NASA-CR-197726

NCCW-0040

NASA-IVV-94-011
WVU-SRL-94-011
CERC-IA-95-001

NASA/WVU Software IV & V Facility
Software Research Laboratory
Technical Report Series

INTERIM
IN-61-CR
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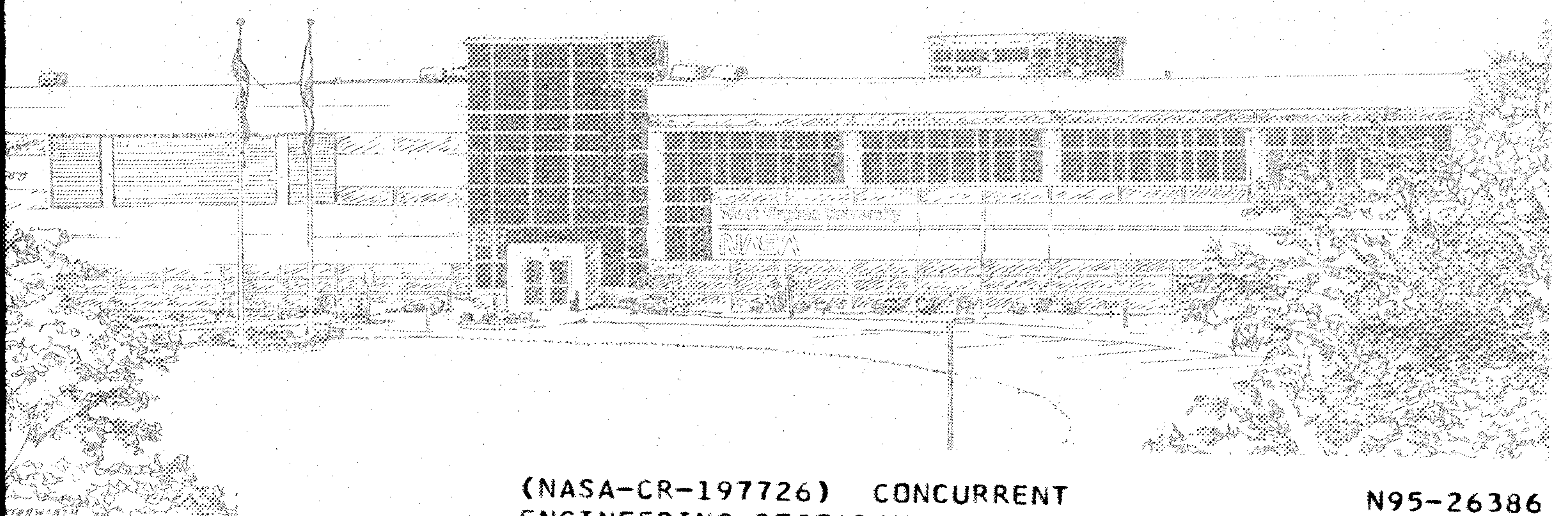
p. 41

Concurrent Engineering Research Center

Annual Report
1993 - 1994



(NASA-CR-197726) CONCURRENT ENGINEERING RESEARCH CENTER Annual Report, 1993 - 1994 (West Virginia Univ.) 41 p

N95-26386

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G3/61 0047894

National Aeronautics and Space Administration

West Virginia University

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George J. Sabolish 4-10-95	John R. Callahan 4-18-95
George J. Sabolish Date	John R. Callahan Date
Manager, Software Engineering	WVU Principal Investigator

WVU CERC

Concurrent Engineering Research Center

ANNUAL REPORT

1993-1994

January 1995

West Virginia University
PO Box 6506
Morgantown, WV 26506

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Concurrent Engineering Research Center

ANNUAL REPORT 1993-1994

§ CERC Mission

The Concurrent Engineering Research Center (CERC) is an independent, interdisciplinary research laboratory at West Virginia University (WVU). CERC's mission is:

"To research, develop, demonstrate, and advance information technologies that enable collaboration among an enterprise."

The focus is on demonstrating the use of generic communication technologies in application areas that are deemed national priorities. CERC was established in 1988 as part of the Department of Defense's Defense Advanced Research Projects Agency (DARPA -- now ARPA) Initiative in Concurrent Engineering (DICE). During the first three years of this initiative, CERC was a subcontractor to the General Electric Corporation. Since then, CERC has been funded directly by DARPA, as well as by other agencies.

For the first four years of the DICE program, CERC developed generic computer technologies that enable manufacturing organizations to become collaborative enterprises. The technological feasibility of these technologies was validated through pilot sites at General Electric Aircraft Engines (aircraft engine design) and Westinghouse Electronic Systems Group (electronic system design). To prove the generic nature of these technologies and to meet emerging national needs, CERC is now demonstrating the use of collaboration technology in other national thrust areas.

§ CERC Projects

(D)ARPA Initiative in Concurrent Engineering (DICE)

<u>Background</u>

In 1987 the Defense Advanced Research Projects Agency (DARPA --now ARPA) created an industry/government/academia task-force to examine the issue of technology needed to improve the product development process, particularly as it applies to advanced weapon systems. After studying the Japanese industry practices and holding a number of focused workshops around the country, DARPA concluded that advanced computer software to assist a human team in considering all aspects of a product (including manufacture and logistical support) concurrently from the outset, is essential for the development of high-quality products in the shortest possible time at competitive costs. This led DARPA to launch a new 5-year, $100M technology development initiative called DICE, the DARPA Initiative in Concurrent Engineering.

To fulfill this mission DARPA formed an industry/university consortium to develop the technology and demonstrate its application in the real world. The major program elements of DICE are:

1. Developing an information architecture to aid the practice of Concurrent Engineering with appropriate computer support -- the so-called DICE Architecture.
2. Establishing the Concurrent Engineering Research Center (CERC) at West Virginia University as a continuing "National Institute" to research and promote Concurrent Engineering technology and best practices, regardless of origin.
3. Conducting Pilot Projects jointly with industry, to gain experience in incorporating DICE technology into an existing infra-structure, and to verify its cost-effectiveness by appropriate metrics.

The charter of DICE may now be stated as follows:
Develop, Integrate, Validate and Disseminate technologies that enable the practice of Concurrent Engineering in the military and industrial base of America.

In what follows we outline these program elements and conclude with a list of accomplishments.

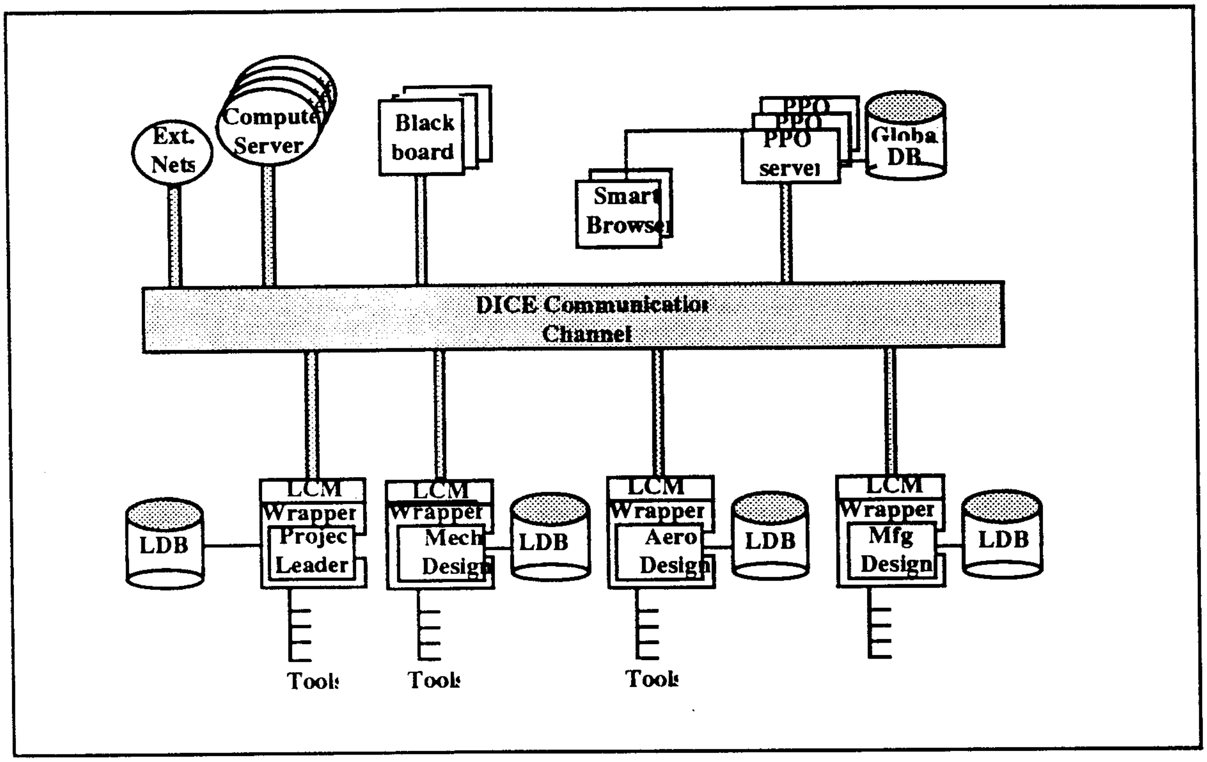
<u>The DICE Consortium</u>

The DICE program was carried on in the first two years by a consortium of universities and industrial/software companies with General Electric Corporation's Aircraft Engines Group (GEAE) serving as the Prime Contractor. The Concurrent Engineering Research Center (CERC) at West Virginia University served as the principal sub-contractor with responsibility for the DICE Architecture, and its integrated demonstration. Later, all the universities and companies involved in the DICE project held separate research contracts from DARPA.

During the last five years many universities and companies have been part of the DICE Consortium. General Electric Aircraft Engines, General Electric Corporate Research and Development, Westinghouse Electronic Systems Group, Carnegie-Mellon University, Rensselaer Polytechnic Institute, represent some of the major centers.

<u>The DICE Architecture</u>

Put simply the DICE Architecture is an information system that enables members of a Virtual Team (connected by a high speed computer network) to communicate and coordinate information flow so as to promote cooperation and achieve rapid consensus. The domain experts, of course, retain their CAx (x represents Design, Engineering, Manufacturing, etc.) tools as the primary means of design, analysis and simulation but these are no longer wielded in a private workspace for single perspectives. There is sharing at every level.



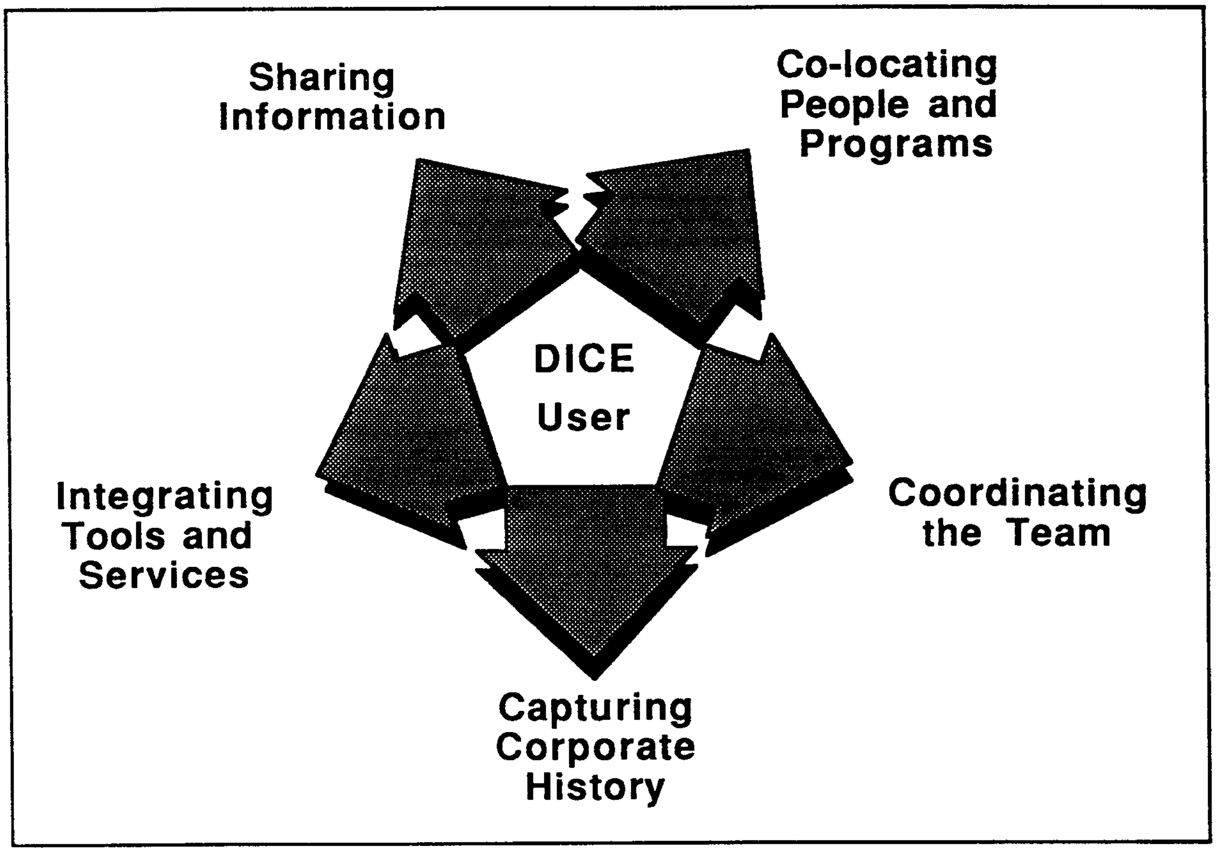
The Information Bus Architecture

The underlying motivation for the DICE Architecture is to confer the same benefits on large teams composed of many perspectives and geographically distributed information resources, as small tiger teams derive when working in proximity. This is accomplished by creating an open system that allows the deployment of the services underlying the DICE Architecture on an existing heterogeneous computer network.

The system provides a set of generic services to the virtual team and these are shown on the upper part of the channel through which they communicate. The generic services fall into a taxonomy of five categories:

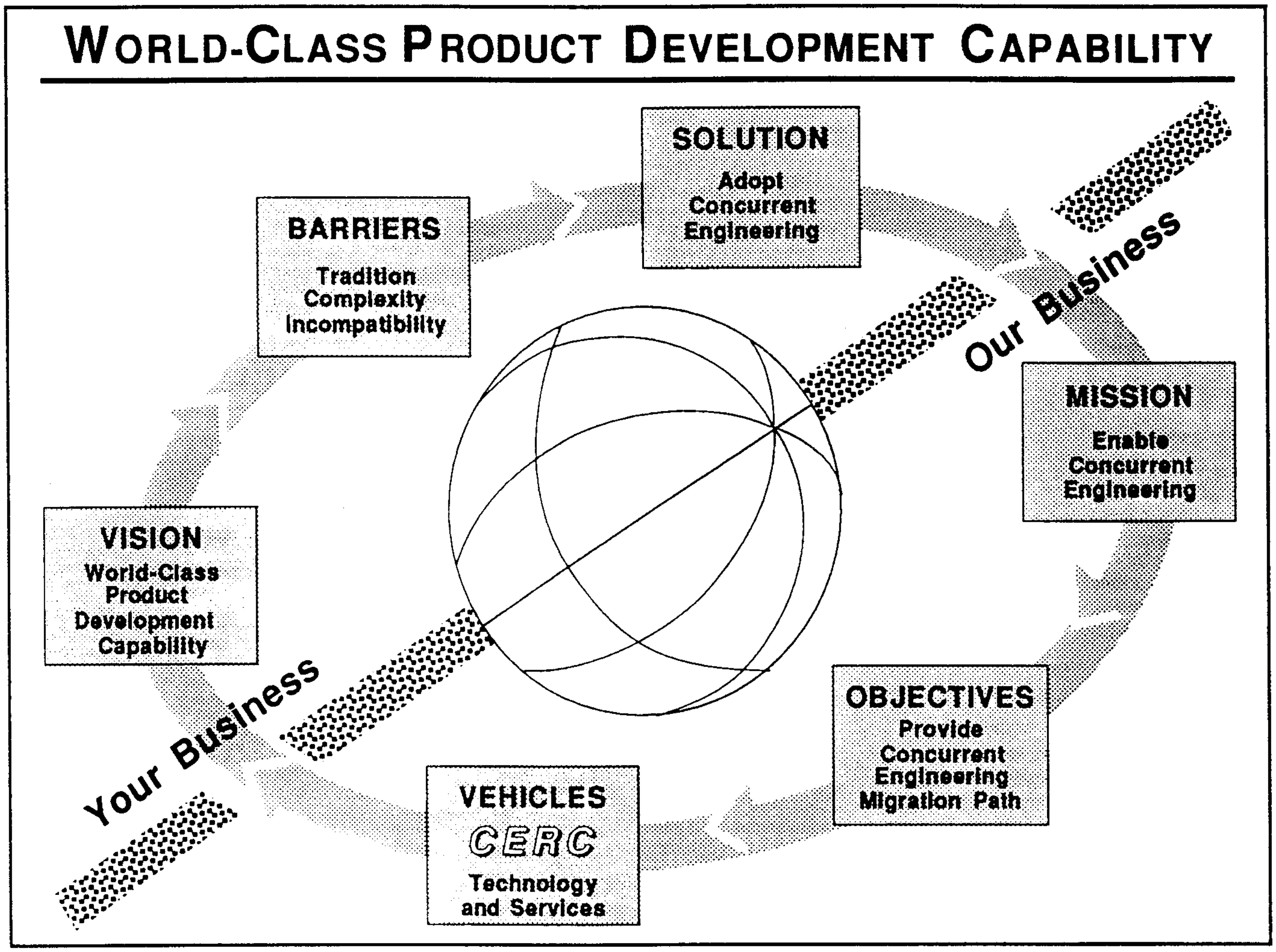
1. Virtual Collocation of People and Computer Programs
2. Team Coordination
3. Information Sharing
4. Integration of CAx tools with the Architecture

5. Capture of Design Intent in a Corporate Memory



Modular Services Supporting CE Teams

CERC has been an important element of the DICE program. The primary mission of CERC is best illustrated schematically as shown below:



The vehicle for accomplishing this mission is the Concurrent Engineering Testbed which show-cases both DICE developed technologies, as well as contributions from elsewhere. How organizations can improve their own information networks and data bases to support the needs of concurrent engineering is the theme. Industrial organizations can migrate to the practice of concurrent engineering along the path indicated.

CERC staff members and visiting scientists have produced handbooks and a wealth of papers in the area of concurrent engineering to meet the needs of both the educational and the industrial community. Over 20 hours of videotapes systematically expounding the results of the process and product improvement methodologies and software have been produced in CERC's electronic classroom. Annual conferences were held during the first four years. Besides, the IEEE Computer Society publishes the proceedings of an annual international Workshop on Enabling Technologies, Infrastructure for the Collaborative Enterprise (WET-ICE) organized every year spring by CERC.

Through the involvement of members of the teaching faculty at West Virginia University, new courses are being taught, and many standard courses are being re-vamped to enshrine the important results and techniques accompanying this powerful new concept in engineering.

Collaboration Technology for Real-Time Treatment of Patients: National Library of Medicine (NLM) Project

The goal of this effort is to make health care more effective and affordable by applying modern computer technology to improve collaboration among diverse and distributed health care providers.

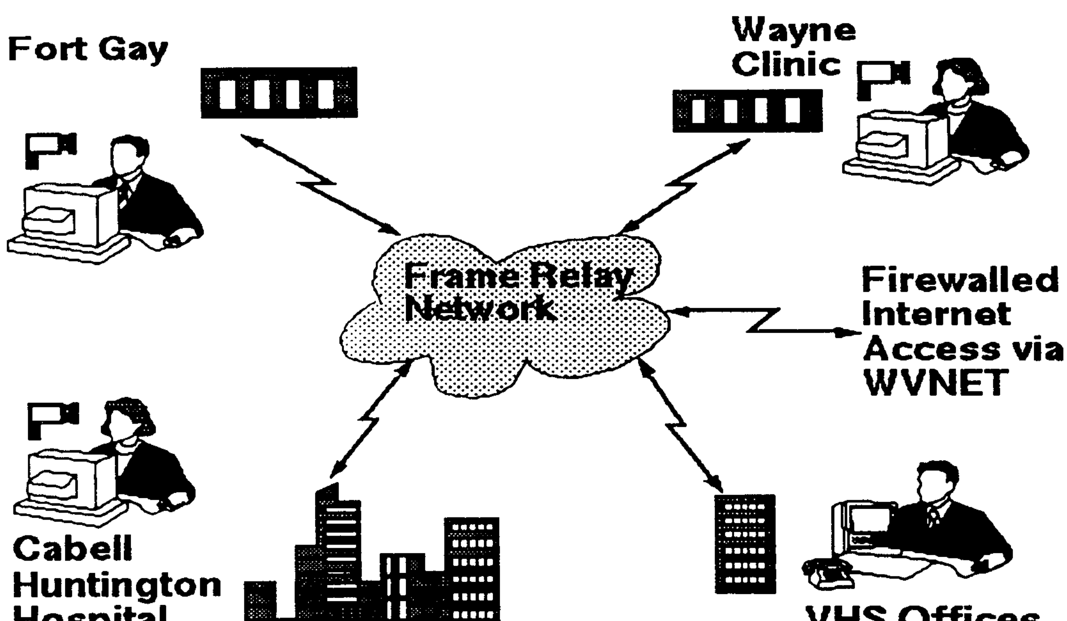
Information sharing, communication, and coordination are basic elements of any collaborative endeavor. In the health care domain, collaboration is characterized by cooperative activities by health care providers to deliver total and real-time care for their patients. Communication between providers and managed access to distributed patient records should enable health care providers to make informed decisions about their patients in a timely manner. With an effective medical information infrastructure in place, a patient will be able to visit any health care provider with access to the network, and the provider will be able to use relevant information from even the last episode of care in the patient record. Such a patient-centered perspective is in keeping with the real mission of health care providers.

Today, an easy-to-use, integrated health care network is not in place in any community, even though current technology makes such a network possible. Large health care systems have deployed partial and disparate systems that address different elements of collaboration. But these islands of automation have not been integrated to facilitate cooperation among health care providers in large communities or nationally.

CERC and its team members at Valley Health Systems, Inc., and Cabell Huntington Hospital form a consortium committed to improving collaboration among the diverse and distributed providers in the health care arena. As the first contract recipient of the multi-agency High Performance Computing and Communications (HPCC) Initiative, this team of computer system developers, practicing rural physicians, community care groups, health care researchers, and tertiary care providers are using research prototypes and commercial off-the-shelf technologies to develop an open collaboration environment for the health care domain. This environment is called ARTEMIS -- Advanced Research TEstbed for Medical InformaticS.

ARTEMIS leverages existing CERC-developed technology as well as the concurrent engineering approach of involving the customer from the onset of the project. ARTEMIS will be field-validated at participating sites in southern West Virginia. Our team will deploy a set of software systems in a growing number of health care facilities, in a phased manner, and will demonstrate:

- physicians treating patients using patient records and other knowledge from distributed sources;
- primary care physicians consulting with remote specialists in the areas of perinatology and radiology, facilitated with computer support for X-rays, ultrasound, voice annotations, and other multimedia information; and
- primary care and specialized care providers collaborating via a community care network to meet a community's health care needs.



Community Care Network

The team will also measure the system's effectiveness in reducing health care costs. In addition, they will focus special attention on issues related to quality assurance, privacy, confidentiality, and data integrity.

Collaborative Environment Research in Collaborative Environments for Independent Software Verification and Validation (IV&V)

Several researchers at CERC are currently performing research for the National Aeronautics and Space Administration (NASA) in Independent Software Verification and Validation (IV&V). Due to the complex nature of computer software, the failure of computer systems in manned and unmanned space missions can be costly in terms of lives and dollars. The National Academy of Sciences' National Research Council, at the request of Congress, highly recommended that NASA institute software IV&V on many of its large projects including the Space Shuttle, Space Station, and the Earth Observing System (EOS). Yet, very little is known about the true effectiveness of software IV&V or the best methodologies for improving the quality of computer software.

CERC is involved in two projects with NASA on software IV&V:

1. The construction of a Collaborative Environment for IV&V directly under NASA's EOS Data and Information Systems (EOSDIS) project; and

2. Performing research in direct cooperation with NASA Headquarters regarding the development of new techniques, tools, and standards for software V&V within all aspects of NASA software development projects.

1. NASA EOS Data and Information Systems Project (EOSDIS):

This project, which commenced in November of 1992, spans various aspects of IV&V including IV&V Process, IV&V methodology, Collaborative Environment to Support IV&V and IV&V tools and methods. As part of this effort, we have also hosted a workshop that brings together the researchers and practitioners of IV&V especially in the context of the IV&V project and the NASA Center for IV&V in Fairmont. Several software modules for this project are developed at the Concurrent Engineering Research Center and integrated the CERC testbed. Several faculty from Computer Engineering and Computer Science are working together on this project, to build an integrated IV&V environment. This work is sponsored through a direct grant with the EOSDIS project at NASA Goddard Space Flight Center in Greenbelt, Maryland.

2. NASA Cooperative Agreement on Research in Independent Software Verification and Validation (IV&V):

NASA, the Department of Defense, and other government agencies have used IV&V on large, complex projects for many years with great success that has saved lives and dollars. Yet, as new types of software systems are constructed with new software development techniques (e.g., object oriented models), it is necessary to research the effectiveness of existing IV&V methods and develop new methods. CERC, in cooperation with NASA, is performing empirical research in software engineering and developing new techniques and tools to improve the practice of software

IV&V. CERC is involved in many ongoing NASA projects including EOSDIS, Space Shuttle, and Space Station by working directly with IV&V contractors (e.g., Intermetrics Corporation) to ensure the quality of their IV&V efforts in many major NASA programs. This work is sponsored through a cooperative agreement with NASA Headquarters' Office of Safety and Mission Assurance, Software Technology Division at the NASA IV&V Facility in Fairmont, West Virginia.

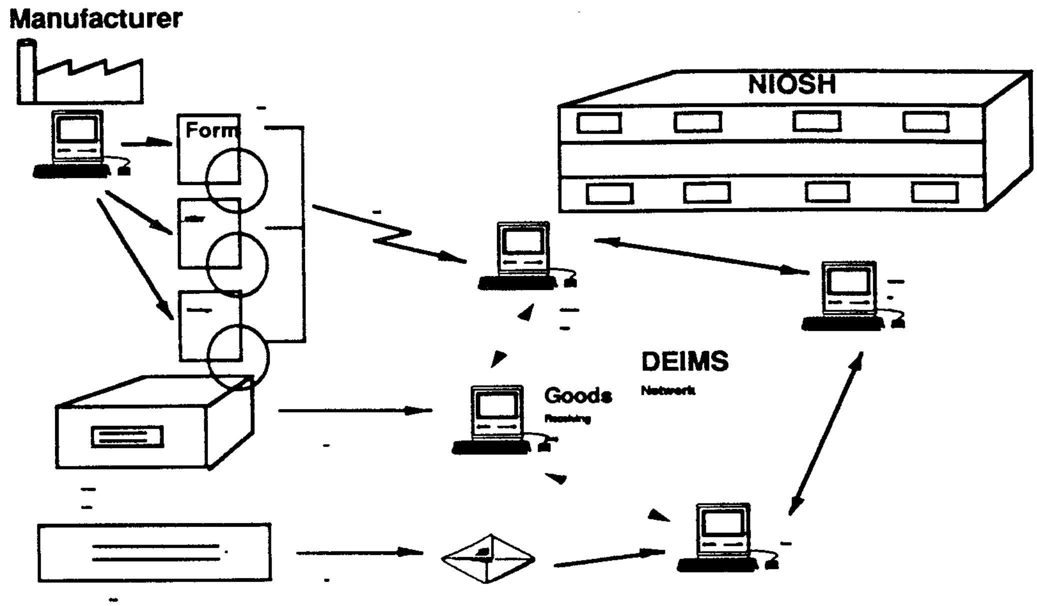
National Institute for Occupational Safety and Health (NIOSH) Cooperative Agreement

Certification of Respirators at NIOSH

The National Institute for Occupational Safety and Health has awarded a cooperative research grant to CERC for two years beginning October 1993. The objective is to instill the practice of Concurrent Engineering in the Product Approval process used by NIOSH to certify the Respirator equipment that safeguards workers in industry.

The Product Approval process at this Federal laboratory begins with the submission of a standard multi-part application form, accompanied by a fee and samples of the equipment to be certified. The standard application form specifies the nature of the certification request and has attachments containing graphic data such as drawings and labels, test data in the form tables, quality assurance procedures containing flowcharts, and several other attachments, besides. Currently the submission is in paper form. CERC is working on an improvement that will have the manufacturers submit the entire standard form and attachments via Internet in a standard manner -- using Electronic Data Interchange (EDI). This will constitute the first significant change in the process.

Subsequently, the application undergoes over 18 steps of processing within NIOSH. Often, the need for clarification from the manufacturer increases the number of steps, and lengthens the time to complete the processing. The entire process is driven by the flow of paper files through the labs and offices of NIOSH. CERC proposes to develop a prototype work flow using a commercial client-server computer package that will enable the master databases of tests, the application documents needed as input for each step, and the results arising therefrom, to be kept on-line throughout the certification process. Messages conveyed to the NIOSH staff on the DEIMS network (which stands for the Division of Safety Research Electronic Information Management System) will alert them regarding work items for each certification task. In this way tasks will be conveyed with the relevant data as soon as they are ready for processing. The wait-time and time to find information will thereby be reduced. Moreover, the status of every application will be known. Interactions with the manufacturers will also take place via multimedia e-mail so that the whole process can seamlessly involve participants within and outside NIOSH.



Electronic Respirator Certification

The requirement of security and privacy is to be handled by encryption of the application before transmission. Standard compression techniques will be used to reduce the data transmission times. A very important feature of the software is that attachments to the standard application form containing files in arbitrary format can be transmitted, without the need for NIOSH to have a copy of the software used by the manufacturer to create those files. This interoperability is achieved by using a standard exchange format such as encapsulated PostScript (EPS), and it will simplify the processing at NIOSH immensely.

A moment's reflection will show that the Product Approval described here has elements that characterize much of the processing by state and federal agencies of applications from the public; if anything, it is more complex than the common public interactions with agencies of the government. In developing the Product Approval application it will therefore be useful to maintain its generality, so that the prototype developed may be applied *mutatis mutandis* to the large class of work flows associated with the processing within organizations of application forms submitted by clients.

The first year of the grant is over. A survey of manufacturers has been completed to identify the crucial elements. A re-design of the application processing has been done with the help of a team of NIOSH technical staff who perform the work. A new system design has been completed from scratch and documented in a report. In the second year a prototype will be developed with all the essential features. Furthermore, a way to instrument the test apparatus so that computers can be used to control the tests and acquire the data will be investigated.

3M Continuous Fiber Metal Matrix Composite (CFMMC) Model Factory Program

The driving theme of the 3M Continuous-Fiber, Metal-Matrix Composite (CFMMC) Model Factory program is to reduce the effort and cost to qualify CFMMC materials to a minimum consistent with a desired level of confidence. A rapid qualification capability is essential for offsetting the potential for multiple, lengthy, and costly qualifications spawned by the complex structural behavior and failure mechanisms of CFMMC materials.

The goal of WVU's program was to develop, validate, and transfer into practice a rapid and cost-effective qualification process that would serve the needs of the 3M Model Factory and become the basis of a center supporting national needs in the integrated development of products based on CFMMC materials for diverse applications. Our technical approach embraceD efforts to design, implement, and demonstrate an integrated environment for the rapid qualification of CFMMC materials. The work was carried out by a team consisting of CERC, the College of Engineering, the College of Arts and Sciences, and Science Applications International Corporation.

<u>Features</u>

The rapid qualification capability (RQC) involves four elements:

- the fast translation of component design specifications into qualification requirements;
- the use of validated material behavior models;
- the rapid access to the best of past practices, data, and capabilities; and
- the generation of "smart", compressed test plans.

Phase 1 objectives and accomplishments were five-fold:

- to provide software tools to assist in the conceptual design of MMC components
- to provide a *rapid* qualification methodology for CFMMCs in support of a wide range of applications
- to implement and validate the qualification methodology through a pilot program
- to pave the way to an integrated product development (IPD) environment for CFMMC materials, processes and products and
- to provide program management and system administration ensuring effective communication among all 3M Model Factory subcontractors including CFMMC data base access.

The central idea of our approach was to create an exemplary rapid qualification capability (RQC) that can later be made specific to the proprietary environments of 3M (the producer) and its future customers (the users). To increase its portability, the RQC makes use of the STEP standard for product data exchange as well as other computer-system standards.

Phase 2 activities were as follows:

- Achieve operational (pilot) status of the rapid qualification capability, which was prototyped in Phase 1
- Demonstrate that the advanced qualification capability reduces the time and cost of qualifying advanced composite materials consistent with a desired level of uncertainty
- Engage in technology transfer activities through a pilot project at a selected user's site.
- experimental validation of a micromechanical model for predicting residual stress distributions in consolidated MMC materials
- implementation of smart-test planning in the integrated qualification environment
- development of a statistical methodology, based on smart-test planning concepts, for reducing the variability and optimizing the fiber manufacturing process
- development (from available technology) of a design application capability for pressure-cast aluminum composites reinforced by alumina fibers; and
- creation of a business plan for a combined application and qualification center for metal-matrix (and other) composite materials.

CERES-Global Knowledge Network (CERES-GKN)

The Vision and Mission of CERES-GKN

In the modern industrial world the harmful effects of engineering products are transferred across the globe, polluting during use, and sometimes polluting even more at the final disposal stage. In the inter-dependent economies of the future, assemblies and components will be designed and produced in all parts of the world and come together as diverse products elsewhere, and will be used in still other places. Since engineering artifacts carry their pollution production propensities worldwide, the solution to the problem of producing environment-friendly end-products must be implemented globally.

Design for the Environment (DfE, also known as Green Engineering) needs to be rapidly propagated as a standard approach for product developers worldwide. The knowledge needed to design green products is quite diverse, highly dispersed, and constantly evolving. There are techniques being invented constantly to reduce the pollution potential of various products and processes. The immediacy of the problem demands that any advances made anywhere to limit some source of pollution, or avoid it altogether by the use of a new process or a new material, must be disseminated immediately and adopted for the benefit of the world by every other producer who could exploit that knowledge.

A salutary result will be an actual increase in world trade and diminution of danger to the environment simultaneously. The experience with recycling has shown that the crucial problem is to create a market of large enough size -- that will then justify the measures to capture the product at the disposal stage and feed it back to provide economic inputs to the same or other industries. Similarly, designing for the environment will become the norm only when demand for new environment-friendly processes, materials, and technologies takes off. Regulations and laws are but one means to achieve it; the other side of the bargain is the rapid dissemination of new knowledge, and the rapid dissemination of the commercial intelligence needed to exploit it.

The natural medium to make this technical and commercial knowledge commonly accessible is via the Internet (Data Bases, Simulation tools, Design for the Environment Evaluation and Trade-off tools, Best Manufacturing Practices Advisers from the DfE viewpoint, Consulting Expertise, Royalty arrangements, etc.). This electronic information network already spans the globe. However, the tools available today on Internet for knowledge discovery are far from adequate. Besides, it is not easy to import knowledge lying in proprietary private data bases and place them (some for a fee, some for free) in a commonly visible format. Finally, there is the large problem of organizing the DfE knowledge in a hierarchy meaningful to designers working in different fields.

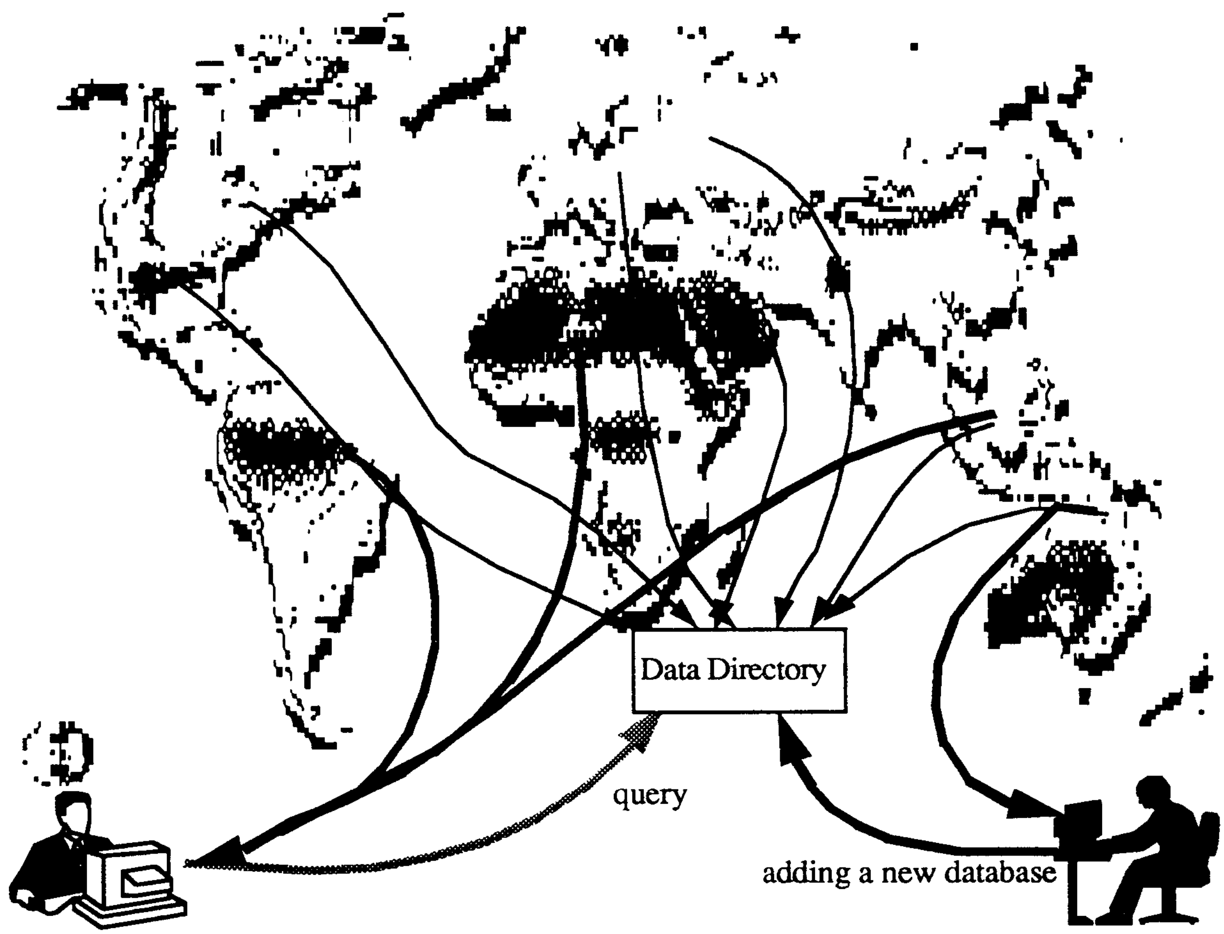
<u>The International Consortium</u>

To address this very important problem an international consortium has been formed called the CERES-GKN, consisting of universities, research laboratories, and industrial participants from several countries (Germany, UK, the Netherlands, Japan, Russia, Italy, and USA). The Environmental Protection Administration, the Department of Commerce, and the National Science Foundation have actively participated at the creation of this consortium.

The Consortium is incorporated as a not-for-profit educational and scientific organization in Rome, Italy, with HQ there in order to enhance its international character.. Its operation is under the applicable laws of Italy and the generally accepted international standards and practices. Regional offices are also presently established in Japan and the United States. The operation of the organization is controlled by its Board of Directors under the guidance of an international advisory board.

The Program

CERES-GKN is undertaking the creation of a network of knowledge bases to enable decision makers from around the world to make environmentally sound, technologically feasible and economically justifiable choices during development of products and processes. The emerging global information infrastructure, Internet and the World Wide Web (WWW, often referred to as The Web), in particular, will form the basis of this effort. The major goal is to build an easy-to-use goal-oriented interface that will only present the relevant information in a form that is appropriate to the context.



CERC is seeking the assistance of international funding agencies to create an initial prototype network that will demonstrate the concept and utility of global knowledge sharing. The funds will be used by CERC to create a communications infrastructure and a secretariat to coordinate activities of consortium members, to support the organization of workshops, and to stage demonstrations. At first the prototype network will have nodes in the countries stated above, though it will be accessible from anywhere in the world.

Subsequently, the contributing nodes will be expanded to cover other leading centers worldwide. Meanwhile, funds for the actual development of the underlying information technology are being sought from other agencies, such as the Advanced Research Projects Agency and the National Science Foundation.

The separate research and development proposals CERC is making to those agencies will result in a new set of tools and a taxonomy of engineering design knowledge that will significantly advance the state of the art. Once developed, it could be widely used to structure almost any domain for global knowledge sharing. We are convinced the fruits of CERES-GKN research will ultimately benefit many other internationally challenging areas, as well. Therefore, CERC is also currently seeking the support of international organizations and foundations for the CERES-GKN organizational purposes during the crucial formative stage. Efforts are currently underway to establish cooperative relations with world bodies such as the United Nations Environment Program (UNEP), and other related national initiatives.

The CERES-GKN network will be accessible to all through gateways in each country/region without charge (except when the owner of proprietary information has established a pay-for-use mechanism). This network will include mechanisms for handling pay-for-use proprietary information and conducting electronic commerce in environmental technologies and technology transfer.

The inaugural workshop was held in April 1994, in the United States under the sponsorship of West Virginia University (CERC) and the National Science Foundation, and in collaboration with Pennsylvania State University (Applied Research Lab), Environmental Protection Agency (EPA), and the Department of Commerce (all of USA). Delegates from USA, Japan, The Netherlands, Belgium, Germany, UK, Italy, Russia and Poland participated in this workshop and constituted the initial consortium. A follow-up meeting was held in Delft, The Netherlands, on 7 November 1994 to formalize the operation of the consortium.

The Projects

The current consortium members are working on the following projects:

1. CERES-GKN Prototype (Concurrent Engineering Research Center, USA). A demonstration prototype based on the Web and the Mosaic client software is under development. Nodes at the Delft Technical University, University of Ghent, University of Roma at Torvergata and the Concurrent Engineering Research Center will form the initial network.

2. CERES-GKN Meta Model (Universität der Bundesrwehr). This project aims to create a meta model that will provide a uniform front-end to all users to hide the diversity of information sources.

3. GKN-IPA - An Intelligent Personal Assistant for CERES-GKN (Concurrent Engineering Research Center, USA). This is based on the concept of intelligent agents and deals with the task of discovering, assembling and presenting information to persons engaged in the design of products and processes.

4. Water Treatment Knowledge Base (University of Ghent).

§ CERC Technologies

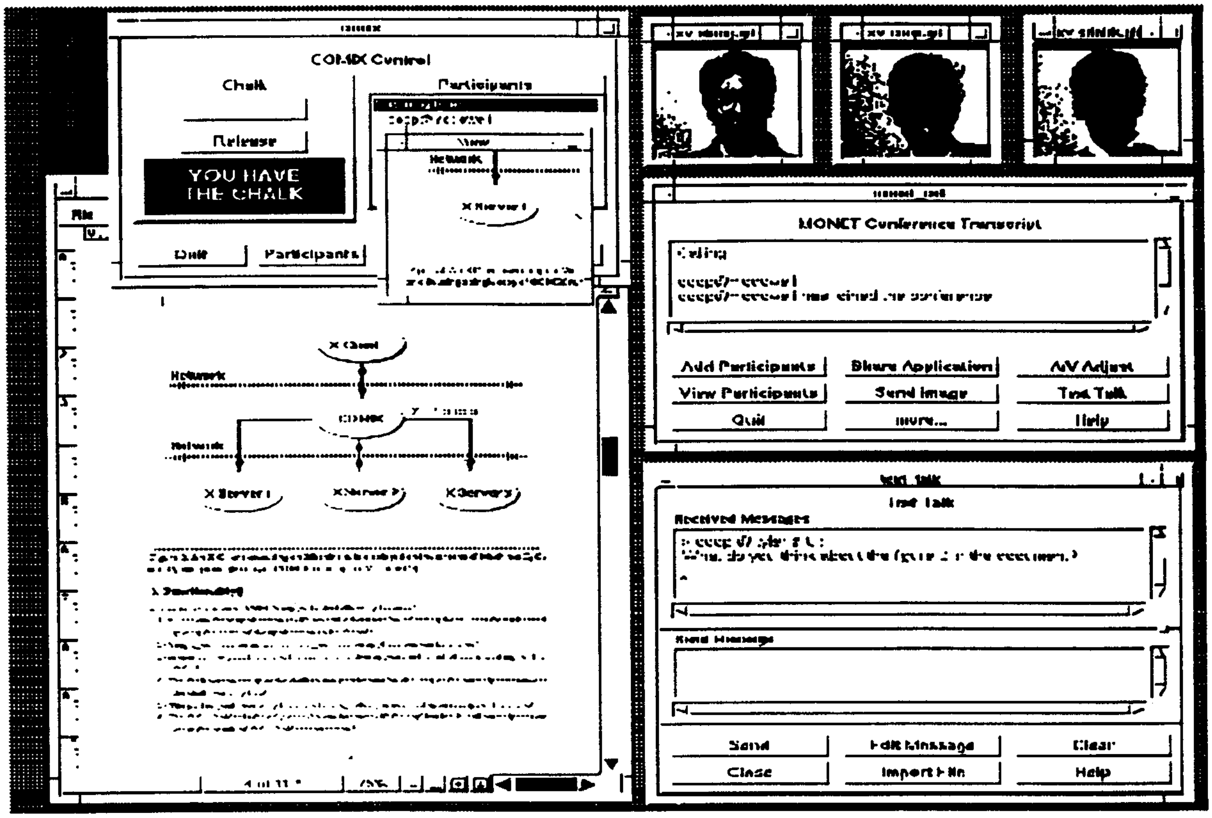
Meeting On the NETwork (MONET)

When people who are geographically dispersed are required to meet at the same location, significant travel time, money, and energy are spent, leading to decreased productivity. Moreover, in most meetings and conferences, the participants are not equipped with all of the information they might need to function effectively. In other words, they are dislocated from their ideal work environment. Furthermore, some meetings are totally unstructured and free-form, which diminishes their effectiveness. Finally, many of these meetings have no good mechanisms to archive all of the events that occur for future use.

By using existing computer and communications technology, teams can overcome the distance barrier. Overcoming this distance barrier can not only cut travel costs and travel time, but it can also increase productivity by enabling individuals to participate in conferences and meetings from the office or home.

One type of technology that can be used to overcome the distance barrier is a computer-based, real-time multimedia conferencing system to facilitate the virtual collocation of people and programs, which can enable effective communication and cooperation among multiple participants over a computer network. Such a system is also known as a desktop conferencing system.

CERC has developed a desktop conferencing system called Meeting On The NETwork (MONET), which provides multimedia conferencing capability at various levels (text, graphics, voice, and video), depending on the bandwidth available. It also provides facilities for archiving minutes of a meeting and for sharing computer applications by several people.



MONET Window

MONET emulates face-to-face meetings, allowing users to see each other's facial expressions, hear each other's voices clearly, and use white boards and other media to draw pictures, take notes, and point to items on the screen. Such communication makes cooperative work over a network more effective. The conferencing capabilities of MONET also includes transparent access to the resources of the network and the ability to collaboratively work on programs and data.

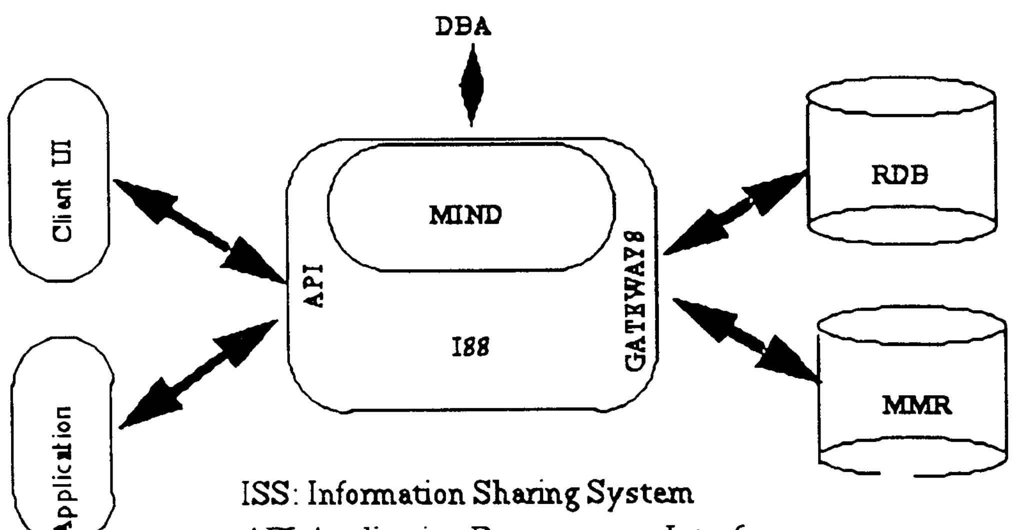
While different implementations of MONET on a wide variety of platforms have been successfully completed, the inter-operability of MONET-like systems across different hardware and software platforms (such as workstations, Personal Computers, Macintoshes) pose significant challenges. CERC is currently working on an inter-operable MONET system based on a virtual machine (MONETVM) architecture.

Information Sharing System (ISS)

The goal of the Information Sharing System (ISS) is to provide the means for an organization to effectively disseminate information, thus enabling effective work in concurrent engineering endeavors. Because corporate information already exists in a variety of computer information repositories such as databases, documents, drawings, and data files it is imperative that an information sharing system be integrated with these sources of information. For this reason, a shrink-wrapped solution cannot be deployed in a variety of customer sites with little or no customization.

Keeping this in mind, the Information Sharing System is intended to provide the user with a system that is integrated with representative information repositories, along with methodologies that enable its implementation in a phased manner. Intellectual precursors to this system include the Knowledge Server and the PPO Server; efforts carried out in earlier phases of the DICE project.

One component of the Information Sharing System is the Model-based Information Directory (MIND) module that provides organization and structure for the information that is stored in the various data repositories. This Information model will define the information that the user can access via the Information Sharing System. Integrated with the Information Sharing Model are the interfaces to various representative data repositories.



ISS: Information Sharing System
API:Application Programmers Interface
MIND:Model-based INformation Directory
DBA:Database Administrator
RDB:Relational Database
MMR:Multi-Media Repository

Architecture of the Information Sharing System

<u>New Version</u>

The new release of the ISS (v3.0), while maintaining the philosophy and goals of earlier work, breaks new ground in its implementation. The changes in implementation have been driven by inter-operability issues. The current popularity of Mosaic and http-protocol and the emerging acceptance of Common Object Request Broker Architecture (CORBA) efforts, have prompted us towards a strategy of using http protocol to support client-end inter-operability and CORBA specifications and protocols for server-end inter-operability. To support http protocol effectively, we came up with notion of lay-out pages. These pages specify in HTML format the information that a user would like to see. The new release also supports updates to databases and a two-phase commit protocol.

The current release of ISS supports the following features:

- allows specification of the layout pages that serve information to the user in customizable pages whose composition is dynamic
- supports the building of gateways to relational database management system. We have prototypes of gateways to Oracle Relational DBMS and file repositories.
- provides an application programming interface for the Information Sharing System
- is deployable over a wide area network
- is compliant with http and CORBA specifications
- incorporates security features

Overall Functionality

The Information Sharing System provides access to information in various data repositories through a single view. A user accessing the system can be oblivious of the location, representation format, and access techniques for the data residing in the constituent repositories.

The Information Sharing System keeps track of the repositories that hold the information. It knows what information is in which repository and how to retrieve it. It also keeps track of the logical organization of the information in the various repositories by maintaining a model of the available data. The model maintains a mapping of the actual information in the repository. The system provides access to the model to enable a user to view how each piece of information relates to other information in the collective repositories.

The repositories and the information contained in them is assumed to be established in an organization before incorporating the Information Sharing System, and every attempt will be made not to disrupt the normal processing of that information. The added advantage of the Information Sharing System is that the existing information will be modeled to show the relationships among the data. The terminology also may be overridden to provide a consistent terminology for all data, regardless of the naming convention used in the repository where the data resides.

Technology Transfer and Future work

Software developed by this effort will be ready for field trials in April 1995 in a health care domain. One module of the system, Web* has now been released in public domain.

The Web* software allows the linking of any information source to a Web client such as Mosaic by allowing a person to specify HTML or other ascii-based templates which are dynamically filled in when requested by user. The templates embed TCL commands and are interpreted and can be used to retrieve and dynamically fill the templates with information. Web* comes with interfaces to call CORBA-compliant clients. One of the key features of Web* is that it provides mechanisms to deal with the stateless nature of http-protocol.

The ISS system can form the basis for the implementation of intelligent access to heterogeneous information and a number of projects are now in a position to utilize and extend this technology:

- To provide access to distributed multi-media patient archives in the Advanced Research TEstbed for Medical Information Systems (ARTEMIS) project
- To model and provide access to structured engineering information and knowledge in relational, object-oriented, and knowledge-bases and unstructured information (text files, multimedia files) in a seamless fashion for the Collaboration Environment to Conserve Earth RESources (CERES) project
- We are investigating the use of this core technology to be used as an intelligent access to information related to technology dissemination, and managing corporate memory.

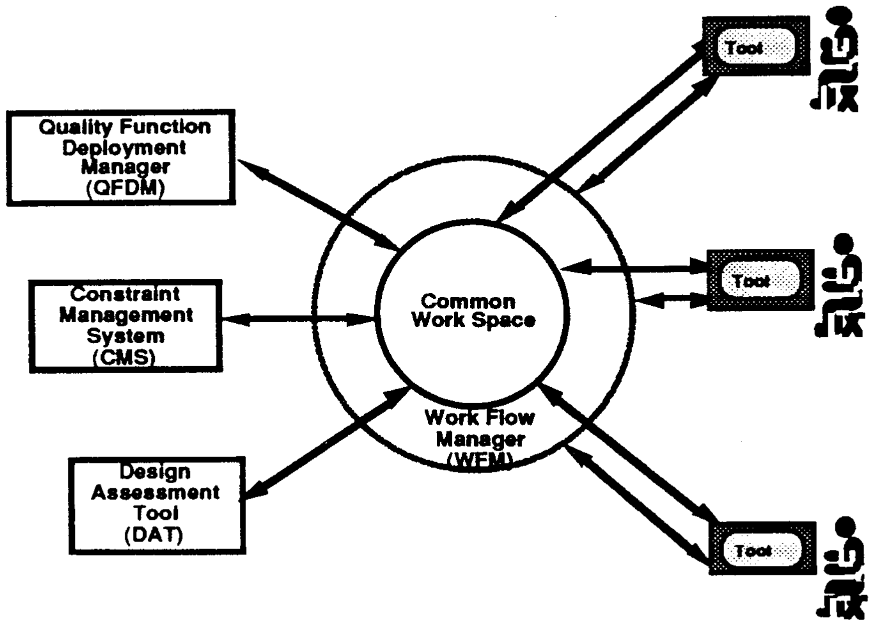
Project Coordination Board (PCB)

The Project Coordination Board (PCB) is a DICE coordination service for teams of users who are linked together in the performance of work over a long period of time and build up the product's data definition gradually over that time. It works on the basis of a common workspace in which firstly, the tasks that are being worked on by team members at any time are visible to all, and, secondly, the actual product data decisions that result from these tasks in multiple perspectives are asserted onto slots in a structured data model and made visible to team members. These commonly visible tasks and product data are the fundamental bases of the coordination provided. In addition to this there are notification mechanisms, attached to the product data model, so that changes to specific product data are notified by messages to those perspectives that have expressed a dependence on them.

The following activities in a distributed team would contribute to enhancing the coordination when multi-functional concerns in an enterprise have to be taken into account:

- Team formation, structuring, and management of the personnel deployed throughout the organization in multiple teams, working together on several projects at once in different roles.
- Planning, scheduling, and managing of project related team activities, based on activity models that use a shared information data base. This capability needs to be provided through a "Work flow Manager" module that manages the resources, analyzes the project for schedule optimization, generates reports, and disseminates task assignments via the generic communication services.
- Sharing of common views of the evolving product design to allow prompt notification of any changes and decisions to all the team members. This capability can be offered through a blackboard scheme that provides common visibility of the product model, at different levels of granularity through a graphical interface.
- Directing the flow of information among the team members and supporting negotiations for conflict resolution.
- Managing product requirements and constraints in a persistent manner throughout the product development process. This activity is supported by a "Constraint Manager" that will capture and maintain a constraint network for continuous evaluation of the product/process parameters as they are "posted" on the blackboard.
- Monitoring of the product development cycle through continuous tracking and assessment of pre-selected "figures of merit" that reflect the quality of the design and the decision-making process. This activity is supported by a "Design Assessment Tool" that will apply quality evaluation models to an attribute of the product, and evaluate and display performance metrics in the form of graphical and/or tabular reports.

A Constraints Management System (CMS) is also attached to the product data, expressing the known customer, manufacturing, or other constraints that tie the various product data attributes into dependent relationships. In this way the project and the organization can, at once, enforce customer focus and take into account the physical or manufacturing constraints that are needed to achieve consistent, manufacturable products, satisfying or exceeding requirements. Conflicts are noted at the earliest time and notified to the project leader and team members for action.



Project Coordination Framework

Reporting and assessing of product performance is also available as an automated service once the project leader specifies which product data attributes are to be directly tracked and what performance measures are to be computed by specified programs based on the product data held or pointed to in the PCB. It must be stated that product data attributes may be explicit data attributes, or pointers to CAD files, that contain data attributes. The performance monitoring of the product is done by a module called the Design Assessment Tool (DAT), a module that maintains the format and content of a typical assessment procedure that has been specified. The DAT executes whenever invoked (or at periodic intervals) and displays the results graphically and in the form of a report. In this way the project leader can obtain a "goodness" measure of the current state of the design based on multiple criteria, presumably reflecting the customer priorities.

The notion of the team itself as something that is configured into a data base of team members with specific roles during a project, is a notion that is reinforced by the PCB. A team member may belong to several projects, each with its own set of team members, tasks, and product data model; whenever users in the organization sign on to a project via the PCB from their workplace, they immediately see tasks waiting for them, other tasks being done by other members of that project team, and the current state of the product data. Consensus building is emphasized by team members being notified of changes and having to respond to them. The PCB, with its significant capabilities for sharing and disseminating vital project information, is visualized as a key element for coordinated team work when the participants are distributed.

Web-Integrated Software Environment (WISE)

The NASA Cooperative Research Project on IV&V is building the Web-Integrated Software Environment (WISE) to support management and measurement of software development efforts. WISE uses Mosaic and World-Wide-Web technology to control a "to-do" list of issues and problems in a software project. Developers, managers, and customers can view the status of a project at any time from many platforms (UNIX, DOS, Windows, Mac) by viewing project metrics, delivery dates, and inspections. They can track issues and their subsequent resolution.

FAst CASE Development Environment (FACADE)

The NASA Cooperative Research Project on IV&V is building a FAst CASE Development Environment (FACADE) as part of an effort to investigate the advantages of rapid development methods (RDMs). FACADE lets a developer build new software as a system of modules in which each module is initially implemented by a set of scripts instead of code. The scripts act as a temporary implementation for specific tests run on the system as a whole. In this fashion, the entire software runs from the first day of the project but only on a limited set of tests. The software evolves as more tests (and scripts) are written and modules are implemented eventually with code. When a module is coded, the tests can be re-executed so that it can always be exercised within the context of a complete system. The software is complete when all modules have been coded and the scripts can be abandoned. The remaining tests can also be used in late life cycle software testing activities.

Reliable Multicasting Protocol (RMP)

The NASA Cooperative Research Project on IV&V has developed a network communication protocol in conjunction with the University of California at Berkeley and Cornell University for reliable delivery of broadcast packets in local and wide area computer networks. The Reliable Multicasting Protocol (RMP) was developed at CERC and is currently undergoing extensive independent verification and validation (IV&V). Many parties around the Internet have fetched the RMP library including other parts of NASA, the Army, and American, Asian, and European software companies.

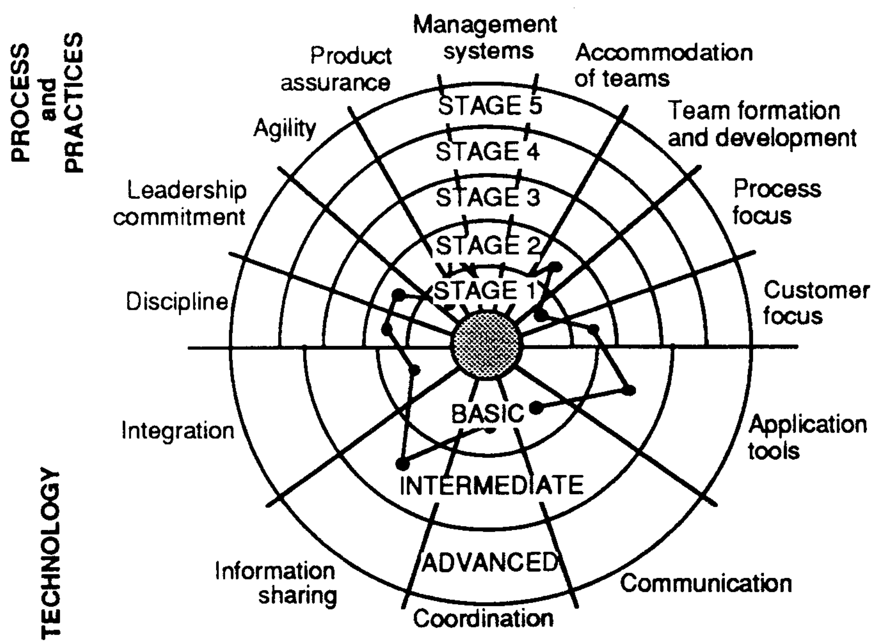
§ Readiness Assessment for Concurrent Engineering - (RACE)

Experience has shown that the successful adoption of Concurrent Engineering (CE) or Integrated Product Development (IPD) by an organization requires a phased transformation that inculcates the fundamental principles and practices of CE as well as an enduring commitment to improving all aspects of the organization and its processes.

Assessing an organization's readiness to adopt CE is one of the key preliminary steps in CE implementation. CERC has developed an accepted CE readiness assessment procedure to help organizations in adopting CE practices and the supporting collaborative technologies. The procedure will support process improvement using metrics and identify barriers to deploying the collaborative CE enabling technologies.

CE readiness can best be conceptualized in terms of two major components: the product development Process and Technology. The process component encompasses nine major elements such as Customer Focus, Team Formation, Agility, and others. It follows a readiness scale similar to the Software Engineering Institute's (SEI) Capability Maturity Model. The Technology component covers five areas (application tools, communication, coordination, and information sharing services, and integration). For each critical element a set of key criteria, maturity stage definitions, issues to be addressed, and metrics to be tracked have been identified.

Readiness Assessment Diagram



CERC has applied this method called RACE (Readiness Assessment for Concurrent Engineering) to assist a number of organizations. The method employs a questionnaire for assessing the readiness of an organization to adopt CE. The results of this assessment, when combined with interviews with executives and managers, provides an excellent basis for developing CE implementation plans in organizations.

§ CERC Testbed

The CERC Testbed facility is dedicated to prototyping, evaluating, and demonstrating integrated, distributed systems designed to support collaboration in specific application domains. We support research and development of solutions to both general and specific systems integration problems.

Scenarios

The Testbed team has broad experience in the implementation of example solutions based on real-world scenarios. We have developed complex scenarios which demonstrate the application of concurrent engineering principles and technologies to both mechanical and electrical design and manufacturing. During 1994 we focused primarily on creating systems which support collaborative health care delivery.

Tools for integration

The CERC Testbed maintains an environment which supports experiments in systems integration. This includes a variety of networked computers running most major operating systems. Several of these machines are equipped to support multimedia applications including video digitizing and compression. We employ a variety of commercial software such as computer-aided design tools, commercial databases, document processors, and spreadsheets. In addition, we develop custom "wrappers" for domain and tool specific integration solutions.

Demonstrations

A primary mission of the Testbed is to promulgate emerging collaboration technologies. Our proven approach is through live demonstrations of integrated systems based on real-world scenarios. Visitors have the opportunity to observe cutting-edge approaches designed to support familiar processes. Our facility is not only a research laboratory, but is also equipped with modern presentation equipment. Throughout the year, we conduct demonstrations for groups of visitors from academia, government agencies and national laboratories, and the health care, manufacturing and consulting industries. We also travel to a variety of state, national, and international meetings to conduct remote demonstrations of collaboration technologies.

§ CERC Facilities

Space

CERC is housed in approximately 40,000 square feet of state-of-the-art space, containing offices, laboratories, conference rooms, and supporting space, on the first five floors of Concurrent Engineering Research Center building located at 886 Chestnut Ridge Road, Morgantown, WV. This building was extensively remodeled during 1990-1992, with CERC's occupancy of the building beginning June, 1992.

Satellite Uplink and Distance Learning Facility

CERC has a Ku-band satellite earth station which provides uplinking and downlinking capabilities. The facility has been used televise courses on CE technologies as well as to support the uplinking requirements of several WVU groups for both informational and educational activities. Recently the facility was connected to the WVU fiber system to provide remote access from other WVU buildings. An upgrade to provide redundancy to the system is planned for the future.

Computing Infrastructure

CERC's computing environment consists of approximately 80 Unix based workstations and servers and 50 Macintosh and IBM compatible PCs. This infrastructure was improved during the past year by:

- connection to the WVU fiber backbone WINnet which allows for higher communications rates to WVU and WVNET;
- connection of a dedicated communications link to the NASA IV&V research facility in Fairmont, WV; and
- the additional of several new workstations.

§ People

The CERC team comprises 28 full-time staff, 6 faculty, 31 graduate research assistants and 6 part-time staff. Academic qualifications and area of work for key staff are as follows (in alphabetical order):

• George Almasi - Member of Technical Staff

Academic Qualifications:	MS Computer Science, West Virginia University, 93
	MS / EE, Cluj Technical University (Romania), 91
Current Research Area:	Health care informatics
Research Interest:	Inter-operability, Object-Oriented Programming

• Alan Butcher -- Assistant Director, Computing Services

Academic Qualifications:	MS Computer Science, West Virginia University, 83
Area of Work:	Computer Systems Administration
Research interest:	Simulation, Graphics

• John R. Callahan - Asst. Prof., Computer Science

Academic qualifications:	Ph.D. Computer Science, University of Maryland
Current Research Area:	Working on research in independent verification and validation of computer software.

• Mary Carriger -Coordinator of External Relations

Academic qualifications:	MA English, West Virginia University
Area of work:	Coordinates and researches present and future efforts/tasks through active interface with industrial and academic affiliates. Oversees the publication and distribution of all organizational literature and technical writings and coordinates other technical services for the external concurrent engineering community, including on-line services and workshops.

• K. J. Cleetus - Associate Director

Academic qualifications:	Ph.D. Physics, Massachusetts Institute of Technology
Current Research Area:	Enhance collaboration in virtual CE teams: Cooperate and View (precursors of MONET) to exchange graphics and text among knowledge workers, project coordination services to support product development, and communication services. He is currently the principal investigator for a project to infuse CE in the working of a federal laboratory.
Research Interest:	CERES-GKN is another project in which he hopes to contribute in the future.

• Tad Davis - Member of Technical Staff

Academic Qualifications:	MS Computer Science, West Virginia University, 93
Current Research Area:	Health care informatics, Mosaic
Research Interest:	Information Sharing, AI, User Interface

• William B Duff, Jr. - Producer/Director

Academic Qualifications:	3.5 yrs. college, working on BORBA Degree
Area of Work:	Doing videos for CERC, NTU class in the spring, various technical downlinks, animations for CERC, satellite transmissions for agriculture in the Mountain State, and various WVU broadcasts.

• Matthew Fuchs - Member of Technical Staff

Academic qualifications:	Ph.D. Computer Science, New York University 95, (expected)
Current Research Area:	Developing an intelligent network browser which will use SGML to support the development of active, self-routing documents to be used in several application areas.
Research interest:	Mobile distributed computing, distributed multi-user interfaces, and platform independent user interfaces.

• V. Jagannathan - Associate Professor, Computer Sciences

Academic qualifications:	Ph.D. Electrical Engg., Vanderbilt University, 81
Current Research Area:	collaboration technology for health care, intelligent agent architectures, Internet, information sharing, mobile computing.

• Anagha Karandikar - Interim Assistant Director, Operations

Academic qualifications:	MBA University of South Carolina, 89
Area of work:	Manages financial and administrative operations of CERC, sets policy, ensures compliance with all federal and WVU rules and regulations on grants, contracts and other operations.

• Srinivas Kankanahalli - Asst. Prof., Computer Science

Academic qualifications:	Ph.D. Computer Science, New Mexico State University, 91.
Current Research Area:	Multimedia, Collaborative Environments, parallel and distributed computing.

• Raghu Karinthi - Asst. Prof., Computer Science

Academic qualifications:	Ph.D. Computer Science, University of Maryland, College Park, 90
Research Interests:	Computer Graphics, Multimedia, Collaborative Environments

• Shiye Qiu - Associate Member of Technical Staff

Academic qualifications:	MS Math & CS, both from West Virginia University,
Current research area:	Distributed multi-media file archiving system and its graphical user interfaces.
Research interest:	Multi-media database, distributed computing, Internet technologies, graphical user interfaces.

• Ravi S. Raman - Member of Technical Staff

Academic qualifications:	MBA, MS Computer Science, MS /EE, West Virginia University
Current Research Area:	Multimedia user interfaces to support collaboration among health care providers in distributed clinics

Research Interests:	Applications and technologies to enable electronic transactions from distributed locations via communication protocols, electronic information interchange, data encryption and authentication.

• Ramana Reddy - Director, Professor - Computer Sciences

Academic qualifications:	Ph.D. Industrial Engineering, West Virginia University
Current Research Area:	Design for Environment, multimedia conferencing, mobile computing, health care informatics, AI in collaborative design, intelligent simulation.

• Sumitra Reddy - Research Associate Professor

Academic qualifications:	Ph.D. Physics, West Virginia University
Current research area:	Evaluation and effectiveness of Collaborative software in rural clinics
Research interest:	Collaborative software development, health care informatics.

• Robert R. Shank - Member of Technical Staff

Academic qualifications:	MS Computer Science, West Virginia University
Current research interest:	Systems integration and networking for health care delivery, user interfaces, and real-time multimedia. Manages CERC Testbed.

• Wu Wen - Member of Technical Staff

Academic qualifications:	D.Phil., Oxford University, 92
Current research area:	Wireless communication, mobile computing
Research interest:	Quality of Service(QoS) through open distributed processing.

• Bin Zhou - Associate Member of Technical Staff

Academic qualifications:	MS, Computer science, West Virginia University, 94
Current research area:	Health care informatics, multimedia
Research interest	Multimedia conferencing, object oriented methodology.

§ Library and Technical Services

CERC maintains a technical library of concurrent engineering and information technology literature. Materials include almost 700 reference books and textbooks, nearly 700 technical papers, contract deliverables, computer hardware and software manuals, and periodicals.

In addition to its physical library, CERC also maintains a "virtual" library -- an electronic repository containing many of CERC's technical reports, CERC's public domain software, organizational information, technical abstracts, and other information. Currently, Internet users can access these documents through the World Wide Web, Gopher, and anonymous ftp.

To further its mission of advancing information technologies, CERC hosts an annual "Workshop on Enabling Technologies: Infrastructure for Collaborative Enterprises," sponsored by the Institute of Electrical and Electronics Engineers (IEEE) Computer Society and with support and cooperation from the American Association for Artificial Intelligence (AAAI) and the Association for Computing Machinery (ACM). The workshop features presentations from top researchers in the field, as well working groups that address current topics; the proceedings are published by IEEE Computer Society Press.

§ Recent Publications

<u>Journal Papers</u>

X
- "A Parallel Algorithm for Computing Polygon Set Operations", R. Karinthi, K. Srinivas and G. Almasi, to be published in the Journal of Parallel and Distributed Computing in 1995.

- "Computer Support for Collaborative Work", R. Reddy, R. Karinthi, V. Jagannathan, and K. Srinivas, Guest Editorial, Volume 3, Number 2, International Journal of Intelligent and Cooperative Information Systems (IJICIS), June 1994.

- "Model Based Information Access", V. Jagannathan, R. Karinthi, G. Almasi, and M. Sobolewski, Volume 3, Number 2, International Journal of Intelligent and Cooperative Information Systems (IJICIS), June 1994.

<u>Conference Papers</u>

- Callahan, J. and G. Sabolish, A Process Improvement Model for Software Verification and Validation, in Proceedings of the 19th Annual Software Engineering Workshop, NASA Goddard Space Flight Center, Greenbelt, MD, November 30-December 1, 1994.

- Callahan, J. and J. Morrison, Use of SCR Techniques in Software Verification and Validation, 4th Annual Software Cost Reduction Project Workshop, Naval Research Laboratory, Washington, DC., November 28-29, 1994.

- "Applications of Mosaic in Health Care Delivery" K. Srinivas, K. Gopinath, V. Jagannathan, R. Karinthi, Matthew Fuchs, Y. V. Reddy, George Almasi and Tad Davis, Proceedings of the WWW Conference, Chicago, IL, October 17-20, 1994.

- Callahan, J., R. Wood, T. Zhou, Software Risk Management Through Independent Verification and Validation, in Proceedings of the 4th

International Conference on Software Quality, American Society for Quality Control, McLean, VA, October 3-5, 1994.

- "CE: The Disposal Perspective" K.J. Cleetus, Sixth International Conference on Design Theory and Methodology, ASME, Minneapolis, MN, Sep 12-14, 1994.

- "An Algorithm for Retrieval of Integrated Information" G. Almasi, R. Karinthi and V. Jagannathan, Proceedings of the First International Conference on Concurrent Engineering: Research and Applications, Pittsburgh, PA, August 29-31, 1994.

- "A Collaborative Environment for Independent Software Verification and Validation" R. Karinthi, K. Srinivas, S. Reddy, R. Reddy, C. Cascaval, W. Jackson, S. Venkatraman and H. Zheng, Proceedings of the Third Workshop on Enabling Technologies: Infrastructure for Collaborative Enterprises, Morgantown, West Virginia, April, 1994.

- "A Parallel Algorithm for Computing Polygon Set Operations", R. Karinthi, K. Srinivas and G. Almasi, Proceedings of the International Parallel Processing Symposium, Cancun, Mexico, April 26-29, 1994.

- Callahan, J. and T. Montgomery, A Decentralized Software Bus based on IP Multicasting, 3rd Annual Workshop on Enabling Technologies in Collaborative Environments, April 1994.

- "Architectural Alternatives for Community Care Networks" Proc. 3rd Workshop on Enabling Technologies: Infrastructure for Collaborative Enterprise. p 42-47, 1994 by V. Jagannathan, C. Gollapudy, R. Karinthi, K Srinivas, R. Reddy, S. Reddy

- "Functional Specifications for Collaboration Services" G. Almasi, A. Babadi, W. Brandt, A. Butcher, J.R. Callahan, K.J. Cleetus, M.E. Fotta, C. Gollapudy, N. Gradetsky, S. Iyer, V. Jagannathan, R. Karinthi, R.R. Lawson, D.M. Nichols, R.S. Raman, R.R. Shank, M. Sobolewski, K. Srinivas, X. Zhang. Proceedings of the Third Workshop on Enabling Technologies: Infrastructure for Collaborative Enterprises, April 1994. IEEE Computer Society Press.

- "Modeling Evolving Product Data for Concurrent Engineering" K.J. Cleetus, Seventh Annual Engineering Data Base Symposium, ASME, San Diego CA, Aug. 9-11, 1993.

- "CE: The Disposal Perspective" K.J. Cleetus, Sixth International Conference on Design Theory and Methodology, ASME, Minneapolis, MN, Sep 12-14, 1994.

Book Chapters

- "Accurate Z-Buffer Rendering", R. Karinthi, in "Graphics Gems V" Academic Press, to be published in 1995.

- "Evaluating Product Machinability for Concurrent Engineering", Dana Nau, Guangming Zhang, Satyandra Gupta, and R. Karinthi, in "Concurrent Engineering : Contemporary Issues and Modern Design Tools" Chapman and Hall, 1993.

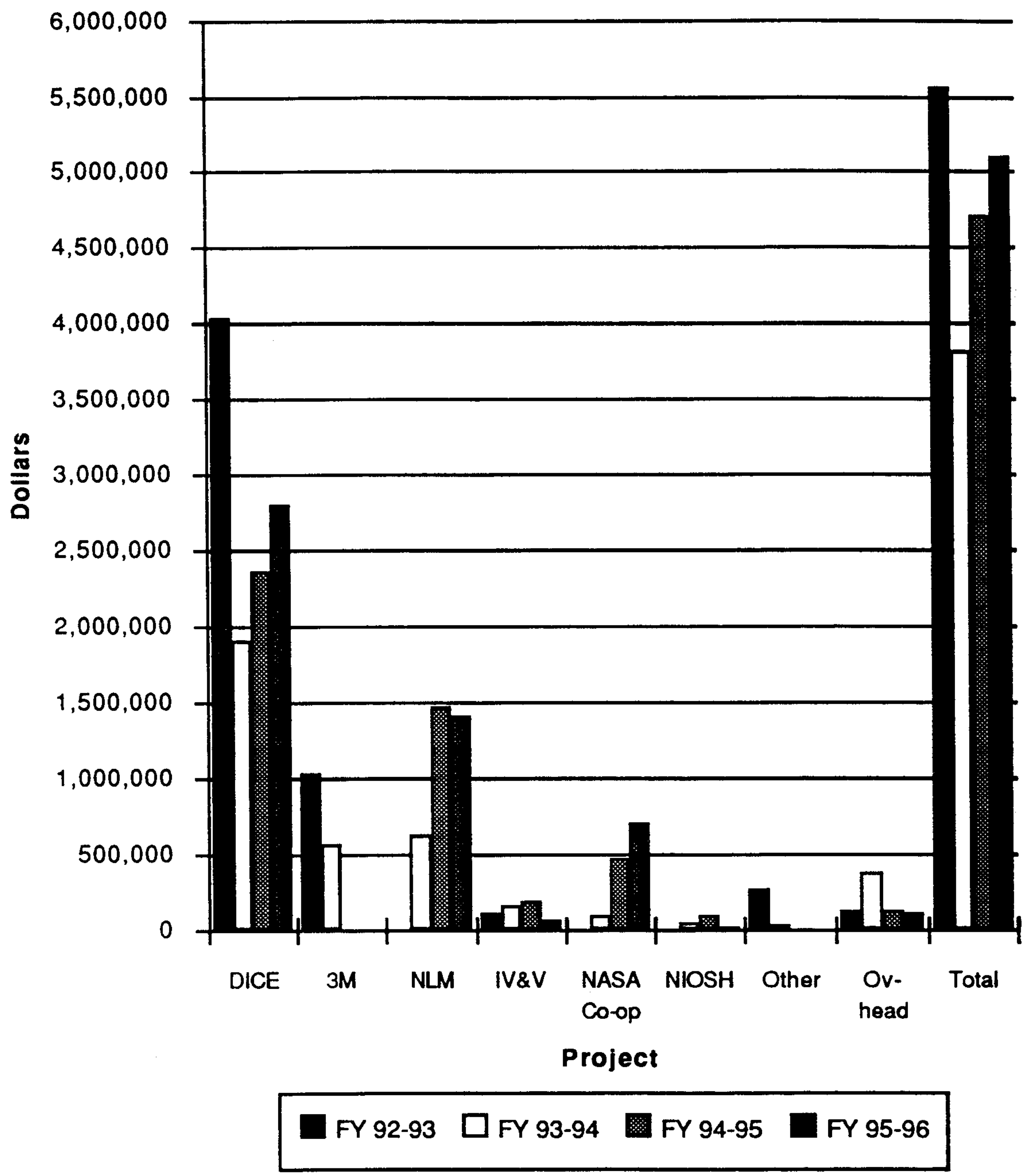
§ Financial Information

CERC operates on an annual budget of approximately US$5 million, 98% of which is through grants and contracts funded by the federal government and private agencies. The following is a detailed look at sources of and applications of revenue for the previous two and next two fiscal years.

Budget Summary: Fiscal Years '93 - '96

	FY 92-93	FY 93-94	FY 94-95	FY 95-96
Revenue Sources				
DICE Grant	4,032,643	1,914,024	2,369,809	2,793,731
3M Contract	1,038,972	556,755	0	0
NLM Contract	0	623,469	1,472,515	1,406,517
NASA IV&V Grant	102,923	154,385	185,262	69,473
NASA IV&V Co-op Agreement	0	93,325	475,304	699,265
NIOSH Grant	0	52,728	96,658	23,208
Other Contracts (TRW etc.)	264,221	38,562	0	0
Overhead	117,520	381,738	117,636	115,770
	5,556,279	3,814,986	4,717,184	5,107,964
Expenditures				
Salaries	2,069,281	1,361,973	1,553,964	1,902,824
Graduate Assistants	314,711	196,423	326,423	383,446
Fringe Benefits	379,691	395,836	443,751	551,819
Travel	108,456	61,040	129,144	130,749
Communications/Software	71,329	63,356	209,053	160,250
Equipment	484,524	107,777	497,378	280,770
General Expenses	50,888	28,878	55,948	49,846
Maintenance	89,571	66,217	97,635	73,287
Repairs & Alterations	42,468	3,357	5,203	1,500
Indirect Cost	1,356,802	955,169	1,167,735	1,297,555
Subcontracts	586,255	251,022	203,000	253,419
NMT/Transfers	2,303	323,938	27,950	22,500
	5,556,279	3,814,986	4,717,184	5,107,964

CERC Revenues by Project by Fiscal Year



§ Vision for the Future

The Collaboration Environment

Computers and communication networks form the substrate of technology to create a new kind of cooperative environment. However there are many advances in computer communications that have been spurred by the requirements of virtual team working-- transparency in access to programs and people on the network is an important theme. The early attempts at using networks to improve the communication among team members utilized special equipment and the facilities installed in a separate room. Advances in communications and computer hardware have now made it possible to satisfy the special requirements of multi-media team communication without leaving the accustomed workplace of the employee. Today it is possible to think of a team being brought together on the network and sharing distributed data and having group transactions like meetings, notifications, scheduling of work, propagation of results, and so forth, being conducted entirely via the network with the aid of some CE services. This constitutes the Virtual Team.

The Virtual Team consists of team members in different perspectives of the product development, wielding powerful CAD tools in their private workspace, but publishing their results to a shared information base. Besides, an overarching coordination service exists to schedule work, report progress, notify persons, generate work authorizations, and carry out entire suites of coordinated processes among multiple perspectives, without the benefit of face-to-face meetings.

The combination of computers and telecommunication networks has inspired a new class of computer applications that emphasize the kind of coordinated team work that lies at the heart of Concurrent Engineering. These applications focus on supporting groups of people who work together and use their computers primarily as tools to mediate their interaction in problem-solving. Programmers building such applications find themselves faced with a host of new requirements; since many of these are generic in nature it is natural to define and construct the basic building blocks using which solutions may be developed quicker. In this paper we review the need for a comprehensive set of such services, useful for building work group solutions.

New Requirements

Collaboration brings new requirements to conventional computer services. Not only must the Operating System (OS) of a computer provide a substrate of communication with other computers, but now there should be distributed information that keeps every computer informed about who is where and using what kind of computer and communication protocol so that the user need not bother -- for the user the remote will look local. Data bases need to be based on models of information that show the ownership and interest profiles of the people who will use the data. These information models should accommodate the diversity of proprietary formats in which the actual data are kept and their distribution over several computers. User interfaces must support client-server distribution of computing processes, and have elements that enable collaborating programs in different computers to address and adjust to the characteristics of different screens and devices. Project management once took place by a single manager receiving schedule and task information from each member manually and publishing a time line at periodic intervals; now it must happen entirely over the network; schedules and tasks must get assigned and reported automatically so that progress is visible all the time to everyone who needs to know.

Library of Reusable Services

Can such a great realignment in computer processing take place without starting anew and rebuilding every computer application from scratch to be collaboration aware? The answer is a hope-filled 'yes'. CERC's Vision is that, if a certain number of new computer services are built around the paradigm of collaboration and made available to application developers (and some to end users directly), then a new wave of collaborative applications can be designed having all the desired features of collaboration, with very little new code to be written for each application.

The thesis is that the specific collaboration aspect of applications can be expressed in terms of a relatively 'small' library of services. Therefore, whether the collaborative application is for medicine or for engineering, the same library will serve. If crafted right, the same library may even serve for different species of computers -- we are not sure yet, but there is hope that the diversity of computer platforms need not pose a special difficulty, if some base-level standards are adopted.

Reuse is a very high motivator for CERC's work. When the program of developing the comprehensive collection of reusable collaboration services has been achieved, there will be a significant reduction of effort for the community of application developers. While CERC takes up the challenge of gradually building up this library, we encourage everyone else to contribute to this effort also, and expand its scope.

Organization of the Services

This library of services can be organized around the important entities for collaboration and coordination of work in single organizations, or among several enterprises:

TEAMS or GROUPS

The structure, identity and roles of the participants and the actions by which they are formed, dissolved, and operated. Forms of group working for ad hoc task forces. Specific services for group meetings and conferences.

WORK PROCESSES

The practices of the company in various departments, placed in a repository and reused repetitively in fragments. Additional support for the use of ad hoc processes exploiting informal relationships and connections to solve the problem at hand.

INFORMATION MANAGEMENT (including USER INTERFACES)

The actions by which the data necessary to arrive at decisions in any field may be modeled, and instantiated repetitively, so as to record and process the transactions of collaboration. A host of data manipulation services for rich data types.

INFRASTRUCTURE SUPPORT

The base level of connectivity and protocols for transporting data between computers with flexibility, efficiency, inter-operability, and location transparency. Managing data exchange with full trust, security and controlled access.