE

This section presents perspectives of current major efforts to develop standards, technologies, organizations, and programs (STOPs). An examination of key activities within these efforts has resulted in the documentation of a baseline of these STOPs. This baseline serves both as a stand-alone reference and as input data for further analyses (such as Section 3).

The establishment of the baseline was done through an extensive data collection effort. Information was gathered from other reviews both in the literature and in related programs (such as the EIP Needs Analysis and State of the Art Assessment tasks). Input was also obtained from the Institute for Defense Analyses (IDA), Microelectronics and Computer Technology Corporation (MCC), NIST, and the review panel listed at the end of the Preface. Relevant OPs were selected and examined. These include both official standards-setting organizations and organizations that are involved in other aspects of standards development and deployment. Both public and private programs were also considered when their primary objective was the establishment of some standard or technology component of the information infrastructure. Information STs were also identified and examined. These STOPs were then researched to identify their significant descriptive attributes.

One of the objectives of creating the baseline was to document an inventory of STOPs available for the development of an information infrastructure. To help assess this inventory, several different perspectives on the baseline data were created. By describing the STOPs from various perspectives, different aspects of these complex entities are more easily highlighted and recognized.

In developing the baseline, proprietary and *de facto* ST were included. In their current state, such STs would be inadequate in providing sufficiently open infrastructure components. Still, two reasons make their inclusion in the study useful. First, they represent capabilities that can be evaluated to provide an illustrative reference. Second, it may be more cost effective to open a proprietary ST than to develop a functionally equivalent neutral one.

The following subsections document the baseline, describe the ways data are formatted, and give the related rationale.

2.1 BASELINE DATA PRESENTATION FORMAT

Items that constitute the baseline are referred to as being either a standard, a technology, an organization, or a program. The following definitions are used here:

Standard*:* A definition of a method or technique, achieved either by a tangible specification or by stable implementations. These may be public or proprietary.

Technology*:* An embodiment of a method or technique that either is loosely defined (e.g., in early development), or refers to a broad class of capabilities (which may involve related but different standards).

Organization*:* A body of people that advances the development of STs and has a permanent existence beyond the development needs of any particular STs.

Program*:* A body of people that advances the development of STs, but has limited existence, usually tied to the completion of a phase or phases of ST development.

The baseline data are summarized in three subsections and presented in detail in three appendices. First, Section 2.2 describes several organizing concepts used to clarify and summarize presentation of the baseline data. Then, Section 2.3 introduces each of the organizations and programs in the baseline. Appendix A provides more detailed profiles of each of these OPs. Section 2.4 introduces the standards and technologies in the baseline. Appendix B describes each of these STs. Section 2.5 summarizes the relationships between the OPs and the STs by identifying which OPs drive various deployment stages of major STs. The details of these relationships are provided in Appendix C. Section 2.6 discusses possible uses of the baseline.

2.2 ORGANIZING CONCEPTS

To better understand the interrelationship among STOPs, it is useful to organize them in several ways: in terms of integration activities within an enterprise, in terms of views of the enterprise, and in terms of the deployment activities needed to successfully introduce integration technologies.

A generic view of manufacturing, adapted from the AMT Standards Reference Model [1], provides a convenient way to categorize activities engaged in by the various

OPs and to characterize the activities to which particular STs pertain. The ten technical categories used in this study are:

- Integration Frameworks and Architectures: Overall integrating representations, models, and schemas of the enterprise and its component parts (e.g., APP, SAA, GM-C4 frameworks).
- Operating Systems and Distributed Environments: Components used to provide system services (I/O, process management, and others) to applications (e.g., Portable Operating System Interface for Computer Environments (POSIX), Unix, MS-DOS, NetWare)
- Communications: Components used to connect applications, allowing applications to transfer data and control among themselves (e.g., Open Systems Interconnection (OSI) and Transmission Control Protocol/Internet Protocol (TCP/IP)).
- Data Management Systems: Components used to store, manage, and retrieve data. Data management includes knowledge bases, database management systems (DBMS), information management systems, data dictionaries, and schema implementations.
- Application Development Tools and Methods: Tools and methods used to model and build applications (e.g., application generators).
- Data Representations: High-level data representation standards (e.g., STandard for the Exchange of Product data (STEP) and Electronic Data Interchange (EDI)).
- Information Modeling Tools and Methods: Tools and methods used to construct models of the enterprise and its components (e.g., Integrated Computer-Aided Manufacturing (ICAM) Definition Language (IDEF) and Semantic Unification Meta-Model (SUMM)).
- User Interfaces: Components that allow users to interact with the applications making up the integrated enterprise (e.g., Motif and X/Windows).
- Programming Languages: High-level languages used to represent algorithms. This category includes APPs (e.g., Ada and C++).
- Security Tools and Methods: Tools and methods used to control access to applications and data (e.g., Kerberos).

An second way of organizing baseline STs is in terms of the view of enterprise integration for which the ST is relevant. The three views used here are as follows:

- Business View: View of an enterprise held by the technology user. It is based on the concept of looking at a tool (software or otherwise) as a means to an end, with no concern for how the tool actually works. The business view includes satisfying enterprise goals, justification requirements, performance measurement, and organizational activity support. For this view, the overall function of a tool is important, not the underlying technology.
- Information View: View held by information management specialists. It is concerned with data flow within the enterprise. The Information View looks at where data comes from and where it must go, but not how it moves.
- Technology View: View of an enterprise that encompasses the standards and devices used to implement and execute applications.

A third organizing concept is the sequence of deployment activities needed for successful technology development and market building. Eight deployment activities are considered in this report:

Technology Development

- Modeling: Which OPs are responsible for developing the models used by the ST.
- Standards: Which OP is responsible for developing the standard associated with the ST.
- Method/Tool: The OPs that are developing methods or tools which use and support the ST.
- Prototype: Which OPs have developed prototype systems using the ST.
- Standard Validation/Demonstration: Which OPs are involved in validation or demonstrations of the ST.

Market Building

- Product Certification: Which OPs are responsible for developing tests or certifying products that use the ST.
- User Guidelines: Which OPs are developing guidelines on how to best use the ST.

- Awareness and Education: Which OPs are working to increase user awareness of the ST.

2.3 OPs PROFILES

Profiles in Appendix A provide an overview of each of the 27 organizations and programs included in the baseline study. Each profile has two parts: a matrix and accompanying textual information. The matrix relates the activities engaged in by that OP to the technical categories and to the view of enterprise integration introduced above. The text provides non-technical profile information about that program or standards organization. An overview table, Table 1, "Organization Summary Chart," on page 11, summarizes for each of the organizations the areas in which they are active.

2.4 STs BRIEFS

ST briefs provide a succinct description of standards and technologies that may affect the development of an information infrastructure. The 85 STs considered in this study are described in Appendix B. A summary listing of these STs, organized under the 10 technology categories, appears in Table 2, "Standards Summary Chart," on page 13.

2.5 OPs DEPLOYMENT FORCES

Deployment Force matrices indicate which OPs are involved in different aspects of developing and deploying the various STs in the baseline. As critical STs are identified, these matrices show which OPs may benefit from assistance with deployment activities. The matrices also identify critical deployment activities that still require a sponsoring OP. Deployment Force matrices for the 10 technical categories are given in Appendix C. Table 3, "Deployment Forces Summary," on page 15 summarizes the coverage of deployment activities by technical category.

2.6 USES OF BASELINE DATA

A number of useful questions concerning the status of STOPs relevant to information infrastructures for enterprise integration can be answered directly from the baseline data in the summary charts depicted in Table 1, Table 5, and Figure 1, and in more detail in Appendices A, B, and C. For illustration, we use the baseline data to address the following questions:

1. What OPs are concerned with information modeling?
2. What STs are proposed or in place concerning user interfaces?

3. What OPs are involved with POSIX, and what are their interests?
4. Which of the STs are most critical to success in implementing a National Information Infrastructure?
5. What is the completion and acceptance status of the critical STs?

The first question, "What OPs are concerned with information modeling?", can be answered from Table 1. More details on particular OPs can be found in Appendix A.

The second question, "What STs are proposed or in place concerning user interfaces," can be answered by consulting the list of STs grouped by technical category, to be found in Table 2, "Standards Summary Chart," on page 13. Descriptions of those STs can be found in Appendix B, and identification of OPs actively involved in deploying specific STs can be found in the user interface technical category matrix in Appendix C.

To answer the third question, "What OPs are involved with POSIX, and what are their interests," requires (1) scanning the listing of STs grouped by technical category in Table 2, "Standards Summary Chart," on page 13, (2) noting the category of POSIX, and (3) then consulting the appropriate technical category matrix in Appendix C.

Many other interesting questions (e.g., questions 4 and 5) cannot be answered directly by consulting the baseline data. They require further analysis and often additional data. The specific analytic techniques needed, of course, depend on the questions being asked. The next section presents analyses of the two questions just raised, as examples of the types of analyses that the baseline data makes possible.

Table 1. Organization Summary Chart

	Integ. Framewks & Archs.	Comms.	OSs & Dis. Envs.	Data Mgmt. Systems	User Interfaces	Security Tools & Methods	Info. Modeling Tools & Methods	Applics. Dev. Tools & Methods	Data Reps.	Config. Mgmt.	Standard Libraries	Programming Languages
GOVT												
DoD	X	X	X	X	X	X	X	X	X	X	X	X
NIST	X	X	X	X	X	X	X	X	X	X	X	X
Industry Sector Org.												
AIA	X							X				
AIAG									X			
EIA		X							X			
IEEE		X	X			X	X	X		X		X
ISA										X		
MCC	X											
NCMS	X							X				
NEMA		X										
OMG	X			X			X					
SEMA-TECH	X							X				
SME		X										

Table 1. Organization Summary Chart (Continued)

	Integ. Framewks & Archs.	Comms.	OSs & Dis. Envs.	Data Mgmt. Systems	User Interfaces	Security Tools & Methods	Info. Modeling Tools & Methods	Applics. Dev. Tools & Methods	Data Reps.	Config. Mgmt.	Standard Libraries	Programming Languages
Tech. Sector Org.												
CFI	X	X	X	X				X	X		X	
COS		X							X	X		
IPO							X		X			
MAP/TOP		X								X		X
OSF			X		X	X		X		X		
UI			X		X							
Users Alliance	X	X	X	X	X							
X/OPEN			X	X				X				X
Other												
ANSI	X	X		X		X			X			X
IAB		X								X		
ISO	X	X	X	X		X	X		X	X		X
Private Comps.	X	X	X	X	X	X	X	X	X	X		X

Table 2. Standards Summary Chart

Category	STs
Integration Frameworks and Architectures	Portable Common Tool Environment (PCTE) CAD Framework Initiative (CFI) Engineering Information System (EIS) General Motors CAD/CAM/CAE/CIM (GM-C4) Integrated Computer-Aided Manufacturing Factory of the Future (ICAM-FoF) AD/Cycle Application Portability Profile (APP) Systems Application Architecture (SAA) Network Applications Support (NAS) NewWave
Operating Systems and Distributed Environments	Portable Operating System Interface for Computer Environments (POSIX) OSF/1 System V Release 4 Unix (SVR4) MicroSoft Disk Operating System (MS-DOS) OS/2 Mac (Macintosh) System 7 Object Management Group (OMG) Open Distributed Processing (ODP) Distributed Computing Environment (DCE) Object-Oriented, Change-Oriented Reference Environment (OO-CORE) Process-Oriented Management System (POMS) ANSAWare Cimplicity Distributed Object Management Facility (DOMF) Object Linking and Embedding (OLE) NetWare LANManager Vines
Communications	Transmission Control Protocol/Internet Protocol (TCP/IP) Manufacturing Automation Protocol/Technical and Office Protocol (MAP/TOP) Government Open Systems Interconnection Profile (GOSIP) Transparent File Access (TFA) Network Computing System/Remote Procedure Call (NCS/RPC) Government Network Management Profile (GNMP) X.500
Data Management Systems	Information Resource Dictionary System 1 (IRDS1) Information Resource Dictionary System 2 (IRDS2) Remote Database Access (RDA) Protocol SQL Object-Oriented SQL (OO-SQL) Hypermedia Common Data Model (CDM)

Table 2. Standards Summary Chart (Continued)

Category	STs
Application Development Tools and Methods	X/Open and POSIX APIs Integrated Design Support System (IDS) Knowledge-Based Systems (KBS) Application Generators PlantWorks Neural Net Source Code Control System (SCCS)
Data Representations	Standard for the Exchange of Product Model Data (STEP) Electronic Data Interchange (EDI) Initial Graphics Exchange Specification (IGES) Computer Graphics Metafile (CGM) Standard Generalized Markup Language (SGML) Raster Format Open Document Architecture/Interchange Format/Language (ODA/ODIF/ODL) Graphical Kernel System (GKS) Programmer's Hierarchical Interactive Graphics System (PHIGS)
Information Modeling Tools and Methods	ICAM Definition language 0 (IDEF0) ICAM Definition language 1x (IDEF1x) Yourdon Jackson System Design (JSD) Knowledge-Based Systems (KBSs) Structured Systems Development (SSD) Semantic Unification Meta-Model (SUMM)
User Interface	X-Windows (X) Motif Open Look POSIX 1201 (XVT) MS-Windows Presentation Manager DECWindows Macintosh Toolbox
Programming Languages	Ada C C++ Cobol Fortran Lisp Pascal Prolog Smalltalk
Security Tools and Methods	POSIX 1003.6 Kerberos DES

Table 3. Deployment Forces Summary

Category	# of STs	TECHNICAL DEVELOPMENT					MARKET BUILDING		
		Modeling	Standards	Method/ Tool	Prototype	Standard Val/ Dem	Product Certification	User Guidelines	Awareness & Education
Integration Frameworks and Architectures	4	xxxx	xxxx	xxxx	xxxx	xxxx	—	xxx	xxxx
Operating Systems and Distributed Environments	5	xxxx	xxxx	xxxx	xxxx	xxx	xx	xxxx	xxxx
Communications	2	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx
Data Management Systems	4	xxxx	xxxx	xxx	x	xx	—	xx	xx
Application Development Tools & Methods	1	xxxx	xxxx	xxxx	xxxx	—	—	—	xxxx
Data Representations	4	xxx	xxxx	xx	xx	xx	xxx	xxx	xxxx
Information Modeling Tools & Methods	2	xxxx	xx	xx	xx	xx	—	xx	xx
User Interface	7	—	xx	xxxx	xxxx	xxxx	—	xxx	xxxx
Programming Languages	3	xxx	xxx	xxxx	xxxx	x	x	—	xxxx
Security Tools & Methods	3	xxxx	x	xxx	xxx	xxx	x	xxx	xxxx
Symbol Coverage	— 0%		x 25 –10%		xx 50 –10%		xxx 75 –10%		xxxx 100%

3. ANALYSIS USING THE BASELINE AND RELATED DATA

This section illustrates how analysis of the baseline data can be used to support the process of developing and implementing integrated information infrastructures. To do so, we analyze example questions 4 and 5 from Section 2.6:

- Which of the STs are most critical to success in implementing a National Information Infrastructure?
- What is the completion and acceptance status of the critical STs?

These two questions relate to the criticality and status of STs relevant to enterprise integration. Identification of STs most critical to implementing a national information infrastructure can help sharpen monitoring efforts and direct resource allocation decisions. Knowledge of the relative status of STs can indicate where additional deployment efforts are needed to insure timely wide-spread adoption of critical STs.

3.1 DETERMINING CRITICAL STs

The approach used to answer the question, "Which of the STs are most critical to success in implementing a National Information Infrastructure," is to relate the baseline STs to expressed business needs. These needs represent the objectives and high-level business strategies of a successful integrated enterprise. This relationship is established in a two-step process, first relating business needs to activities that an integrated enterprise may undertake to satisfy those needs, and then relating the activities to supporting technical categories and STs within categories. The analysis presented here is based upon work done by the EIP Needs Analysis team, and makes use of the Quality Function Deployment (QFD) methodology.

3.1.1 QFD Methodology

QFD is a widely accepted methodology used in design to evaluate the importance of different (potentially conflicting) solutions in meeting system requirements. It is particularly valuable when there are many variables (needs and solutions) involved. Its use in this report allows for a reasonably consistent analysis of the complex information in the baseline. It is a systematic method of comparing over 80 STs in meeting the demands of an integrated information infrastructure. The results of analysis can be easily manipulated (like a spreadsheet) to determine the effects of different profiles of business needs and activities.

The basic concept of QFD is to relate "what the customer wants" (needs and requirements) to "how product features meet those wants" (solutions). A chart is used to record the evaluation of how each solution contributes to each need or requirement. Further, QFD supports decomposition, in that a solution at a higher level can, in turn, be considered a need at a lower level of analysis. In this analysis to identify critical STs, "customer wants" relating to "product features" translates at the first level into "business needs" relating to "activities," and at the second level into "required activities" relating to "STs" (Figure 1).

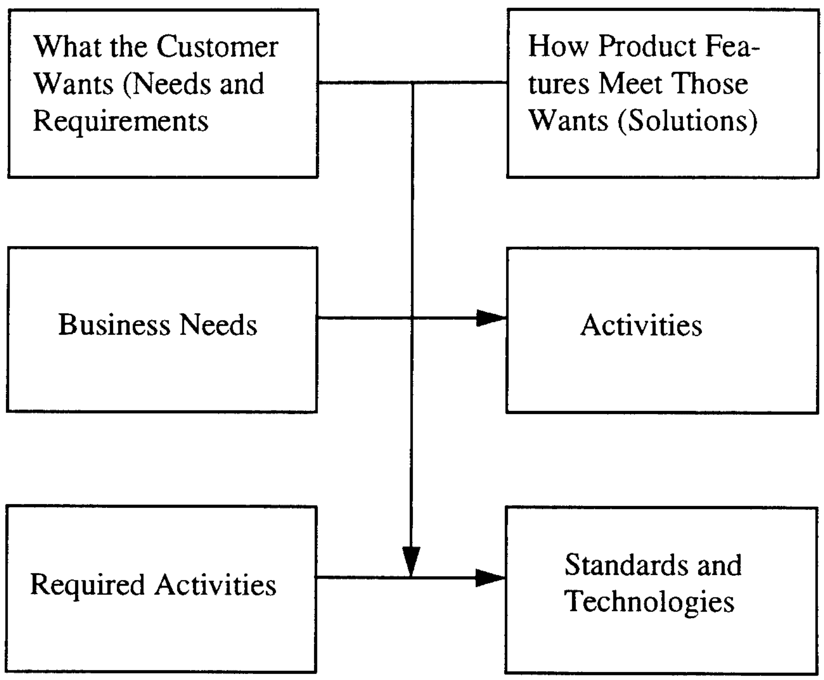

Figure 1. Relating Business Needs to Standards and Technologies

In a QFD matrix, each row represents a need or requirement, and each column represents a solution feature. At the intersection of each need and solution, a symbol is placed representing how well that particular solution satisfies that particular need.

A weighting can also be associated with each need or requirement (row) indicating its relative importance. (This weighting may be derived from higher level QFD analyses.)

The weighting and individual matrix values are used to generate a total score for each solution (column). This score indicates the overall importance of a particular solution in meeting the weighted needs.

The QFD methodology outlined here is independent of the specific method used to evaluate the fit of solutions to needs, and a number of different methods have been used in industrial practice. The methods used in this report are discussed in the following section.

3.1.2 EIP Requirements Matrices

As noted above, the EIP Needs Analysis team developed two levels of QFD charts to correlated high level business needs to specific technologies meeting those needs. The process used by the EIP team in developing their list of business needs and requirements is described in their report, *Needs Analysis and Requirements Definition.* At the time of this study, both charts were still in draft form, but their form as presented here is adequate to illustrate this analysis.

Both the EIP Needs Analysis team and the IDA team maintained close communication throughout their projects to ensure maximum leverage of each other's work. Toward that end, a common list of STOPs was used by each team. However, due to the difference in scope and objectives of the two projects, the second-level charts (relating required activities and STs) differ in some minor ways. Some needs and requirements not directly related to information infrastructure were dropped from the matrix presented here, and some relevant standards were added.

The QFD chart relating needs to requirements is presented in Figure 2. Brief descriptions of the needs and requirements are given in Appendix D. These definitions of needs and requirements are the result of EIP program efforts to define generic business functions and distill their effects. They are intended to capture the general case, and may not be the most appropriate for all situations. For a first-cut analysis in developing an information infrastructure, they provide a useful framework.

The following example describes how to read the QFD chart. One of the business needs identified (first row) is *Reduce Life Cycle Cost of Information Systems*. Looking across that row, several requirements (columns) intersect that row with a symbol shown at the intersection. The type of symbol indicates the degree of importance of the requirement to meeting the business need. Requirements such as *Communication Standards*, *System/Network Administration Standards*, *Data Interchange Standards*, *Reuse of Knowledge and Modules* have high importance to *Reduce Life Cycle Cost of IS*. *Bounded Customization*,

MATRIX		WEIGHTS
Strong	●	9
Medium	○	3
Weak	▲	1

Generic

Information Systems Integration

	Business Needs		Requirements	IMPORTANCE	Communication stds.	Systems/network admin.std.	Data interchange stds.	Reuse of knowledge and modules	Long term maint./access of data	Handle large quantity of data	Modular applications, systems	Application platform independence/interoperability	Distributed applications, systems	Data Management	Design Tools	Migration management	Enterprise framework/architecture	Tools/procedures for EI development/testing
Customer Oriented	Cost	Reduce Life Cycle Cost of IS		6	●	●	●	●	●	●	●	●	●	●		●	●	●
		Reduce Product life cycle costs	New product	9	○	○	●	●		○	●		●	○	●	○	●	
			Post-prod. dist. & field sup	6	▲	▲	○	○	●	○	●		●	○		○	○	
		Reduce material costs		3				▲										
		Reduce overhead costs		9		○	○	●		○	▲			○	○			
		Reduce labor costs		1	▲			○					○		●			
	Quality	Meet customers needs	performance	9	●	○	●	▲		○	▲							○
			features	3						▲								
			reliability/durability	9	○		○	○			▲			○				○
			conformance	6	○		○											
			serviceability	9	○		○	○	●	○	○			○		○		○
			aesthetics	1														
			perceived quality	6														
	Delivery	Rapid new product development	Reduce BCNs	9			○	○			○	●					●	
			Fast engineering process	9	○	○	●	●		●	○	○	●	●	●	○	●	
			Reduce # prototypes	6				▲		●	○	○	●		●	▲	○	
			Imp. integration of lines	3	●	●	●	▲		○	●	●		●		●	●	●
			Reduce # process changes	3			▲	▲				○					▲	
			Faster tooling delivery	3	▲		●	○						▲				
			Reduce cost of tooling	1			○	○						▲				
		Fast delivery of orders	Predictable suppliers	6					▲								▲	
			Improve supplier planning	6	○		○						○	○			▲	▲
			Stable build schedules	1										○			▲	
			Supplier quality	9			▲							○				
Running the Business	Market Development			6														
	Access Information	Payables/Receivables		3	○	○	○	○		●	○	○		●			○	
		Personnel		6					○					○			▲	
		Cost Management	Cost allocation	6				○			○	○		○		○	○	
			Product pricing	3				●			○	○		○		▲	○	
	Justify Investments	Small firms need skills		3														
		Small firms lack information		3				▲				●		○			○	
		Big firms lack accounting		6												▲	▲	
	Reduce Risk of Legal			3			○		●					●				
	Security			6	●	●			○			○	○	●			○	○
	Environmental Regula			3				○	○			○		●			○	
	OSHA Regulation			1				○	○			○		●			○	
	Financial Regulation			3				○	○			○		●			○	
	EEO Regulation			1				○	○					●			○	
ABSOLUTE IMPORTANCE					379	258	546	516	282	354	378	318	363	574	252	213	475	186
Interaction Points					120		200		40	40	20	60	120	240	80	40	100	
Revised Importance					499	258	746	516	322	394	398	378	483	814	332	253	575	186

MATRIX		WEIGHTS
Strong	●	9
Medium	○	3
Weak	▲	1

	Business Needs		Requirements	IMPORTANCE
Customer Oriented	Cost	Reduce Life Cycle Cost of IS		6
		Reduce Product life cycle costs	New product	9
			Post-prod. dist. & field sup	6
		Reduce material costs		3
		Reduce overhead costs		9
		Reduce labor costs		1
	Quality	Meet customers needs	performance	9
			features	3
			reliability/durability	9
			conformance	6
			serviceability	9
			aesthetics	1
			perceived quality	6
	Delivery	Rapid new product development	Reduce BCNs	9
			Fast engineering process	9
			Reduce # prototypes	6
			Imp. integration of lines	3
			Reduce # process changes	3
			Faster tooling delivery	3
			Reduce cost of tooling	1
		Fast delivery of orders	Predictable suppliers	6
			Improve supplier planning	6
			Stable build schedules	1
			Supplier quality	9
Running the Business	Market Development			6
	Access Information	Payables/Receivables		3
		Personnel		6
		Cost Management	Cost allocation	6
			Product pricing	3
	Justify Investments	Small firms need skills		3
		Small firms lack information		3
		Big firms lack accounting		6
	Reduce Risk of Legal			3
	Security			6
	Environmental Regula			3
	OSHA Regulation			1
	Financial Regulation			3
	EEO Regulation			1
ABSOLUTE IMPORTANCE				
Interaction Points				
Revised Importance				

0

Tools/procedures for EI development/testing
●
O
O
O
●
▲
O
186
186

MATRIX WEIGHTS: Strong ● 9; Medium O 3; Weak ▲ 1

			Business Needs \ Requirements	IMPORTANCE	Generic: Human Factors: Consistent user interface	Psychologically compatible interface	Generic: Quality: Bounded customization	Establish process based on cust. req.	Process control & feedback	Simplified process	Buildable Products	Continuous improvement	Management by Fact	Policy: U.S. Govt.: CALS	Acquisition regulations	Certification of product and process	Certification of people	Int'l.: Harmonize trading practices	Acctg: Activity based accounting
Customer Oriented	Cost	Reduce Life Cycle Cost of IS		6			O			O				O				O	
		Reduce Product life cycle costs	New product	9	O	O	●		O	●	●	●	O	●				O	▲
			Post-prod. dist. & field sup	6	O	O	●		O	O		O	▲	●				▲	
		Reduce material costs		3					●			O	O						O
		Reduce overhead costs		9		O	O		O	O		O	●		N	N	N	O	O
		Reduce labor costs		1			O		O	O		O							O
	Quality	Meet customers needs	performance	9			O	●	●			O	●		▲	●	●		
			features	3			O	●				O	●						
			reliability/durability	9				●	●			O	●	O	▲	O	O		
			conformance	6				●	●		O	O	●		●	●	●		
			serviceability	9			●	●				O	▲	O	▲	O	O		
			aesthetics	1				●	O			O	O						
			perceived quality	6				●							O	●	●		
	Delivery	Rapid new product development	Reduce BCNs	9		O	O	O	O	O	●			●	▲	N	▲		
			Fast engineering process	9	O	O	O		O	O				●	▲	N	N		
			Reduce # prototypes	6			O				●				N	N	N		
			Imp. integration of lines	3	●	●			O	●									
			Reduce # process changes	3		O			O	●	●			●	▲	▲			
			Faster tooling delivery	3		O								●			▲		
			Reduce cost of tooling	1		O	O			O				●					
		Fast delivery of orders	Predictable suppliers	6					●			O	O	●				O	
			Improve supplier planning	6		O			●			O	O						
			Stable build schedules	1			O						O		N	▲	N	O	
			Supplier quality	9			▲		●			●	●	●	▲	●	●		
Running the Business	Market Development			6			●	●					●					O	
	Access Information	Payables/Receivables		3	O	▲		O		O				●				O	O
		Personnel		6		O							O		▲	▲	●		O
		Cost Management	Cost allocation	6	O	▲						O	●		▲	▲	▲		●
			Product pricing	3	O	▲						O	●						●
	Justify Investments	Small firms need skills		3															●
		Small firms lack information		3					●										●
		Big firms lack accounting		6															●
	Reduce Risk of Legal			3					O				O		●	●	●	●	●
	Security			6	O	O			▲				O		▲	O	●	O	
	Environmental Regula			3	O	O			O				O		▲	●	●	O	
	OSHA Regulation			1	O	O			O				O					O	
	Financial Regulation			3	O	O			O				O		●	●	O	O	
	EEO Regulation			1		O			O				O		▲	▲	O		
ABSOLUTE IMPORTANCE					174	264	441	477	648	267	261	393	702	594	205	440	516	192	291
Interaction Points					20	40				40									
Revised Importance					194	304	441	477	648	307	261	393	702	594	205	440	516	192	291

MATRIX WEIGHTS: Strong ● 9; Medium O 3; Weak ▲ 1

			Business Needs \ Requirements	IMPORTANCE	Linkage: Cross-disciplinary, [illegible] teams	Reduce [illegible]	Design in the loop	Prod. schedule/JIT in the loop	[illegible]
Customer Oriented	Cost	Reduce Life Cycle Cost of IS		6	O	O			
		Reduce Product life cycle costs	New product	9	●	O	●	●	●
			Post-prod. dist. & field sup	6	O	O		O	O
		Reduce material costs		3	▲			●	O
		Reduce overhead costs		9		O	●		
		Reduce labor costs		1					O
	Quality	Meet customers needs	performance	9	●	O	●		●
			features	3	O		O		O
			reliability/durability	9	●		●		●
			conformance	6	O	O	O		O
			serviceability	9	●	O	O		O
			aesthetics	1	O	O	O		O
			perceived quality	6					
	Delivery	Rapid new product development	Reduce BCNs	9	●	▲	●		●
			Fast engineering process	9		●	●		●
			Reduce # prototypes	6					●
			Imp. integration of lines	3	●	▲	O	●	O
			Reduce # process changes	3	●		O	O	●
			Faster tooling delivery	3	O		●		●
			Reduce cost of tooling	1	O		O		●
		Fast delivery of orders	Predictable suppliers	6	O			●	O
			Improve supplier planning	6	O	O	O	●	O
			Stable build schedules	1				●	
			Supplier quality	9	O	O	O	●	▲
Running the Business	Market Development			6					
	Access Information	Payables/Receivables		3				O	
		Personnel		6	O				
		Cost Management	Cost allocation	6			▲		▲
			Product pricing	3	O	O	▲		▲
	Justify Investments	Small firms need skills		3					
		Small firms lack information		3					▲
		Big firms lack accounting		6					
	Reduce Risk of Legal			3					
	Security			6		O			
	Environmental Regula			3		O			
	OSHA Regulation			1		O			
	Financial Regulation			3		O			
	EEO Regulation			1		O			
ABSOLUTE IMPORTANCE					630	354	645	369	675
Interaction Points					80				
Revised Importance					710	354	645	369	675

Figure 2. (

2

Consistent user interface	Psychologically compatible interface	Detailed customization	Establish process based on cust. req.	Process control & feedback	Simplified process	Buildable Products	Continuous improvement	Management by Fact	CALS	Acquisition regulations	Certification of product and process	Certification of people	Harmonize trading practices	Activity based accounting
Generic: Human Factors	Generic: Human Factors	Generic: Quality							Policy: U.S. Govt.				Policy: Int'l.	Acctg
		○			○				○				○	
○	○	●		○	●	●	●	○	●				○	▲
○	○	●		○	○		○	▲	●				▲	
				●			○	○						○
	○	○		○	○		○	●		N	N	N	○	○
		○		○	○		○							○
		○	●	●			○	●		▲	●	●		
		○	●				○	●						
			●	●			○	●	○	▲	○	○		
			●	●		○	○	●		●	●	●		
		●	●				○	▲	○	▲	○	○		
			●	○			○	○						
			●							○	●	●		
	○	○	○	○	○	●			●	▲	N	▲		
○	○	○		○	○				●	▲	N	N		
		○				●				N	N	N		
●	●			○	●									
	○			○	●	●			●	▲	▲			
	○								●			▲		
	○	○			○				●					
				●			○	○	●				○	
	○			●			○	○						
		○						○		N	▲	N	○	
		▲		●			●	●	●	▲	●	●		
		●	●					●					○	
○	▲		○		○				●				○	○
	○							○		▲	▲	●		○
○	▲						○	●		▲	▲	▲		●
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				●										●
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				○				○		●	●	●	●	●
○	○			▲				○		▲	○	●	○	
○	○			○				○		▲	●	●	○	
○	○			○				○					○	
○	○			○				○		●	●	○	○	
	○			○				○		▲	▲	○		
[illegible]	264	441	477	648	267	261	393	702	394	205	440	516	192	291
[illegible]	40				40									
[illegible]	304	441	477	648	307	261	393	702	394	205	440	516	192	291

MATRIX WEIGHTS: Strong ● 9; Medium ○ 3; Weak ▲ 1

	Business Needs		Requirements	IMPORTANCE	Cross-disciplinary, entrepreneurial teams	[illegible]	Design in the loop	Prod. schedule/JIT in the loop	Concurrent engineering	Clear expectations of performance	Expand job to include problem solving & decision	Job satisfaction/worker motivation	Job specific skills	Strategic Plan	Management/labor relations	Leadership/champion	Entrepreneurial culture/Risk taking	Adaptive learning culture	Establish/manage inter organization relations	User groups consensus on requirements
					Organization: Linkage					Job Design/Rewards			Skills	Change Management					Inter Organization	
Customer Oriented	Cost	Reduce Life Cycle Cost of IS		6	○	○								●					○	●
Customer Oriented	Cost	Reduce Product life cycle costs	New product	9	●	○	●	●	●	○		○	○	○	○	●	○	●	●	
Customer Oriented	Cost	Reduce Product life cycle costs	Post-prod. dist. & field sup	6	○	○		○	○	○	●	○	○	○	▲	○	○	○		○
Customer Oriented	Cost	Reduce material costs		3	▲			●	○	▲	○	○		▲	▲	●		▲		○
Customer Oriented	Cost	Reduce overhead costs		9		○	●							▲		●		▲		
Customer Oriented	Cost	Reduce labor costs		1					○	○	○	○	▲	▲	○			▲		
Customer Oriented	Quality	Meet customers needs	performance	9	●	○	●		●	○	●	○	●	○	▲	●	○	▲	○	
Customer Oriented	Quality	Meet customers needs	features	3	○		○		○	○		○	○	○		●	○	▲		
Customer Oriented	Quality	Meet customers needs	reliability/durability	9	●		●		●	○	●	○	●	○	▲	●		▲	○	
Customer Oriented	Quality	Meet customers needs	conformance	6	○	○	○		○	○	●	○	●	○	▲	●		▲	○	
Customer Oriented	Quality	Meet customers needs	serviceability	9	●	○	○		○	○		○	○	○	▲	●		▲		
Customer Oriented	Quality	Meet customers needs	aesthetics	1	○	○	○		○	○	○	○	●	○		●		▲		
Customer Oriented	Quality	Meet customers needs	perceived quality	6										○						
Customer Oriented	Delivery	Rapid new product development	Reduce ECNs	9	●	▲	●		●	○			○	▲			○	▲	●	
Customer Oriented	Delivery	Rapid new product development	Fast engineering process	9		●	●		●			○	○	●		○	○	○	●	
Customer Oriented	Delivery	Rapid new product development	Reduce # prototypes	6					●				○			○	●	○	○	
Customer Oriented	Delivery	Rapid new product development	Imp. integration of lines	3	●	▲	○	●	○	○	○		○	▲		○	○	○	○	
Customer Oriented	Delivery	Rapid new product development	Reduce # process changes	3	●		○	○	●				○	▲			○	▲	●	
Customer Oriented	Delivery	Rapid new product development	Faster tooling delivery	3	○		●		●	○									●	○
Customer Oriented	Delivery	Rapid new product development	Reduce cost of tooling	1	○		○		●	○								▲	●	○
Customer Oriented	Delivery	Fast delivery of orders	Predictable suppliers	6	○			●	○					○	○	▲	○		●	○
Customer Oriented	Delivery	Fast delivery of orders	Improve supplier planning	6	○	○	○	●	○					○		▲		○	▲	
Customer Oriented	Delivery	Fast delivery of orders	Stable build schedules	1				●						○					●	
Customer Oriented	Delivery	Fast delivery of orders	Supplier quality	9	○	○	○	●	▲				●	●	▲	●		▲	○	○
Running the Business	Market Development			6										○		○	○			●
Running the Business	Access Information	Payables/Receivables		3				○											○	○
Running the Business	Access Information	Personnel		6	○															
Running the Business	Access Information	Cost Management	Cost allocation	6			▲		▲					▲			●	▲		
Running the Business	Access Information	Cost Management	Product pricing	3	○	○	▲		▲					●			●	▲	▲	
Running the Business	Justify Investments	Small firms need skills		3									●			●		●		
Running the Business	Justify Investments	Small firms lack information		3					▲							●				
Running the Business	Justify Investments	Big firms lack accounting		6										●		●	○			
Running the Business	Reduce Risk of Legal			3									○			○				
Running the Business	Security			6		○							○	○	▲			▲		
Running the Business	Environmental Regula			3		○							○	○		○				○
Running the Business	OSHA Regulation			1		○					○	○	○	○		○				▲
Running the Business	Financial Regulation			3		○							○							▲
Running the Business	EEO Regulation			1		○							○	○		○				▲
ABSOLUTE IMPORTANCE					630	354	645	369	675	210	297	198	556	595	105	837	342	285	531	215
Interaction Points					80					140	80							40	80	
Revised Importance					710	354	645	369	675	350	377	198	556	595	105	837	342	325	611	215

Figure 2. QFD Chart: Business Needs and Requirements

(3)

Simplified Processes, etc., have a moderate level of importance. No requirements are shown as having a low level of importance. The remaining requirements have, in this analysis, little importance to *Reduce Life Cycle Cost of IS*.

The business needs (rows) and requirements (columns) were developed through an interview process with 20 industry experts. These experts also assigned the importance ratings to each business need and the matrix weights for each need-requirement pair. The Absolute Importance value for each requirement was calculated as the sum for that requirement of each need's Importance multiplied by the weight for the need-requirement pair. Each Absolute Importance value was then revised to reflect the requirement's interaction (complementary or conflict) with other requirements. The resulting Revised Importance indicates the contribution of a requirement to providing solutions for the full set of business needs.

The QFD chart relating requirements to technologies is presented in Figure 3. The requirements are those used in Figure 2. Definitions of the STs can be found in Appendix B.

The Importance rating for each requirement (row) in Figure 3 are the Relative Importance values scaled to the indicated range of values. The matrix weights were scored by the EIP team based on literature search and interviews with industrial experts and vendors. The final Importance values for technologies and standards were derived using the same weighted sum calculation described above for Figure 2. Both QFD charts are still in draft form, and further review may lead to some changes in scoring.

The information presented in Figure 3 is summarized in Table 4, which presents a ranking of the technology categories. This table shows the relative importance of the categories to the EIP needs. The score is the weighted sum of the maximum score within that category for each row in Figure 3 normalized from 0 to 10 and rank ordered.

MATRIX / WEIGHTS: Strong ● 9; Medium ○ 3; Weak ▲ 1	Requirements		Technologies	Importance rating (from EP)	Integration Frameworks and Architectures										Operationg Systems & Distributed Environments																	
					PCTE/PCIS	CFI	EIS	GM-C4	ICAM-FoF	AD/Cycle	APP	SAA	NAS	New Wave	POSIX	OSF/1	SVR4	MS-DOS	OS/2	Mac System 7	OMG	ODP	DCE	OO-CORE	POMS	ANSA	Cimplicity	DOMF	OLE	NetWare	LANManager	VINES
Generic	Information Systems Integration	Share data/knowledge	Communication stds	6				●			●	●	●	●	▲	●	●									●						
			System/network admin. std.	1				●			●	○	○	○	●	●	●			○	▲	▲	●	○		○		○	▲	●	●	●
			Data interchange std.	9		○	○	●			●		●	●	▲		▲													○	▲	○
			Reuse of knowledge/module	6	●	●	●			●	●	●	●	●	●	●					●	●	○	●		○	●	○	○			
			Long term maint./access of	3		●	○	○		●	●	●	●	●	●	○	▲			○	○	●	○	●		○	●	●	●	●	●	●
			Handle large quantities of data	3	●	○		●			●	●	●	●	○	▲					○		○	●		○	○					
		Modular application, systems		3	●	●		●	●	●	●	●	●	●	●	●	●	○	○	●	●	●	●	○		●	●	●	○			
		Application platform independence/interoperab		3	●	●	▲	●	○		●		●	●	●	●	●					●	●	○		○	▲	○	○	○	○	○
		Distributed applications, systems		6	○	○		●	●		●	●	●	●	▲	●	○		○	○	●	●	○	●		●	●	●		○	○	○
		Data Management		9	○	○	○	●	○	○	●		●	●	▲		○				●			●		▲	●	○	○	●	●	●
		Design tools		3	●	●	●	●		●			●	●	○	○					○		●	○		○				○		○
		Migration management		1	○		●		○	○			○	●	▲						●		●	●		○		○			○	
		Enterprise framework/architecture		6	▲		○	○	●		●	●	●	●	○	○	○		○	○	○	●	●	●			○	○		○	○	○
		Tools/procedures for EI development/testing		1	●		▲	●	○	●			○	●	○	○	○		○		○	○	●	●		○	○	○	○	○	○	○
	Human Factors	Consistent user interface		1		●	●	●			▲	●	●	○	●	●	●		●	●										○	▲	○
		Psychologically compatible interface		3		●					▲	○	○	○		○			○	○											▲	
	Quality	Bounded Customization		3						○		○	○	○					●													
		Establish process based on cust. req.		6																												
		Process control & feedback		6					○	●			●										○	○	●		●			▲		▲
		Simplified processes		3		○	○	●													○											
		Buildable Products		3	○	▲	▲			○	N				N	N			●		N	N	N			N						
		Continuous improvement		3				○	○																●							
		Management by Fact		9					○																							
	Linkage	Cross-disciplinary,entrepreneurial teams		9																												
		Balance centralization/decentralization		3																												
		Coordination mechanisms	design in large	6		●	●	●	○		○	○	○	○			○				○	○	●	●		●		○	○	▲	▲	▲
			prod. sched./JIT in the larg	3				●	○			○	○	○			○				●	●	●	●	●	●	●	○	○			
			concurrent engineering	9		○	●	●	○	○	○	○	○	○			○				●	○	●	●		●		○	○	▲	▲	▲
Organization	Job Design/Rewards	Clear expectations of performance		3																												
		Expand job to include problem solving & decisi		3																												
		Job satisfaction/worker motivation		1																												
	Skills	Job specific skills		6																			○									
	Change Management	Strategic plan		6											○																	
		Management/labor relations		1																												
		Leadership/champion		9																												
		Entrepreneurial culture/Risk taking		3																												
		Adaptive learning culture		3					○				○																			
	Inter Organization	Establish/manage inter organization relations		6					○		○		○				▲															
		User groups consensus on requirements		1					○		○				○																	
	Accounting	Activity based accounting		3																												
Policy	U.S. govt.	CALS		6							●				●	●	●				●											
		Acquisition Regulations		1																												
		Certification of Products and Processes		3																												
		Certification of People		6																												
	International	Harmonize trading practices		1																	▲											○
		Absolute importance			234	372	331	630	315	273	619	381	684	609	298	339	318	9	120	93	464	319	414	525	108	369	357	243	148	225	196	228

Figure 3. QFD Chart: Requirements and Technologies

Table 4. EIP Category Ranking

Technology Category	Relative Score
Integration Frameworks and Architectures	10.0
Operating Systems and Distributed Environments	9.5
Communications	6.6
Data Management Systems	6.5
Application Development Tools and Methods	5.5
Data Representations	5.4
Information Modeling Tools and Methods	4.8
User Interfaces	2.3
Programming Languages	2.3
Security Tools and Methods	1.8

Table 5 ranks each of the STs within a given category by their total score from the QFD matrix, normalized to a scale of 0 to 10. This table shows the relative importance of STs within a category.

3.2 DETERMINING THE STATUS OF STS

The approach used to answer the question, "What is the completion and acceptance status of the critical STs," is to relate the baseline STs to 11 aspects of the development and successful deployment of a standard or technology. The analysis uses criteria obtained from the NIST APP and POSIX Open Systems Environment (OSE) [3], with some additions by the IDA team, and employs the QFD methodology introduced previously.

3.2.1 Methodology

The 11 criteria used in this analysis are specification availability, level of consensus, product availability, completeness, maturity, stability, *de facto* usage, problem/limitation-freeness, conformance testing, future plans, and predominance. These criteria and how they are scored are described in more detail in Appendix E.

The scores are derived in two ways. The NIST APP document scores some of the STs in the baseline, and these scores were used directly in the matrix. The others STs were scored by the IDA team through interviews and literature reviews.

Table 5. Standards and Technologies by Category

Category	Technology	Importance
Integration Frameworks & Architectures	NAS	10.0
	GM-C4	9.2
	APP	9.0
	New Wave	8.9
	SAA	5.6
	CFI	5.4
Operating Systems & Distributed Environments	OO-CORE	7.7
	OMG	6.8
	DCE	6.1
	OSF/1	5.0
	SVR4	4.6
	NetWare	3.3
Communications	MAP/TOP	7.3
	GOSIP	6.4
	TCP/IP	3.9
	X.500	3.9
Data Management Systems	OO-SQL	7.8
	IRDS2	4.0
	RDA Protocol	3.7
	SQL	2.8
	IRDS1	2.1
Application Development Tools & Methods	PlantWorks	3.1
	KB Systems (Application Development)	2.9
	Application Generators	2.6
	IDS	2.6
	X/Open + POSIX APIs	2.3
Data Representations	STEP	6.5
	SGML	3.6
	EDI	3.5
Information Modeling Tools & Methods	KB Systems (Info. Tools)	4.4
	SUMM	3.2
	Yourdon	2.1
	IDEF1X	2.1
	IDEF0	2.1
User Interfaces	POSIX 1201 (XVT)	3.2
	Motif	2.9
	Open Look	2.9
	X-Windows	2.4
Programming Languages	Ada	2.7
	C++	1.6
	C	0.9
	Fortran	0.7
Security Tools & Methods	POSIX 1003.6	1.8
	DES	1.4
	Kerberos	0.9

3.2.2 ST Status Matrix

The QFD chart relating STs to status criteria is presented in Figure 4. The scores for each ST are summed to give an overall relative status rating.

3.3 SUMMARY OF RESULTS: CRITICAL STs AND THEIR STATUS

Table 6 summarizes information from Figure 4. For most technical categories, a small number of STs dominate in order of importance. Those STs are included in this table, as are a few STs rated of medium importance but with high relative status.

The STs are divided into two major groupings: Proprietary and Standards/Consortia. Proprietary technologies are those products or technologies developed by a single company or a closed partnership. Standards/Consortia are those STs developed by recognized standards bodies or consortia groups whose membership is open to anyone. The distinction helps to identify if the important technology with a category is mostly proprietary (in which case standards activities may need to be started). It also shows where investment may be applied (towards standards and consortia as opposed to proprietary technologies).

Key STs are summarized for each category:

- Integration Frameworks and Architectures: This category is characterized by the relative absence of standards activity. The CAD Framework Initiative (CFI) under MCC is one of the few open efforts but it is limited to a particular application area. An "open" framework, similar to SAA, NAS, GM-C4, or NewWave, needs to developed. The NIST APP is a start, though it tends to be a collecting framework rather than an integrating one.
- Operating Systems and Distributed Environments: Three different types of functional sub-areas require attention: traditional operating systems, distributed environments, and distributed object management systems. Unix derivatives are the primary contenders for the traditional operating system. SVR4 from Unix International and OSF/1 from the Open Software Foundation, both of which reference the POSIX standard, scored well in this evaluation. The many derivatives of Unix being developed emphasize the importance of moving the POSIX efforts forward so that a common standard exists. Both of these operating systems are beginning to develop capabilities to support distributed environments as well. A key contributor in this area is the Open Distributed Processing (ODP) effort begun by the International Organization for Standardization (ISO) to develop a reference model as a basis for future distributed processing standards.

Standards & Technologies	Current Status	Specification Availability	Level of Consensus	Product Availability	Completeness	Maturity	Stability	De facto usage	Problem-freeness	Conformance Testing	Future Plans	Predominance	Overall Status Rating
Integration Frameworks and Architectures	PCTE/PCIS	●	▲	○	▲	▲	▲	▲	▲	▲	●	▲	29
	CFI	○	▲	▲	●	●	○	○	○	▲	●	●	51
	EIS	○	▲	▲	●	●	○	▲	▲	▲	○	●	41
	GM-C4	▲	▲	○	●	●	○	▲	●	○	●	○	51
	ICAM-FoF	○	▲	▲	●	●	●	▲	○	▲	▲	▲	39
	AD/Cycle	○	▲	○	○	○	○	▲	○	▲	●	○	33
	APP	●	○	▲	○	○	○	▲	○	▲	●	○	39
	SAA	▲	▲	▲	●	●	●	○	●	▲	●	○	55
	NAS	○	▲	▲	●	●	●	○	●	▲	●	○	57
	New Wave	○	▲	▲	○	○	●	○	●	▲	●	○	45
Operating Systems & Distributed Environments	POSIX	●	○	○	○	●	○	○	○	●	●	▲	55
	OSF/1	●	▲	○	●	●	●	▲	○	▲	▲	▲	47
	SVR4	●	○	●	●	●	○	●	○	▲	○	○	61
	MS-DOS	●	▲	●	●	●	●	●	▲	▲	○	●	69
	OS2	○	▲	●	●	●	○	▲	▲	▲	●	▲	47
	Mac System 7	▲	▲	●	●	●	○	▲	○	▲	●	○	49
	OMG	○	○	▲	●	▲	○	▲	○	▲	●	○	37
	ODP	▲	●	▲	○	▲	▲	▲	▲	○	●	○	33
	DCE	●	▲	○	●	●	●	▲	○	▲	●	○	57
	OO-CORE	▲	▲	▲	●	▲	▲	▲	▲	▲	●	●	35
	POMS	▲	▲	▲	●	●	●	▲	○	▲	▲	▲	37
	ANSA	○	▲	▲	●	○	▲	▲	▲	●	●	○	41
	Cimplicity	▲	▲	▲	●	●	○	▲	○	▲	●	○	41
	DOMF	▲	▲	○	○	○	▲	▲	●	▲	●	▲	33
	OLE	▲	▲	▲	○	○	▲	▲	○	▲	●	▲	25
	NetWare	○	▲	●	○	●	○	●	○	○	●	●	61
	LANManager	○	▲	○	○	●	○	▲	▲	▲	●	▲	35
	VINES	○	▲	●	○	●	○	▲	○	▲	●	○	45
Communications	TCP/IP	●	○	●	●	●	○	●	○	▲	●	○	67
	MAP/TOP	●	●	○	●	●	○	▲	○	●	○	▲	59
	GOSIP	●	●	○	●	●	○	○	○	●	○	▲	61
	TFA	○	▲	○	▲	▲	▲	▲	▲	▲	○	●	25
	NCS/RPC	○	▲	▲	▲	▲	▲	▲	▲	▲	○	●	23
	GNMP	●	○	▲	▲	▲	▲	▲	▲	○	●	▲	31
	X.500	●	●	○	●	●	●	○	●	○	●	▲	73
Data Management Systems	IRDS 1	●	○	▲	○	●	○	▲	▲	○	▲	●	43
	IRDS 2	▲	○	▲	●	▲	▲	▲	▲	▲	●	●	37
	RDA Protocol	○	▲	▲	○	▲	○	▲	▲	▲	○	●	27
	SQL	●	●	○	●	●	●	●	●	○	●	●	87
	OO-SQL	▲	○	▲	●	▲	▲	▲	○	▲	●	●	39
	Hypermedia	▲	▲	○	▲	○	▲	▲	○	▲	○	●	27
	CDM (IISS)	○	▲	▲	●	●	●	▲	○	▲	▲	▲	39

MATRIX		WEIGHTS
Strong	●	9
Medium	○	3
Weak	▲	1

Figure 4. ST Status Matrix

Standards & Technologies	Current Status	Specification Availability	Level of Consensus	Product Availability	Completeness	Maturity	Stability	De facto usage	Problem-freeness	Conformance Testing	Future Plans	Predominance	Overall Status Rating
User Interfaces	X-Window	●	●	○	○	●	●	●	▲	▲	●	●	71
	Motif	●	○	○	●	●	●	○	○	○	●	○	63
	Open Look	●	▲	▲	●	●	●	▲	○	▲	●	○	55
	POSIX 1201 (XVT)	▲	○	○	○	▲	▲	▲	▲	▲	●	○	27
	MS-Windows	●	○	●	●	●	●	●	○	▲	●	●	79
	Presentation Manager	●	▲	○	●	●	●	▲	○	▲	●	○	57
	DECWindows	○	▲	○	○	●	○	▲	○	▲	●	▲	37
	MacIntosh Toolbox	○	▲	○	●	●	●	▲	●	▲	●	○	57
Security Tools and Methodologies	POSIX 1003.6	●	▲	▲	▲	○	▲	▲	▲	▲	○	○	25
	Kerberos	○	○	○	○	●	●	○	○	▲	○	●	49
	DES	●	○	●	○	●	●	●	○	▲	▲	●	65
Information Tools and Methodologies	IDEF0	○	○	●	●	●	○	▲	○	▲	●	○	53
	IDEF1x	○	○	●	●	●	○	▲	○	▲	●	○	53
	Yourdon	●	○	●	●	●	●	○	●	▲	○	○	67
	Jackson	○	▲	○	○	●	●	▲	○	▲	○	▲	37
	Knowledge based systems	▲	▲	●	●	●	▲	▲	○	▲	●	▲	45
	SSD	○	▲	○	○	●	●	▲	○	▲	▲	▲	35
	SUMM	▲	○	▲	○	▲	▲	▲	▲	▲	○	●	25
Programming Languages	ADA	●	●	●	●	●	○	○	○	●	○	▲	67
	C	●	●	●	●	●	○	●	●	●	●	○	87
	C++	○	○	●	●	●	○	○	○	▲	●	▲	53
	COBOL	●	●	●	●	●	●	●	●	●	○	○	87
	Fortran	●	●	●	●	●	●	●	●	●	○	○	87
	LISP	●	○	●	●	●	○	▲	●	▲	○	▲	57
	Pascal	●	●	○	▲	●	●	▲	●	●	○	▲	63
	PROLOG	○	○	●	○	●	○	▲	○	▲	○	▲	39
	Smalltalk	○	○	●	○	●	○	▲	○	▲	○	▲	39
Application Development Tools and Methodologies	X/Open + POSIX APIs	●	○	○	○	●	○	▲	○	●	●	●	61
	IDS	○	▲	▲	▲	○	●	▲	○	▲	○	▲	27
	Knowledge based systems	▲	▲	●	●	●	▲	▲	○	▲	●	▲	45
	Application generators	▲	▲	●	○	●	▲	○	○	▲	●	○	43
	PlantWorks	▲	▲	▲	●	●	●	▲	○	▲	▲	▲	37
	Neural Nets	▲	▲	●	●	▲	▲	▲	▲	▲	●	▲	35
	SCCS	▲	▲	○	▲	▲	▲	▲	▲	▲	▲	○	15
Data Representation	STEP	○	▲	▲	●	▲	▲	▲	▲	○	●	○	33
	EDI	●	○	●	●	●	▲	●	○	○	●	●	73
	IGES	●	●	●	▲	○	●	●	●	▲	○	○	65
	CGM	●	●	●	●	●	●	●	●	●	●	●	99
	SGML	●	●	▲	○	●	●	▲	●	○	○	○	59
	Raster Format	○	○	●	●	●	●	▲	●	○	○	○	61
	ODA/ODIF/ODL	●	●	▲	●	▲	○	▲	○	▲	○	▲	41
	GKS	○	●	●	●	●	●	●	●	●	●	○	87
	PHIGS	○	●	●	●	○	●	●	●	○	●	●	81

MATRIX		WEIGHTS
Strong	●	9
Medium	○	3
Weak	▲	1

Table 6. Important STs by Category

Category	Importance	Proprietary	Standards/Consortia
Integration Frameworks and Architectures	10.0	NAS GM-C4 SAA NewWave	CFI APP
Operating Systems and Distributed Environments	9.5	OO-CORE NetWare DCE	OMG SVR4 OSF/1
Communications	6.6		MAP/TOP GOSIP TCP/IP X.500
Data Management Systems	6.5	OO-SQL	SQL IRDS2 RDA IRDS1
Application Development Tools and Methods	5.5	PlantWorks KB Systems Application Generators	X/Open IDS
Data Representations	5.4		STEP SGML EDI
Information Modeling Tools and Methods	4.8	KB Systems Yourdan	SUMM IDEF0 IDEF1x
User Interfaces	2.3		POSIX 1201 (XVT) Motif Open Look X-Windows
Programming Languages	2.3		Ada C++ C Fortran
Security Tools and Methods	1.8		POSIX 1003.6 DES

Distributed object management is also emerging as a critical technology for the future. IBM has developed OO-CORE to support object management. The Object Management Group (OMG) is also heavily involved in promoting object standards (such as the Object Request Broker).

- Communications: The need for standards in the area of communication has long been recognized. As a result the OSI family of standards (MAP/TOP/GOSIP) clearly dominate this category. TCP/IP (which was often the third member of the list) must also be considered both because of its large installed base and open nature. The OSI standards define more functionality than TCP/IP, but TCP/IP is on a trajectory where it continues to adopt OSI functionality. It is still seen by many as an interim step to full OSI compatibility.

- Data Management Systems: The first ANSI IRDS standard (IRDS1) is based on the relational model. It defines the information captured by an Information Resource Dictionary as well as the services provided by enterprise processing facilities. Future object-oriented systems are focusing on the second IRDS standard (IRDS2) that is under consideration. The high level of interest in this work indicates the importance of promoting this relatively young effort. The Remote Database Access (RDA) protocol is seen as an important standard to enable the operation of distributed databases. IRDS1, IRDS2, and RDA, while not scoring particularly well, are included here for reasons discussed in Section 3.4 on page 34. OO-SQL is an object-oriented extension to SQL. It is used as the data manipulation language developed by IBM as part of its OO-CORE project. The importance assigned to OO-SQL and OO-CORE indicates the need to bring these technologies into the public arena where an open development process can take place.

- Application Development Tools and Methods: The X/Open APIs define a toolkit of program interface calls across a number of functional areas. This effort stands out in its effect on architectural and business needs. Also, other useful tools and methods are proprietary in nature, such as application generators and knowledge-based systems. Although seen as important, there is little or no standards activity associated with these areas.

- Data Representation: This area has also experienced intense standards activities. There are many different data representation standards that are specific to an application area. Combining scores across a spectrum of requirements emphasizes those standards that have the broadest scope such as STEP (the Standard for the Exchange of Product Data). STEP is clearly an important ISO effort that is bringing together a number of national efforts to build an engineering data exchange specification. Much work remains in the development of Application Protocols and test tools. Other representation standards that are important include the ANSI Electronic Data Interchange (EDI) standards for exchanging business documents, Standard Generalized Markup Language (SGML) for document markup, Programmer's Hierarchical Interactive Graphics System (PHIGS) which is a three-dimensional graphics standard and Computer Graphics Metafile (CGM) which defines a graphics file format.

- Information Modeling Tools and Methods: IDEF0 and IDEF1x are important standards for process and information modeling for large organizations. There are, however many different modeling tools available. SUMM is an effort to define the mechanics that will allow integration of data models and schema defined by various modeling languages. Knowledge-based systems are also being used for information modeling, but lack any significant standards activity.
- User Interfaces: X-Windows is a key standard, which is also found integrated with the higher-level functions in Motif and Open Look. Motif (OSF) and Open Look (Unix International) provide extensive libraries for building graphical user interfaces. The POSIX 1201 effort is important because it is attempting to build a single common application interface (using the XVT technology) that sits above Motif and Open Look.
- Programming Languages: This area already has a number of well-developed standards and technologies (Ada, C, Cobol, Fortran, Lisp) and primarily needs only maintenance. Extensions for objects (e.g., C++) or APIs (e.g, X/Open) are the key development activities.
- Security Tools and Methods: POSIX 1003.6 is a key standard under development which will provide comprehensive security access and control for applications. The Data Encryption Standard (DES) is now part of GOSIP (Government Open Systems Interconnection Profile).

The current status of the STs identified in Table 6 is given in Table 7.

Table 7. Status of Critical STs

Category	Technology	Importance	Status
Integration Frameworks and Architectures	NAS	10.0	5.8
	GM-C4	9.2	5.2
	APP	9.0	3.9
	New Wave	8.9	4.5
	SAA	5.6	5.6
	CFI	5.4	5.2
Operating Systems and Distributed Environments	OO-CORE	7.7	3.5
	OMG	6.8	3.7
	DCE	6.1	5.8
	OSF/1	5.0	4.7
	SVR4	4.6	6.2
	NetWare	3.3	6.2
Communications	MAP/TOP	7.3	6.0
	GOSIP	6.4	6.2
	TCP/IP	3.9	6.8
	X.500	3.9	7.4
Data Management Systems	OO-SQL	7.8	3.9
	IRDS2	4.0	3.7
	RDA Protocol	3.7	2.7
	SQL	2.8	8.8
	IRDS1	2.1	4.3
Application Development Tools & Methods	PlantWorks	3.1	3.7
	KB Systems (Application Development)	2.9	4.5
	Application Generators	2.6	4.3
	IDS	2.6	2.7
	X/Open + POSIX APIs	2.3	6.2

Table 7. Status of Critical STs (Continued)

Category	Technology	Importance	Status
Data Representations	STEP	6.5	3.3
	SGML	3.6	6.0
	EDI	3.5	7.4
Information Modeling Tools & Methods	KB Systems (Info. Tools)	4.4	4.5
	SUMM	3.2	2.5
	Yourdon	2.1	6.8
	IDEF1X	2.1	5.4
	IDEF0	2.1	5.4
User Interfaces	POSIX 1201 (XVT)	3.2	2.7
	Motif	2.9	6.4
	Open Look	2.9	5.6
	X-Windows	2.4	7.2
Programming Languages	Ada	2.7	6.8
	C++	1.6	5.4
	C	0.9	8.8
	Fortran	0.7	8.8
Security Tools & Methods	POSIX 1003.6	1.8	2.5
	DES	1.4	6.6
	Kerberos	0.9	4.6

An artifact of using broad requirements (business or technical) is that the results emphasize those STs that are more broadly based. However, any strategic plan must consider the difficulty of integrating these STs with the legacy of existing and future proprietary solutions. Systems based on today's operating systems (MS-DOS, VMS, Unix), windowing environments (MS-Windows, Macintosh), and networks (Novell and TCP/IP) must be able to fit within the information integration infrastructure. In fact, there has been some success mixing these principal components to construct usable information infrastructures. A U.S. information infrastructure must support these and other very popular technologies.

3.4 COMMENTS ON THE ANALYSIS

The analysis of critical STs and their current status presented here is heavily dependent on the choice of framework or reference model for expressing "what the customer wants." The use of requirements derived from business needs, as in the EIP Needs Analysis task, can be defended as reflecting the wants and perceptions of those who must ultimately pay the bill for enterprise integration. It also includes the organization, procedural, and personnel aspects of enterprise integration, as well as the technical ones.

Other evaluation frameworks could be used. As part of its work, the IDA team prepared similar analyses based on the NIST APP Framework, presented in the NIST Application Portability Profile [2] and on a framework representing a consensus position of the EISWG. Both of these frameworks focused more heavily on the hardware and software aspects of enterprise integration, to the exclusion of organizational and personnel ones. However, the relative importance of the technical categories was quite similar in all cases, as was the identification of critical STs. (In the Data Management Systems category, three STs were included in the summary table, Table 6, because of their scores in these other analyses.)

The current analysis takes a very broad look at STs. The STs in the baseline vary in their breadth (e.g., number of areas covered by the standard). The analysis currently favors STs that are very broad in their scope. Activities such as GM-C4 and NAS tend to score high because they receive scores for many different need areas. Other standards that are more narrowly focused on one particular set of needs (such as STEP) may be important, but receive a lower total score.

This problem can be corrected by comparing STs only within a particular element of the framework. A single framework element can be elaborated in terms of its specific needs and the STs can be scored for how well they meet those needs. Then a comparison across the STs can determine those that are most critical in fulfilling that particular framework requirement. This approach will provide a more focused analysis. It will also require a better definition of the framework or architecture.

Standards must also be analyzed with respect to their compatibility. Some standards overlap, others are cross-referenced. Some are competing (i.e., they cannot be used together), others are complementary. A thorough analysis would ideally identify a complete, consistent, and compatible set of STs for each element within the framework, a set that is sufficient for meeting the requirements of the framework. This type of analysis is difficult to do since it requires detailed knowledge about each of the standards and their interrelationships and compatibility. Much of this information has not yet been collected.

Once a standard or technology is identified as a potential development target, the ST Status Matrix can be used to identify its weak points. A specific strategy should be developed for each ST to help improve its status in each of its weak areas. For instance, a particular standard may uniquely address a need, but suffer from specification instability and not be well known. Alternatively, a technology may be mature, in de facto usage, but lack standard status for widespread acceptance. The Deployment Forces summaries in Appendix C can also be consulted for an ST to determine the relevant organization(s) responsible for different deployment activities. This information can be used to guide the development strategy

4. CONCLUSIONS AND ISSUES

Building the U.S. information infrastructure will be a continual effort. Today's planning requires understanding, from many perspectives, the demands for and capabilities of information technology. This report attempts to establish a baseline of the important STs for information integration and the OPs behind them. The information in this report represents the start of an analysis of the critical technologies needed to support integrated enterprises within the next decade. It identifies some key areas and issues that must be addressed in order to advance infrastructure development.

The report presents a model for evaluating the importance and status of any standard or technology. The model is presented in sufficient detail that different scores can be substituted for the current ones based on additional review and input, allowing future work to modify the results of the model to include new or more accurate information. The model can also be extended to include new STOPs as further information becomes available.

4.1 CONCLUSIONS FROM ST CRITICALITY ANALYSIS

The analysis presented here takes a broad view of the importance of STs in meeting the general needs of an information infrastructure. It does not differentiate between STs with a broad scope and those addressing a narrow set of requirements. With that caveat, some general conclusions can be reached from this analysis:

- *Operating Systems and Distributed Environments* and *Integration Frameworks and Architectures* are critical foundation technologies which must be established. These two categories scored the highest across all evaluation frameworks. Several potentially important STs were identified. Since much of the work in this area is proprietary or consortial, there is still a need to promote standards in these areas. The lack of unifying standards may lead to market fragmentation that will slow the development of an information integration infrastructure.
- *Data Management, Communications and Data Representation* STs are next in importance. The information infrastructure requires standards that support

highly integrated information management systems across the entire enterprise. The need for standards in these areas has long been recognized as evidenced by the preponderance of standards available. There is still a need to organize these standards into a consistent framework and to ensure that they are compatible.

- *Application Development Tools and Methods* and *Information Modeling Tools and Methods* are scored as equally important for information infrastructures as the group above. However, standards development in these categories is less advanced. This reflects their focus on the broader process of translating requirements into system implementations, rather than on data structures within those implementations.
- Other categories such as *User Interface, Programming Languages*, and *Security Tools and Methods* are also important. STs in some of these categories are more important in the development of applications. Since this report focused on information infrastructure, they did not score very high.

4.2 NEED FOR REFERENCE MODEL

The importance of integration frameworks supports the necessity of identifying a reference model that can be used to guide the selection of standards and technologies for an integrated information infrastructure. A detailed reference model identifies the major architectural elements of the information system and their interrelationships. It also provides a framework for identifying needed interface, representation, or other standards. It provides an organizing structure that helps to characterize the STs and their relationships.

The need for a reference model is widely recognized. As a result several activities are developing reference models in this area including proprietary models (GM-C4), vendor models (EISWG), and standards efforts (CIM/OSA). Consensus is needed around a single reference model (or group of related models) from which a coherent set of standards can be developed. These models must be driven from clearly articulated and prioritized business needs. The information in this report and its companion reports lays the foundation for capturing some of these critical business drivers. Future tasks should look at how well these business needs are captured in current and emerging reference models.

A single reference model, with its benefits for analysis and decision-making, does not imply a single view of information integration. Business needs vary with the corporation, its market sectors, and its strategies. It is unlikely that a single set of standards will emerge to fit all these varying needs. Still a well-designed reference model can support profiles of standards suited for different needs (such as the use of the OSI reference model for communications standards). Future analysis should look at this question in greater detail. Business needs should be captured for different segments of the industry in order to identify the major profiles that may be required to meet those needs.

Further, at least in the context of a National Information Infrastructure, other demands besides those of industrial enterprise integration will help shape the infrastructure. A national information infrastructure is viewed by many as doing "... for the flow of information—words, music, movies, medical images, manufacturing blueprints, and much more —what the transcontinental railroad did for the flow of goods a century ago and the interstate highway system did in this century ... [it can be] ... a national resource that would improve education, health care, scientific research, and the ability of corporations to compete in the world economy, among many other things."[5] To the extent that analogies with, for example, the interstate highway system are accurate, then unanticipated uses of the infrastructure and resulting major changes in the way the nation lives and works will occur. Some of these uses and changes will come from the industrial sector, and be adopted by others. But others, equally attractive, will come from outside of industry and be adopted by that sector. It is important that any reference model be flexible enough to incorporate this pattern of infrastructure development.

4.3 OTHER ISSUES

As critical STs are identified, effective deployment strategies must be put in place. It is never sufficient to simply bring the standard to approved international standard status or to prototype the technology. The Deployment Forces Tables (Appendix C) and the ST Status Matrix (Figure 5 on page 27) identify some of the activities and issues that determine the success or failure of a standard or technology. A strategy to deploy critical information technologies must take these issues into consideration.

It is important to maintain a sense of timing and evolution about infrastructure development. The EIP program is a significant effort focused on identifying appropriate responses to near-term demands for information integration. These responses may take the form of finding ways to use existing and near-term STs more effectively. The needs anticipated 10 years or more in the future appear to require the development of new technologies and architectures. Also the development of strategies and methods for aiding the transition towards these forms of information integration must be planned and pursued.

APPENDIX A. ORGANIZATION AND PROGRAM PROFILES

Organizations and Programs (OPs) Profiled

Automotive Industry Action Group (AIAG)

American National Standards Institute (ANSI), Inc.

Application Portability Profile (APP) - NIST Program

Computer Integrated Enterprise (CIE)/Computer Aided Manufacturing International (CAM-I) Program

Computer-Assisted Design (CAD) Framework Initiative, Inc. (CFI)

Corporation of Open Systems (COS)

Enterprise Integration Program (EIP)

Engineering Information System (EIS)

Enterprise Networking Event '88 International (ENE 88i)

Federal Information Processing Standards Publications (FIPS Pubs)

Institute of Electronics and Electrical Engineers (IEEE), Inc.

Initial Graphics Exchange Specification (IGES)

Integrated Information Support System (IISS)

Information Resource Dictionary System (IRDS)

Manufacturing Automation Protocol (MAP) and Technical Office Protocol (TOP)

National Center for Manufacturing Sciences/Computer Integrated Operations (NCMS/CIO)

National Institute for Standards and Technology (NIST) Shop of the 90s

Open Distributed Processing (ODP)

Object Management Group (OMG)

Open System Foundation (OSF)

Open System Foundation/Distributed Computing Environment (OSF/DCE)

Product Data Exchange Using STandard for the Exchange of Product Data (STEP) (PDES)

Portable Operating System Interface for Common Environments (POSIX)

Remote Data Access (RDA) Protocol

SEMATECH Strategic Cell Controller Project (SCC)

Transmission Control Protocol/Internet Protocol (TCP/IP)

X/Open

Outline

The profile of each OP consists of a matrix describing activities of the program with text providing non-technical profile information. Each profile follows the same outline, although not every section is available for every OP.

Title: The complete title of the organization or program.

Scope: A summary of the scope of work in which the OP is involved.

Level of Effort: The type of membership, support, and resources.

Performers: Who is involved in the OP.

Duration: How long the effort has been in existence.

Primary Milestones: The primary deliverables and expected dates of completion.

Intent: The mission or purpose of the OP.

Definitions: Definitions of significant terms specific to this OP.

Description of Work Done: A description of the organization and a summary of the standards or technologies developed.

Results: The significant accomplishments of this OP.

Technology Transfer Approach and Plans: What activities and approaches are being taken to deploying the STs.

Linkages: The relationships and links maintained by this OP with other OPs.

References: Location for additional information about the OP.

Primary Contacts: Individuals who can be contacted for further information on the OP.

Matrix Notes: Notes on information presented in the matrix.

Title: American National Standards Institute (ANSI), Inc. – Organization

Scope: Supporting development of information technology related standards. ANSI is the U.S. technical advisory group to the International Organization for Standardization (ISO).

Level of Effort: The work is done by working groups composed of members. The working groups are sponsored by ANSI and work items are picked by ISO established procedures.

Performers: Members of ANSI. There is a participation fee for each working group.

Duration: Ongoing

Intent: To develop information technology related standards and test procedures. The standards are published by ANSI/ISO.

Description of Work Done: The work in communications is related to Open Systems Interconnection (OSI), Fiber Data Digital Interface (FDDI), and packet switching. In the area of operating systems, ANSI is looking into the Portable Operating System Interface for Computer Environments (POSIX) work of the Institute of Electronics and Electrical Engineers (IEEE), and has worked on graphic and database management standards. It has developed standards on user interface and human factors, and has worked on security and several programming languages (Ada, Apt, C, Pascal, Cobol, Fortran, Basic, PL/1).

Results: Standards have been published in the above mentioned areas except for POSIX.

Linkages: IEEE, NEMA, the National Institute for Standards and Technology (NIST), the Corporation of Open Systems (COS), Manufacturing Automation Protocol/Technical and Office Protocol (MAP/TOP).

Table A-1. American National Standards Institute (ANSI) Matrix

Technical Categories	Business View	Information View	Technology View
Integration Frameworks and Architectures			
Operating Systems and Distributed Environments			• POSIX/IEEE
Communications			• FDDI X3.139 • X3.148 • X3.166 • T1.504 • OSI
Data Management Systems			• GKS X3.124 • PHIGS X3.144 • IRDS X3.138 • EDI X12 • NDL X12 • SQL X3.135, X3.168
Application Development Tools and Methods			• Computer Program Abstracts X3.88
Data Representations			
Information Modeling Tools and Methods			
User Interfaces		• Human Machine T1.203 • Human Factors Engineering IEEE1023	
Programming Languages		• Human Machine T1.203	• Ada MIL-STD-1815A • APT X3.37 • C X3.159 • Pascal • IEEE770X3.97 • Cobol X3.23 • Fortran X3.9 • Basic X3.113 • PL/1 X3.53
Security Tools and Methods			• Encryption X3.105

Title: Application Portability Profile (APP) – National Institute of Standards and Technology (NIST) Program

Scope: An integration mechanism using the functionality of the U.S. Government's Open System Environment (OSE) to define an APP in terms of open systems specifications organized into major service areas. The OSE functions included as part of the APP are those that have been identified as important to a broad spectrum of Federal agencies.

Intent: APP is not a standard. APP provides guidance to assist Federal agencies in making informed choices regarding the selection and use of OSE specifications, and in the development of application profiles based on the APP. It is directed toward managers and project leaders who have the responsibilities of procuring, developing, and maintaining information systems supported by heterogeneous application platforms.

Definitions:

- **OSE.** A conceptual framework that provides a context for user requirements and standards specification. It provides a set of information system building blocks with associated interfaces, services, protocols, and data formats.
- **OSE Reference Model.** Establishes a context for understanding how the disparate technologies required as part of an OSE relate to each other. It also provides a mechanism for identifying the key issues associated with applications portability and interoperability.
- **Profile.** A selected suite of specifications that define these interfaces, services, protocols, and data formats for a particular class or domain of applications.

Description of Work Done: NIST Special Publication 500-187, *Application Portability Profile*, describes APP as the U.S. Government's OSE profile. The report describes the service areas and components included in the APP and provides evaluations of recommended specifications for the majority of the service area components. One of the conclusions of this report was a desire to see all of the OSE specifications take the form of a Federal Information Processing Standard (FIPS).

Results: Although the OSE concept is relatively new, it has matured to the status of an emerging international consensus on the functionality (i.e., the collection of interfaces, protocols, services, and supporting formats) that should be included in an OSE (see reference to POSIX below).

Technology Transfer Approach and Plans: There is a shared recognition that no single vendor can supply all necessary information technology systems and services. The need to improve portability and interoperability has resulted in widespread interest in standards. By understanding and using APPs, a framework can be developed using the proper standards and information technology to satisfy specific user needs.

Linkages: Related standards for APPs: Portable Operating System Interface for Common Environments (POSIX), Government Open Systems Interconnection Profile (GOSIP), OSE Reference model, OSE, and Open Systems Interconnection (OSI).

References:

Emerging Technologies Group, Inc. *An Analysis of Application Environments*. Dix Hills, NY, 1989.

X/Open Company, Ltd. *X/Open Portability Guide*. Issue 3, Volumes 1-7. Englewood Cliffs, NJ: Prentice-Hall, 1988.

Title: Automotive Industry Action Group (AIAG) – Organization

Level of Effort: Donated time from member companies plus modest membership fees based on company gross sales.

Performers: Both administrative and technical personnel from nearly 700 member companies.

Duration: Ongoing, begun in 1982

Primary Milestones: Numerous white papers and reports, as well as published standards for members in electronic data interchange and bar coding.

Intent: The purpose of AIAG is to improve productivity in the automotive industry. It acts as a forum for automotive manufacturers and suppliers to reach consensus solutions to common business needs.

Description of Work Done: To date, a number of standards have been generated involving the exchange of information between companies. Automotive versions of electronic data interchange transaction sets and bar coding are examples of this. In most cases, AIAG has used the approach of choosing specific, well defined subsets of standards promulgated by other standards bodies.

Ongoing work includes radio frequency identification systems, application protocols for IGES data transfers, and telecommunications standards. AIAG is also studying quality standards, with a look toward rationalizing the current piecemeal system in the automotive industry.

Results: Clearly there is enough interest in the idea of such an organization to keep AIAG going. As to the actual adoption and use of its standards within elements of the automotive industry, the picture is not so clear. A wide variety of companies has joined and maintained membership. The level of active participation at the individual working groups is perhaps a better indicator of the interest in the program, but is unavailable.

Technology Transfer Approach and Plans: The primary technology transfer approach is based on publication of white papers detailing the problems and publication of the standards which address those problems. Standards are published directly and publicized through the AIAG monthly magazine and through direct people contact. Since the AIAG management and technical staff are on loan from the member companies, a natural link occurs in those companies who participate. In addition, the working groups which undertake the actual standards development work are made up of volunteers from the member companies. This provides another avenue for moving information back to the companies.

Linkages: Wherever possible, the AIAG bases its work on existing national and international standards. Examples include ANSI X12 for electronic data interchange and IGES for geometric data exchange.

References: *Actionline*, monthly publication for AIAG members.

Primary Contact:

Joe Phelan, Executive Director
AIAG
26200 Lahser Road, Suite 200
Southfield, MI 48034
(313) 358-3570

Matrix Notes:

The majority of AIAG's work is built on top of existing standards. It typically finetunes or selects a subset of an existing standard, then carefully defines its use for the automotive industry. The following are additional notes on some of the matrix entries.

- **Electronic Data Interchange Transaction Sets.** Standardized transaction sets based on ANSI X12 for electronic data exchange appropriate to automotive industry.
- **Bar Coding.** Bar coding standard established for automotive industry for automatic identification of parts and documents.
- **Radio Frequency Identification.** Non-optical method for accomplishing the same purpose as bar coding. Automotive standard currently being established.
- **Initial Graphics Exchange Specification (IGES) Application Protocols.** Currently developing a family of carefully defined subsets of the IGES data exchange standard to serve automotive industry needs.

Table A-2. Automotive Industry Action Group (AIAG) Matrix

Technical Categories	Business View	Information View	Technology View
Integration Frameworks and Architectures	• Automotive Data Interchange Models		
Operating Systems and Distributed Environments			
Communications		• Electronic Data Interchange • Transaction Sets • Magnetic Tape Labeling	
Data Management Systems			• Bar Coding • Radio Frequency Identification
Application Development Tools and Methods			
Data Representations		• IGES Application • Protocols	• Non-Uniform • Rational B-Splines • IGES
Information Modeling Tools and Methods			
User Interfaces			
Programming Languages			
Security Tools and Methods			

Title: Computer Integrated Enterprise (CIE)/Computer Aided Manufacturing-International (CAM-I) Program

Scope: CIE focuses on the management approach to enterprise integration. The mission of the CIE group is "to guide enterprise decision makers in focusing resources towards achieving strategic business goals through a successful management approach for organizational knowledge and technical resource utilization."

The current objectives of the CIE are to:

- Be the premier, world-wide focus for defining, analyzing and promoting the CIE concept.
- Provide leadership and support for program members in implementing CIE in their companies.
- Create a common understanding and acceptance of CIE.

The CIE program is currently focused on the following deliverables:

- CIE guidelines and methods. A manual for implementing enterprise integration.
- Case studies of best implementations.
- An extensive digest of relevant literature.
- Journeyman Conferences. Periodic trips and findings taken by the CIE group to visit enterprises and review actual implementations.
- Engineering integration decision framework. A reference model for decision making in the process of implementing and operating the integrated enterprise. This is thought to be the complementary (organizational/implementation) piece to the Computer Integrated Manufacturing/Office System Architecture (CIM/OSA).

Level of Effort: Membership group (14 sponsors at $22K per year plus about 1.5 person-months of labor per member per year). It has been working on this program for three years and currently are planning for three more years. The group contracts out about three person-years of work per year.

Performers: Members and university affiliates. Most of the work is done by the member representatives, each of whom dedicates about 1.5 months per year. In addition, some work is contracted out to university affiliates.

Duration: 1988–1994

Intent:

a. Prime motivation for initiating the CIE CAM-I membership was the poor rate of return on investments in information technology. The CIE program was designed to assist a group of peer sponsors from industry to work together to understand the barriers to successful integration and to define a set of guidelines for accelerating the pace of adoption. Executive forums, reports, and the Journeyman Conferences are the primary mechanisms for technology transfer to members and their executives and decision makers.

b. What barriers does this program address?

   1. **Management barriers.** Spheres of control and empowerment; issues around communication and understanding of goals; and the ability to make timely and informed decisions.

   2. **Organizational barriers.** Bifurcation of functions (design/manufacture); lack of standards and meaningful measurements of performance; excess, non-value-added activities, internal competition, cannibalization of autonomous organizations; and levels of hierarchy and communication.

   3. **Cultural barriers.** Geographical; implied rules, methods, processes "handed down" by tradition; "not invented here" (NIH) syndrome; education and training; and lack of shared goals.

   4. **Functional barriers.** Lack of understanding of business processes; no change "know-how"; and technology.

   5. **Strategic barriers.** International market access and international competition; poor strategic planning; poor interpretation of market "signals"; ineffective performance measurement; and government regulation of international trade.

c. Will the CIE program lead to the development of new standards? Yes, management methods for CIE implementation and standards for decision support tools. CIE is also collaborating with CIM/OSA and the International Organization for Standardization (ISO) committee TC184/SC5/WG1.

d. What were the original project objectives? Develop guidelines and methods to support the implementation of CIE.

Description of Work Done:

- Digest of relevant literature
- Journeyman I&II Conferences
- Guidelines and Methods (version 1.1)
- Numerous case studies of "best practice"
- First draft of the Decision Framework

The work of the CIE is primarily done through study groups and working committees. No new methods are used in the process of the CIE group. However, a guideline and methods document, to guide the process of implementing enterprise integration, is a specific deliverable of the CIE group.

Results: As stated above, the primary technical transfer mechanism of the CIE program is directly to the executives and decision makers in the member companies. Most of the tangible results of this work are enterprise integration programs and projects in the member companies.

- LTV Aerospace has initiated a program at the division level.
- General Dynamics has created a CIE office at the decision level.
- Honeywell and Kodak are reported to have corporate-level programs and General Motors is using pieces of the CIE model in several plants and divisions.

Cost justification criteria are outlined in the guideline and will be carried out in the individual member pilots and programs. It should be noted that the CIE program is working jointly on measurements of strategic deployment and measurements of the extent of integration with the CAM-I Cost Management System program, the developers of the activity-based costing (ABC) model. The focus of the CIE group is on practice rather than products so it is unlikely that many new products will emerge from this effort. No market studies have been performed to gauge market interest in this work. Again, as a membership-based group, the primary focus is transferring technology into the member organizations.

CIE is now beginning to develop alliances with other standards bodies and consortia. They are willing to share some of their results to influence standards relating to the technical architecture for enterprise integration and CIM.

Technology Transfer Approach and Plans: The major focus of technology transfer are the member companies. CIE does sponsor conferences for executives in the member firms plus invited guests. In addition, the CIE group hopes to participate in and influence the CIM/OSA effort, ISO's TC184/SC5/WG1, the Computer-Aided Logistics Support (CALS) program, and the Product Data Exchange Standard (PDES). It will also eventually publish some of its material for general distribution.

Near-term and long-term plans:

- Complete CIE framework.
- Influence TC184/SC5/WG1. Several detailed papers have been submitted.
- Build links to other consortia for collaborative efforts (Lehigh, CAM-I/CMS, Microelectronics and Computer Technologies Corporation (MCC), National Center for Manufacturing Sciences (NCMS)) in the areas of standards development and benchmarking.
- Refine metrics and standards for implementation.
- Develop detailed specifications for decision support tools.

Work submitted to standards committee: CIE has submitted several responses to the ISO committee on CIM frameworks, most recently the response to TC184/SC5/WG1-N163, the CEN/CENELEC document, based on CIM-OSA.

Linkages:

- CIE is currently linked to ISO's WG1. It is interested in forming links with the NCMS Computer-Integrated Operations Special Interest Group (CIO SIG) and with MCC.
- Recently, CIE held a joint working session with the CMS group in CAM-I to discuss performance measures for CIM.
- Internationally, CIE is interested in forming relations with several ESPRIT projects including the AMICE CIM-OSA and the Integrated Modeling of Products and Processes Using Advanced Computer Technologies (IMPPACT). Mr. Bob Boykin, the Executive Director of CIE, is an action officer for the European Community/United States cooperative initiative.

Table A-3. Computer Integrated Enterprise (CIE) Matrix

Technical Categories	Business View	Information View	Technology View
Integration Frameworks and Architectures	• Decision framework for CIM implementation • Functional & semantic models (IDEF/NIAM) • Guidelines & methods for CIM implementation • Managing the process of change: technically and organizationally	• Tool framework for decision support and enterprise modeling tools	
Operating Systems and Distributed Environment			
Communications	• Activity communication • How decisions are communicated	• Electronic mail (email) • Electronic conferencing	
Data Management Systems	• Corporate strategy for Data Management		
Application Development Tools and Methods	• None yet. Future interest in business methods		
Data Representations	• Develop semantic models using NIAM, business models, information models, not technology	• Working toward a business development language	
Information Modeling Tools and Methods	• Strategic integration of modeling methods for support of EI life cycle • ABC risk analysis simulation • How, when to make decisions • What is the topology/ taxonomy of enterprises		
User Interface	• Labor/Management. relations • Organizational issues in adopting new technology		
Programming Languages			
Security Tools and Methods			

Title: CAD Framework Initiative, Inc. (CFI) – Organization

Scope: CFI is a consortium created to promote standards that facilitate and enable electronic computer-assisted design (CAD) tool integration. Member companies include tool vendors, workstation vendors, semiconductor suppliers, and end users.

Level of Effort: International consortium of 50+ members, including 8 CFI Sponsor members. The membership is approximately 60% North American, 20% European, and 20% Asian. The eight CFI Sponsor members are U.S. corporations.

Performers: Most of the technical work is performed by more than 200 volunteers from member companies and organizations. CFI has a staff of 13.

Duration: Ongoing, begun in 1988

Primary Milestones:

- Founded (November 1988)
- First CFI meeting in Europe (October 1989)
- EuroCFI and CFI Meeting in Japan (CFIMJ) formed (April 1990)
- 1990 Integration Project Demonstrated (Design Automation Conference (DAC) 1990)
- 1991 Integration Project Demonstrated (DAC 1991)
- CFI Release 1.0 Pilot Projects (January–September 1992)
- Standards for Electronic Design Automation, Release 1.0 (December 1992)
- CFI Release 2.0 Pilot Projects (September 1993–March 1994, projected)
- Standards for Electronic Design Automation, Release 2.0 (June 1994, projected)

Intent: Since 1988, CFI has been working to make it simpler, faster, and less costly to use design automation tools and design data by developing specifications for a CAD framework. CFI's mission is to define and support the adoption of standards which make it easier to integrate design data and to integrate and interoperate design automation tools for the benefit of users and vendors worldwide.

Description of Work Done: CFI defines a CAD Framework as a software infrastructure that supports the application environment for CAD tools. While recognizing that the design-tool framework concept has many domain independent components and should be broadly applicable, CFI is focusing on the application environment of electronic component design.

The technical activities of CFI are conducted under a single Technical Coordinating Committee, chaired by CFI's Vice-President of Technology. Since 1991, the technical efforts have been organized into two groups:

- **Electronic Design Information Working Groups:** Design Representation (Library and Design Hierarchy, Timing/Delay Data and Constraints), Simulation Backplane, Component Information Representation Electronic Data Book (Dictionary, Framework, Scenarios), Application-Specific Integrated Circuit (ASIC) Library Standard, Technology CAD Device Modeling (TCAD Semiconductor Process Representation, TCAD Semiconductor Wafer Representation).
- **Domain Independent Services Working Groups:** Inter-Tool Communication, Tool Encapsulation Specification, Extension Language, Task and Session Management, Design Object Management.

The 1990 Integration Project featured the Design Representation Programming Interface (DR PI) for electrical connectivity data. Twenty-two companies participated in this project, which was demonstrated at DAC 1990. The 1991 Integration Project focused on the "framework cockpit," adding Tool Encapsulation Specification and Inter-Tool Communication functionality to the DR PI. It was demonstrated at DAC 1991.

The two integration projects were basically proof of concept demonstrations. CFI realized that feedback from actual experience integrating CAD tools was critical to the efficacy and usability of its standards. Beginning in 1992, the integration project efforts were expanded to multiple pilot projects that would exercise the emerging CFI technology in actual tool integration situations. The pilot projects, like beta test sites, provide feedback on critical issues (e.g., incorrect or missing functionality) to the responsible CFI working groups. The working groups use Quick Response Teams to address the issues raised (in less than one week, if possible). The Pilot Projects help assure a usable standard, while accelerating the standard development process.

For Release 1.0, four pilot projects were undertaken in 1992. The Hewlett-Packard/Cadence/Mentor Graphics project focused on the Design Representation Electrical Connectivity information model and programming interface. The Sun Microsystems project focused on Inter-Tool Communications. The EuroCFI project (Gesellschaft fur Mathematik und Datenverarbeitung MBH (GMD), Cadlab, Siemens-Nixdorf) embedded CFI technology into the JESSI Common Framework, focusing on the Inter-Tool Communications programming interface and message dictionary. The IBM Inter-Framework Protocol project used the Inter-Tool Communications programming interface, Tool Encapsulation Specification, Extension Language, and error handling programming interface components of Release 1.0.

CFI's Standards for Electronic Design Automation, Release 1.0 were published in December 1992 in four volumes:

- Design Representation Programming Interface Electrical Connectivity.
- Inter-Tool Communications Programming Interface.
- Tool Encapsulation Specification.
- Computing Environment Services, comprising the following:

  Base System Services (POSIX, the Portable Operating System Interface for Computer Environments)

  Base Networking Services (X/Open Transport Interface

  Basic User Interface (X11R4)

  Extension Language: Core Language Selection (Scheme, IEEE P1178/D5)

  Error Handling Programming Interface.

Release 2.0, work in progress, is targeted at the "front-end integration" task, addressing integration of front end tools (e.g., schematic capture, synthesis, simulation, and timing analysis) for ASIC and printed circuit board (PCB) design. It will include new or extended standards for design view selection, dynamic evaluation of user and design information for tool invocation, expanded Inter-Tool Communication messaging, and design object selection and access. Siemens-Nixdorf, IBM, and Hewlett-Packard have proposed Release 2.0 pilot projects.

Release 3.0 will address integration of back-end tools for physical design and test. CFI is discussing linkage for Release 3.0 with PDES, Inc. and PAP-E.

Technology Transfer Approach and Plans: The primary means for technology transfer from CFI is through the direct participation of personnel from the member companies involved in the work. This involves the working group activities as well as the pilot projects. CFI will work with vendors who wish to brandmark their tools as CFI compliant. CFI is working on a certification program; it hopes to have the program in place for the Design Representation Programming Interface during the fourth quarter of 1993. This will likely involve reference software that demonstrates a correct use of each programming interface.

Linkages: CFI is endorsing some existing standards, such as POSIX and X11 for computing environment, Scheme for extension language, and EXPRESS for information modeling. For the most part, CFI is developing its own solutions to the other needs and problems which arise.

CFI also has links to Electronic Data Interchange Format (EDIF), PDES, Inc., PAP-E, Object Management Group (OMG) and Microelectronics and Computer Technology Corporation (MCC).

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CFI also has on-line documentation available via ftp or email. An empty email message, where there is not text in the mail body, to cfi-server@cfi.org with subject "help" will get a reply about using the server.

Matrix Notes: The entries are basically self-descriptive. Most of the work is self-developed. Only those pieces called out as named standards are existing or nearly complete standards. The following is additional information on selected topics from the matrix.

- **Exception Handling Interface.** An approach to handling problems which arise when data is being moved around. Broadly applicable to areas beyond the immediate interest of CFI.
- **Tool Encapsulation Specification.** An approach for describing software tools in a computer-readable format. For a general type of tool, a set of descriptors is devised which characterizes a specific example of such a tool based on a number of abstract tool capabilities and characteristics.
- **Very High Speed Integrated Circuit (VHSIC) Hardware Design Language (VHDL), Electronic Design Interchange Format (EDIF).** Information modeling methods/languages intended for integrated circuit design.
- **Scheme.** A programming language derived from Lisp.

Table A-4. CAD Framework Initiative, Inc. (CFI) Matrix

Technical Categories	Business View	Information View	Technology View
Integration Frameworks and Architectures	• Electronic Design Logical Connectivity Model	• Programming & Database Subroutine Library based on Data Representation	• EXPRESS for Information Model
Operating Systems and Distributed Environments		• POSIX Tools • Exception Handling Interface	• POSIX
Communications	• Inter-tool Communication Use Architecture	• Message Protocol • Programmatic Subroutine Library	• Programming Language • TCP/IP
Data Management Systems		• Storage Manager Interface • Common Interface to Database • Configuration Management • Component Interconnect Rules for Building Standard Libraries	• Distributed Files and Data • Unix File Systems
Application Development Tools and Methods		• Tool Encapsulation Specification	
Data Representations	• VHDL	• EDIF • VHDL • Electronic Design Information Model	
Information Modeling Tools and Methods			
User Interfaces		• Style Guidelines	• X11 Underlying Standard
Programming Languages		• Scheme	• C • C++
Security Tools and Methods		• (Part of Database Management Work)	

Title: Corporation of Open Systems (COS) – Organization

Scope: Developing and promoting open systems technologies, in particular Open Systems Interconnection (OSI) based communications profile. COS is also interested in Integrated Services Digital Network (ISDN) efforts. COS also promotes development of conformance testing activities including the development of test systems, test procedures, and harmonization. The organization is also involved in several training educational activities related to open communications systems.

Level of Effort: COS is a consortium of about 100 companies, a mixture of users, vendors, and systems integrators. These include manufacturing, process, and financial companies on the user side; and computer and communications manufacturers on the vendor and systems integrator side. COS has a full time staff of about 50 people and is located in McLean, Virginia. Its main funding comes from membership dues and revenue generated by its offered services.

Performers: COS has done work in-house in the training area and in offering test services, but has mostly contracted with outside companies for building test systems. Several member companies have also participated in technical areas of test procedure development and implementors agreements.

Duration: Ongoing.

Intent: To support and promote technologies based on open systems for communications.

Description of Work Done: COS has developed a "COS mark" program (along the lines of a "seal of approval") to assess conformance of products complying to OSI standards. It has acquired conformance testing tools and are making them available to their members. COS has developed training material and offers conferences and workshops on open systems. The members have organized themselves into special interest groups (SIGs) and, through them, have developed the required agreements. There are SIGs for Manufacturing Automation Protocol/Technical and Office Protocol (MAP/TOP) users, Integrated Services Digital Network (ISDN), and testing policy. The Users Alliance for Open Systems is also part of COS.

Results: COS has developed a procedure for the COS mark program. It offers conformance testing for OSI based products. It has conducted and continues to conduct seminars, conferences, and workshops on open systems.

Technology Transfer Approach and Plans: COS is making its conformance testing tools and services available to the member companies and is promoting its activities through an education, awareness, and training program.

Linkages: COS is linked to the Computer and Business Equipment Manufacturers Association (CBEMA), the National Institute of Standards and Technology (NIST), American National Standards Institute (ANSI), X/Open, the MAP/TOP Users Group, and the Users Alliance for Open Systems.

Table A-5. Corporation of Open Systems (COS) Matrix

Technical Categories	Business View	Information View	Technology View
Integration Frameworks and Architectures	• User Requests for Open Systems		
Operating Systems and Distributed Environments			
Communications	• Strategies for OSI	• OSI	• OSI
Data Management Systems			
Application Development Tools and Methods	• Conformance Testing • Policies & Procedures	• Education and Awareness of OSI Testing	• Conformance Testing Tools
Data Representations			
Information Modeling Tools and Methods			
User Interfaces			
Programming Languages			
Security Tools and Methods			

Title: Enterprise Integration Program (EIP) – Air Force Program

Scope: The EIP program is divided into six phases:

- Phase I includes the following tasks: needs analysis and requirements definition for enterprise integration across industry, state-of-the-art assessment of technologies and methods needed for enterprise integration, enterprise integration guidelines, core specifications for particular industry architectures, research and development analysis and prioritization, and advisory and review board selection.
- Phase II will include functional specification of pilot sites for integration, research and development of technologies identified as missing, education and training in the concepts of enterprise integration to industry and the pilot sites, technology and product awareness within the concepts of enterprise integration, pilot-site preparation, national consensus building on enterprise integration guidelines, and testing of enterprise integration guideline-compliant products.
- Phase III will implement and demonstrate the EIP technologies in a production environment using pilot sites, conduct advanced research and development, and perform a follow-on assessment of enterprise integration at the pilot sites.
- Phase IV will perform additional research and development.
- Phase V will extend the enterprise integration guidelines and develop additional technology to support additional standards.
- Phase VI will perform more implementations.

Phases IV, V, and VI are optional. Work related to these phases will be performed if approved by the U.S. Air Force at a later date.

Level of Effort: The total contract value (phases I through VI) is on the order of $58 million. Funding for phases I, II, and III will be about $23 million.

Performers: The program sponsor is the U.S. Air Force. SofTech, Inc. leads a team composed of BDM International, Cimflex Technowledge Corporation, Cincinnati Milacron, Dravo Automation Systems, Honeywell, Industrial Technology Institute, Martin Marietta, McDonnell Douglas, Microelectronics and Computer Technology Corporation (MCC), Price Waterhouse, Rensselaer Polytechnic Institute, and Wizdom Systems.

Duration: EIP began April 1, 1991, and is scheduled to end March 31, 1996.

Intent: The EIP objective is to contribute to a national initiative for information systems integration for inter-enterprises and intra-enterprises. EIP will accomplish this objective by assisting in national consensus building; stimulating the development of commercial products; and validating the EI framework and guidelines as well as the core functional specifications and related standards. EIP aims to bring about a fairly wide consensus among industries and their subcontractors by focusing on the needs of the wide spectrum of companies that comprise these subcontractors and using their knowledge, perspectives, and experiences. Although EIP will stimulate the development of standards and commercial products embodying these standards, its work is not directly intended to lead to the development of new standards. Its support of various standards efforts, however, is intended to help lead to the acceptance of these standards.

The deliverables of this program are research results in specific problem areas of enterprise integration, a group of industries that subscribe to the enterprise integration vision, products (from vendors) that solve parts of the enterprise integration problem and seamlessly interface with other products, and pilot sites that implement enterprise integration using these products.

Description of Work Done: The overall program is in its early stages and currently the needs analysis and requirements task is in progress.

Results: None yet.

Technology Transfer Approach and Plans: EIP has a comprehensive technology transfer plan which includes the establishment of advisory and review boards to aid technology transfer, educate users, and begin consensus building on enterprise integration efforts. Technical experts from the Air Force and industry will form these boards. A Senior Executive Review Board will be established to provide long-term strategic planning input.

Conformance and performance testing of products will be performed by neutral organizations selected by the program. Appropriate knowledge and information will be transferred to the testing organizations.

Full-scale pilot implementation sites will be chosen and established to demonstrate both intra- and inter-enterprise integration.

Education and training programs will be established to offer workshops and courses to build public awareness in the enterprise integration strategies adopted by this program, and provide in-depth training in the program's core specifications and the products and technologies used in the pilot implementations. These training programs will be geared to a wide spectrum of management and technical personnel.

EIP will have an advocacy program which will set up and administer user groups. These groups will include academia, government, and industry, and will provide formalized input to contractors, vendors, and standards bodies, thus helping to establish a national consensus for the enterprise integration guidelines developed in this program.

Finally, a comprehensive cost-benefit analysis model will be created to assess the benefits of enterprise integration at the pilot sites and justify the technology adoption decisions taken at these sites. Also, relevant measurement criteria will be developed to assess the success of this program in its technology transfer tasks.

Linkages: This program will participate in International Organization for Standardization (ISO) committees and working groups which are working on integration guidelines. Representatives from such standards committees will be invited to participate in consensus building activities. Users groups established by EIP will provide inputs to the relevant international standards committees.

Reference: EIF contract led by IBM and Northrop, sponsored by U.S. Air Force MANTECH.

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Table A-6. Enterprise Integration Program (EIP) Matrix

Technical Categories	Business View	Information View	Technology View
Integration Frameworks and Architectures	• CIM-OSA	• CIM-OSA • CALS	• CIM-OSA • CALS
Operating Systems and Distributed Environments			• POSIX
Communications			• OSI • GOSIP
Data Management Systems	• Functional Specifications • Standards • Standard Compliant Products (Configurations)		• SQL • PDES • IRDS
Application Development Tools and Methods	• User Groups • Advocacy Program • Training • Pilot Sites		• API Knowledge Base Systems • Conformance and Interoperability Test Tools and Methods
Data Representations			• PDES
Information Modeling Tools and Methods	• IDEF	• IDEF	• IDEF, EXPRESS
User Interface			• X-Windows
Programming Languages			
Security Tools and Methods			

Title: Engineering Information System (EIS) – Air Force Program

Level of Effort: Phase 1 – $14 million; Phase 2 – $4 million; Phase 3 - $1 million.

Performers: Honeywell, Xerox, Intermetrics, Inc., CAD Language Systems, Inc., McDonnell Douglas Electronic Systems Company, Arizona State University, and TRW.

Duration: Phase 1 – June 1987 to September 1989; Phase 2 – August 1989 to July 1991; Phase 3 – June 1990 to September 1991.

Primary Milestones: Completion of Phase 1 – the EIS Specifications; completion of Phase 2 – the prototype system; completion of Phase 3 – application demonstrations.

Intent: This project was intended to develop a framework which addresses the problem of integrating computer-aided design/manufacturing/engineering (CAD/CAM/CAE or CAx) and computer-aided integration (CIM) tools. While intended to be applicable to design in general, the initial effort was for the design of integrated circuits. Many CAx/CIM tools exist, but getting them to work together has proven very difficult. The difficulty of transferring information from one tool to another was and is seen as a major barrier to enterprise integration and competitive manufacturing enterprises. The program was intended to lead to a design framework which is widely accepted in the electronics industry in the short term and generally across industries in the long term. Specifically, the initial focus for candidate standards was on data representation and interoperability across environments.

The original project requirements were determined by an Institute for Defense Analyses (IDA) team with the help of workshops and interviews. The original project objectives were to develop a framework for a system which integrates a wide variety of CAx tools and to demonstrate a prototype version of that framework on a deliberately mixed set of computer hardware and software. The actual system requirements were very detailed and specific, both in short- and long-term goals.

Definitions:

- **Engineering Information Systems (EIS).** A framework for integration based on information sharing, providing the functions of tool integration, data exchange, engineering management and control, information management, and system administration.
- **Electronic Computer-Aided Design (ECAD).** Computer system for assisting a designer in the process of creating the design for an electronic component or system.

Description of Work Done: EIS work comprised two parts: a framework (or integration infrastructure) and domain-specific information models. The EIS program shows the many advantages of looking at the engineering environment problem in terms of the two parts. The framework technology is independent of domains and is equally applicable to many domains and life-cycle phases. A domain-specific information model of the engineering design process for integrated circuits was developed and used to determine its information needs. Thus, part of the program was the development of models for ECAD and for the administration of the design system.

The EIS was entirely implemented using an object-oriented approach. Low-level tools and methods were developed to implement the ECAD system. "Wrappers" were used to allow existing CAx tools to fit into the system. Wrappers are software interfaces which modify the user interface of existing software packages to fit a model defined for each type of tool (CAD system, finite element analysis, etc.). Communications throughout the system are handled via messages between the various system components.

Standards (or near-standards) used for this work include Integrated Computer-Aided Manufacturing (ICAM) Definition Language (IDEF1x), Portable Operating System Interface for Computer Environments (POSIX), X-Windows, EXPRESS, Motif, Ada, and C. Major pieces of the EIS work were submitted to standards organizations as prototype or strawman standards. The core of the proposed new standards is made up of the common information model (via the "object type standards" and the "common exchange format standard") and transparent communication ("via protocol independent network interface standards").

Results: The program team claims significant external support and input through the workshops and reviews conducted periodically during the program. The program was well publicized via a widely distributed newsletter. As yet, however, the results have been demonstrated only in one demonstration site. No evidence exists of any cost justification studies for use of the EIS. No evidence exists of any commercialization efforts of results of the program. The team appears to have concentrated on producing prototype standards, some of which have been handed off to standards organizations. To date, the primary objectives of the EIS program seem to be on track, having met the basic objectives through Phase 2. Phase 3 is not yet complete. A prototype EIS for integrated circuits was generated in Phase 2, with implementation in a demonstration site to be undertaken as part of Phase 3.

Technology Transfer Approach and Plans: The primary means for technology transfer was through submission of major pieces as prototype or strawman standards of the EIS work to standards organizations. The core of the proposed new standards is made up of the common information model (via the Object Type Standards and the common exchange format standard) and transparent communication (via protocol independent network interface standards). During the project, a newsletter was widely distributed to keep a wide variety of interested people informed. Future plans include a variety of demonstration sites, including some with different design domains (besides integrated circuits).

Linkages: The EIS program used a few existing standards (see above), and considered many more in the development process.

References:

EIS Program. *EIS Specification Documents*. Three-volume set: *EIS Organization and Concepts*, *EIS Specifications and Guidelines*, and *EIS Engineering Information Model*.

EIS Program. *EIS Update*, a series of newsletters produced by the EIS project team during Phases 1 and 2. Produced from July 1988 to March 1991.

Linn, J. L. and R. I. Winner. *The Department of Defense Requirements for Engineering Information Systems*. Two-volume set. Alexandria, VA: Institute for Defense Analyses, July 1986.

A series of EIS Workshops open to people interested in the EIS program, held January 1988, November 1988, November 1989, and March 1991.

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Matrix Notes:

ECAD Model. Engineering information model for ECAD environment. Deals with both the product and the design process. Includes capabilities such as schematic capture and placement.

Administrative Model. Model of required system underlying ECAD Model. Deals with the operational concerns of four identified participants: system implementor, system administrator, data administrator, and end user.

Application Object Model. Set of "objects" which models the engineering design application.

Message architecture. Defined approach to building messages to be sent within the EIS.

Wrappers. Software interfaces which reside between engineering programs and the user. They provide a means to ensure that different programs which serve the same purpose look essentially alike to the user.

Message primitives. Define how system messages should be constructed.

Engineering Design Framework. Structure in which to place the tools of engineering design.

Application Object Model (AOM) Services. EIS capabilities supporting the use and maintenance of the AOM.

ECAD Tool Templates. Templates for building and integrating tools which support ECAD.

EDIF, IDEF1x, VHDL. Information modeling methods and languages. EDIF and VHDL are intended for integrated circuit design.

Browser. Tool for looking at object-oriented data base.

Policies. Mechanism for controlling EIS and its use.

Table A-7. Engineering Information System (EIS) Matrix

Technical Categories	Business View	Information View	Technology View
Integration Frameworks and Architectures	• ECAD Model - Product - Design Process • Control of Design Process	• Administrative Model • AOM • Policies - Upon Entry - Upon Exit	
Operating Systems and Distributed Environments			• POSIX
Communications		• Message Architecture	• Wrappers • Message Primitives
Data Management Systems	• Engineering Design Framework	• AOM Services	
Application Development Tools and Methods			• Browser
Data Representations			
Information Modeling Tools and Methods	• ECAD -Schematic Capture -Placement		• EDIF • IDEF1X • VHDL
User Interface	• Common User Interface by Function		• X-Windows • ECAD Tool Templates
Programming Languages			
Security Tools and Methods			

Title: Enterprise Networking Event '88 International (ENE 88i) – SME program

Level of Effort: Total funding was on the order of $50 million. Due to the broad base of contributors and sources of funds, higher specificity would be very difficult.

Performers:

- **Sponsor.** Society of Manufacturing Engineers (SME).
- **Co-sponsors.** Corporation for Open Systems (COS) and the Manufacturing Automation Protocol/Technical and Office Protocol (MAP/TOP) Users Group (MTUG).
- **Network booth sponsors.** The users of MAP and TOP: Boeing, TRW, Deere, General Motors (GM), The USAF/Industry Coalition, Department of Trade and Industry (UK), ESPRIT.
- **Contributing vendors.** AT&T, Digital Equipment Corporation (DEC), IBM, Allen Bradley, Concord, Retix, and others had products ready for the event.
- **Related conformance testing.** The Industrial Technology Institute developed, supported, and operated systems for testing conformance to the MAP/TOP 3.0 specifications.
- **OSI protocols.** COS was responsible for some Open Systems Interconnection (OSI) protocols like Transport, File Transfer Access Method (FTAM) and Message Handling Service (MHS).

Duration: Work on the Event was started in June 1986. The actual Event took place June 6–8, 1988.

Intent: The Event was organized to show users that the time had come to implement MAP/OSI networking and to give vendors a vehicle by which they could present and promote their products. The co-sponsors, COS and MTUG, intended it to be the largest demonstration ever of standards-based products interoperating in a real-life, networked-enterprise configuration.

The Event addressed data communications standardization and the interoperability of complying products, intra- and inter-company communications, and manufacturing. It offered a common communications platform for developing and implementing distributed applications. It also was the first large-scale demonstration of enterprise integration via networking in the commercial world.

The Event was not intended to lead to the development of new standards. However, the large amount of work that went into product development, testing, and ensuring interoperation led to refinements of the standards by identifying ambiguities and implementation problems. This led to products of better quality and the acceptance of implementations by users.

The deliverables of the Event were:

- The three-day show, the centerpiece of the Event, in which users and vendors cooperated to display world-wide connectivity and interoperation using standards-based products and applications encompassing functional areas of an enterprise from order processing to manufacture and shipping.
- A forum for user-vendor contact for mutual discussions and evaluations of each other's needs, offerings, future plans, and commitment to enterprise integration and open systems.
- A conference on open systems along with workshops and tutorials designed to help users understand OSI, its effects on industry, and strategies for migration.

Description of Work Done: The work done in this project included the following:

The development of test tools and methods, especially conformance test systems for the following protocols: Manufacturing Message Specification (MMS), Network Management (NM), Directory Services, 802.4 CB MAC, 802.2 Class 3, Initial Graphics Exchange Specification (IGES), Transport, FTAM, MHS.

The development of applications using products conforming to OSI standards:

- The demonstration of enterprise-wide connectivity using OSI networking technology.
- The development of methods for deploying large-scale, "very" multi-vendor networks.
- The development of enabling tools that would help applications developers integrate OSI services.
- The interoperation of standards-based products and applications built by different vendors.
- Technical sessions, workshops, and tutorials.

Results: Many manufacturing users see OSI enterprise-wide networking and open systems as a key technology for integration. Thus, the Event was seen by them as an important launchpad for the acceptance and widespread adoption of OSI-based profiles such as MAP/TOP.

MAP/TOP 3.0 was the networking standard being showcased at the Event. The Saturn plant at Spring Hill, Tennessee, exclusively using MAP/TOP, represents a site implementation that uses some of the products resulting from the Event.

Currently, the cost of implementing MAP/TOP networking solutions is higher than other available technologies. Thus, at a departmental level it may not be seen as cost effective. At the corporate level, where achieving enterprise integration via multi-vendor open networks is a long-term strategic objective, cost is a less important factor. Some independent private cost-benefit studies have been performed. Many have concluded that long-term strategic benefits can be derived from investing in OSI technology.

The program team strongly emphasized vendor participation. About 60 companies participated. Most of these vendors have MAP/TOP 3.0 compliant products in the market today. Some vendors announced new products at or after the event. However, this number was fewer than was hoped for.

Technology Transfer Approach and Plans: The Event did not have an explicit technology transfer plan. However, the demonstration, which was the most important and visible part of the Event, served as a vehicle for technology transfer. Large corporations representing both users and vendors as well as smaller vendor companies participated in the demonstration.

A number of committees were formed from among the participating companies. These were responsible for various aspects of the preparation for the Event and its execution. There were a number of "staging areas" around the country, each with its team leader and user-vendor team. The COS and ITI test committees were responsible for development and validation of the test systems that would then be used to test vendor products for conformance at each staging area. There were finance, management, and organization committees as well.

An important technology transfer objective of the Event was to build awareness among users that open systems are a reality and the products and tools to realize them are quickly becoming available.

The conference, which offered technical sessions, workshops, and seminars was another important technology transfer vehicle aimed at helping users understand OSI technology and its potential and formulate long-term and migration strategies.

It was anticipated that after the Event, participating vendors would rapidly introduce new OSI-based products that would enable users to realize true multi-vendor interoperation.

Although a large number of vendors showed early commitment, not as many of the products anticipated have been released.

Linkages: The Event concentrated on OSI and MAP/TOP networking and did not attempt to integrate and maintain compatibility with legacy systems (like TCP/IP) and older versions of standards. There was however, correspondence and dialogue with U.S. GOSIP and European OSI and MAP/TOP efforts. The advantage of close contact with legacy systems like TCP/IP is that newer efforts can learn from the pitfalls such systems have already encountered and earn the following and acceptance of Transmission Control Protocol/Internet Protocol (TCP/IP) users. Establishment of a working relationship with the Internet Activities Board would have helped U.S. OSI and MAP/TOP efforts define an acceptable migration path for existing users of TCP/IP and obtain for itself wider acceptance in the long run.

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Table A-8. Enterprise Networking Event '88 International (ENE 88i) Matrix

Technical Categories	Business View	Information View	Technology View
Integration Frameworks and Architectures		• OSI Reference Model • Allen-Bradley's 5-Level Pyramid Model	• Bridges, Routers, and Application Layer Gateways
Operating Systems and Distributed Environments			• Unix
Communications			• Proprietary
Data Management Systems		• Relational Data Model • Configuration Management: NIST Implementors' Agreements, ENE Participants' Agreements	• Relational Database Technology
Application Development Tools and Methods	Staging Areas		• Conformance/ Interoperability Test Tools and Methods • Application/ Development Customization Toolkits • Systems Integration Tools
Data Representations			• ASN.1 • IGES
Information Modeling Tools and Methods		• Network Connectivity Diagrams	
User Interfaces			
Programming Languages			
Security Tools and Methods			

Title: Federal Information Processing Standards Publications (FIPS Pubs) – National Institute of Standards and Technology (NIST) Program

Scope: Develop publications for U.S. Government-wide standards for computer software, hardware, data management, networks, and security.

Level of Effort: Only those standards that promise sizable benefits to the U.S. Government are issued as FIPS.

Performers: Voluntary industry standards organizations work in partnership with the NIST National Computer Systems Laboratory (NCSL).

Duration: Ongoing effort.

Intent: Goals of this program are to:

- Improve the life-cycle efficiency and effectiveness of Federal information technology resources.
- Facilitate the competitive and economic procurement of systems, components, and services.
- Improve the portability of data, software, and technical skills across systems.
- Protect systems and networks against unauthorized access, manipulation, abuse, and protect information from unauthorized modification or disclosure.
- Reduce waste, errors, and unnecessary duplication in the application and use of systems.
- Increase the productivity of the Federal workforce.

Description of Work Done: Develop publications, including standards, guidelines, and program information documents, into the following categories:

- General Publications
- Hardware Standards and Guidelines
- Software Standards and Guidelines
- Data Standards and Guidelines
- Automated Data Processing (ADP) Operations Standards and Guidelines
- Related Telecommunications Standards
- Conformance Tests

Results: FIPS and the specifications they adopt are implemented into computer products. NCSL sees a need for expansion of its efforts in structuring conformance testing to these FIPS, and is in the process of formulating a program.

Technology Transfer Approach and Plans: Several contributions have been made in this area. SGML and SQL are two standards currently used by the Product Data Exchange supporting STEP (PDES) activities.

- The Standard Generalized Mark-up Language (SGML) was a 1987 CALS deliverable for NIST; a validation suite and reference parser were developed. These are both available through NTIS. The ANSI X3V1 committee currently develops standardized test cases under the "conformance testing initiative." These test cases, as they are approved, will be publicly available as a reference application to test for conformance to SGML.
- The SQL test suite, Version 2.0, was released in January 1990. This suite tests compliance with FIPS 127, *Database Language SQL*. Approximately 60 vendors, integrators, standards organizations, and certification agencies presently use the SQL test suite, or its predecessor, Version 1.2, released May 1989. A commercial conformance testing service began at NIST in April 1990.

References:

FIPS Pubs are sold by the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

National Technical Information Service. *The SGML Parser*. Springfield, VA: NIST, 1987. NTIS PB 87- 235115/WCC.

National Technical Information Service. *Database Language SQL*. Springfield, VA: NIST, February 2, 1990. FIPS Publication 127-1.

Title: Institute of Electronics and Electrical Engineers (IEEE), Inc. – Organization

Scope: Supporting development of standards related to information technology.

Level of Effort: Standard-specific working groups are sponsored by IEEE with work items are picked by established procedures.

Performers: The work is done by the working groups composed of both IEEE members and non-members.

Duration: Ongoing.

Intent: To develop standards and test procedures related to information technology. The standards are published by IEEE and, in many cases, submitted to ANSI or the International Organization for Standardization (ISO) to make them international standards.

Description of Work Done: The IEEE efforts related to information technology are local area networks (project 802), operating systems (POSIX, the Portable Operating System Interface for Computer Environments), computer languages (Ada, Pascal, assembly), software engineering, and terminology for simulation.

Results: Standards in local area networks, languages, software engineering, and terminology for simulation exist. The work is underway for POSIX standards.

Table A-9. Institute of Electronics and Electrical Engineers (IEEE), Inc. Matrix

Technical Categories	Business View	Information View	Technology View
Integration Frameworks and Architectures			
Operating Systems and Distributed Environments			• POSIX 1003.1
Communications		• Local Area Networks Project 802 • Interface Standards - Futurebus	
Data Management Systems			
Application Development Tools and Methods	• Terminology for Simulation	• Software Engineering Standards • Software Verification & Validation • Guide to Software Configuration Management	
Data Representations			
Information Modeling Tools and Methods	• Terminology for Simulation		
User Interface			
Programming Languages		• Recommended Practice for Ada	• Pascal • Assembly Language • High-Level Languages for Microcomputers
Security Tools and Methods			

Title: Initial Graphics Exchange Specification (IGES) – IPO Program

Level of Effort: Primarily volunteer effort, with some support from the Department of Defense Computer-Aided Logistics Support (CALS) program.

Performers: Members of the IGES/PDES (Product Data Exchange Standard) Organization (IPO)

Duration: Ongoing.

Primary Milestones: Versions 1, 2, 3, 4, and 5 (completed in 1990) of IGES. Version 5.1, currently under development, is intended for completion by the end of 1991.

Intent: IGES defines a neutral file format for transferring data used to represent the geometric information about a product. These data are typically contained in and generated by a computer-aided design (CAD) program. IGES is composed of a number of "entities" representing low-level items that appear on a drawing.

Results: IGES is a widely used approach for transferring CAD data among differing CAD systems and other destinations, such as computer-aided machining software. Now in its fifth version, it has steadily grown in capability and use. The largest problem with IGES is that it is so big and complex (often capable of accomplishing the same purpose in more than one way) that different software vendor products often are unsuccessful in transferring information using IGES. Therefore, IGES has generally been considered to be difficult to use and far from perfect.

Current activities in the IPO are aimed at correcting this problem of a general lack of focus by adopting the concept of application protocols. An application protocol (AP) is composed of a concept that needs to be transferred from one system to another and the individual entities required to make that transfer. The difference between a traditional IGES transfer and an AP transfer is that a traditional transfer is made up of a set of IGES entities, while for an AP transfer the "entity" being transferred is a concept or idea, with whatever entities are necessary to embody the concept. Because of the much tighter definitions included in the AP, the transfer should be much less prone to problems and misunderstandings.

Technology Transfer Approach and Plans: Numerous CAD, computer-assisted machining, and related software packages supporting IGES are already available. The CALS program has established a CALS Shared Resource Center (CSRC) Metalworking Technology, Inc., in Johnstown, Pennsylvania, to assist small DoD suppliers in adopting

CALS standards and technologies. Since IGES is one of the CALS technologies, the CSRC will serve as an avenue for IGES technology transfer.

Reference:

National Computer Graphics Association. *IGES/PDES Organization Reference Manual.* July 1991.

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Table A-10. Initial Graphics Exchange Specification (IGES) Matrix

Technical Categories	Business View	Information View	Technology View
Integration Frameworks and Architectures	• Application Protocols	• Application Protocols	
Operating Systems and Distributed Environments			
Communications			• Neutral File Format
Data Management Systems			
Application Development Tools and Methods			
Data Representations			• List of entities with attributes
Information Modeling Tools and Methods			
User Interface			
Programming Languages			
Security Tools and Methods			

Title: Integrated Information Support System (IISS) – Air Force Program

Scope: IISS is a U.S. Air Force project to implement a version of the Common Data Model (CDM). CDM is a three-schema architecture for distributed heterogeneous database systems. IISS is not a general engineering information program but intended to produce database systems which could be easily used in an engineering information project.

Level of Effort: IISS is an ongoing effort which to date has cost $50 million over 12 years.

Performers:

- **Control Data.** Overall CDM design and implementation, IISS integration and test, and technology transfer.
- **D. Appleton Company.** CDM software information services and IDEF1X methods.
- **ONTEK.** Defining and testing a reference integrated system.
- **Simpact Corporation.** Communication development
- **Structural Dynamics Research Corporation.** User Interface, Virtual Terminal, and Network Transaction Manager.
- **Arizona State University.** Test-bed operations and support.

Duration: Begun in 1978, its major parts are completed. Some work is still in progress.

Intent: IISS was one of the first efforts to build large scale integrated information systems. The goal was to implement a system based on the then new Three Schema Architecture for databases and show its applicability to the problems associated with manufacturing large weapon systems. This effort promotes enterprise integration by demonstrating the feasibility of large three schema databases.

The project was restricted to developing large distributed heterogeneous databases so they complied with the standards (e.g., SQL) existing at the time for databases. Other components of the IISS system are proprietary although efforts are currently underway to explore porting IISS to make better use of industry standards in the area of communication and database access by using Open Systems Interconnection (OSI) and Remote Database Access (RDA).

The major deliverable for this project was an integrated database which ran under IBM and Digital Equipment Corporation (DEC) hardware. Currently, Intel is working on a system running Unix to add to IISS.

Description of Work Done: A prototype Three Schema Architecture database system has been developed. It currently runs under VAX/VMS and IBM MVS. To implement this system, IISS developed a data definition language called Neutral Data Definition Language (NDDL) used to produce a data dictionary called the Common Data Model (CDM). Access to the CDM is provided by the Neutral Data Manipulation Language (NDML).

At compile time, a precompiler scans the source for NDML statements. When one is found, the precompiler replaces it with a subroutine call. It then generates a subroutine which sends messages to the machines which hold the actual data. The messages contain SQL commands which are executed at the remote machine and then returns results.

Results: As one of the first three-schema databases, the project produced important results. Although not in general use, IISS has had a major impact on current efforts in enterprise integration. IISS concepts and approaches played a role in the current Air Force Enterprise Integration Program.

Technology Transfer Approach: At this time there is little effort going on regarding technology transfer. There was a major demonstration of a fully operational prototype at Arizona State University in 1987. Currently, a version of IISS is running at the U.S. Air Force MANTECH labs at Wright Patterson AFB, Ohio.

Linkages: Currently there is little linkage from IISS to other standards work. This may change as the Air Force is considering porting it to standard-based applications.

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Matrix Notes:

- **CDM.** A data dictionary used to implement a three-schema architecture. It has a Definitions Model for External Schemas, a Meta Model to represent Conceptual Schemas, and a Data Model to represent Internal Schemas. CDM also supports CDM Administrative Procedures to facilitate easy construction of data models. A CDM Toolkit is also provided to compile programs, generate reports, and other support functions.
- **NDDL.** The language used by CDM builders and administrators to build and maintain IISS data
- **NDML.** The language used to access the CDM and associated databases.

- **NTM (Network Transaction Manager).** A facility used to provide interprocess communication both within a processor and to remote machines. It transports database access commands and keeps track of where a process should reside.

Table A-11. Integrated Information Support System (IISS) Matrix

Technical Categories	Business View	Information View	Technology View
Integration Frameworks and Architectures	• CDM Definitions	• CDM Meta Model	• CDM Data Model
Operating Systems and Distributed Environments			• VMS • MVS • Unix
Communications			• GOSIP 1.0 • DECNET • SNA
Data Management Systems		• Entity Attribute	• IRDS •
Application Development Tools and Methods	• CDM Toolkit Utilities -Report Writer -Translators -Comparison	• CDM Administrative Procedures	• NTM • Configuration Management: IISS Code Manager NTM
Data Representations	•		
Information Modeling Tools and Methods	• IDEF 1X	• IDEF 1X	
User Interface	• NDDL Forms		
Programming Languages		• NDDL	• NDML • SQL • Cobol • Fortran • C
Security Tools and Methods		• Access Control Based on User Role	

Title: Information Resource Dictionary System (IRDS) – ANSI Program

Level of Effort: Volunteer effort by interested parties.

Performers: International Organization for Standardization (ISO) JTC1 SC21/WG3 and American National Institute (ANSI) X3H4.

Duration: 1980 through present.

Intent: The IRDS Standards began as two parallel efforts in 1980. The goals of both the ANSI and NIST efforts were to develop data dictionary standards for the description, control, and management of information. By developing these standards data dictionaries, computer-aided software engineering (CASE) tools would be able to share information. In 1983 the two efforts merged under the name IRDS with the ANSI technical committee adopting the National Institute of Standards and Technology (NIST) draft standard. In 1985 the United States presented the IRDS proposal (IRDS1) to ISO. ANSI and ISO versions of IRDS1 have continued to evolve and the standards efforts have been expanded to encompass the entire data repository and the programming interface.

The IRDS1 Standards efforts intended to provide the builders and users of enterprise integration information frameworks facilities to create, maintain, and access an Information Resource Dictionary (IRD) and the associated IRD definitions. Examples of the information that may be captured in the IRD include:

- Data needed by the enterprise,
- Process information for manipulating the enterprise data,
- Physical resource information for processing the enterprise data,
- Human resource information,

The IRDS1 Standard is not intended to provide a standard definition of any information. Instead the Standard will provide a framework that can be used to define the information which will be captured in and maintained by an IRD.

The IRDS1 Framework is used to identify the enterprise data, hardware, interfaces, and the services provided by the enterprise processing facilities. Data interchange formats and data modeling schemes are examples of the types of information that may be described by the framework.

In 1992, ANSI and ISO agreed to evolve the IRDS1 standards by incorporating object-oriented concepts. The vision of an IRDS composed of distributed repository objects providing IRDS services through object-oriented, application programming interfaces is referred to as IRDS2. An IRDS2 repository will provide object management services, database management services, database access facilities, data modeling facilities, CASE support facilities, dictionary facilities, encyclopedia facilities, glossary facilities, and thesaurus facilities.

Definitions:

IRDS1:

- **Database.** A collection of interrelated data stored together with controlled redundancy according to a schema to serve one or more applications.
- **Database integrity.** The consistency of a collection of data in a database.
- **Export.** The function of extracting information from an IRDS and packaging it to an export/import file.
- **Import.** The function of receiving data from an export/import file into an IRDS.
- **IRD.** Part of a repository managed by an IRDS in which the information resources of an enterprise may be recorded.
- **Value.** An abstraction with a single characteristic that can be compared with other values and may be encoded.
- **Data modeling facility.** A set of data structuring rules and an associated set of data manipulation rules.
- **Application schema.** A set of definitions that control what may exist at any time in an application.

IRDS2:

- **Application programming interface (API).** A set of functions that provide the complete interface required by an application for obtaining services from a tool or facility.
- **Behavior.** The observable effects of an object performing the requested operation, including its results.
- **Content module.** A specification, for a particular universe of discourse, of a set of object types including the rules governing the interaction and behavior of objects of these types, and optionally one or more instances of these types.
- **Core object model.** The specification of the behavior of the root object type. All other object types inherit properties, operations, and integrity rules from the root object type.

- **Facility.** An implementation of a content module with methods to support all operations defined by the content module's object types and the capability to store the module's persistent objects.
- **IRDS base services.** That set of services that are inherent to IRDS systems, for example, naming, versioning, and object life cycle services.
- **IRDS kernel.** The combination of the core object model, its underlying defining and normative schemas, and the set of base services inherent to IRDS systems.
- **IRDS service profiles.** Content modules whose subject area is some aspect of the IRDS system as a universe of discourse.
- **Object type.** A specification of properties (attributes and relationships), operations which define the behavior of objects of that type and integrity rules that apply to those objects.
- **Root object type.** The object type that packages primitive properties, operations, and integrity rules that must be used as the basis for all other object types.
- **Service.** A related set of operations that are invoked through the interfaces for one or more object types in response to requests or detected conditions.

Description of Work Done: IRDS1 is a data dictionary standard developed in parallel by both ISO (JTC1 SC21/WG3) and ANSI (X3H4). The ANSI IRDS standard is based on the entity-relationship (ER) model and would be applicable to both the NDL and SQL database languages. The ER data model is fully extensible and captures both meta and meta-meta data. The ISO IRDS standard uses a relational model for data capture. However, the ISO standard is also based on ISO SQL.

The ISO IRDS Framework (ISO 10027) provides a common basis for developing information resource dictionaries (IRDs) which are sharable repositories for the definition of the information relevant to all or part of an enterprise.

There is an ISO proposal for a Command Language and Panel Interface (DP 8800-1, March 1987). However this project has been suspended until the Committee Draft of IRDS Service Interface (CD 10728) reaches Draft International Standard (DIS) status. There are working drafts of the IRDS Design Support for SQL Applications and IRDS Export/Import.

The Accredited Standards Committee X3, Information Processing Systems, has plans for the development of an IRDS Extensions to Support CASE Environments for the Information Exchange standard. In planning the evolution of the IRDS standards, ANSI and ISO have been influenced by the NIST Reference Model for Frameworks of Software Engineering Environments, and by the work of the Object Management Group.

IRDS2 will be based on an object model, and will use an Object Query Language with a "select-from-where" clause (possible SQL3) for selecting a set of objects for retrieval. A core object model will support the definition of generic base services that together form the kernel of the IRDS system. That kernel will support implementation of IRDS service profiles and content modules that represent the models for the information the IRDS contains. Together, the set of content modules for an IRDS system define the information model for an enterprise.

X3H4 has proposed changes to the ISO IRDS Standard (IS 10728) to introduce some object-oriented concepts, including extensible operations and multiple inheritance. X3H4 technical reports under preparation include *Repository Context Reference Model Technical Report* and *Repository Services Architecture Technical Report.* ANSI and ISO are working to revise the ISO IRDS Framework Standard (IS 10027) to include the concepts of IRDS2.

Results: The ANSI draft IRDS standard, X3.138-1988, was adopted by the U.S. Government as FIPS-156 (Federal Information Processing Standard) in 1989. In this standard, a command language interface, an abstract panel interface, and an IRD-IRD data exchange format were all specified. An upgrade to FIPS-156 is not expected until 1995. The U.S. Government has mandated that all data dictionaries used by the government comply with ANSI IRDS.

X3H4 is working with ISO to develop IRDS2 which will provide an object-oriented user interface and complete data repository facilities. The proposed revision to the ISO IRDS Standard (IS 10728) reached CD status in June, 1993.

Linkages: ANSI, ISO, NIST, Object Management Group (OMG)

References:

Beyer, H. et. al. *A Comparison Analysis of Repository Approaches*. September 1990.

Jones, Mark R. "Evolution of Repository Technology," *Database Programming and Design*, April 1992.

Lewis, Geoffrey. "CASE Integration Frameworks," *SunWorld*, July 1991.

National Institute of Standards and Technology. *Reference Model for Frameworks of Software Engineering Environments*. December 1991. NIST SP 500-201.

Object Management Group. *The Common Object Request Broker: Architecture and Specification (CORBA).* Revision 1.1. December 1991. OMG Document 91.12.1.

Object Management Group. *Object Services Architecture.* Revision 6.0. August 1992. OMG Document 92.8.4.

Object Management Group. *Object Management Architecture Guide.* Revision 2.0. September 1992. OMG Document 92.11.1.

Table A-12. Information Resource Dictionary System (IRDS) Matrix

Technical Categories	Business View	Information View	Technology View
Integration Frameworks and Architectures		• IRDS 1 - ER Models Relational • IRDS 2 - Object Oriented	• RDBMS • OODBMS
Communications			
Operating Systems and Distributed Environments			• OSF DCE • OMG CORBA
Data Management Systems		• Relational • Object Oriented	• RDBMS • OODBMS • SQL
Application Development Tools and Methods		• Extensions to CASE Environments	
Data Representations		• Naming Conventions • Resources • Data modeling schemes • Data interchange formats	
Information Modeling Tools and Methods			
User Interface			
Programming Languages			
Security Tools and Methods			

Title: Manufacturing Automation Protocol/Technical and Office Protocol (MAP/ TOP) Users Group – Society of Manufacturing Engineers (SME) Program

Performers: MAP/TOP Users Group. The MAP effort was spearheaded by General Motors while Boeing took the major initiative in progressing TOP. Today the MAP/TOP Users group is administered by the Corporation of Open Systems (COS) and includes many large corporations, their suppliers, and others concerned with factory and office automation.

Duration: The MAP/TOP effort started in the early 1980s. Currently, both MAP and TOP are in their third versions. The Users Group is active and has regular meetings with the main focus being testing, international harmonization, and presenting a unified front to vendors of MAP and TOP-based products.

Primary Milestones: MAP Version 1.0 appeared in 1984. Version 2.0, which added a lot of functionality to the upper layers, was released in 1985. March 1985 saw the release of Version 2.1 which included FTAM. The MAP Enhanced Performance Architecture (EPA) was released in 1986. The EPA is a three-layer version of MAP meant for specialized real-time needs.

TOP Version 1.0 was released in November 1985. Both TOP 1.0 and MAP 2.1 were frozen for a period of time to make changes to the profiles and remove errors in their specification. MAP and TOP versions 3.0 were released in 1987, and represented major upgrades from their previous versions.

An important milestone for both MAP and TOP was the Enterprise Networking Event '88 International (see information on **ENE 88i** in this report) which demonstrated interoperability of MAP and TOP products from different vendors in a real-life, network-enterprise configuration.

Intent: The Manufacturing Automation Protocol was established to define a local area network for terminals, computing resources, and programmable devices within a plant or a complex. Though intended for local area networks (LANs), the architecture supports wide area network interconnection.

Description of Work Done:

MAP. MAP comprises 12 Open Systems Interconnection (OSI) protocols covering the 7 layers of the OSI Reference Model. Additionally, there is a "stream-lined" model called the Enhanced Performance Architecture (EPA) that operates over just three layers: Physical, Datalink, and Application. The EPA is targeted for applications that require rapid response times and are very fault tolerant.

As the names states, MAP is intended for manufacturing. Consequently, the selection of the protocols correspond to those appropriate to the factory floor. Where this difference becomes critical is in the selection of the Physical Layer protocol and one of the Application layer protocols.

For the physical layer, MAP has selected the IEEE 802.4 (ISO 8802/4) Broadband and Carrierband technology. This technology allows multiple channels over a single physical medium. One could run up to six disparate MAP networks over a single cable. But more importantly, one can simultaneously run non-MAP networks over the same MAP backbone. The broadband will support voice, video, Integrated Services Digital Network (ISDN), Ethernet, etc.

In addition to its multi-services, multi-protocol, multiLAN support, broadband cable is well-suited to the factory floor due to its low-loss characteristics and its ability to provide shielding from electrical and magnetic interference. Broadband obviates the need for later upgrades.

MAP recommends carrierband technology for single-channel, shorter networks (about 700 to 1000 meters between communicating stations) with fewer nodes (32 per segment). Examples of appropriate applications would be control or supervisory subnetworks.

At the Application layer, MAP specifies six protocols:

- ACSE (Association Control Service Element)
- ROSE (Remote Operation Service Element)
- FTAM (File Transfer, Access, and Management)
- Directory Services
- Network Management
- MMS (Manufacturing Message Specification)

MMS is a protocol very rich in services and complexity. Though it is applicable to a wide range of factory-floor applications, MMS does not describe application-specific information. That job falls under the charter of four companion standards organizations. Companion standards contain the semantics of the factory-floor device. The devices, along with their responsible organizations, are Numerical Control Devices (Electronics Industry Association (EIA)), Programmable Controllers (National Equipment Manufacturers Association (NEMA)), Robot Controllers (Robot Institute of America (RIA)), and Process Control Systems (Instrument Society of America (ISA)).

In the long view of enterprise integration, MAP should be coupled with TOP (described below). Together they address the most of the network communications problems of a CIM enterprise.

TOP. The TOP profile addresses the communication networking requirements for commercial, engineering, and government implementations. The TOP effort recognizes the need for enterprises to reduce costs and yet increase quality. Open systems in this information age are one way to accomplish this. To reduce risk and expedite adoption, it specifies from the internationally recognized body of standards defined by OSI. Furthermore, in the interest of portability, it specifies application programming interfaces.

The TOP program has three basic goals:

- To promote the design, development and testing of TOP products.
- To act as a procurement tool for users.
- To educate users.

The fact that MAP and TOP complement each other is no accident. They were designed from the beginning to both work in the enterprise. TOP specifically addresses the method of interconnection to MAP networks in its specification.

TOP employs the common (and inexpensive, relative to MAP) IEEE 802.3 Carrier Sense Multiple Access/Collision Detection (CSMA/CD) technology at its lower layers. This technology is easy to install and maintain. TOP also allows IEEE 802.5 Token Ring because of the popularity that low-level protocol enjoys and X.25 for wide area network (WAN) connectivity.

The real richness of TOP comes in its selection of Application layer protocols. These include:

- X.400 Message Handling Services (Electronic Mail)
- Product Definition Interchange Format (using Initial Graphics Exchange Specification (IGES))
- Office Document Interchange Format (using ODA)
- Computer Graphics Metafile Interchange Format (using Graphical Kernal System (GKS) and Computer Graphics Metafile (CGM))
- File Transfer, Access and Management (FTAM)

- Virtual Terminal (VT)
- Directory Services (DIS 9594)
- Network Management (ISO DP 9596)

TOP plans to accept other standards as they become mature while providing backward compatibility. Examples would include the Fiber Data Digital Interface (FDDI), ISDN, Product Data Exchange Specification (PDES), Computer Graphics Interface (CGI), Distributed Transaction Processing, Remote Database Access (RDA), and Electronic Data Interchange (EDI) (as transferred by X.400).

TOP integrates the engineering and office LANs by intent. By the use of a lower-layer bridge (802.3 to 802.4), one can interconnect with the MAP factory floor nets and enjoy total enterprise integration.

Technology Transfer Approach and Plans: Technology transfer is mainly through the MAP/TOP Users Group and trade shows like Autofact. Conformance testing is another important means of transferring technology. SME (Society of Manufacturing Engineers) offers MAP/TOP training.

Linkages: MAP/TOP has strong links to the International Organization for Standardization (ISO) because most of the standards it uses are ISO standards. There are links to IEEE for similar reasons (lower-layer protocols). SME and COS are other organizations to which MAP and TOP have strong ties.

Table A-13. Manufacturing Automation Protocol/Technical and Office Protocol (MAP/TOP) Matrix

Technical Categories	Business View	Information View	Technology View
Integration Frameworks and Architectures			• OSI Reference Model
Operating Systems and Distributed Environments			• Network Management Applications • Directory Server Applications
Communications			• OSI Protocols: MHS, FTAM, MMS, NM, DS, ASCE, SESSION, Presentation TP4, CLNS, • X.25 • IEEE 802, Bridges, Routers, and Application Layer Gateways
Data Management Systems			
Application Development Tools and Methods			• Conformance/ Interoperability Test Tools and Methods • Application Development and Customization Toolkits • Systems Integration Tools
Data Representations			• ASN.1 • IGES
Information Modeling Tools and Methods			
User Interfaces			
Programming Languages			• Application Programming Interfaces (APIs)
Security Tools and Methods			

Title: National Center for Manufacturing Sciences/Computer Integrated Operations (NCMS/CIO) – Organization

Scope: Developing and promoting information integration efforts for manufacturing. NCMS has sponsored work in the area of Next Generation Controller (NGC), Manufacturing Automation Protocol/Technical and Office Protocol (MAP/TOP) study, Media Access Selection, Manufacturing Message Specification (MMS) promotion, and a program in Design for Integration.

Level of Effort: NCMS is a consortium of manufacturing companies. The funding comes from membership dues and supporting Federal funds. Revenue from royalties accrued based on technology transfer activities is also anticipated. NCMS has around 140 members.

Performers: Most of the strategic planning is done by various special interest groups (SIGs) within NCMS. These SIGs are formed by representatives from member companies. Projects are approved by SIGs and executed by member companies.

Duration: Ongoing.

Intent: To support and promote the development and transfer of advanced manufacturing technologies to member companies.

Description of Work Done: NCMS has sponsored several information technology related projects for manufacturing. They include NGC needs and requirements, a MAP/TOP study, Media Access Selection for manufacturing networks, MMS promotion, and (currently) a design for integration program. NCMS has also engaged in number of technology transfer activities in these areas.

Results: NCMS has completed reports on NGC needs and requirements. It has also completed the MAP/TOP and media access selection study. NCMS is actively promoting MMS and has developed a tutorial, a white paper, and a MMS product guide.

Technology Transfer Approach and Plans: NCMS has a separate technology transfer division working on the issues of transferring results of the projects to member companies. These activities include "hand holding," education and training, and developing and/or supporting computer-based tools.

Table A-14. National Center for Manufacturing Sciences/Computer Integrated Operations (NCMS/CIO) Matrix

Technical Categories	Business View	Information View	Technology View
Integration Frameworks and Architectures	• Design for Integration Model		
Operating Systems and Distributed Environments			
Communications	• Manufacturing Networks	• MMS Product Guide • Conferences/ Workshops on MMS	• Local Area Networks • MMS
Data Management Systems			
Application Development Tools and Methods			
Data Representations			
Information Modeling Tools and Methods			
User Interfaces			
Programming Languages			
Security Tools and Methods			

Title: National Institute of Standards and Technology (NIST) Shop of the 90s – NIST Program

Scope: An effort to integrate the typical design to manufacturing functions required in a small machine shop.

Level of Effort: Approximately $200K per year, 2.5 full-time equivalent (FTE), plus donated hardware and software.

Performers: NIST shops personnel.

Duration: Official start, 1986; effective start 1988; continuing at least through FY 1992.

Intent: The purpose of this project is to demonstrate that a typical machine shop can integrate the design and manufacturing functions via a computer network assembled out of readily available components. The overall objective of the project is the broad adoption of existing shop-integrating technologies by small machine shops. This is based on the belief that this kind of change in the way the shops operate will make them more competitive. The biggest barrier to machine shop integration is the lack of belief and trust in the claims of the existing integration tool vendors resulting from previous disappointments. The project arose out of the recognition that the previously existing Automated Manufacturing Research Facility was doing work which was primarily going to be of use to large firms. The Shop of the 90s was seen as the small firm solution.

Description of Work Done: A working machine shop within NIST was integrated via the use of commercial off-the-shelf (COTS) hardware and software. Most of the equipment and software was donated to the program. The approach is entirely designed around existing, commonly available IBM personal computer (PC) compatible microcomputer hardware and software (including MS-DOS as the operating system), along with standard machine tools and coordinate measuring machines. These include commercial computer-assisted design (CAD), computer-assisted manufacturing (CAM), project-planning and tracking and other software. The computer system is composed of a set of PCs connected by an IBM local area network. Most of the equipment was donated by a set of vendors supporting the work. The PCs are dedicated to specific functions, but that need not be the case in smaller shops. The entire concept can be run on one machine.

Results: There has been a great deal of interest in the program, especially from state agencies which have used Shop of the 90s personnel in seminars and workshops. Additional interest is represented by the continuous stream of visitors who wish to investigate the Shop of the 90s.

Cost justification has been based on the concept that the Shop of the 90s is a working machine shop, competing with outside shops for internal NIST business. The project has included a number of vendors as partners who have strong interests in making their products work in such integrated systems. The main functional goal of the project was to link the various hardware and software systems into a functioning, integrated whole using COTS technologies. This has been accomplished.

Technology Transfer Approach and Plan: Dissemination of results has been primarily through seminars, workshops, and demonstrations (often on the road) plus frequent visitors at the NIST facility. The traveling shows are limited by the budget, especially since recent tightening of rules has made it difficult, if not impossible, for non-Federal organizations to share the cost. The road shows are delivered only at the written invitation of some Federal or state agency or a non-profit organization. The audience may be made up of private companies, but a for-profit cannot be the sponsor. Generally, outside visitors to the NIST site also must be sponsored by an appropriate agency.

There is also a "beta" test site at a machine shop located near Baltimore, Maryland, where a similarly integrated shop is in operation to demonstrate that a "real" shop can also use the Shop of the 90s approach. The assistance given to that shop is in exchange for access by NIST and other organizations.

In addition, many articles have been placed in newspapers and widely read trade and industry magazines. Those have served to stimulate interest in further information. There are currently no plans to do any transfer activities outside of the ones listed here. Given the uncertainty of funding after FY 1992, the focus is shifting from transfer to further technology work, so that as much ground can be covered as possible, should the funding disappear.

Linkages: The Shop of the 90s is based on the *de facto* standards of IBM-compatible computers and the MS-DOS operating system. These form the platform upon which the project was built. Outside of the contributions of the hardware and software vendors, there is little linkage to any other effort.

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National Institute of Standards and Technology. *Manufacturers, Skiers Gain Competitive Edge*. Gaithersburg, MD: National Institute of Standards and Technology. [n.d.] NIST Special Publication 809.

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Table A-15. National Institute of Standards and Technologies (NIST) Shop of the 90s Matrix

Technical Categories	Business View	Information View	Technology View
Integration Frameworks and Architectures			
Operating Systems and Distributed Environments			• MS-DOS
Communications			• IBM Proprietary LAN
Data Management Systems		• MS-DOS File Server	
Application Development Tools and Methods			
Data Representations			• Proprietary to Commercial Software
Information Modeling Tools and Methods			
User Interfaces			
Programming Languages			
Security Tools and Methods			

Title: Open Distributed Processing (ODP) – American National Standards Institute (ANSI) Program

Scope: ODP is chartered to produce an international standard reference model for distributed processing.

Level of Effort: Currently, only the members of the U.S. and international committees are engaged in definition of the reference model. A European group is currently developing prototype ODP software. A U.S. group (ODP Consortium or ODPC) is currently in the formation stages to ensure that an adequate testing infrastructure exists to ensure acceptance of the ODP standard.

Performers:

- X3T3 Committee - Development of ODP reference model
- Open Distributed Processing Testbed Initiative (ODPTI) - Conformance and interoperability testing
- Advanced Network Systems Architecture (ANSA) - Prototype ODP software

Duration: 1987 to present.

Intent: The ODP effort began to produce a reference model for distributed processing. The reference model will form the basis for distributed processing standards which will allow compliant applications to communicate in a transparent manner. This is a key effort since no enterprise integration effort can expect to get far without the ability to communicate transparently between applications.

Description of Work Done: ODP work is progressing along three fronts. The first of these is the development of the ODP reference model. Second, the reference model is being used as the basis for a prototype ODP system, ANSA. Finally, ODPC is being set up to provide the testing infrastructure needed to support products.

Results: The ODP standards effort is focusing on developing a unified model of objects. To accomplish this, they have identified five viewpoints:

- Enterprise View. The Enterprise View describes objects in terms of the expectations of the entire enterprise, including policies and procedures. However, aspects of an enterprise which have nothing to do with computation are not represented.

- Information View. The Information View focuses on the information processing requirements of objects. It models the information structure and relationships of both manual and automatic processing.
- Computation View. The Computation View concentrates on the structure of the applications (what functions will run where). It is independent of the specific hardware to be used and represents a computational model of the Information View.
- Engineering View. The Engineering View concerns support aspects of applications. This includes the needs for performance, reliability, and security.
- Technology View. The Technology View concerns the actual realization and implementation of the components. This view addresses exactly what hardware and software is needed to implement the specified distributed system.

In addition to these viewpoints, the ODP effort is addressing issues of controlling the distributed name space. This work involves a process called Trading. A Trader will take the name of a desired service and return an interface to a server which can provide the desired service. A trader however is more complex than existing name service facilities. An ODP trader can provide access to a service similar to the desired one if an exact match is not available. The trader in some concepts also controls all communications between servers and clients.

To develop prototype software, a European consortium called Architecture Projects Management Ltd. (APM) has been formed. APM currently has a prototype ODP system. ANSA. ANSA consists of a mechanism for interprocess communication and a prototype Trader. Using ANSA, distributed applications can register interfaces for the services they provide, query the Trader to find interfaces to desired services, and communicate with applications providing those services.

Technology Transfer Approach and Plans: ODPC was formed to address technology transfer issues. The consortium's main goal initially is to develop and support the infrastructure needed to support the standard when it is developed. This includes a test center for conformance and interoperability testing and for sample applications. ODPC has a grant of $3 million from ESPRIT to fund this work.

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Table A-16. Open Distributed Processing (ODP) Matrix

Technical Categories	Business View	Information View	Technology View
Integration Frameworks and Architectures	• ODP Reference Model • Enterprise View	• ODP Reference Model • Information View • Computation View	• ODP Reference View • Engineering View • Technology View
Operating Systems and Distributed Environments		• Trader	• Trader
Communications		• OSI	
Data Management Systems			
Application Development Tools and Methods			
Data Representations			
Information Modeling Tools and Methods			
User Interfaces			
Programming Languages			
Security Tools and Methods		• Trader	

Title: Object Management Group (OMG) – Organization

Level of Effort: International, U.S.-based consortium of about 270 members.

Performers: Member companies, OMG staff.

Duration: Ongoing, begun in 1989.

Primary Milestones:

- Founded (April 1989)
- Object Management Architecture Guide (September 1990)
- Object Request Broker Request for Proposal (RFP) (October 1990)
- Object Model Request for Information (RFI) (March 1991)
- The Common Object Request Broker Architecture and Specification (CORBA), Revision 1.1 (December 1991)
- Object Management Architecture Guide, Revision 2.0 (September 1992)
- Object Services RFP (October 1992)
- C++ Language Mapping RFP (December 1992)
- Object Request Broker 2.0 Extensions RFI (January 1993)

Intent: OMG is dedicated to maximizing the portability, reusability, and interoperability of computer software and the business benefits derived from them. The OMG is committed to creating a framework and supporting specifications for commercially available object-oriented environments.

The OMG provides a reference architecture with terms and definitions upon which all adopted specifications are based. Implementations of these specifications will be made available under fair and equitable terms and conditions. The OMG will create industry standards for commercially available object-oriented systems, emphasizing distributed applications development.

The OMG provides an open forum for industry discussion, education, and promotion of OMG-endorsed technologies. The OMG coordinates its activities with related organizations and acts as a technology marketing center for information on object-oriented software.

The overall technical goal of OMG is to adopt interface and protocol specifications that define an object management architecture supporting interoperable applications based on distributed interoperating objects. The specifications are to be based on existing technologies that can be demonstrated to satisfy OMG's Technical Objectives.

Description of Work Done: The technical work of the OMG is done in the Technical Committee (TC). The TC has subcommittees (including Reference Model and Object Model subcommittees), Task Forces, and Special Interest Groups (SIGs). SIGs have been formed for Class Libraries, Databases, Object Query, Analysis & Design, End-User Requirements, and Parallel Object Systems.

OMG's standards are based on existing technology. The adoption process is for a Task Force of the TC to issue an RFI; then based on the responses, to issue an RFP. The task force evaluates the proposals and recommends action to the TC. At present there are four task forces: Object Request Broker (ORB), Object Model Revision, Object Services, and ORB Revision.

In 1989 OMG developed its Object Management Architecture (OMA), described in the Reference Model section of the *Object Management Architecture Guide*. The reference model provides a conceptual roadmap for assembling technology that satisfies OMG's technical objectives. It is intended to influence the high-level architecture and component designs of specific proposed approaches while accommodating a variety of design solutions. Thus, the reference model identifies the major components of OMA and describes the functions of each component. It also describes the permitted interactions among components and the interfaces for such interaction. The OMA has four main components: Application Objects, Common Facilities, Object Services, and the ORB.

CORBA, a realization of the ORB component of the OMA, was the first technology adopted by the OMG. It describes the interfaces for accessing object in a distributed environment. An interface definition language, a dynamic interface, and a read-only interface to an object repository have been established.

The Interface Definition Language (IDL) is the interface to the ORB Core. It is a language binding meant to make a sub-system available from a given language. IDL will enable language-independent object interfaces to achieve *intra*operability and *inter*operability of ORBs. The only language currently supported is ANSI C, and responses to the RFP to standardize on IDL mappings for C++ were due in April 1993.

The most crucial component of the Object Services portion of the OMA is a common object model for describing object/class structure. The object model defines a language-independent object structure and appropriate components and profiles. It will be used as a basis for defining design portability across all OMG specifications. The Core Object Model has been published in revision 2.0 of the Object Management Architecture Guide. The component and profile sections of the object model will be done separately.

Once the ORB and Object Model are in place, a group of important lower-level Object Services is necessary to make a commercially viable system. The Object Services task force issued an RFP for event notification, life cycle, naming, and persistence services; responses were due in February 1993.

Technology Transfer Approach and Plans: A major means of technology transfer is through the participation of member company staff. Furthermore, the RFI-RFP approach to acquiring new technology components also provides a means of transferring technology and promoting awareness.

Linkages: OMG members, International Organization for Standardization (ISO) JTC1/SC21/WG7, American National Standards Institute (ANSI) X3T3, Open Software Foundation (OSF), Unix International (UI).

OMG specifies the use of existing technology and standards like X/Open endorsed standards, the Portable Operating System Interface for Common Environments (POSIX), ANSI C, and networking protocols like the Open Systems Interconnection (OSI) and the Transmission Control Protocol/Internet Protocol (TCP/IP). Its goal is to use popular standards where possible.

References:

Object Management Group. *The Common Object Request Broker: Architecture and Specification (CORBA), Revision 1.1.* December 1991. OMG Document 91.12.1.

Object Management Group. *Object Services Architecture, Revision 6.0.* August 1992. OMG Document 92.8.4.

Object Management Group. *Object Management Architecture Guide, Revision 2.0.* September 1992. OMG Document 92.11.1.

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Table A-17. Object Management Group (OMG) Matrix

Technical Categories	Business View	Information View	Technology View
Integration Frameworks and Architectures	• OMG Object Model • OMA Reference Model	• Classical Object Model • Generalized Object Model	
Operating Systems and Distributed Environments	• Object Services • Common Facilities	• System Management	• OSF/1 • DOS • OS/2 • Unix • Object Services
Communications	• Object Request Broker	• Object Model • Interface Definition Language	• OSI • TCP/IP • X/Open APIs • RPC • Remote Object Network Access
Data Management Systems	• Distributed Object Management	• OODBMS • Object Services	• APIs to OODBMS & RDBMS
Application Development Tools and Methods	• Object Factory • Common Facilities	• OO CASE Tools, Rapid Prototyping	• Object Services
Data Representations	• Application Objects		• XDR • NDR • ASN.1
Information Modeling Tools and Methods	• Object Services	• Common Facilities	•
User Interfaces		• Object Interfaces	• X/Motif • Windows
Programming Languages			• ANSI C • C++
Security Tools and Methods	• Authentication	• Discretionary Access Control, Concurrency Control	

Title: Open Software Foundation (OSF) - Organization

Level of Effort: International, U.S.-based consortium of about 350 members; OSF has about 280 employees worldwide.

Performers: Member companies, OSF staff.

Duration: Continuing.

Primary Milestones:

- Founded (May 1988). Commits to compliance to X/Open and the Portable Operating System Interface for Common Environments (POSIX) in developing an open operating system.
- Announcement of Motif (December 1988).
- Distribution of Motif (August 1989).
- Release of OSF/1 (November 1990).
- Announcement of the Distributed Management Environment (DME) (September 1991).
- Release of the Distributed Computing Environment (DCE) (December 1991).

Intent: OSF was formed in 1988 to counter what was generally perceived to be AT&T's "unfair advantage" in determining the direction of Unix specifications. It would be wrong, however, to think of OSF only as a specifier of an operating system. As of late it has been releasing specifications for a DCE and a DME. These specifications will be based on existing products but will support international as well as industry standards.

Description of Work Done: OSF/1 is based on IBM's AIX operating system and the Carnegie-Mellon "real-time Unix" operating system, Mach. OSF releases so-called snapshot versions to its members, prior to general release. The snapshot release was started in November 1990. OSF/1 was released for general distribution in November 1990.

In addition to an operation system, OSF has release its version of a graphical user interface (GUI) toolkit for use in an X-Windows environment, Motif. Motif has competition from Unix International's OpenLook but is generally considered to have a substantial lead in applications being developed by independent software vendors. Motif 1.1 is the latest update to Motif (May 1991).

On June 13, 1989, OSF issued an Request for Technology (RFT) for the DCE. The response were expected to address solutions to the problems of creation, use, and support of distributed applications. It received 50 letters of intent to submit. Thirty-two organizations submitted twenty-nine proposals. On May 14, 1990, OSF announced the results.

DME is OSF's solution to both system and network management. In July 1990, OSF issued an RFT for DME and, by the end of September, had received 42 responses. The technologies selected include a "comprehensive and cohesive management model consisting of a user interface, a management infrastructure with object and event services, application services, such as software licensing, installation and printer management, plus a host management facility." On September 17, 1991, an announcement was made of the technologies selected.

Technology Transfer Approach and Plans: OSF's method for technology transfer rests on four cornerstones:

- Special interest groups (SIGs) define the scope and requirements for the RFTs.
- The RFT process (Open Technology Acquisition). OSF issues an RFT via numerous channels. OSF members, industry consultants, standards groups, and RTF respondents evaluate the RFT.
- Member meetings provide forums for ideas, review, and input to evaluation teams.
- Technology "snapshots" are provided to members. These are technologies under development. The intent is for members to provide feedback, similar to beta testing.

After these steps listed above, the specifications are put into general release.

Linkages: OSF members, X/Open, the National Institute for Standards and Technology (NIST), the Portable Operating System Interface for Computer Environments (POSIX), the Internet Activities Board (IAB), OSI/NM Forum, the Object Management Group (OMG).

Table A-18. Open Software Foundation (OSF) Matrix

Technical Categories	Business View	Information View	Technology View
Integration Frameworks and Architectures	• Strategic Marketing - Prevent AT&T/SUN from monopolizing Unix markets (i.e., Unix and open systems)	• Distributed Computing	• Unix
Operating Systems and Distributed Environments			• POSIX (MACH KERNEL)
Communications			• TCP/IP • OSI • DFS (NCS)
Data Management Systems			
Application Development Tools and Methods			
Data Representations			• X.500
Information Modeling Tools and Methods			• RPC/IDL • X/Open APIs
User Interfaces			• Motif • X-Windows
Programming Languages			
Security Tools and Methods			• POSIX 1003.6 • Kerberos

Table A-19. Open Software Foundation (OSF)/ Distributed Computing Environment (DCE) Matrix

Technical Categories	Business View	Information View	Technology View
Integration Frameworks and Architectures	• DCE Architecture		
Operating Systems and Distributed Environments	• Distributed Management Environments • Distributed Naming Service	• Naming Service • Time Service	• DOS, OS/2 • Unix (POSIX), AIX, ULTRIX, Domain OS, HP-UX, SINIX • X.500 Domain Name Service, Network Time Protocol
Communications		• NFS, SMBP • RCP • High-level interface description compiler	• Pipes, ODP, OSI, TCP/IP, OS/2 • Threads • POSIX 1003.4a
Data Management Systems	• Distributed File System • POSIX 1003.1	• NFS "Only-compatible"	• RPC
Application Development Tools and Methods			• XPG3 • X/Open APIs
Data Representations			• XDR • ASN.1 • ASCII • EBCDIC • Sun XDR
Information Modeling Tools and Methods			
User Interface			
Programming Languages		• DCE IDL	• ANSI C
Security Tools and Methods	• X.509 • POSIX 1003.6	• Encryption • Authentication	• Access control lists • Kerberos

Title: Product Data Exchange Specification (PDES) Using STandard for the Exchange of Product Data (STEP) – IGES/PDES Organization (IPO) Program

Level of Effort: Primarily volunteer effort, with some support from the Department of Defense (DoD) Continuous Acquisition and Lifecycle Support (CALS) program.

Performers: Members of the Initial Graphics Exchange Specification (IGES)/PDES Organization (IPO) in association with the International Organization for Standardization (ISO) TC184/SC4.

Duration: Ongoing.

Primary Milestones: Completion of Version 1 of STEP, expected some time in early 1992.

Intent: PDES is the U.S. effort in support of the international development of STEP (STandard for the Exchange of Product data). STEP is intended to be the standard under which product data can be transferred within or between enterprises. In the STEP arena, product data includes any information required for the design, manufacture, and support of a product.

Results: STEP is a very large standard. As a result, it is being assembled by approving a variety of "Parts" that each concentrate on a specific piece of the overall standard. To date, progress is nearly complete on what is being called Version 1 of STEP. Version 1 will not include many of the Parts which are planned.

Technology Transfer Approach and Plans: The CALS program has established a CALS Shared Resource Center (CSRC) at Metalworking Technology, Inc., in Johnstown, Pennsylvania, to assist small DoD suppliers in adopting CALS standards and technologies. Since PDES is one of the CALS technologies, the CSRC will serve as an avenue for STEP technology transfer. In addition, the U.S. Navy is funding the development of tools which will help in STEP adoption.

Linkages: Direct contact between the IPO committees and ISO TC184/SC4 working groups.

References:

National Computer Graphics Association. *IGES/PDES Organization Reference Manual.* July 1991.

Primary contacts:

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Matrix Notes:

Application Protocols (APs). Basic pieces in which STEP is going to be implemented. An AP defines the use of the basic bits and pieces of STEP so that through the AP, one can transfer all the data necessary to define an idea or concept related to a product. The development of hundreds, if not thousands of APs, is expected for the wide variety of products covered by STEP, from garments to aircraft to documents.

Table A-20. Product Data Exchange Specification (PDES) Matrix

Technical Categories	Business View	Information View	Technology View
Integration Frameworks and Architectures	• Application Protocols	• Application Protocol • Data Models	
Operating Systems and Distributed Environments			
Communications			• EXPRESS
Data Management Systems	• Application Protocols	• Application Protocols	
Application Development Tools and Methods			
Data Representations		• EXPRESS • EXPRESS-G	• EXPRESS
Information Modeling Tools and Methods		• IDEF0 • NIAM	• EXPRESS
User Interface			
Programming Languages			
Security Tools and Methods			

Title: Portable Operating System Interface for Common Environments (POSIX) – IEEE program

Level of Effort: Many hundreds of person-years.

Performers: The POSIX effort is sponsored by the Institute of Electrical and Electronics Engineers (IEEE), Inc. Committee members are drawn from different companies.

Primary Milestones: Work on this effort dates back to 1984 when UniForum (formerly `/usr/group`) published its `/usr/group` standard in an attempt to standardize a profusion of Unix-based systems for minicomputers and microcomputers appearing in the market. Subsequently, in 1985, this work was transferred to IEEE. In 1987, IEEE, with the support of `/usr/group`, brought POSIX to the International Organization for Standardization (ISO). IEEE 1003.1 first appeared as a standard in 1988, and the ISO standard appeared in 1990, along with IEEE 1003.1 1990.

The first standard developed in this family is IEEE 1003.1, also known as ISO/IEC 9945-1, *Information Technology—Portable Operating System Interface—Part 1: System Application Programming Interface (API) in the C Language.*

Intent: The POSIX effort was established with the primary purpose of achieving portability of applications written by users and developers.

- The primary objective is to achieve source portability of application programs over a wide variety of Unix platforms using existing definitions of the Unix system.
- Only the interface is to be defined, without stipulating the implementation approach which is left to the vendor.
- As far as possible, only one means of realizing a capability has been specified.
- As far as possible, POSIX tries to accommodate popular historical implementations by following a "minimal change" philosophy. This minimizes the additional work to be done by application developers.
- Alignment with other concurrent activities within the POSIX effort is maintained.

The activities under the POSIX umbrella are as follows:

- Language-independent descriptions of the system interface specified in IEEE 1003.1.
- C, Ada, and Fortran bindings for the above.
- Shell and utility facilities.

- Verification testing methods.
- Real-time facilities.
- Security considerations.
- Network interface facilities.
- System administration.
- Graphical user interfaces.
- Profiles for different classes of platforms like supercomputers, multiprocessors, real-time systems, and transaction processing systems.

Thus, POSIX is an "umbrella effort" that offers broad coverage of the features and facilities required to develop and maintain highly portable applications. From a generic industry view, it offers the promise of a highly functional standardized interface without specifying implementation policy. At the particular industry level, it will be possible to use just those components of POSIX that are required. It provides a key component of information integration in the enterprise by performing the following:

- It allows applications to migrate to different platforms with minimum developer effort.
- It offers developers and programmers a uniform interface which does not change in functionality (with platforms) and does require relearning. As a result, development and maintenance are made less expensive.
- It permits tools (computer-assisted software engineering (CASE), development, end-user, management) to work in the same manner and across platforms, thereby consolidating the investments made in such tools.
- It integrates with other services like communications and user interfaces to offer a highly transparent environment to user and developer alike.

Technology Transfer Approach and Plans: The basic POSIX technical approach is already popular, being based on Unix. It is (or will soon be) required by many Federal agencies and is rapidly being adopted by vendors.

When products become available, rapid conformance testing can be expected. The National Institute of Standards and Technology (NIST) has established a conformance testing policy of POSIX for the Federal Information Processing Standards (FIPS). Currently, tests exist for the 1003.1-1988 version of POSIX but efforts are underway to update the tests as new standards are adopted.

Linkages: POSIX is most strongly linked to the Unix operating system. It also specifies language bindings like C, Ada, and Fortran, as well as an API for directory services.

Primary Contact: Roger Martin, NIST.

Table A-21. Portable Operating System Interface for Common Environments (POSIX) Matrix

Technical Categories	Business View	Information View	Technology View
Integration Frameworks and Architectures		• Guide to POSIX Open Systems Environments (1003.0)	
Operating Systems and Distributed Environments		• Directory Services Naming	• Systems Services (1003.1) • Real-Time Extension (1003.4) • System Administration (1003.7) • Namespace and Directory Services (1003.13)
Communications	• Mail • File Transfer • Remote Execution	• Protocol Independence (1003.12) • Transparent File • Access (1003.8)	• X.400 API (1224) • Common OSI and FTAM API (1238.1&2) • Remote Procedure
Data Management Systems			• Transaction Processing (1003.11) • Transparent File Access (1003.8)
Application Development Tools and Methods		• Multiprocessing Real-Time Testing Utilities	• Shell & Utilities (1003.2) • Test Methods (1003.3) • Multiprocessing • (**Note**: APIs could be viewed as standard libraries.)
Data Representations			
Information Modeling Tools and Methods			
User Interface		• Style Guide (1201.2)	• Windowing Toolkit (1201.1) • X Lib (1201.?)
Programming Languages			• C bindings (1003.1) • Ada bindings (1003.5) • Fortran bindings (1003.9)
Security Tools and Methods			• Access Control Lists • Audit Mechanisms • Privilege Mechanisms (1003.6)

Title: Remote Database Access Protocol (RDA) – International Organization for Standardization (ISO) Program

Scope: This is a standardization effort, currently within the domain of the ISO.

Level of Effort: Primarily volunteer in nature, therefore difficult to estimate. By comparison, it has received light to moderate attention relative to other ISO information technology standards efforts.

Performers: Until the involvement of ISO, the ANSI X3H2.1 committee was the focus of efforts through early developments. NIST has also established a SIG group for RDA within its Open Systems Interconnection (OSI) Implementors' Workshops.

Duration: 1986 through 1991 (estimated). It is expected that RDA will become a full ISO standard by mid-1991.

Intent: Information systems architects recognized that there was a missing piece in the ISO OSI communications model which had to provide the mechanisms required by a distributed database system. Distributed database access is viewed by many as an important ingredient in integrating enterprises. RDA is intended to fill in this missing piece.

Description of Work Done: Documents (and debates) describing the RDA standard have been the most visible output. It is unclear to what degree development has progressed within suppliers.

Results: There is a small group of users which value the RDA standard. To most, it is substantially hidden under the covers, or obscured by its partner standards such as TP (Transaction Processing), SQL, CCR (Commitment, Concurrency, and Recovery Protocol), and OSI protocols. Regardless, it is a necessary mechanism in the OSI scheme of things.

There is a key user/vendor group called the SQL Access Group whose primary focus is the advancement of the use of the SQL data management language. Effective use of RDA within the SQL scheme of things is being defined there. This may include non-OSI use of RDA.

Technology Transfer Approach and Plans: A planned public demonstration of SQL (and supporting RDA) technology was planned for July 1991. The SQL Access Group is sponsoring it; membership includes Apple, Bull, Digital Equipment Corporation, Hewlett Packard, Ingres, Lotus, Microsoft, NCR, Oracle, Sun, Sybase, and X/Open. Market support infrastructure appears to be more through SQL circles than OSI (or others). X/Open continues to include SQL, as promoted by the SQL Access Group, in the X/Open guidelines and efforts. Again, RDA is somewhat under the covers here.

Linkages: RDA was designed to link with the OSI Communications standards. RDA also maintains some conceptual linkage to the ANSI/SPARC Model for Database Management System (DBMS). Others include standards work generated through ISO committee SC 21, and the ODP (Open Distributed Processing) standards.

References:

International Organization for Standardization. ISO 9579, *Generic RDA Protocol and Service Specifications*. (Specific version unidentified at time of this report.)

"SQL Access: A Cure for the Nonstandard Standard." *Data Communications*. March 1991.

"Emerging OSI Functionality." *Open Systems Data Transfer*. Omnicom, Inc. December 1989.

Table A-22. Remote Database Access Protocol (RDA) Matrix

	Business View	Information View	Technology View
Integration Frameworks and Architectures		• Distributed Databases (DDBMS)	• OSI Model • ANSI/SPARC DBMS Model
Operating Systems and Distributed Environments		• X/Open • SPG4	
Communications		• Client Server • OSI • MAP/TOP	• ROSE • ACSE • TP
Data Management Systems		• Heterogeneous DBMSs	
Application Development Tools and Methods			
Data Representations			• DML (RDA) • ASN.1
Information Modeling Tools and Methods			
User Interface			• SQL
Programming Languages			• SQL (Language Binding TBD)
Security Tools and Methods			• SQL Access FAP

Title: SEMATECH Strategic Cell Controller (SCC) Project – SEMATECH Program

Scope: This project's objective is to drive the development of cell controller technology as it specifically applies to semiconductor manufacturing processes. The SCC project is designed to integrate with three other projects within SEMATECH's Corporate Information Management (CIM) Architecture Program. The other projects are entitled Advanced Development Environment, Systems Infrastructure, and Integrated Manufacturing Model.

Level of Effort: The entire SEMATECH yearly funding is about $200 million. Half is from its 14 members, and half from the Defense Advanced Research Projects Agency (DARPA). The specific funding of the SCC project is unavailable.

Performers: These include participants from SEMATECH's 14 member companies: AMD, AT&T, Digital Equipment Corporation, Harris Corporation, Hewlett Packard, Intel, IBM, LSI Logic, Micro, Motorola, National, NCR, Rockwell, Texas Instruments. These participants (often 30 to 40 individuals per company) will work with SEMATECH permanent staff for lengths of up to 2 years.

Duration: The project is beginning this year (1991), and is expected to last through 1994. It is divided into two phases, each about two years long.

Intent: Cell control in the semiconductor industry is relatively primitive compared to cell control in other manufacturing industries. This, combined with intense foreign competitive pressure, is spurring the type of cooperative development represented by this project. Further, in conjunction with the related SEMATECH CIM projects, the SCC is an attempt to break the limitations of dependency on legacy systems.

If the project reveals voids in the current global base of applicable standards, new standards will be developed. One void may be in the area of semiconductor processes and their models.

Project objectives and deliverables will result from each phase. The Phase 1 objective is to develop maintainable and changeable semiconductor cell controllers. Phase 2 will concentrate on simplifying controller programming so that non-programmers can do the changing/modifying (through the use of high-level software modules).

Description of Work Done: Object-oriented tools and methods will be the key approaches and philosophy used in SCC development. Models and applications specific to the semiconductor industry will be developed. Appropriate standards will be employed wherever possible. For instance, OSF/1 will provide the basic computing platform.

Results: No results have been generated as yet. The hope is that the results will significantly help productivity. Many semiconductor manufacturers are currently saddled with problems resulting from their existing (legacy) systems. Appropriate new products and processes are not being developed fast enough to satisfy the needs of the semiconductor manufacturing industry.

The results are expected to be usable in SEMATECH member companies and available on a wide variety of hardware platforms, with software modules serving as an applications platform. Since many member companies are also platform hardware and/or software vendors, such companies are expected to provide results in product form.

Technology Transfer Approach and Plans: Pilot implementations are planned as part of the SCC project. As mentioned above, some SEMATECH companies will likely supply the SCC technology as products. SEMATECH will also work with national labs and universities to transfer technology. Some semiconductor process standardization groups may be organized to work on areas not currently being covered. An important project objective is that semiconductor processing equipment suppliers be able to absorb this new technology and supply compatible products, as well as improve their own product quality.

Linkages: The object-oriented philosophies can be found in texts by authors such as Mellor, Booch, and Colbert. Key standards will be drawn from the OSF/1 sanctioned profile. Tie-ins to enterprise integration programs will be examined. Finally, this work will be coordinated with the other SEMATECH CIM Architecture Programs.

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Table A-23. SEMATECH Strategic Cell Controller (SCC) Matrix

Technical Categories	Business View	Information View	Technology View
Integration Frameworks and Architectures	• Manufacturing Plant-to-Cell Levels	• Sematech's Integrated Model (IM)	• OSF/1 • Sematech CAS (CIM Systems Architecture)
Operating Systems and Distributed Environments			• OSF/1
Communications			• OSF/1
Data Management Systems			• OSF/1
Application Development Tools and Methods			• Object-Oriented • Sematech ADE (Advanced Development Environment)
Data Representations			
Information Modeling Tools and Methods			• Object-Oriented Analysis (Colbert, Booch, Mellor)
User Interface			• OSF/1
Programming Languages			• OSF/1
Security Tools and Methods			• OSF/1

Title: Transmission Control Protocol/Internet Protocol (TCP/IP) - Department of Defense Program

Performers: BBN, University of California at Berkeley, other universities.

Duration: The development of TCP/IP began in the mid-1970s, and by the late 1970s the protocols took their current form. In 1980, TCP/IP adoption had begun and by 1983 all the hosts on the ARPANET were using it. In the mid-1980s the NSFnet backbone had been funded. Currently, the IAB oversees internet activities.

Primary Milestones: TCP/IP is a mature technology and is being enhanced in areas like network management (Simple Network Management Protocol (SNMP)). Currently, a bulk of IAB work focuses on migration to newer and more "standard" technologies like Open Systems Interconnection(OSI).

Intent: The intent of developing the TCP/IP protocol suite was to provide a robust, low-cost, and easy-to-implement technology to realize a national research network that we now know as the DARPA Internet.

Description of Work Done: TCP and IP are just two protocols in the TCP/IP suite. There exist a large number of other protocols in the suite that perform other functions such as address resolution, mail transfer, and network management. In most part, the protocols are stable and mature, and current work focuses on enhancements to provide better functionality and interoperability.

Technology Transfer Approach: DARPA initially made available the TCP/IP protocol to research and educational institutions at little or no cost. Moreover, since it was built on Berkeley Unix (which was the most popular operating system at such institutions), TCP/IP gained wide acceptance.

The IAB uses volunteers to serve on its task forces charged with various responsibilities to maintain and improve ARPANET services.

Further technology transfer is achieved by making the specifications public so that vendors can use it. Currently there exist a large number of TCP/IP-based commercial off-the-shelf (COTS) products.

Linkages: IAB, International Organization for Standardization (ISO).

Table A-24. Transmission Control Protocol/Internet Protocol (TCP/IP) Matrix

Technical Categories	Business View	Information View	Technology View
Integration Frameworks and Architectures	• Internetworking • Peer-to-Peer Communications • Client-Server Interaction	• Gatenet Model (RFC 871) • Client-Server Model	• Gateways • Sockets • Streams • PCI
Operating Systems and Distributed Environments	• Network Maintenance • Network Management	• NFS • AFS • Proprietary	• Unix • POSIX • Proprietary • ICMP, SNMP, CMOT
Communications	• Electronic Mail • File Transfer • Remote Login	• Hierarchical Naming (Domain Name System) • Internetworking Protocol	• SMTP, POP • FTP • TELNET • DNS • TCP, UDP • IP, ICMP, EGP, GGP
Data Management Systems			
Application Development Tools and Methods		• Remote Execution • Network Application Debugging	• Sun RPC • Socket and Stream Libraries • Echo, Finger, Ping, etc.
Data Representations			• *Ad hoc* • Sun XDR
Information Modeling Tools and Methods			• Queuing Models • Simulation
User Interface			
Programming Languages			• C • Other
Security Tools and Methods		• Trusted Hosts, Superusers • Trusted Third-Party Authentication	• 4.3 BSD Routines • MIT Kerberos

Title: X/Open - Organization

Scope: Developing and promoting open systems technologies. X/Open is working on developing user requirements for open systems and portability guides (XPG), and developing verification suites for XPGs.

Level of Effort: X/Open is a consortium of users and vendors. It is headquartered in United Kingdom with branch offices in the United States and Japan. It has its own full-time staff promoting open systems concepts by developing requirements, portability guides, and conformance test systems for XPGs. X/Open is mainly funded by membership dues and any royalties generated by licensing their products. It has about 90 members.

Performers: X/Open performs some work in-house and some is contracted out to other companies. It has established good working relationships with the Open Software Foundation (OSF) and the Object Management Group (OMG).

Duration: Ongoing.

Intent: To support and promote open systems based technologies. It was formed as a consortium of users and vendors.

Description of Work Done: X/Open is working on a user requirements document for open systems. It has developed portability guides for transport, object management, and X.400 protocols. It has worked with the Corporation of Open Systems (COS) Mark Program and has developed verification suites for portability guides. X/Open organizes conferences and workshops to promote its concepts. It has organized its contributors into working groups (User Console Program, System Vendor, and Software Vendors).

Results: X/Open has published portability guides for transport, object management, and X.400 protocols.

Technology Transfer Approach and Plans: X/Open is making its specifications and services available to companies, and is promoting its activities through education, awareness, and training program.

Linkages: X/Open is linked to the User Alliance for Open Systems, COS, OSF, and OMG.

Table A-25. X/Open Matrix

Technical Categories	Business View	Information View	Technology View
Integration Frameworks and Architectures	• Strategic Marketing: Enable Euro-vendors Some Control of Unix Platform Interfaces (i.e., Unix and Open Systems)	• Application Portability	• Unix
Operating Systems and Distributed Environments			• POSIX (XSI)
Communications			• OSI (XTI) • TCP/IP (XTI) • KERMIT • ANSI Terminal Emulation
Data Management Systems			• SQL • ISAM
Application Development Tools and Methods		• X/Open Portability Guidelines (XPG3)	
Data Representations			
Information Modeling Tools and Methods			
User Interface			• X-Windows • Curses
Programming Languages			• C • Cobol
Security Tools and Methods			

APPENDIX B. STANDARDS AND TECHNOLOGIES BRIEFS

This appendix contains brief descriptions of standards and technologies grouped by the 10 technical categories:

- **Integration Frameworks and Architectures**: Overall integrating representations, models, and schemas of the enterprise and its component parts (e.g., Application Portability Profile (APP), Systems Application Architecture (SAA), GM-C4 (CAD/CAM/CAE/CIM) frameworks).
- **Operating Systems and Distributed Environments**: Components used to provide system services (I/O, process management, and others) to applications (e.g., Portable Operating System Interface for Computer Environments (POSIX), Unix, MS-DOS, NetWare)
- **Communications**: Components used to connect applications, allowing applications to transfer data and control among themselves (e.g., Open Systems Interconnection (OSI) and Transmission Control Protocol/Internet Protocol (TCP/IP)).
- **Data Management Systems**: Components used to store, manage, and retrieve data. Data management includes knowledge bases, database management systems (DBMS), information management systems, data dictionaries, and schema implementations.
- **Application Development Tools and Methods**: Tools and methods used to model and build applications (e.g., application generators).
- **Data Representations**: High-level data representation standards (e.g., Standard for the Exchange of Product Data (STEP) and Electronic Data Interchange (EDI)).
- **Information Modeling Tools and Methods**: Tools and methods used to construct models of the enterprise and its components (e.g., Integrated Computer-Aided Manufacturing (ICAM) Definition Language (IDEF) and Semantic Unification Meta-Model (SUMM)).
- **User Interfaces**: Components that allow users to interact with the applications making up the integrated enterprise (e.g., Motif and X/Windows).
- **Programming Languages**: High-level languages used to represent algorithms. This category includes APPs (e.g., Ada and C++).

- **Security Tools and Methods**: Tools and methods used to control access to applications and data (e.g., Kerberos).

B.1 INTEGRATION FRAMEWORKS AND ARCHITECTURES

Frameworks and architectures apply the divide-and-conquer principle to break up a complex problem into tractable, logical, and interfaced components. These components can then be solved and integrated incrementally.

B.1.1 PORTABLE COMMON TOOL ENVIRONMENT (PCTE)

PCTE started as an ESPRIT project in 1983, and grew into a major initiative for the definition and prototyping of a software engineering environment (SEE) framework interface. PCTE is not an environment in itself, but a framework or structure that will be the basis for the construction of the SEE.

PCTE focuses on data integration and offers facilities to builders of large-scale software environments. Its main areas of strength are the repository definition and data integration services. In doing this, PCTE aims at providing comprehensive interface definitions for data and tool integration, supporting multiple programming languages, and providing a migration path for existing tools. It uses the entity-relationship model for some basic definitions, but does not follow it closely. However, it recognizes data independence as an important means for tool integration and for maintaining the separation between policy and mechanism.

The PCTE project is in a fairly advanced stage, with early products already in use. The PCTE+ project, which is a PCTE variant and incorporates some improvements over PCTE, is also in an advanced stage of development.

B.1.2 CAD FRAMEWORK INITIATIVE (CFI)

CFI was established in 1988 with the objective of "developing worldwide industry guidelines for electronic design automation tools and their supporting environments that will remove barriers to integration." It is an international consortium of about 50 corporate members.

CFI is working to standardize seven functional areas of a framework environment:

- An Architecture for a framework that will allow tools and framework components to be interoperable and interchangeable.
- The Design Data Management task that relates to the management of design information and design meta-data within the framework environment.

- The Design Methodology Management task for specifying the representation and execution of design policies.
- The Design Representation task that relates to representation and access of CAD data.
- The Inter-tool Communication task that builds guidelines to support both the interoperation of applications and framework components and the exchange of control information and data.
- The System Environment task that develops guidelines and adopts standards to support portability, coexistence, and cooperation of tools and data.
- The User Interface task that develops guidelines for the consistent appearance and behavior of the framework environment from the user's perspective.

The 1991 CFI integration project exhibited cooperating tools from 30 companies that used CFI's tool abstraction specification, its inter-tool communication mechanism, and its programming interface. The project also demonstrated the use of its information model and programming interface for hierarchical electrical net lists. The specifications and interfaces are the main products created by CFI to date. Work on further development is in progress.

B.1.3 ENGINEERING INFORMATION SYSTEM (EIS)

The EIS program has targeted the data interchange framework area with a concentrated focus on standards for electronic components and circuits. The EIS work has two parts:

- The Integrating InfraStructure (IIS), a framework or integrating infrastructure within which product information can be managed throughout the product life cycle. The IIS presents a homogeneous view of product data that could reside in a heterogeneous distributed hardware environment. By providing this functionality, the IIS facilitates integration of CAx (e.g., computer-assisted design (CAD), computer-assisted manufacturing (CAM)) tools.
- A pair of information models: the engineering administration model and the integrated circuit (IC) CAD model. The former deals with the services provided by EIS (e.g., data exchange, error handling, configuration management, tool invocation facilities, and communication). The IC CAD model is specific to the

electronic component domain and addresses the design, layout, simulation, and testing of electronic circuits and ICs.

EIS uses an object-oriented approach in its specification and implementation. Wrappers (software encapsulation techniques) are used to facilitate integration with existing tools, and messages between system components are used to facilitate communication. Popular standards and tools like IDEF, POSIX, X-Window, Motif, Ada, and C are used throughout. As a result, pieces of EIS work are being used by standards organizations as starting points.

The EIS program is currently in its closing stages, with detailed specifications already complete. The final phase, phase 3, will develop a fully functional implementation demonstrating the EIS concepts, guidelines, and model.

B.1.4 GENERAL MOTORS CAD/CAM/CAE/CIM (GM-C4)

C4 is a project internal to the GM Corporation to develop a framework that will offer portability and interoperability of software applications through GM. Not much is publicly known about the project except that it will focus on open and widely implemented standards to meet GM technical and business requirements.

B.1.5 INTEGRATED COMPUTER-AIDED MANUFACTURING FACTORY OF THE FUTURE (ICAM-FOF)

The ICAM-FoF project was initiated by the U.S. Air Force in 1981. The FoF conceptual framework is a structure for understanding activities and information focusing on factory management and functional relationships. It addresses important enterprise functions such as marketing, customer service, product engineering, materials management, production, logistics, and quality issues. Related work includes a FoF functional framework, an FoF integration concept, and an integrated computer-based systems architecture.

The FoF project has received inputs from a wide range of contributing companies and has had its outputs used and validated by many organizations as well. It is thus a time-tested guide for modernization activities, although it may be lacking in state-of-the-art thinking.

B.1.6 AD/CYCLE

IBM's Application Development (AD)/Cycle offers an enterprise modeling approach supported by an integrating framework and a set of application development tools. The framework provides the integrating platform that enables data sharing and cooperation among the tools. AD/Cycle conforms to the IBM System Application Architecture (SAA) guidelines. Parts of AD/Cycle that were not originally covered by SAA, such as the programming interface to Repository Manager, have been added to SAA as extensions.

The AD/Cycle enterprise modeling approach is supported by tools that assist in the creation, analysis and validation of an enterprise model, which can then be used to generate applications. The enterprise model data and business process requirements are centrally stored in entity-relationship form by the Repository Manager. The central control of data helps maintain consistency of the data and makes the data available for other tools in the framework.

The architectural components of AD/Cycle include:

- User Interface: Implements the SAA Common User Access (CUA) guidelines.
- Workstation Services: A set of Presentation Manager and OS/2 services.
- Work Management: Provides consistency in tool invocation.
- Tool Services: Common functions required by tools independent of where they execute.
- AD Tools: The application development (AD) tools themselves.
- AD Information Model: The specification of the data that can be shared by the tools.
- Repository Services: Centralized management of application development data.
- Library Services: Support for application configuration control.

B.1.7 APPLICATION PORTABILITY PROFILE (APP)

APP, the U.S. Government's Open System Environment (OSE) Profile, was published by the National Institute for Standards and Technology (NIST) in April 1991 (NIST Special Publication 500-187). The APP defines an OSE reference model and set of specifications (i.e., profile) for interfaces, services, protocols, and data formats used within the reference model. The OSE reference model is composed of three entities and two interface components:

Entities

- Application Software: Programs, data, training, and documentation.

- Application Platform: The software and hardware components that provide services to the Application Software.
- Platform External Environment: Users, information services, and communication services.

Interface Components

- Application Program Interface (API): Connects the Application Software with the Application Platform by providing user interface, information interchange, communications, and internal system services.
- External Environment Interface (EEI): Supports information transfer between the Application Platform and the External Environment.

The APP profile specifications fall into seven categories:

- Operating System Services
- User Interface Services
- Programming Services
- Data Management Services
- Data Interchange Services
- Graphics Services
- Network Services

Each of the categories contains a list of alternative specifications that can be selected with an APP platform. For example, the Programming Services category specifies Ada, C, Cobol, Fortran, and Pascal.

B.1.8 SYSTEMS APPLICATION ARCHITECTURE (SAA)

IBM's SAA has the goal of providing an environment in which applications can be developed so they can run consistently on various IBM computing platforms (MVS for System 370, OS/400 for AS/400 computers, and OS/2 for PS/2 systems). A later addition to the family of platforms is AIX (IBM's version of Unix). The elements of the SAA framework are Common User Access (CUA), Common Programming Interface (CPI), and Common Communications Support (CCS).

CUA specifies how the system, including the applications, interacts with a person at a workstation or terminal. CUA is a set of guidelines that defines the interaction between humans and computers. CCS controls the interconnect protocols. It also controls how systems communicate with one another to store, retrieve, and move information through the communications network. CPI specifies how a programmer may write and attach a new application to an SAA system, and defines a set of application building blocks consisting of languages and programming services for application programmers. The Distributed Automation Edition (DAE) is the mechanism by which the building blocks and standards forming SAA are distributed to third-party software developers.

SAA is available on IBM systems, although there are plans to extend it to non-IBM Unix systems. The platforms currently supported are IBM MVS, VM, OS/2, MS-DOS, and IBM AIX (a recent addition). IBM's strategy is to build SAA-based frameworks that integrate application domains. Examples of frameworks are AD/Cycle for application development and OfficeVision for office systems. The Information Warehouse is a framework for information access, and is expected to become a product by 1996. Catalogs of SAA-based products in the market can be obtained from IBM.

B.1.9 NETWORK APPLICATIONS SUPPORT (NAS)

NAS architecture is centered around the way an application interacts with the user, data, system, and other applications. This view is directly represented in the NAS architectural model, which Digital Equipment Corporation (DEC) refers to as the Application Integration model. The model has four components:

- Application Access Services used to manage the user dialogue.
- Information and resource sharing services to handle the data dialogue.
- Communications and control services to enable the application dialogue.
- System Access Services to carry the dialogue between the application and the operating system.

Each component of the model is supported by a set of standards and standard-based products and DEC's commitment to support different operating system platforms and newly developed standards.

NAS products are available on DEC VMS, Ultrix, SCO Unix, AT&T Unix System V, MS-DOS, IBM OS/2, and Apple Macintosh platforms. Projected platforms include

IBM's AIX and OSF/1. Each component in the NAS architecture is supported by a set of DEC products:

- Application Access Services are provided by DECwindows, DECforms, LiveLink, and BUILDER.
- Information/Resource Sharing Services are supported by the CDA Toolkit, DECImage, DECPrint, ALL-IN-1, and others.
- Communication and Control Services products are MAILbus and DEC/EDI.
- System Access Services, including POSIX.

B.1.10 NEWWAVE

Hewlett Packard's (HP) NewWave Computing strategy is an evolutionary approach to integration. HP's NewWave architecture consists of the following:

- User Environment
- Application Environment
- Application Integration Services
- Distributed System Services
- Software Development Environment
- Base-level Systems and Networks

The evolutionary approach to integration is reflected by NewWave products such as the NewWave desktop, HP-Sockets, and VUE. Of particular interest is VUE, which allows existing applications to be integrated at the user interface and application data interchange level.

HP's NewWave products are available in MS-DOS, OS/2, Macintosh, HP-UX, SunOS, SCO Unix, IBM AIX, and DEC Ultrix platforms; products for OSF/1 are currently being planned. A feature of the NewWave desktop is its availability for Windows 3.0 platforms. Other noteworthy NewWave products are the HP-Sockets, a set of 12 access routines that can be used to build user interfaces that integrate applications running on HP-UX and MPE XL platforms; and VUE, a graphical user interface shell that can run on several platforms.

Historically, products based on the commercial architectures have been available for NAS and SAA systems since 1988. HP NewWave products became available after HP's announcement of the NewWave strategy in 1990.

B.2 OPERATING SYSTEMS AND DISTRIBUTED ENVIRONMENTS

Operating systems are defined as those components that provide system services (I/O, process management, and others) of a computer to applications. Distributed environments are those capabilities which extend operating systems, more or less transparently, across many physically dispersed computers.

B.2.1 PORTABLE OPERATING SYSTEM INTERFACE FOR COMMON ENVIROMENTS (POSIX)

POSIX is the IEEE-initiated effort to develop a standard for operating systems. It draws much of its technical basis from Unix. A major trend in operating systems is convergence towards POSIX compliancy. Real-time extensions are becoming increasingly important, particularly in the areas of manufacturing, and POSIX is addressing these.

B.2.2 OSF/1

OSF/1 is the Open Software Foundation's standard for operating systems. It is based on Unix, is designed to support OSF's Distributed Computing Environment (DCE), and claims POSIX compliance. OSF/1 also draws upon the Mach operating system work done at Carnegie-Mellon University, providing real-time and multi-processing support.

B.2.3 SYSTEM V RELEASE 4 UNIX (SVR4)

SVR4 is AT&T's commercial version of Unix, and is well-established in the marketplace. It is also the operating system sanctioned and supported by the Unix International (UI) consortium (the competitive alliance to OSF). SVR4 is the choice for supporting UI's Atlas distributed environment. SVR4 also claims POSIX compliance.

B.2.4 MICROSOFT DISK OPERATING SYSTEM (MS-DOS)

MS-DOS is the principal operating system used for personal computers. MS-DOS has an overwhelmingly large installed base and the recent release of 5.1 functionality continues its effective evolution. MS-DOS is limited in many ways compared to the Unix-type operating systems. Transparently positioning MS-DOS in an integrated environment presents many challenges, though it also appears many third-parties are willing to accept that challenge.

B.2.5 OS/2

OS/2 is IBM's multi-tasking operating system, designed to overcome MS-DOS type limitations, for use on personal computers. In many ways, it brings Unix-class features to MS-DOS oriented users. Yet the future of OS/2 is uncertain. IBM claims commitment to it but adds that there are other very good 32-bit technologies out there, i.e., AIX, AS/400. Meanwhile Microsoft, IBM's ex-partner in OS/2 development, continues pushing Windows NT (an OS/2 competitor).

B.2.6 MAC SYSTEM 7

The Mac System 7 greatly extends the services offered by the Apple Macintosh family of personal computers, particularly in the areas of distributed file management, database management, and interprocess communication. Although it is proprietary, it is an important development because of Apple's installed base. It is also relatively inexpensive.

B.2.7 OBJECT MANAGEMENT GROUP (OMG)

OMG has started a major effort to standardize interfaces for distributed objects. Though intended for software portability and reusability, the principles are drawn from and are applicable to distributed computing. The effort is producing the Object Management Architecture, with the Object Request Broker (ORB) as its central element. An announcement of the specification is expected momentarily, and the specification will be made public within a year. Although its own members intend to pursue object-oriented projects, OMG's work is expected to play a major role in the future specification of distributed systems.

B.2.8 OPEN DISTRIBUTED PROCESSING (ODP)

The ODP effort, sponsored by the International Organization for Standardization (ISO), began in 1987 to produce a reference model for distributed processing. This model will form the basis for distributed processing standards which will allow compliant applications to communicate in a transparent manner.

ODP work is progressing along three fronts. The first of these is the development of the reference model. The model is being used as the basis for a prototype ODP system called the Advanced Network Systems Architecture (ANSA). Thirdly, a consortium (ODPC) is being set up to provide the testing infrastructure needed to support products.

B.2.9 DISTRIBUTED COMPUTING ENVIRONMENT (DCE)

DCE is expected to be available for release in the fourth quarter of 1991. DCE is composed of existing products, and is intended to support international standards where applicable. It provides an open architecture that has extensibility built in. DCE is generally thought to be an important development in distributed computing, though products are not expected for at least a year. Somewhat surprisingly, UI has pledged to integrate it into its own distributed computing environment, Atlas.

B.2.10 OBJECT-ORIENTED, CHANGE-ORIENTED REFERENCE ENVIRONMENT (OO-CORE)

OO-CORE draws on the concepts of the ANSI SPARC three-schema architecture, database management, and CIM-OSA to create a tool that supports migration to an object-oriented system from legacy systems. It uses EXPRESS for object specification and a dialect of SQL, called OO-SQL, for object access and management. OO-CORE directly addresses the problem of change, something other frameworks and environments seldom do.

B.2.11 PROCESS-ORIENTED MANAGEMENT SYSTEM (POMS)

POMS is developed by Incode, Inc., Reston, Virginia, for IBM. It functions between the planning or scheduling system and plant floor supervisory control by implementing higher-level instructions, retrieving recipes, and monitoring the status of shop floor operations.

B.2.12 ANSAWARE

ANSAWare, based on the Open Systems Interconnection (OSI) Open Distributed Processing (ODP), gives the user the environment and facilities to create distributed processes. While ANSAWare is still a development effort, it is available for purchase from ISA. Atypically, the prototype is far ahead of the standard. It is unclear at this point how applicable ANSAWare will be to enterprise integration, but it bears watching.

B.2.13 CIMPLICITY

Cimplicity Systems is a collection of factory-floor monitoring and control products for use with different standard computers and operating systems. Cimplicity gives factory personnel a window into the manufacturing process, providing timely information about factory conditions. It lets users easily expand or modify their systems, preserving their initial investment in computers and training, and reducing costs associated with new computer platforms.

The software operates with IBM-type personal computers using Interactive Systems Unix, DEC's VAX/VMS and Ultrix computer platforms, and Hewlett-Packard (HP-UX) based systems. It provides a system architecture that takes data collected from controllers and dynamically knits them together into a global database across computers in the network. Application modules access this global database, providing graphic status monitoring, alarm management, and Statistical Process Control (SPC).

Much of the original Cimplicity development was done on Digital's VMS operating system, using a GE Fanuc-developed application environment to insulate the application modules from the operating system.

B.2.14 DISTRIBUTED OBJECT MANAGEMENT FACILITY (DOMF)

The NewWave distributed application integration architecture has as one of its components a distributed computing facility known as DOMF. It contains many functions one would require from any distributed computing environment. It currently runs under Microsoft Windows, and is scheduled to run under OS/2 and Unix as well.

B.2.15 OBJECT LINKING AND EMBEDDING (OLE)

Microsoft has an application environment solution called Object Linking and Embedding (OLE) that provides a first step toward an object-oriented distributed environment. It extends the Dynamic Data Exchange (DDE) protocols that allow one to use and, to some extent, manage dissimilar objects. Currently, it does not run over a network. It is expected that Microsoft will expand and refine OLE and target it for Windows, Presentation Manager, and Microsoft environments. A number of applications are either implemented, being implemented, or are targeted for OLE, including Lotus 1-2-3 and NewWave. As a platform integration tool, OLE deserves to be considered.

B.2.16 NETWARE

Novell's NetWare, a personal computer-local area network (PC/LAN) operating system, clearly dominates the market with over 50% of the market share, and there is every reason to believe that this dominance will continue. Novell is famous for its foresight, infrastructure, distribution channels, and aggressive marketing. It continues to lead in the important area of connectivity. It recently announced a product shipment that was the result of a joint venture with Sequent Computer Systems. This product allows NetWare to increase its scale of services, as it can handle up to 1,000 users of a relational database management system (DBMS).

B.2.17 LANMANAGER

The LANManager, a PC-LAN operating system, has a fraction of the PC-LAN market share. It is being considered because it was backed at one time or another by Microsoft, IBM, 3Com, and AT&T. Almost simultaneously, 3Com and Microsoft parted ways, and IBM announced it would market NetWare. However, Microsoft announced in October 1991 that it would release a new version of LANManager (version 2.1) and associated products that will increase its connectivity. Added features would include Transmission Control Protocol/Internet Protocol (TCP/IP) support, full integration into Windows, increased interoperability with Novell's NetWare, and support for Apple's Macintosh as LANManager client. These enhancements are consistent with Microsoft's strategic shift to gain added acceptance via Windows (and consequently a decreased emphasis on OS/2) and greater connectivity.

B.2.18 VINES

Banyan's Vines PC-LAN operating system is also increasing its connectivity. Banyan has recently announced an agreement with Digital Communication Associates to market Vines jointly in order to provide SNA connectivity. Additionally, it will seek out ISVs to add value to Vines, releasing APIs to expedite application development. SCO Unix and Banyan recently announced a joint venture to port Vines services to SCO Unix.

B.3 COMMUNICATIONS

Communication protocols and profiles that support open systems communications are dominated by TCP/IP and OSI. Although they are usually compared, their respective scopes are very different, so comparisons can be misleading.

B.3.1 TRANSMISSION CONTROL PROTOCOL/INTERNET PROTOCOL (TCP/IP)

TCP/IP is by far the more popular of the two protocol suites in the United States. It is the *de facto* networking standard, with huge installation base. Any enterprise integration solution must consider TCP/IP.

Strictly speaking, TCP/IP is the name of two key networking protocols. Over the years, TCP/IP has come to more broadly refer to a suite of protocols that together provide full-scale networking capabilities. Originally developed for the ARPANET, TCP/IP was released into the public domain and quickly adopted by U.S. research community. Though somewhat lacking features compared to OSI protocol suites, TCP/IP has the broad-based implementation experience and flexibility that supports continued growth.

B.3.2 MANUFACTURING AUTOMATION PROTOCOL/TECHNICAL AND OFFICE PROTOCOL (MAP/TOP)

MAP and TOP are profiles of OSI standards which define networking for manufacturing and office environments, respectively. They are very similar to each other, and are designed to interoperate with other OSI-type networks quite easily. Though more functional, they have not overcome the wake of TCP/IP's popularity.

B.3.3 GOVERNMENT OPEN SYSTEMS INTERCONNECTION PROFILE (GOSIP)

GOSIP is an OSI networking profile promoted by the U.S. Government for use in its procurements. Whereas TCP/IP addresses internetworking and data transmission, GOSIP addresses a larger picture (e.g., dialogue control, representation) and, consequently, brings with it more complexity and overhead. Again, it remains to be seen how the evolution of TCP/IP and OSI-type profiles such as GOSIP will converge or diverge.

B.3.4 TRANSPARENT FILE ACCESS (TFA)

TFA is an IEEE-sponsored development to create a standard for transparent file management and transmission, independent of knowledge of specific file transfer services or mechanisms. It is a goal of TFA to express the semantics of file systems such as Network

File System (NFS), RFS, AFS, Network Computing System (NCS), in a standard manner. TFA is also known as the IEEE POSIX committee P1003.8, and is a component of the NIST APP.

B.3.5 NETWORK COMPUTING SYSTEM/REMOTE PROCEDURE CALL (NCS/RPC)

NCS/RPC are the distributed file management and remote procedure mechanisms included in the OSF's DCE. They are also called out as components of the NIST APP. This system (developed by HP/Apollo) is the prime competitor of the popular NFS system from Sun.

B.3.6 GOVERNMENT NETWORK MANAGEMENT PROFILE (GNMP)

GNMP is a still developing profile created under the auspices of the NIST. Intended to be similar in style and applicability to GOSIP, it addresses areas related to network management. GNMP is included as part of the APP.

B.3.7 X.500

X.500 refers to the large set of standards which have been developed to define the operation of directory services for use in an OSI environment. Interestingly, a major TCP/IP-based facility, NYSERNet in the eastern United States, is developing an X.500-based system for its TCP/IP environment. It appears that X.500 will continue to gain acceptance in serving as a common element across different communications environments.

B.4 DATA MANAGEMENT SYSTEMS

Data management systems are those software components used to manage the storage and retrieval of data. Technologies included are DBMSs, data dictionary systems, and other information management technologies such as hypertext and hypermedia. Standardization efforts underway are directed towards issues of data management in heterogeneous distributed environments, data dictionaries, and object-oriented data management systems.

B.4.1 INFORMATION RESOURCE DICTIONARY SYSTEM 1 (IRDS1)

The first IRDS standard (ANSI X3H4) is based on the relational model. It is intended to provide a framework that defines the information that will be captured and maintained by an Information Resource Dictionary (IRD). The IRDS Framework identifies the enterprise data, hardware, interfaces, and the services provided by the enterprise processing facilities.

B.4.2 INFORMATION RESOURCE DICTIONARY SYSTEM 2 (IRDS2)

A second IRDS (ANSI X3H4 and ISO) is under consideration. IRDS2 will extend the ANSI IRDS 1 standard and be based on object-oriented concepts. A core object model will support generic base services, upon which IRDS2 service profiles and content modules will be implemented. Together, the set of content modules for an IRDS system defines the information model for an enterprise.

B.4.3 REMOTE DATABASE ACCESS (RDA) PROTOCOL

RDA Protocol standard has been developed to enable interoperability of database management systems. It is expected to become a full ISO standard by the end of 1991. RDA is a mechanism to enable the operation of distributed databases and their access.

B.4.4 SQL

SQL is a relational database query language developed at IBM in the mid-1970s. SQL has been available in IBM products, System R and DB2, since the late 1970s. The usefulness of the language was recognized early on; non-IBM SQL products were actually available before IBM formally released its SQL based products. The ANSI X3H2 Database Committee produced the standard for SQL in the mid-1980s.

B.4.5 OBJECT-ORIENTED SQL

The OO-CORE project at IBM requires the use of an object-oriented data manipulation language (DML) and a language for data definition. The data manipulation language

(DML) for OO-CORE, OO-SQL, is based on the SQL paradigm. The data definition language used by OO-CORE is EXPRESS. Once objects are defined in EXPRESS, they are edited by using OO-SQL data definition commands. Still, OO-CORE objects are not bound a relational database model (but neither do they preclude it).

It is the intent of OO-SQL to provide a language that adapts to the CIM-OSA 3x3x4 "cube" model, yet is simple to use and understand.

B.4.6 HYPERMEDIA

While the vision of hypermedia has been in existence since the 1950s, standards support (such as HyTime, ISO/IEC DIS 10744) has just recently begun to appear. The vision of hypertext is to put information on-line and build links between associated information, regardless of platform or physical location. Once these links are in place, the very simple and primitive human gesture of pointing will allow users to access information quickly. Notecards (by Xerox) and Augment (by Engelbart) have existed as commercial products for quite some time, but with serious limitations that have prevented their widespread use. Several hypermedia environments (such as HyperBase and Guide) exist for the PC, and many PC programs use hypertext systems for on-line help.

B.4.7 COMMON DATA MODEL (CDM)

CDM is part of the Integrated Information Support System (IISS). The CDM is the data dictionary used to provide uniform access to the databases in the system. The IISS project, sponsored by the U.S. Air Force, began in 1978. The goal of the project was to implement a system based on the then-new Three Schema Architecture for databases (ANSI 1977), and show its applicability to the problems associated with the manufacturing of large weapon systems. The project was restricted to developing large distributed heterogeneous databases so they complied with the standards existing at the time for databases (ANSI Three Schema Architecture and draft SQL).

There is a prototype IISS CDM system in existence, implemented on VAX VMS and IBM MVS systems. The system includes a data definition language (NDDL or Neutral Data Definition Language) used to create the Common Data Model, and a data manipulation language (NDML or Neutral Data Manipulation Language) used to access the data. There are no efforts being made to standardize or make products from the IISS components, although the IISS program has conducted studies to develop a system based on current database standards.

B.5 APPLICATION DEVELOPMENT TOOLS AND METHODS

Application Development Tools and Methodologies are those tools and techniques used to improve programmer productivity, and technologies that contribute to the development of applications. These include application generators, graphical user interface builders, standard communication libraries and application profiles, and application development environments. We include in this category the technologies developed in the field of artificial intelligence.

B.5.1 X/OPEN AND POSIX APIS

The Application Protocol Interfaces (APIs) developed by the X/Open Consortium and the incipient IEEE POSIX Application Environment Profiles (AEPs) (POSIX 1003.4, 1003.10, 1003.12, 1003.13, 1003.14, 1238, and 1238.1) are notable efforts at providing a standard library and interface for applications programming. Standard communications libraries and application environment profiles define interfaces to access different communications protocols and effectively free the software developer from the burden of developing the communications software needed to interface an application with other applications and systems, while adding the benefit of portability, interoperability, and scalability of application software.

B.5.2 INTEGRATED DESIGN SUPPORT SYSTEM (IDS)

IDS is a multiphase research initiative sponsored by the US Air Force to develop an architecture for the use and distribution of digital data. Phase I of the program (1984-1988) demonstrated an integrated technical information system capable of capturing, and managing distributed digital data across the entire life cycle of a major Air Force weapon system.

IDS focuses on three concepts: the application of a data-driven approach; optimal use of existing assets; and the implementation of prototype development techniques. The data-driven approach uses the three-schema architecture as a base concept and defines user, enterprise, and computer system views of the data. The user views are represented by IDEF function models. The enterprise view is a logical view of the product data required as defined in the IDS Product Data Conceptual Model (PDCM). The computer systems' view is the software, hardware, data support systems, and assets require to implement an IDS system.

B.5.3 KNOWLEDGE-BASED SYSTEMS (KBS)

The most significant use of KBS technology to date has been in diagnosis. Thousands of diagnostic systems are in use today. Some diagnostic systems are built by having a knowledge engineer interview a domain expert on the problems in the domain and how they are diagnosed. The expert's knowledge is then encoded typically in if-then rules. Another form of diagnosis is called Model Based Reasoning (MBR). MBR systems work by producing a simulation of the domain of interest and using knowledge to diagnose failures by breaking the model in a way that reflects observed symptoms.

To a lesser extent, KBSs are used in planning. Applications ranging from job shop scheduling to planning movements of the Pacific Fleet. Planning systems accept from users desired goals, operations which can be performed, and a set of constraints. The planner then generates a set of operations that when executed will achieve the goals without violating any of the constraints.

B.5.4 APPLICATION GENERATORS

Application generators have been in use for several years. The best results have been obtained in the business data processing field, where commonplace input/output requirements can be abstracted and met by simple high-level instructions or recipes. Several of the application generators currently on the market can be driven directly from a data dictionary generated by a CASE (computer-assisted software engineering) tool. Graphical user interface builders allow the programmer to design and build a graphical user interface interactively. They are typically menu driven and can cut the user interface development time significantly. The principal limitation of application generators is their inability to handle complex non-routine requirements for special-purpose applications.

B.5.5 PLANTWORKS

IBM PlantWorks helps non-programmers devise and operate cell control programs at the supervisory level quickly via graphical, icon-driven, programming techniques. Written for IBM by Measurex Automation Systems (Cupertino, CA) to work on SAA platforms. Released in 1988.

B.5.6 NEURAL NET

Neural networks are made up of many simple, highly interconnected processing elements that dynamically interact with each other. The system as a whole, not any single element, learns and respond to information. Neural nets can discover complex relationships among data and predict trends based on this data. Unlike KBSs, in which the developer supplies the rules, many neural nets learn from the data they process.

B.5.7 SOURCE-CODE CONTROL SYSTEM (SCCS)

SCCS is used to manage and control various versions of machine-readable text including program source code, documentation, and libraries, throughout the life cycle of each. Provided with most Unix-type systems, SCCS is a regularly used tool of software developers. X/Open and the NIST APP include this technology in their profiles.

B.6 DATA REPRESENTATIONS

Data representation and exchange technologies and standards are the focus of some of the most vigorous standards activities. The ability to depict, understand, and exchange complex structured data between heterogenous systems is an important requirement of a geographically dispersed but information-integrated enterprise. The most important benefits derived from this technology are hardware and software independence (thus providing users the choice, for example, of the most suitable CAD/CAM system for the task), and the fact that only a few data translators (pre- and post-processors) are needed.

B.6.1 STANDARD FOR THE EXCHANGE OF PRODUCT DATA (STEP)

STEP is an international (ISO) effort that brings together a number of national efforts to build an engineering data exchange specification. This specification includes complete product definition information as well as related life cycle data for a part or subassembly, be it mechanical, electrical, or electronic.

At this time, STEP is in its infancy. A large amount of standards activity is in progress, with the IGES-PDES Organization (IPO) meeting every quarter. STEP will make extensive use of EXPRESS, an object-oriented language defined in STEP Part 11. EXPRESS has the potential to be used in many information modeling and integration contexts. Although young, STEP will have profound impact on any enterprise-wide information modeling and integration effort.

B.6.2 ELECTRONIC DATA INTERCHANGE (EDI)

The ANSI ASC X12 group of standards for Electronic Data Interchange provides for exchange of business documents and forms such as purchase and change orders, invoices, and shipping notices. The X12 series is comprised of two sets of standards: foundation standards (like the Data Element Dictionary, X12.3) that specify common aspects of business data interchange and transaction set standards that are specific to the nature of documents being transferred (for instance, purchase orders) or transactions performed.

Many companies are already using EDI in some form, often encapsulating it in electronic mail messages. Thus it is not surprising that Electronic Data Interchange for Administration (EDIFACT) and CCITT X.400 (among others) are coordinating their activities to ensure future compatibility.

Presently the need for translating EDI data into data compatible with legacy systems is met by gateway services provided by value-added networks run by GE, AT&T,

IBM, BT Tymnet, and others. Some software vendors also provide translation software for such purposes.

The X12 set of standards will play a major role in any broad EI-related project. They are especially critical to organizations that are seeking to improve operations by instituting JIT methods or those that have a large number of trading partners.

EDI standards often face incompatibilities due to differences in their data dictionaries. There is a fair amount of work in progress not only to remove such incompatibilities, but also to evolve new standards and to define an "Open EDI Model" for the identification and coordination of existing and future standards and services.

B.6.3 INITIAL GRAPHICS EXCHANGE SPECIFICATION (IGES)

IGES applies to product data interchange. It covers drawings, documentation, and other manufacturing-related information such as tolerances, form features, and material properties. IGES has traditionally been used to exchange data between CAD/CAM and finite element analysis systems. IGES does not cover the complete product life-cycle or specify manufacturing processes for the parts it describes or their relationships.

IGES is widely specified in the U.S. as an ANSI standard (Y14.29-1989), a planned FIPS PUB, and as part of CALS with many implementations that are commercially available. The IPO has an aggressive IGES program and has just announced the release of IGES 5.1.

Although IGES defines representations for engineering data, it does not specify other components such as user interfaces and machine-machine interfaces. At times, this weakness has led to incompatibilities between systems claiming IGES compliance. The fact that there is no conformance testing for IGES aggravates the problem.

B.6.4 COMPUTER GRAPHICS METAFILE (CGM)

CGM is a file format to define any kind of picture or drawing. It is independent of device requirements and translatable into the native formats of specific hardware. CGM is a FIPS PUB (128) and a part of CALS. Many CGM implementations for different platforms are available.

B.6.5 STANDARD GENERALIZED MARKUP LANGUAGE (SGML)

SGML is a standard that defines language and grammar for document markup, separating document structure from presentation. It specifies the required and permitted set of markups for documents and states how they are distinguished from text.

As a technology SGML is fairly stable. However, there is lack of consensus in deciding on the particular markup to be used for different kinds of documents. Several products are beginning to become available, including parsers, structured document preparation environments (e.g., ArborText), and electronic book interfaces (e.g., DynaBook).

B.6.6 RASTER FORMAT

Raster Format refers to the data representation format defined in military standard 28002. This standard is part of the CALS profile of standards. MIL-R-28002 identifies the requirements to be met when raster graphics data represented in digital, binary format are delivered to the Government.

B.6.7 OPEN DOCUMENT ARCHITECTURE/INTERCHANGE FORMAT/-LANGUAGE (ODA/ODIF/ODL)

ODA is a means to achieve complete interchangeability (among applications on different platforms) of documents in respect of structure, content and layout. ODIF is an ASN.1 encoding standard for such documents. ODA/ODIF is a an ISO standard (ISO 8613) and a part of both CALS and TOP. However, product availability is still scanty. Although ODA is a standard, the general area of document structure and encoding is still a studied topic, and new findings may bring about changes to the standard. Moreover, as implementations appear, some minor changes to the standard need be considered.

B.6.8 GRAPHICAL KERNEL SYSTEM (GKS)

GKS is a graphic service that provides interfaces for programming two-dimensional graphics in a device-independent manner.

B.6.9 PROGRAMMER'S HIERARCHICAL INTERACTIVE GRAPHICS SYSTEM (PHIGS)

PHIGS, like GKS, is a graphics service that provides interfaces for programming graphics in a device-independent manner. While GKS is two dimensional, PHIGS has a three-dimensional capability. Programming interfaces for various popular programming languages are available. PEX, the PHIGS Extension to X Window, has just become available and will enhance PHIGS' acceptance by vendors and users.

B.7 INFORMATION MODELING TOOLS AND METHODS

A wide variety of information modeling techniques typically support the specification and design phases of a traditional software project. The view here, however, is broader than just software projects. The information modeling task could be that of modeling the activities of an organization or a project.

B.7.1 ICAM DEFINITION LANGUAGE 0 (IDEF0)

IDEF0 is almost entirely based upon the Structured Analysis and Design Technique (SADT) developed by Douglas Ross in the 1970s. The IDEF0 method is used to model decisions, actions, and activities of an organization and the relationships between them. It supports the well-known principles of structured programming and design, i.e., modularization, abstraction, information hiding, and localization.

IDEF0 has enjoyed substantial success in defense programs and projects. A number of vendors offer products that support IDEF0/SADT modeling. The Air Force has invested heavily in building the infrastructure, developing expertise, and popularizing the methodology.

B.7.2 ICAM DEFINITION LANGUAGE 1X (IDEF1X)

IDEF1x was developed under the ICAM program by Hughes Aircraft and DACOM. It is a data modeling technique used to produce an information model that represents the structure and semantics of information within a business environment or system. It makes use of the Entity-Relationship (E-R) approach to semantic data modeling.

IDEF1x is well tested and proven in a number of Air Force and private projects. Therefore, like IDEF0, it is well understood and accepted. Software products that support IDEF1x are available.

B.7.3 YOURDON

This methodology was developed in the 1970s for requirements specification and design of commercial data processing systems, which are largely data driven. This method models data flow and the transformations data undergoes as it is processed.

The advantage of this method is that it is mature and well understood. It can be quickly used to understand and graphically document a data-processing system. This documentation is then useful for the next phase, design and implementation. A number of Computer-Aided Software Engineering (CASE) vendors offer variants of this method.

B.7.4 JACKSON SYSTEM DESIGN (JSD)

This method was developed in the mid-1970s by Michael Jackson in the U.K. The modeling paradigm followed by JSD is based on a set of event-driven processes that perform transformations on data. These processes communicate using a message-passing scheme, and read but do not modify each others' data.

Commercial products that support JSD are available. It is also supported in part by many CASE tools. JSD is popular in data processing and transaction-oriented applications. It does not take the broad view of supporting enterprise activity as a whole.

B.7.5 KNOWLEDGE-BASED SYSTEMS (KBSS)

KBSs have demonstrated their use as decision-making aids in complex environments. Their basic approach is to examine data about a system in light of domain-specific knowledge that has been built into them, and arrive at conclusions about the state of the system. In complex business and manufacturing organizations, they permit large volumes of data to be processed to arrive at intelligent decisions. KBSs have been used in many situations.

Specifying, designing, and building KBSs is a form of information modeling task that is inherently different from the tools and methods discussed above. Their utility is in bringing pre-encoded knowledge to bear on data in support of decisions, rather than passing data through a series of predetermined transformations.

KBSs are often very narrow in their area of applicability, and off-the-shelf, application-specific packages are sometimes available. These can usually be tuned somewhat to suit specific situations. The other approach to building such systems is to buy commercial expert system shells and program them for the specific problem at hand. The most important difference between conventional software development and building an expert system is that in the latter, domain knowledge (usually from an expert) has to be codified and incorporated (the knowledge engineering phase).

KBSs can be used to construct a variety of decision-making aids for manufacturing enterprise applications, especially in scheduling, optimization, design, and maintenance. However, the lack of any kind of consensus in standardizing interfaces with other components of an information system (like databases) is a significant concern.

B.7.6 STRUCTURED SYSTEMS DEVELOPMENT (SSD)

SSD is a methodology originated (by Kenneth Orr) in the mid-1970s. It is based upon the use of Warnier diagrams, and is particularly useful as an organized approach to data modeling. This method is often found integrated with many CASE tools.

B.7.7 SEMANTIC UNIFICATION META-MODEL (SUMM)

SUMM is a still developing technology and potential standard which will assist the integration of information models. Work is currently being carried out within the IPO Dictionary Methodology Committee. Based upon the use of first-order predicate logic and linguistics principles, SUMM is targeted to enable the interoperable use of modeling languages such as EXPRESS, IDEF, and NIAM.

B.8 USER INTERFACES

Graphical user interfaces (GUIs) provide a significant improvement over textual input and output. The technology was spawned from the developments in windows technology, graphics hardware, and low-cost computer interfacing devices. The purpose of these user interfaces is to provide a consistent, intuitive, and simplified look to an application from the user's point of view. The amount of code needed to implement graphical user interfaces sometimes exceeds the amount of code used to implement the actual operations involved in the application. For this reason, great effort has been devoted to the development of graphical user interface generators, which are tools that help accelerate the development of the graphical user interface.

B.8.1 X-WINDOWS (X)

X is a network-oriented windowing system based on the client-server model, developed jointly by MIT's Project Athena and DEC. X is platform independent. Commonly associated with Unix systems, it has also been ported to Amiga, Macintosh, VMS, and recently DOS platforms. X Windows Version 11, Release 1 (X11.1), became available in September 1987, and its latest release of X11.4 was January 1990. Since the second release, control of the X standard has been under the X Consortium (formed in January 1988). Extensions to the standard being considered include the addition of the Programmers' Hierarchical Interactive Graphics System (PHIGS), the Graphical Kernel System (GKS), and scalable fonts.

B.8.2 MOTIF

OSF Motif is an X Window toolkit released by the OSF in 1987. Motif was one of the candidate toolkits presented to the IEEE P1201 committee for standardization of the toolkit layer of the X Window model; it was rejected (together with Open Look) because of lack of consensus. Motif is one of the most popular X Window toolkits in commercial applications.

B.8.3 OPEN LOOK

Open Look is a set of guidelines for developing graphical user interfaces endorsed by Sun Microsystems and AT&T. The original development work was done by Sun, AT&T, and Xerox between 1986 and 1987. Open Look was one of the candidates (OSF Motif was the other) for a standard for the toolkit layer of the X Window interface model; it was rejected because of lack of consensus. The IEEE P1201 committee abandoned the idea of standardizing the toolkit layer of the X Window model after the experience with Motif and Open Look. Open Look conforming GUIs are important because of the large installed base of systems produced by Sun Microsystems and AT&T.

B.8.4 POSIX 1201 (XVT)

Efforts to produce a standard toolkit for X have been hindered by the fierce competition between Motif and Open Look. Current standardization efforts concentrate on providing a software layer on top of the toolkits that will make application programs toolkit independent. This layer is referred to as a Layered Application Program Interface (LAPI), and was submitted for consideration to the IEEE P1201.1 committee by XVT, the U.S. Air Force Strategic Air Command (SAC), and the National Aeronautics and Space Administration (NASA). The P1201.1 has recently selected the XVT proposal as the basis for the standard.

B.8.5 MS-WINDOWS

Microsoft Windows 3.0 is a GUI intertwined with operating system functionality that runs under MS-DOS. Windows 3.0 includes its own API. Microsoft and third parties provide software development tools for MS-Windows. Windows/NT, under development, is an extension to Windows 3.0 that will run on Unix platforms.

B.8.6 PRESENTATION MANAGER

Presentation Manager (PM), developed for IBM by Microsoft, is the GUI provided with the IBM OS/2 operating system. Presentation Manager conforms to IBM's SAA guidelines.

B.8.7 DECWINDOWS

DECWindows is a proprietary product of DEC. It supports and enhances the X Window System; current implementations use the XUI (X User Interface) toolkit. DEC plans to migrate to OSF/Motif. Extensions of X included in DECwindows are Imaging Postscript and PEX (PHIGS + Extension to X).

B.8.8 MACINTOSH TOOLBOX

The Macintosh Toolbox was the first widely accepted GUI. The Toolbox is a library of routines implemented in ROM and is the only user interface provided to Mac applications. This fact, and Apple's public guidelines for interface programming, has led to consistency in its use.

B.9 PROGRAMMING LANGUAGES

The languages reviewed are a sample of the most commonly used and popular languages. The languages were developed to satisfy different needs in different areas of computer programming. Even when they are based on completely different programming paradigms, they can still be classified as general purpose programming languages.

B.9.1 ADA

Ada is a general purpose programming language developed by the French company Cii-Honeywell Bull under contract from the U.S. Department of Defense (DoD) after a competitive selection process. It is the only language among the ones described here that was developed following the criteria of this process. The Ada Language Reference Manual was published in 1980, and the language became a national standard in 1983 (ANSI/MIL-STD-1815-A) and an international standard in 1987 (ISO 8652). The language was developed using Pascal and Algol-68 as a baseline. Ada provides more features and directly implements more concepts useful for effective software engineering than any of the other languages described in this section. The language was created to control the high costs of maintenance brought about by the proliferation of multiple languages and dialects in the different branches of the DoD for embedded software applications. The language is still a general purpose language used in applications other than embedded systems, and the DoD has directed that Ada be used in DoD systems development.

B.9.2 C

C is a general purpose, high-level programming language used in various kinds of software development, including operating systems, system level software (e.g., special purpose processors), and business and scientific application software. It was developed at the AT&T Bell Laboratories by Dennis Ritchie during the 1970s and has become popular because of its close association with the development of the Unix operating system.

The national standard for C (ANSI X3J11) was approved in December 1989 after a long process. The international standard (ISO/IEC 9899) is still in the draft stage.

B.9.3 C++

C++ is one of the object-oriented extensions to the C language. C++ was developed at AT&T by Bjarne Stroustroup in the late 1980s. Except for a few details, C++ is a superset of C. C++ incorporates the concept of classes by extending the C structure construct. It also provides better type checking and other facilities not available in C. The latest version of C++ (Version 2.0) incorporates multiple class inheritance.

B.9.4 COBOL

Cobol is a language widely used since the early 1960s for business applications of computers. As is the case with most other widely used languages, Cobol has evolved through a sequence of design revisions, beginning with the first version in 1960, the second in 1972, and the latest standard in 1985 (ANSI X3.23-1985, ISO 1989-1985), revised again in 1989 (addendum X3.23A).

Cobol is designed for use in programming self-documenting, business-oriented applications. An estimated 60 to 80% of Federal government applications are written in Cobol. Major vendors offer Federal Information Processing Standards (FIPS) Cobol.

The current standard does not include real-time operating system and communications components. It is most complete in the areas of data manipulation and business-financial applications. The X3J4 committee is in the process of adding new functionality for communication interfaces and screen management, and compatibility with previous versions of the standard will be maintained. Historically, such compatibility has been one of Cobol's stronger points.

B.9.5 FORTRAN

Fortran is a widely used language for scientific and numeric computing. The design of the language centers around a single primary goal: execution efficiency. Fortran was developed in the 1950s before structured programming concepts were developed. Successive revisions (Fortran 66, Fortran 77 (ANSI X3.9-1978, ISO 1539-1980), Fortran 90) have incorporated structured programming elements to the language. For example, the "if-then-else" control structure was added in the Fortran 77 standard, and "do-while" and case statements were incorporated in the Fortran 90 standard. The latest Fortran standard is Fortran 90 (ANSI X3J3), approved in April 1991.

Fortran was originally developed to assist in the development of scientific calculation applications, but it has since been extended to cover other types of applications. Libraries are available for assisting in the development of information systems, real-time, and process control systems. An IEEE Working Group is currently defining a POSIX/Fortran binding.

B.9.6 LISP

Lisp was designed by John McCarthy and implemented in the late 1950s at MIT. Lisp was designed to manipulate symbolic rather than numeric data and is a very popular language within the artificial intelligence community. Over the past 30 years several Lisp dialects have been developed, with the ANSI X3J13 subcommittee currently standardizing a dialect known as Common Lisp. Drafts of the standard have gone through many reviews, and the committee is now in the process of writing the standard in specification form.

Lisp is a very flexible programming language, with a simple and uniform syntax. It is interactive and is usually embedded in a programming environment that includes dynamic storage allocation and automatic garbage collection, incremental compilation, and language extensibility.

Flavors (MIT) and Loops (Xerox PARC) are two object-oriented extensions to Lisp. The Common Lisp Object System (CLOS) is an object-oriented extension to Common Lisp.

B.9.7 PASCAL

Pascal was created by Nicklaus Wirth in the early 1970s to provide a language suitable for teaching computer programming as a systematic discipline. The language is based on fundamental computer programming concepts.

Pascal is a structured programming language still primarily used in teaching environments for training computer science students in the concepts of programming. It has also gained popularity in general application areas such as business, science, engineering, and U.S. Government applications. National and international standards for the language were approved in 1983 (ANSI/IEEE 770X3.97, ISO 7185).

B.9.8 PROLOG

Prolog is an implementation of predicate logic as a programming language. The origins of the language are in mathematical theorem proving, developed in the early 1970s at the Faculty of Sciences at Luminy in Marseilles, France. Interest in the language received a boost from the Japanese fifth generation computer effort, formally started in 1981, which selected Prolog as the language of choice for knowledge processing and artificial intelligence applications.

Prolog is a non-procedural language. In procedural languages one specifies step by step how computations are carried out by the computer. In Prolog one specifies facts and rules about relationships among entities and then asks questions about the relationships. Prolog extensively uses recursion and a unique backtracking mechanism, and its variables do not represent storage locations. A Prolog procedure is a collection of rules rather than a single closed module of a subroutine.

Prolog is a popular language used in artificial intelligence applications, such as expert systems and knowledge engineering. Other applications include symbolic computation, natural language processing, very high-level languages, natural language interfaces to databases, deductive databases, and automatic programming.

Implementations of Prolog have been available since the mid-1980s. Prolog exists in multiple dialects, with implementations from Marseilles and the University of Edinburgh, Scotland, being the most widely used.

B.9.9 SMALLTALK

Smalltalk was developed by the Learning Research Group at Xerox PARC during the 1970s. The first commercial version of Smalltalk-80 was released in 1983, with the first versions running on personal computers. One example is Smalltalk V, which became available in 1986.

Smalltalk is a programming system instead of an isolated language. It provides an interactive development environment that includes a user interface graphics toolkit, which makes it particularly useful for exploratory programming and rapid prototyping. A salient characteristic of the Smalltalk environment is that the programmer has access to every part of the system, including its implementation. The syntax of Smalltalk is simple and conceptually powerful, as it uses two basic concepts, objects and messages.

The Smalltalk language demonstrated that object-oriented programming is a very useful technique for software development, and has had a major influence in the development of other object-oriented languages.

B.10 SECURITY TOOLS AND METHODS

In a distributed computing environment in which large volumes of data are being constantly accessed, used, and updated, security plays a major role. Some data is restricted to certain individuals, while other data is meant for machines. This section deals with controlling individuals' access to data and computing services in a networked environment.

B.10.1 POSIX 1003.6

This POSIX committee, formed in March 1988, has been charged to "develop specifications for standard interfaces to security services and mechanisms for portable applications." These specifications will include system call interfaces and system commands. POSIX 1003.6 focuses mainly on access control and audit logging services.

This standard is still in draft form and in the process of balloting. It is expected to be a full IEEE standard by mid-1992. Thus there are no current products that conform to this standard. However, a number of Unix variants offer access control list services. Because this standard will be part of the POSIX family, it is of strategic importance to builders and users of open computing platforms.

B.10.2 KERBEROS

Kerberos is a trusted third-party authentication service that was developed as part of Project Athena at M.I.T. It uses an authentication server, which is the only entity on the network that knows the passwords. Both users and services have passwords, thereby permitting users access to only the desired set of services.

Kerberos has been adopted by OSF for its Distributed Computing Environment (OSF/DCE). It has been widely used in a large university environment with considerable success.

B.10.3 DATA ENCRYPTION STANDARD (DES)

DES, an encryption standard that originated at IBM, was adopted by the U.S. Government in 1977. DES is now a part of GOSIP, version 2. It is a complex product cipher with an algorithm that is freely available on hardware, and is therefore popular in applications such as banking transactions that demand security, but not at the extreme level of military operations.

APPENDIX C. ORGANIZATION AND PROGRAM DEPLOYMENT FORCES MATRICES

Table C-1. Integration Frameworks and Architectures

	TECHNICAL DEVELOPMENT					MARKET BUILDING		
	MODELING	STANDARDS	METHOD/TOOL	PROTOTYPE	STANDARD VALIDATION/DEMO	PRODUCT CERTIFICATION	USER GUIDELINES	AWARENESS & EDUCATION
SAA	• IBM[a]	• IBM	• IBM	• IBM	• IBM		• IBM	• IBM • Private
NAS	• DEC	• DEC	• DEC	• DEC	• DEC		• DEC	• DEC • Private
PCTE	• ECMA • TC33	• ECMA • TC33	• Private	• Private	• Private			• Private Users Group
HP New Wave	• HP	• HP	• HP	• HP	• HP		• HP	• HP • Private

a. Different parts of IBM responsible for technical development stages.

Table C-2. Operating Systems and Distributed Environments

	TECHNICAL DEVELOPMENT					MARKET BUILDING		
	MODELING	STANDARDS	METHOD/TOOL	PROTOTYPE	STANDARD VALIDATION/DEMO	PRODUCT CERTIFICATION	USER GUIDELINES	AWARENESS & EDUCATION
POSIX	• IEEE	• IEEE • ISO/IEC	• IEEE	• Private	• IEEE	• NIST • X/OPEN	• X/OPEN	• IEEE • X/OPEN
UNIX SVR4	• AT&T	• UI	• UI	• UI	• UI	• AT&T • (code)	• UI	• UI
OSF/1, OSF/DCE	• OSF	• OSF	• OSF	• OSF	• OSF	• OSF	• OSF	• OSF •
OMG	• University • Private • OMG	• OMG	• University • Private	• University • Private	•		• OMG	• University • Private
MS-DOS	• Microsoft	• Microsoft • (de facto)	• Microsoft	• Microsoft • Private	• Microsoft		• Microsoft	• Microsoft • Others

Table C-3. Communications

	TECHNICAL DEVELOPMENT					MARKET BUILDING		
	MODELING	STANDARDS	METHOD/TOOL	PROTOTYPE	STANDARD VALIDATION/DEMO	PRODUCT CERTIFICATION	USER GUIDELINES	AWARENESS & EDUCATION
OSI MAP/ TOP GOSIP	• ISO	• IEEE • CCITT • ANSI • NIST-OIW • ECMA • EWOS	• NIST • CNMA • Private	• NIST • Private • Public • Domain	• MAP/TOP • NIST • CNMA • SPAG	• COS • NIST • CCT • NCC	• COS • NIST • SME	• COS • INTEROP • SME • Private
TCP/IP	• DARPA • IAB	• DARPA • IAB	• BBN • University	• BBN • DARPA • University	• DARPA • University	• AD HOC	• DARPA • NSF	• IAB • INTEROP • Trade Demos • Private

Table C-4. Data Management Systems

	TECHNICAL DEVELOPMENT					MARKET BUILDING		
	MODELING	STANDARDS	METHOD/TOOL	PROTOTYPE	STANDARD VALIDATION/DEMO	PRODUCT CERTIFICATION	USER GUIDELINES	AWARENESS & EDUCATION
IRDS1	• NIST/ • ANSI/ • SPARC	• ANSI	• ANSI					
RDA Protocol	• OSI	• ISO/IEC	• SAG		• SAG		• X/OPEN	• SAG • X/OPEN
SQL	• RDBMS	• ANSI • SAG	• SAG • Private	• Private	• SAG		• SAG	• SAG
IRDS2	• OODBMS • Model	• ANSI • ISO						

Table C-5. Application Development Tools and Methods

	TECHNICAL DEVELOPMENT					MARKET BUILDING		
	MODELING	STANDARDS	METHOD/TOOL	PROTOTYPE	STANDARD VALIDATION/DEMO	PRODUCT CERTIFICATION	USER GUIDELINES	AWARENESS & EDUCATION
X/OPEN and POSIX APIs	• ISO	• X/OPEN • MAP/TOP • IEEE • Private	• Private	• Private				• X/OPEN • Private

Table C-6. Data Representation

	TECHNICAL DEVELOPMENT					MARKET BUILDING		
	MODELING	STANDARDS	METHOD/TOOL	PROTOTYPE	STANDARD VALIDATION/DEMO	PRODUCT CERTIFICATION	USER GUIDELINES	AWARENESS & EDUCATION
IGES PDES/ STEP	• IPO	• ISO • IPO	• PDES, Inc. • IPO • Private	• PDES, Inc. • Private	• IPO	• CAD DETC • (starting)	• IPO	• IPO • Users Groups • Private
QDA/ ODIF/ ODL	• ISO	• ISO • ANSI • NIST				• NIST	• NIST • ANSI • CALS	• NIST • ANSI • CALS
SGML	• ISO	• ISO • NIST						• CALS
EDI		• ANSI	• Private	• Private	• AIAG	• AIAG	• CALS • AIAG	• ANSI • CALS

Table C-7. Information Modeling Tools and Methods

	TECHNICAL DEVELOPMENT					MARKET BUILDING		
	MODELING	STANDARDS	METHOD/TOOL	PROTOTYPE	STANDARD VALIDATION/DEMO	PRODUCT CERTIFICATION	USER GUIDELINES	AWARENESS & EDUCATION
IDEF Family (including SA/SD	• SofTech	• DoD	• SofTech	• SofTech	• SofTech • Private		• SofTech • Private	• SofTech Users Group
Semantic Unification Meta-Model SUMM	• Boeing • IPO							

Table C-8. User Interface

	TECHNICAL DEVELOPMENT					MARKET BUILDING		
	MODELING	STANDARDS	METHOD/TOOL	PROTOTYPE	STANDARD VALIDATION/DEMO	PRODUCT CERTIFICATION	USER GUIDELINES	AWARENESS & EDUCATION
X-Windows		• MIT-X Consortium	• MIT-X Consortium	• MIT-X Consortium	• MIT-X Consortium			• MIT-X Consortium • Private
MOTIF		• MIT-X Consortium	• OSF • Private	• OSF	• OSF • Private		• OSF	• OSF • Private
OPEN LOOK		• MIT-X Consortium	• UI • Private	• UI	• UI • Private		• UI	• UI • Private
MicroSoft Windows			• Microsoft • Private	• Microsoft	• Microsoft • Private		• Microsoft	• Microsoft • Private
Macintosh Toolbox			• Apple	• Apple	• Apple		• Apple	• Apple • Private
DEC-Windows			• DEC	• DEC	• DEC		• DEC	• DEC
Presentation Manager			• IBM • Private	• IBM	• IBM		• IBM	• IBM • Private

Table C-9. Programming Languages

	TECHNICAL DEVELOPMENT					MARKET BUILDING		
	MODELING	STANDARDS	METHOD/TOOL	PROTOTYPE	STANDARD VALIDATION/DEMO	PRODUCT CERTIFICATION	USER GUIDELINES	AWARENESS & EDUCATION
C Fortran Pascal Cobol		• ANSI • IEEE (POSIX)	• Private	• Private				• Private
Ada	• DoD	• IEEE • ANSI	• SEI • Private	• SEI	• SEI • DoD	• AJPO		• SEI • DoD
C++	• AT&T		• Private	• Private				• Private

Table C-10. Security Tools and Methods

	TECHNICAL DEVELOPMENT					MARKET BUILDING		
	MODELING	STANDARDS	METHOD/TOOL	PROTOTYPE	STANDARD VALIDATION/DEMO	PRODUCT CERTIFICATION	USER GUIDELINES	AWARENESS & EDUCATION
Kerberos	• MIT		• MIT • OSF	• MIT • OSF	• MIT • OSF		• MIT • OSF	• MIT • OSF
DES (GOSIP)	• ISO		• NIST	• NIST	• NIST	• NIST	• NIST	• NIST
POSIX 1003.6	• POSIX	• POSIX (in program)						• OSF

APPENDIX D. DESCRIPTIONS OF EIP NEEDS AND REQUIREMENTS

D.1 NEEDS

The needs in the EIP Business Needs and Requirements Matrix, Figure 2 on page 20, are defined in the following subsections.

Customer Oriented

Reduce Costs

Reduce information system cost: Costs of information systems include the purchase of hardware and software, development, and system support and maintenance.

Reduce costs of new product introduction: Costs associated with new product introduction, from conception through the establishment of manufacturing operations.

Reduce costs of post-product distribution and field support: The cost of managing a product after it leaves the factory. Included are costs of distribution, support, warranty, archiving product and customer information, disposing of obsolete material and equipment, and providing spares and service.

Reduce material cost: Cost of material used in production.

Reduced overhead cost: Overhead costs include all costs that do not contribute directly to "making the product." Examples include white collar salaries, energy, and administrative and marketing expenses.

Reduce labor cost: Labor costs are those applied directly to product manufacturing, e.g., "touch" labor.

Improved Product Quality

Performance: The primary operating characteristics of a product.

Features: Those secondary characteristics that supplement the product's basic functioning. An example would be air conditioning in a car.

Reliability/Durability: Reliability reflects the probability of a product's malfunctioning or failing within a specific period of time. Durability is a measure of product life in both economic and technical dimensions.

Conformance: The degree to which the product meets its design specification.

Serviceability: The measure of how quickly and easily a product can be repaired upon failure, and how easily maintenance can be performed.

Aesthetics: How a product looks, feels, tastes, sounds, or smells. It is a matter of personal judgment.

Perceived quality: A subjective measure based on an individual's prior biases and prejudices. Reputation is a primary contributor to perceived quality.

Deliver Products in a Timely Manner

Reduce Engineering Change Notices (ECNs): Reducing the number of changes made to a design after it has been formally communicated downstream.

Fast engineering process: Efficiency of the design process, no wasted steps of processes.

Reduce number of prototypes: Making each prototype conform as closely as possible to the final product to minimize the time and expense of making additional prototypes.

Improve integration of lines: Design manufacturing processes so that the output of one machine can go directly into another machine without human intervention.

Reduce number of process changes: Reduce the number of changes made in the product manufacturing process after it has been designed.

Faster tooling delivery: Fast design and manufacture of tools so that the tools can be delivered sooner. This aids in rapid debugging of manufacturing processes.

Reduce cost of tooling: Reduce labor and material spent on design and production of tooling.

Predictable suppliers: Suppliers who can respond in a predictable manner to changes in product demand.

Improve supplier planning capacity: Assist suppliers in planning their scheduling, routing, and capacity planning to promote better integration within the enterprise.

Stable build schedules: Stable production schedules allow reliable fabrication and assembly schedules to be generated and make it easier for suppliers to provide on-time delivery.

Supplier quality: Improve quality of supplier parts to support stable schedules and just-in-time (JIT) inventory practices.

Running the Business

Market Development

Market development: A vendor's ability to identify, reach, and generate demand within potential markets.

Access Information

Payables and receivables: Rendering payment to debtors, collecting payment for goods and services.

Personnel: Personnel information includes all data on a company's employees, including prior work activity, training, skills inventory, pay, taxes, and benefits.

Cost allocation: Information and logic applied to determining the proper allocation of funds to produce a product. Included are all sources of expense—capital, department, office operations, strategic planning, etc.

Product pricing: Determination of the sale price of a product. Derived from market considerations and from analysis of costs of manufacturing, overhead, labor, and materials.

Justify Investments

Small firms need skills to make case for enterprise integration (EI) investment: Small firms do not have the expertise to develop a persuasive case to banks and other capital sources for investment in EI.

Small firms lack information to make case for EI investment: Small firms have difficulty obtaining information to support a case for investment in EI.

Big firms lack accounting processes to support EI: Traditional accounting processes do not provide the data necessary to track cost in a manner that is conducive to justifying capital investments in EI.

Legal, Security, Regulation

Reduce risk of legal claims: Risk comes from two sources: (1) liability associated with activity at different points in a product's life cycle, and (2) lack of compliance with regulatory requirements.

Security: Security systems to protect information from unauthorized access. Included are topics such as product designs, process operations, personnel, finance, accounting, and strategic planning.

Environmental regulation: Information needed throughout a product's life cycle to demonstrate compliance with Environmental Protection Agency (EPA) regulations.

OSHA regulation: Information needed throughout a product's life cycle to demonstrate compliance with regulations of the Occupational Safety and Health Administration (OSHA).

Financial regulation: Information needed throughout a product's life cycle to demonstrate compliance with financial regulations. Included are data on earnings, sales, purchasing, stocks, retirement funds, payroll, and any other financial activity that may be monitored for compliance.

EEO regulation: Information needed to demonstrate compliance with the regulations of the Equal Employment Opportunity (EEO) Commission.

D.2 REQUIREMENTS

The requirements in the EIP Business Needs and Requirements Matrix, Figure 2 on page 20, and the EIP Requirements and Technologies Matrix, Figure 3 on page 22, are defined as follows.

Generic Requirements

Information Systems Integration

Communication standards: Protocols that describe how the exchange of information will occur between sub-units of an enterprise.

System/network administration standards: Standards for backup and restore activities.

Data interchange standards: Established protocols or rules of data representation, compatibility, and commonality to facilitate the sharing of common data between enterprises. The Product Data Exchange Standard (PDES) and STandard for the Exchange of Product Data (STEP) are examples.

Reuse of knowledge modules: The reuse or dual use of tools, software, product data, and group technology for multiple business needs.

Long-term maintenance and access of data: Established protocol for the maintenance, storage, and retrieval of data over an entire product life cycle.

Handle large quantity of data: The ability to administer, access, maintain, and transmit large volumes of data.

Modular applications, systems: Applications that have well-defined boundaries and interfaces that allow use in a variety of different contexts.

Application platform independence and interoperability: The isolation of applications from specific operating systems or hardware platforms.

Distributed applications, systems: Applications and systems in multiple locations, working in cooperation. The actual location of any part of the application or system is irrelevant to the user.

Data management: The activity of controlling the acquisition, analysis, storage, retrieval, and distribution of data.

Design tools: Tools that can be used to support EI as it relates to the design of products and process.

Migration management: For users, the migration of existing data and systems to an integrated environment. For vendors, the ability to control life cycle changes in a product line.

Enterprise framework and architecture: An orderly, comprehensive structure that can be used to specify, evaluate, implement, and maintain an enterprise's information, business processes, and operational needs.

Tools/procedures for EI development and testing: Tools and methods that will help implement integrated systems and applications, describe the current model of the enterprise, and verify and test any changes.

Human Factors

Consistent user interface: A consistent means of presenting information across systems and applications. Used to reduce the amount of learning required to interact with a system.

Psychologically compatible interface: Interfaces that present information in a form that is compatible with people's familiar methods of perception and information processing.

Quality

Bounded customization: A characteristic of a product that allows users to customize it for their particular needs without presenting the vendor with an uncontrollable (and unknowable) variety of unique installations.

Establish process based on customer requirements: Processes established to support the development of products and services that meet the needs of internal and external customers.

Process control and feedback: A means of measuring the performance of a process, comparing performance to specification, and guiding necessary corrective action.

Simplified processes: Processes designed so as to remove complexity and minimize waste of resources. Optimization should be considered from the highest or most global viewpoint.

Buildable products: Products that can be implemented by vendors.

Continuous improvement (CI): A commitment to proactive, continual participation by employees in the analysis and improvement of the processes of which they are a part. Each employee, through continuous participation in CI, assumes joint ownership and management of those processes through which products and services are delivered right the first time.

Management by fact: An emphasis on decisions based on reliable data and analysis. Also, a concerted effort to develop performance indicators to assess product characteristics, process characteristics, and company operations.

Organization

Linkage

Cross-disciplinary, entrepreneurial teams: Teams that cross disciplinary and/or functional boundaries and have a charter to "start something new." These may be *ad hoc* or permanent, within or between an organizations (e.g., between prime and subcontractors), and include employees at the same or multiple levels.

Balance centralization and decentralization: Decision making needs to made at the lowest appropriate level. Over-centralization yields decision makers who lack information and the ability to directly influence events. Over-decentralization yields decision makers who lack perspective and large-scale influence.

Design in the large: The ability to coordinate large, complex design projects involving many parts and components, multiple design teams, and multiple supplier levels.

Production scheduling and JIT in the large: The ability to coordinate the production of large, complex products involving many parts and components and multiple suppliers using JIT methods.

Concurrent engineering: Coordinating multiple phases of the engineering life cycle (e.g., product design, process design) so that their activities overlap.

Job Design and Rewards

Clear expectations of performance: A clear understanding on the part of individuals of what they are expected to do, what they will be rewarded for, how they will be rewarded if they meet these expectations, and how their behavior relates to larger organizational objectives.

Expand job to include problem solving and decision making: Job designs (including those of workers on the shop floor) that explicitly include some degree of problem solving and decision making.

Job satisfaction and worker motivation: Jobs designed to enhance the motivation and satisfaction of individuals who hold them, thus leading to proactive problem solving and less employee turnover.

Skills

Job specific skills: Skills specific to an individual job, including basic education levels required to perform the job.

Change Management

Strategic plan: A formal long-range plan.

Management and labor relations: Quality of the working relationship between those in management positions and those who are not. In a unionized environment, these relations are explicitly described in the collective bargaining agreement.

Leadership and champion: An advocate for significant change who can serve as the focal point for resource allocation and decision making, and as a buffer against those who oppose the change.

Entrepreneurial culture and risk taking: An organizational culture and formal reward system that tolerates some degree of failure, and that encourages a certain degree of risk taking.

Adaptive learning culture: An organizational culture that rewards individuals and work groups for learning about the organization's changing environment and formulating ways to adapt to likely changes.

Interorganization

Establish and manage interorganizational relations: Consciously managed formal contractual agreements and informal social interactions in support of enterprise goals.

User groups consensus on requirements: Users of hardware and software provide coherent sets of requirements to assist vendors in developing technologies that are widely applicable.

Accounting

Activity-based accounting: Product costing obtained by accumulating cost data for each activity performed by an organizational unit.

Policy

U.S. Government

Computer Acquisition Logistic Support (CALS): An integrated system of systems that can create, transform, store, transmit, and use technical information as it evolves through the design, manufacture, and support of defense weapon systems and equipment. The system is intended to enable the Department of Defense to design better and more reliable weapon systems more quickly and less expensively; to manage its essential configuration in near real-time; and to plan, acquire, and deliver its essential follow-on logistic support more promptly, economically, accurately, and effectively.

Acquisition regulations: Government regulations that dictate the purchase procedures between the Government and its suppliers, or between Government suppliers and their subcontractors.

Certification of product and process: Government regulations concerning what aspects of product characteristics and manufacturing processes must be recorded and certified to meet criteria determined by the government.

Certification of people: Government regulations concerning the special qualifications needed by personnel engaged in particular aspects of manufacturing of goods purchased by the government.

International

Harmonize trading practices: The development of true international standards, as opposed to unique flavors of standards for different countries

APPENDIX E. STANDARDS AND TECHNOLOGIES STATUS CRITERIA

These 11 criteria were obtained from the National Institute of Standards and Technology (NIST) and the Portable Operating System Interface for Computer Environments (POSIX) Open System Environment (OSE), with some additions and modifications by the Institute for Defense Analyses team.

1. *Specification Availability:* A high evaluation indicates that the specification is publicly available from well-known sources, such as the International organization for Standardization (ISO), the American National Standards Institute (ANSI), the National Technical Information Services (NTIS), the Institute of Electrical and Electronics Engineers (IEEE), or major publishing houses. A medium evaluation indicates that the specification is available, but from lesser known sources. A low evaluation indicates the specification is generally unavailable.
2. *Level of Consensus:* A low evaluation is given to specifications that are proprietary, specifications that are not standard, specifications that may be in the process of becoming a standard (e.g., standards committee work-in-progress), or that are widely available across various hardware/software platforms. This criterion is the same as the NIST Level of Consensus and similar to POSIX Openness, Stage of Completion and Geographic Scope of Consensus.
3. *Product Availability:* A low evaluation is given to specifications for which only a very few proprietary products are available. High evaluations are given to specifications for which there is a wide variety of products available from various vendors across different application platforms. Medium evaluations are assigned to specifications that may be proprietary but have many products available from a variety of vendors, or that are public domain specifications with products readily available. This criterion is identical to NIST Product Availability.
4. *Completeness*: A specification is evaluated on the degree to which it defines and covers key features necessary in supporting its intended functional area or service. This criterion is identical to NIST Completeness and similar to POSIX Functional Scope.
5. *Maturity:* Refers to the underlying technology of a specification. A high evaluation indicates that it is well understood (e.g., a reference model is well defined, appropriate concepts of the technology are in widespread use, the technology may have been in use for many years, a formal mathematical

model is defined.) A low evaluation indicates that it may be based on technology that has not been well defined and may be relatively new. This criterion is identical to NIST Maturity.

6. *Stability:* A high evaluation means that the specification is very stable, that no changes are expected within the next two years. A low evaluation indicates that significant or many changes are expected within a relatively short time, or that incompatibilities exist between current and expected releases of the specification. An medium evaluation is given to those specifications that may have changes forthcoming to replace or deprecate features in the existing specifications. This criterion is identical to NIST Stability and POSIX Stability.
7. *De facto usage:* The likelihood that a vendor will independently propose products that conform to this specification whether or not a reference specification is stated in the procurement documents. A high evaluation indicates that most proposed products will conform to the specification. A low evaluation indicates that it is unlikely that the vendor will propose products based on the specifications. A medium evaluation indicates that vendors could go either way. This criterion is identical to NIST De Facto Usage.
8. *Problem-freeness (limitation-freeness):* A low evaluation is assigned to specifications with severe restrictions on use or capabilities (e.g., licensing restrictions) or known problems too difficult or too numerous to overcome (e.g., new releases of the specification are not compatible with previous releases, or not enough is covered in the standard to be useful). A medium evaluation is given to those specifications that require some minor additional facility in order to be fully effective in their intended environment. This criterion is the same as NIST Problems/Limitations and includes POSIX Available for Unencumbered Implementation.
9. *Conformance testing:* A high evaluation indicates that conformance testing tools are publicly available. A medium evaluation indicates either that plans are being made to provide publicly available conformance testing or that some private initial work is under way. A low evaluation indicates that no conformance testing plans are being developed.
10. *Future Plans:* A high evaluation indicates either that large-scale development efforts are being planned, or that the specification will continue to be imple-

mented on a wide-scale basis. A low evaluation indicates that development is not planned, and the specification is not expected to be implemented.

11. *Predominance:* A high evaluation indicates that there is no competition to the specification in its targeted functional area, or that the specification's implementations overwhelmingly control market share with respect to competition. A medium evaluation indicates that there are viable alternatives to the specification. A low evaluation indicates that other alternatives are available and are much more widely accepted.

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LIST OF ACRONYMS

ABC	Activity Based Costing
ACSE	Association Control Service Element
AD	Application Development
ADE	Advanced Development Environment
ADP	Automated Data Processing
ADPS	Application Development Project Support
ADSRS	Automated Drawing Storage and Retrieval System
ADW	Application Development Workbench
AEP	Application Environment Profile
AFS	Andrew File System
AIAG	Automotive Industry Action Group
ALC	Air Logistic Center
AMICE	European Computer Integrated Manufacturing (CIM) Architecture
AMT	Advanced Manufacturing Technology
ANSA	Advanced Network Systems Architecture
ANSI	American National Standards Institute
AOM	Application Object Model
AP	Application Protocol
API	Application Program Interface
APM	Architecture Projects Management
APP	Application Portability Profile
APT	Accredited Portable Operating System Interface for Computer Environments (POSIX) Testing
AQES	Advanced Quality Engineering System
ASCII	American Standard Code for Information Interchange
ASIC	Application-Specific Integrated Circuits
ASN.1	Abstract Syntax Notation One
ASPC	Automated Semiconductor Planning and Control System
ATA	Airline Transportation Association
ATF	Advanced Tactical Fighter
BFM	Business Flow Management

BOM	Bill of Materials
BSD	Berkeley Software Distribution
CACS	Corporate Information Management (CIM) Application Consulting Services
CAD	Computer-Aided Design
CAE	Computer-Aided Engineering
CALS	Computer Acquisition Logistic Support
CAM	Computer-Aided Manufacturing
CAM-I	Computer-Aided Manufacturing-International
CAMO	Computer-Aided Miscellaneous Operations
CAPP	Computer-Aided Production Planning
CASE	Computer-Aided Software Engineering
CAx	Computer-Aided Design/Manufacturing/Engineering
CBEMA	Computer and Business Equipment Manufacturers Association
CCITT	International Telegraph and Telephone Consultative Committee
CCR	Commitment, Concurrency, and Recovery (protocol)
CCS	Common Communications Support
CCIP	Computer-Aided Design (CAD)/Computer-Aided Manufacturing (CAM) Integration Plan
CD	Collision Detection; Committee Draft
CDF	Common Data Format
CDM	Common Data Model
CDRL	Contract Data Requirement List
CE	Concurrent Engineering
CFI	Computer-Aided Design (CAD) Framework Initiative
CFIMJ	Computer-Aided Design (CAD) Framework Initiative in Japan
CGM	Computer Graphics Metafile
CI	Continuous Improvement
CIE	Computer Integrated Enterprise
CIM	Computer Integrated Manufacturing
CIO	Computer Integrated Operations
CIPT	Component Integrated Product Team
CIS	Center for Integrated Systems
CISTAR	Computer Integrated Systems, Technologies, and Resources
CITIS	Contractor Integrated Technical Information Service
CLOS	Common Lisp Object System
CMIP	Common Management Information Protocol

CMOT	Common Management Information Protocol (CMIP) Over Transmission Control Protocol (TCP)/Internet Protocol (IP)
CNMA	Communications Network for Manufacturing Applications
COF	Customer Order Fulfillment
CORBA	Common Object Request Broker: Architecture and Specification
COS	Corporation of Open Systems
COTS	Commercial off the Shelf
CPI	Common Programing Interface
CPTR	Common Problem/Task Report
CSMA	Carrier Sense Multiple Access
CSRC	Computer Acquisition Logistic Support (CALS) Shared Resource Center
CUA	Common User Access
CV	Computer Vision
CVS	Central Version System
DAC	Design Automation Conference
DAE	Distributed Applications Environment
DARPA	Defense Advanced Research Projects Agency
DART	Data Archival and Retrieval
DBMS	Database Management Systems
DCE	Distributed Computing Environment
DDE	Dynamic Data Exchange
DDM	Distributed Data Management
DEC	Digital Equipment Corporation
DECMACS	Development Engine Change Management and Control System
DES	Data Encryption Standard
DETC	Data Exchange Technical Center
DIS	Draft International Standard
DFS	Distributed File System
DME	Distributed Management Environment
DML	Data Manipulation Language
DMU	Digital Mock Up
DNA	Defense Nuclear Agency
DNS	Domain Name System
DoD	Department of Defense
DOE	Distributed Objects Everywhere
DOMF	Distributed Object Management Facility
DP	Draft Proposal

DPA	Digital Pre-Assembly
DPU	Defects Per Unit
DR PI	Design Representation Programming Interface
DRC	Database Relational Common
DS	Directory Services
DSD	Design Support Database
DSOM	Distributed System Object Management
EAP	Electronic Assembly Plant
EBCDIC	Extended Binary Coded Decimal Interchange Code
ECAD	Electronic Computer-Aided Design
ECMA	European Computer Manufacturers Association
ECN	Engineering Change Notice
ECO	Engineering Change Order
EDI	Electronic Data Interchange
EDIF	Electronic Data Interchange Format
EDIFACT	Electronic Data Interchange for Administration
EDS	Electronics Data Systems
EGP	Exterior Gate Protocol
EI	Enterprise Integration
EEI	External Environment Interface
EEO	Equal Employment Opportunity
EIA	Electronics Industry Association
EIF	Engineering Information Facility
EIP	Enterprise Integration Program
EIS	Engineering Information System
EISWG	Engineering Information System Working Group
EIT	Enterprise Integration Technologies
ENE	Enterprise Networking Event
EPA	Enhanced Performance Architecture; Environmental Protection Agency
ER	Entity-Relationship
ESG	Electronic Systems Group
ESPRIT	European Strategic Programme for Research and Development in Information Technology
EWOS	European Workshop on Open Systems
FAP	Formats and Protocols
FARS	Federal Acquisition Regulations
FCS	Factory Control System

FDDI	Fiber Data Digital Interface
FIPS	Federal Information Processing Standards
FIPS Pubs	Federal Information Processing Standards Publications
FOF	Factory of the Future
FTAM	File Transfer, Access, and Management
FTE	Full Time Equivalent
FTP	File Transfer Protocol
GE	General Electric
GEAE	General Electric Aircraft Engines
GGP	Gateway-to-Gateway Protocol
GKS	Graphical Kernel System
GM	General Motors
GM-C4	General Motors Computer-Assisted Design (CAD)/Computer-Assisted Manufacturing (CAM)/Computer-Assisted Engineering (CAE)/Computer-Integrated Manufacturing (CIM)
GMD	Gesellschaft fur Mathematik und Datenverarbeitung MBH (German)
GNMP	Government Network Management Profile
GOSIP	Government Open Systems Interconnection Profile
GUI	Graphical User Interface
HP	Hewlett Packard
I/O	Input/Output
IAB	Internet Activities Board
IAE	International Aero Engines
IBM	International Business Machines
IC	Integrated Circuit
ICAM	Integrated Computer-Aided Manufacturing
ICAM-FoF	Integrated Computer-Aided Manufacturing Factory of the Future
ICMP	Internet Control Message Protocol
ICSI	International Coding System Identifier
IDA	Institute for Defense Analyses
IDE	Inspection Data Entry
IDEF	Integrated Computer-Aided Manufacturing (ICAM) Definition Language
IDL	Interface Definition Language
IDS	Integrated Design Support System
IEC	International Electrotechnical Committee
IEEE	Institute of Electrical and Electronics Engineers
IEF	Information Engineering Facility

IEW	Information Engineering Workbench
IGES	Initial Graphics Exchange Specification
IIS	Integrating InfraStructure
IISS	Integrated Information Support System
ILS	Integrated Logistics Support
IM	Integrated Model
IMPPACT	Integrated Modeling of Products and Processes Using Advanced Computer Technologies
INTEROP	page C-4
IP	Internet Protocol
IPD	Integrated Product Development
IPDS	Integrated Part and Document System
IPG	Integration Product Group
IPMT	Integrated Product Management Team
IPO	Initial Graphics Exchange Specification (IGES)/Product Data Exchange Standard (PDES) Organization
IRD	Information Resource Dictionary
IRDS	Information Resource Dictionary System
IRR	Internal Rate of Return
IS	Information Systems
ISA	Integrated Systems Architecture; Instrument Society of America
ISAM	Indexed Sequential Access Method
ISD	Industrial Sector Division
ISDN	Integrated Services Digital Network
ISEC	Information Systems Corporate Action Group
ISO	International Organization for Standardization
ISST	Information Systems Study Team
ITC	Inter-Tool Communication
ITI	Industrial Technology Institute
IWSDB	Integrated Weapons Systems Database
JAEC	Japan Aero Engine Company
JSD	Jackson System Design
JIT	Just-in-Time
KBS	Knowledge-Based Systems
LAN	Local Area Network
LAPI	Layered Application Program Interface
LAWS	Lockheed Advanced Wiring System

LDRO	Long Data Reference Option
LISP	List Processing
MANTECH	Manufacturing Technology
MAP	Manufacturing Automation Protocol
MBR	Model-Based Reasoning
MCAD	Mechanical Computer-Aided Design
MCAE	Mechanical Computer-Aided Engineering
MCC	Microelectronics and Computer Technologies Corporation
MCO	Manufacturing Change Order
MCS	Material Control System
MHS	Message Handling Service
MIP	Methods Improvement Program
MIS	Management Information System
MIT	Massachusetts Institute of Technology
MKS	Manufacturing Knowledge System
MMS	Manufacturing Message Specification
MP&RS	Material Planning and Release System
MPEP	Mass Properties Estimation Procedures
MRP	Manufacturing Resource Planning
MST	Microelectronics Science and Technology
MTUG	Manufacturing Automation Protocol (MAP)/Technical and Office Protocol (TOP) User's Group
NAS	Network Applications Support
NC	Numerical Control
NCAT	National Center for Advance Technologies
NCC	National Computer Centre; Network Control Center
NCMS	National Center for Manufacturing Sciences
NCS	Network Computing System
NCSL	National Computer Systems Laboratory
n.d.	no date [available]
NDDL	Neutral Data Definition Language
NDL	Network Database Language
NDML	Neutral Data Manipulation Language
NEMA	National Equipment Manufacturers Association
NFS	Network File System
NGC	Next Generation Controller
NIAM	Nijssen Information Analysis Methodology [or Normalized IAM]

NIH	Not Invented Here
NISC	Northrop Information Services
NIST	National Institute of Standards and Technology
NM	Network Management
NTIS	National Technical Information Service
NTM	Network Transaction Manager
ODA	Open Document Architecture
ODIF	Open Document Interchange Format
ODL	Open Document Language
ODP	Open Distributed Processing
ODPC	Open Distributed Processing Consortium
ODPTI	Open Distributed Processing Testbed Initiative
OIF	Operational Integration Framework
OIW	Open Systems Interconnection (OSI) Implementor's Workshop
OLE	Object Linking and Embedding
OMA	Object Management Architecture
OMG	Object Management Group
OO-CORE	Object-Oriented, Change-Oriented Reference Environment
OODB	Object-Oriented Database
OODBMS	Object-Oriented Database Management System
OO-SQL	Object-Oriented SQL
OP	Organization Profile
OPs	Organizations and Programs
ORB	Object Request Broker
OSA	Office System Architecture
OSAT	Office for the Study of Automotive Transportation
OSE	Open Systems Environment
OSF	Open Software Foundation
OSHA	Occupational Safety and Health Administration
OSI	Open Systems Interconnection
PARC	Palo Alto Research Center
PC	Personal Computer
PCB	Printed Circuit Board
PCI	Protocol Control Information
PCTE	Portable Common Tool Environment
PDCM	Product Data Conceptual Model
PDCS	Product Drawing Control System

PDE	Product Data Exchange
PDES	Product Data Exchange Standard
PDS	Product Definition System
PEX	Programmer's Hierarchical Interactive Graphics System (PHIGS) Extension to X Window
PHIGS	Programmer's Hierarchical Interactive Graphics System
PM	Presentation Manager
POMS	Process-Oriented Management System
POSIX	Portable Operating System Interface for Computer Environments
PWA	Printed Wire Assemblies
QA	Quality Assurance
QFD	Quality Function Deployment
R&T	Research and Technology
RDA	Remote Database Access
RDBMS	Relational Database Management System
REF	Repository Enablement Facility
RFC	Request for Comment
RFI	Request for Information
RFP	Request for Proposal
RFT	Request for Technology
RIA	Robot Institute of America
RM	Repository Manager
ROI	Return on Investment
ROM	Read-Only Memory
ROSE	Remote Operation Service Element
RPC	Remote Procedure Call
SAA	Systems Application Architecture
SADT	Structured Analysis and Design Technique
SAG	SQL Access Group
SAI	Standard Access Interface
SC	Sub-Committee
SCC	Strategic Cell Controller
SCCS	Source Code Control System
SCLM	Software Configuration and Library Manager
SE	Software Engineering
SEAS	Standard Electronic Assembly System
SEE	Software Engineering Environment

SGML	Standard Generalized Markup Language
SIG	Special Interest Group
SISP	Strategic Information System Planning
SMBP	Simple Message Block Protocol
SME	Society of Manufacturing Engineers
SMTP	Simple Mail Transfer Protocol
SNA	Systems Network Architecture
SNMP	Simple Network Management Protocol
SOM	System Object Management
SP	Special Publication
SPAG	Standards Promotions Application Group
SPARC	Standards Planning and Requirements Committee
SPC	Statistical Process Control
SPO	Systems Project Office
SQL	Structured Query Language
SSD	Structured Systems Development
STs	Standards and Technologies
STEP	STandard for the Exchange of Product data
STOP	Standards, Technologies, Organizations, and Programs
SUMM	Semantic Unification Meta-Model
TC	Technical Committee
TCAD	TekniCAD (Computer-Aided Design)
TCP	Transmission Control Protocol
TELNET	Telecommunications Network
TES	Tool Encapsulation Specification
TFA	Transparent File Access
TIE	Team Integration Environment
TOP	Technical and Office Protocol
TP	Transaction Processing
TQM	Total Quality Management
TTM	Time-to-Market
UDP	User Datagram Protocol
UI	User Interface; Unix International
U.S.	United States
VECTORS	V2500 Engineering Change Tracking and Online Reporting System
VHDL	Very High Speed Integrated Circuit (VHSIC) Hardware Design Language
VHSIC	Very High Speed Integrated Circuit

VT	Virtual Terminal
VUE	An HP product, part of NewWave environment
WAN	Wide Area Network
WC	Working Committee
WG	Working Group
WISE	Westinghouse Integrated Systems Environment
X	X-Windows
XDR	Exchange Data Representation
XPG	X/Open Portability Guide
XSI	X/Open System Interface
XTI	X/Open Transport Interface
XUI	X User Interface
XVT	Extensible Virtual Toolkit

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13. ABSTRACT (Maximum 200 words)
This document provides an assessment and a baseline of 85 key standards and technologies that will be required over the next 10 years to build the necessary components of an information infrastructure. Both public and proprietary standards were reviewed, and a brief description of each standard and technology is provided. Ten technical categories, adapted from the Advanced Manufacturing Technology Standards Reference Model, were used to categorize organizational and program activities and to categorize these activities by standards and technologies. The results were a series of finding and conclusions, among them: (1) consensus is need around a single model (or group of models) from which a coherent set of standards can be developed; (2) for the National Information Infrastructure itself, the requirements in other areas, such as education and health care, will also be important; (3) a sense of timing and evolution about infrastructure development must be maintained—the needs anticipated 10 years or more in the future appear to require the development of new technologies and architectures leading to systems of autonomous modules; and (4) strategies and methods for aiding the transition towards these forms of information integration must be planned and pursued. This document was prepared as a companion document to IDA Paper P-2664, Information Infrastructures for Integrated Enterprises.

14. SUBJECT TERMS
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