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CRADA FINAL REPORT for CRADA Number C/ORNL 94-MULTI-AMP-0318 United States Automotive Materials Partnership (USAMP)

RAPID TOOLING FOR FUNCTIONAL PROTOTYPING OF METAL MOLD PROCESSES

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ABSTRACT

CRADA No. ORNL 94-MULTI-AMP-0318
United States Automotive Materials Partnership (USAMP)

RAPID TOOLING FOR FUNCTIONAL PROTOTYPING OF METAL MOLD PROCESSES

Abstract

The overall scope of this endeavor was to develop an integrated computer system, running on a network of heterogeneous computers, that would allow the rapid development of tool designs, and then use process models to determine whether the initial tooling would have characteristics which produce the prototype parts.

The major thrust of this program for ORNL was the definition of the requirements for the development of the integrated die design system with the functional purpose to link part design, tool design, and component fabrication through a seamless software environment. The principal product would be a system control program that would coordinate the various application programs and implement the data transfer so that any networked workstation would be useable. The overall system control architecture was to be required to easily facilitate any changes, upgrades, or replacements of the model from either the manufacturing end or the design criteria standpoint. The initial design of such a program will be described below in the section labeled "Control Program Design."

A critical aspect of this research was the design of the system flow chart showing the exact system components and the data to be transferred. All of the major system components (e.g., solids modeler, mesh generator, product simulation module, process simulation module, etc.) would have been configured to ensure data file compatibility and transferability (unambiguous electronic transfer) across the Internet. The intent was to use commercially available packages (for FEA, flow analysis, etc.) to model the various manufacturing processes for creating the die and die inserts in addition to modeling the processes for which these parts were to be used. In order to meet all of these requirements, investigative research was conducted to determine the system flow features and software components within the various organizations (GM, Ford, Chrysler) contributing to this project. This research is summarized in the following report.

Objectives

The objective of the ORNL portion of this project was to produce a package that would provide a seamless transfer of data between different applications using commercially available analyses packages (for FEA, flow analysis, etc.). This system control program package would have coordinated the various application programs and facilitated data transfer on any networked workstation involved in the rapid tooling prototype design and implementation process. ORNL was to design the system flow chart, showing the exact system components and the data to be transferred, and document the functions to be performed by the system control programs. All of the major system components (solids modeler, mesh generator, product simulation module, process simulation module, Y) were to be tested for compatibility and functionality on multiple platforms by using internet file transfer. This task would have verified that all of the major system components could work together using a minimal set of file formats for data exchange. Subsequently, an expert system (or neural network) was to be acquired to interpret the outcome on the product and process simulation modules. Finally, visualization tools were to be chosen for displaying the output of the simulation modules. This task would have required developing the required interfaces and testing the functionality of all of the components in the design methodology on multiple platform environments using internet file transfer. Follow-on efforts in subsequent years would have been focused on applying this seamless control package to the specific technology area down selected at the end of the first year of this program for demonstration of the rapid prototyping concept specifically for the metal mold application.

Discussion of the Status of the CRADA Objectives

Due to a realignment of project priorities by the industrial review committee and the need to focus funding resources on the manufacturing side of this program, this portion (ORNL goals) of the overall CRADA was terminated prior to the completion of the objectives stated above.

Discussion of Research Efforts Prior to Project Cancellation

Control Program Design

In order to minimize the amount of time required to produce a die for a particular automotive product, it would be best if all of the participating engineers involved in component design through die fabrication could sit down in one room until the part and die design were final. Any modifications to the part design due to die casting constraints would be immediately known to the product engineer, and changes could be made. Unfortunately, this situation is rarely possible. The various engineers may be at different locations in a large facility, or may even be in different states. Modifications are made by the time-consuming and expensive process of sending design plans between the interested parties and arranging meetings for all involved. The need for a control program arises from a desire to eliminate these delays.

From the start, it was decided that the system needed to be both collaborative and distributed. It was collaborative in the sense that an engineer should be able to readily share his or her design with colleagues, and that the results of an analysis of a design should be immediately available to all of those colleagues. It was distributed in the sense that each engineer was assumed to have access to a Unix workstation, and that the various software components in an analysis might run on distributed machines, with the results made available to all of the engineers, no matter where they were located.

To accomplish these goals, roughly 5000 lines of code were written. This code is laid out in two basic pieces - a client code and a server code. Both pieces run on all of the workstations involved. The client code presents the user with an interface and is responsible for initiating all of the communication with other users. The server code is a daemon process - running in the background - that receives communications from clients and makes any transferred data available to the client on the same machine.

What follows is a description of the functions performed by these two codes. The interface to these functions was planned to be graphical, based on the industry-standard Motif development system.

1. User and machine registration

Users of the system must register with the system so that when data is made available to all users, the system will know who should be notified. This registration is accomplished by maintaining a file that notes the name, machine address, and program list for each authorized user. The program list is a list of those software components that are available to be run on the indicated machine. When a job is run, the system would be able to access the registration file to determine where a particular step in the analysis could be run.

This file is maintained by all machines that are registered, and is tagged by a version number that is incremented whenever a user is added or removed. Whenever a user starts the client code, it sends a request to all of the machines listed in its registration file asking for the version number of their registration file. The registration file with the latest version number is then propagated to all users on the system, thus ensuring that each user has the most recent list. The server code is responsible for responding to these requests and for receiving and storing the new registration file if necessary.

2. File sharing

The system was designed to share files of any type, not just particular design formats. It does this by maintaining two directory files in a manner very similar to that described above for the registration file. These two files are called the "current parts list" and the "archive parts list." They have the same format and are maintained on every authorized machine. As with the registration file, they contain a version number and all users are ensured of having the latest version.

The current parts list contains a list of the latest versions of the "parts" that are currently in the system. (These are called parts simply because this application is designed for the automotive industry, which is making auto parts. The same technique could apply to any sort of information.) The information supplied for each part includes its title, its current location, and a description. The archive parts list contains older versions of the same parts. This is useful whenever an analysis shows that the design process should revert to an earlier stage and go off in a different direction.

The part is considered to be composed of a single file. (This limitation could be easily removed.) Unlike the part lists, the actual part file is not stored on every machine. Rather, it is stored on whichever machine made the last permanent change. When a designer creates a file, it is stored on his or her machine and the current parts list is modified to indicate the new part's location. When some other designer needs the part, a copy is transferred to the remote machine, but the official version remains on the originator's machine. If the second designer makes a change which is approved by the others, then that copy of the part file gets the official status.

The following basic functions are provided.

Submit design file to network
Retrieve design file from network
Restore design file from earlier version
Show current design files
Show previous design files

3. Job description

To initiate an analysis of a design, it is necessary to define a job by specifying the programs that should be run. The following functions were being implemented when this program was canceled, so currently the only code in place is that used to define the sequence of programs.

Define a job (done)
Get job status
Submit a job
Cancel a job
Retrieve output from a job

Once all of these functions were available, the system would consist of a communications framework that could share data and analyses among any number of users. It is important to realize that this framework does not dictate the type of data that may be transferred between users on different workstations or between different applications. We are assuming, for the purposes of this project, that the separate applications will be able to communicate via common data formats. This will in the beginning limit the number of applications that can be included in the system. However, as standardization of interchange formats occurs, we will be able to plug more applications into this system without modifying the basic framework.

Status of Current Industry Software

At the November 1995 meeting of the project participants, the ORNL presentation requested more guidance and direction for determining the software components that should be a part of the overall system. It was decided that the ORNL staff should meet with the appropriate industry staff to determine how they might best meet their needs.

Towards this end, a meeting was held on Tuesday, November 7, 1995 at the Saturn facility in Spring Hill, Tennessee. Attendees at the meeting, which was held from 9:00 - 11:30 CST, were Michael Bjerke, ORNL; Bob Uhrman, Saturn die cast engineer; Bob Bishop, Saturn product engineer; and Ken Gardner, Saturn product engineer.

At this meeting, Bob Uhrman and Bob Bishop identified many of the steps in the process of getting a product engineer's design transferred to an actual die cast. The following list is a compilation of those steps.

Finite Element Analysis (FEA) on the part
Coordinate Measuring Machine (CMM) on the part }
Car assembly }
CMM on the steel } all done with CATIA
Postprocess die build }
Postprocess part machining
Thermal analysis of the die
Solidification analysis
Process measurement and control
Accepted design practices
Validation
Powertrain assembly
Tool path
Wall stock evaluation
Engineering change system
Tracking 3-D drawings
Communications in 3-D
Mass analysis

Crash analysis

Most of these steps are currently software-assisted. The main problem they have, however, is that there is little compatibility between the various software packages. For example, if the product is a fairly complicated design, such as a transmission housing, the FEA on the part cannot use the file that is produced by CATIA, the design package used at Saturn. The FEA group is forced to make approximations to the design that will allow their codes to run within reasonable execution times and without discontinuities that would cause the simulation not to converge on a solution. As a result, there is a delay in the analyses and the results are generally just approximations.

Another example of this problem is the communication between product and die cast engineer. The product engineer uses CATIA to design a part, and the result is a 3-D wireframe drawing. He needs to send this part design file to the die cast engineer for evaluation of how well the die cast process will be able to make this part. Unfortunately, many engineers have a hard time visualizing the flow of metal into a part during the casting process from the wireframe drawing. What they really need is a solid shaded-surface representation of the part. CATIA can do that, but only with great difficulty and with certain assumptions made by the modeler on the way the part should look. At that point, the die cast engineer can recommend changes, but they cannot just be made to the 3-D drawing and transmitted back to the designer, because the designer must work with the wireframe version.

In parallel, several technical contacts were made to obtain specific information about software integration efforts within GM, Ford, and Chrysler. These contacts were M. Gopikrishnan ("Gopi") at GM, Nagendra ("Nagi") Palle at Ford, and John Grebetz of Chrysler. Nagi summarized that the issue we were trying to address about seamless integration of software throughout design and fabrication was a major issue within Ford. He, in fact, is one of ten members of a corporate committee called "Computer Technology in Manufacturing Committee" who have traveled to various Ford installations around the world to evaluate the manufacturing environment for ease of data exchange and design integration. The conclusion was that the lack of standardization was a communication problem. As an example he discussed the first step in component design which requires generating a solids model. ARIES is used by Engine Powertrain designers, CV is used by transmission designers, PROENGINEER is used by the Body Designers, and SDRC is chosen by the Electric Car people. So, for this first step in part design, Ford does not have a single solids model generator that can be identified as the single choice for this project (in his opinion) from Ford's standpoint because the people who design the part are not the ones who design the tooling. The Ford designers try to interface with each other through IGES files which are incomplete in terms of lines and surfaces that are transmitted from one software package to another. In this case there is significant human intervention required to make up for the lost information using this data transfer format.

The problem is that each distinct software package typically has its own data input/output format which is not completely compatible with other software packages unless these other programs are produced by the same vendor. To circumvent this problem, Nagi commented that his task team has concluded that the only way to make all of the software compatible and integrate easily is to go to just one software vendor who has all of the modules needed to develop the part design through the die design and fabrication. Ford has just announced that they will be standardizing throughout the corporation by going to the SDRC IDEAS pallette of software programs to accomplish this integration. Nagi also gave a contact, Leslie Schonberg in Ford's Advanced Manufacturing Technology Development Center, who is working on the problem of data exchange from CAD packages because this is such a critical issue as members of this project realize. The approach of software standardization within the corporation is being duplicated within GM and Chrysler in that GM is going with their own subsidiary EDS' line of UNIGRAPHICS packages for standardization while Chrysler is going to use the IBM CATIA line for their work. This information has been confirmed by Gopi of GM and Grebetz of Chrysler.

There appeared to be no common ground for selecting one set of software programs that GM, Ford, and Chrysler use throughout the design to fabrication process that this phase of this project could adopt to demonstrate seamless data transfer that would be beneficial and immediately useable by all three automobile manufactures. However, ORNL staff suggested that the seamless transfer methodology could be demonstrated using a correctly chosen set of software components. As will be discussed in greater detail later, demonstrating the benefit of the International Standard called STEP (to be issued) for unambiguous data transfer, in conjunction with the development of the Control Program, could have been the ideal approach for this integration task since it facilitates vendor independent seamless data transfer.

Discussions with Gopi of GM yielded comparable opinions about the current state of data transfer protocol and the evolution of GM towards one family of software packages under the UNIGRAPHICS name. He did comment that Saturn currently uses CATIA but that corporate guidelines in the future undoubtedly will focus all corporate divisions to standardize to facilitate data exchange. Gopi commented that currently some design engineers use UNIGRAPHICS design tools now but because the information is transferred to other software programs outside of this software line, e.g., to PATRTAN, human intervention is definitely needed to facilitate compatibility. UNIGRAPHICS is working to develop interface programs over the next year so that their software will truly integrate with other software lines pertinent to the auto industry. This is essential since for casting applications, Gopi commented that GM uses the MOLDFLOW analysis package which is not a UNIGRAPHICS product. Demonstration of the Standard for the Exchange of Product Data (STEP) in this program would be beneficial for these types of applications.

COORDINATION OF SYSTEM CONTROL PROGRAM DEVELOPMENT WITH TEAM AND STEP INITIATIVES

The industrial participants were informed in December 1996 that there was the potential to leverage several national and international initiatives and projects currently being worked by ORNL and other Department of Energy (DOE) laboratories to facilitate seamless file transfer. Below is a revised assessment of the original intent of the software integration task cast within the context of current manufacturing information systems research. Also mentioned are the projects that could have been potentially leveraged into a revised list of activities for this task. The unifying technology underlying all of the leveraged activities described below is a robust product definition model stored in STEP. In July 1996, STEP became a Standard of the International Standards Organization (ISO). Many software vendors are adopting STEP.

Based upon this new information, we suggested an altered approach to the software integration task. We met with the project team at the February meeting in Spring Hill, Tennessee, and presented a more detailed description of these findings and suggested a slightly modified direction for the project's future software integration activities. First, we will briefly review the presentation that was made at Saturn (see Appendix A). Then we will discuss the proposal presented for work for the remainder of the project year ending June 1997 prior to notification of the termination of this research effort.

Background and Situation Analysis

Product definition and manufacturing information systems are key elements in the ability of any manufacturing enterprise to respond quickly to unanticipated market demands and evolutionary process improvements. In rapidly changing world markets, agile enterprises must simultaneously minimize costs and maximizing quality and customer satisfaction. A key factor in the ability of a manufacturer to respond "agilely" is the ability to optimize their entire production operation from planning through to shipping including suppliers of key components. Typically, product definition and information management systems are huge investments in software development, acquisition, and training and the result is a hardwired, inflexible system that provides an enormous inertia to change. Often change requires a complete redesign and re-implementation with much useful legacy data and systems being discarded because the new system cannot (or if a different vendor is involved, will not) accommodate them. Clearly this situation is not tolerable in the new domain of agile, global competition and a new approach is required.

Current concepts of agility, as well as new developments in the use of object-oriented information systems technology, suggest that our historical approach to development of manufacturing information systems must be abandoned and replaced with a new paradigm that maximizes process execution flexibility. The integrated information systems of the future that enable a truly agile design and manufacturing environment will be based upon "manufacturing feature-driven" product data models and will serve as flexible analytical tools rather than as rigid dictators of process. In addition to relational databases, product, process, and resource data will reside in a variety of knowledge repositories. These repositories will be well characterized and available to business partners within the context of a "virtual enterprise." A data framework will enable complete data sets to be processed in a single operation, as opposed to the historical single record-at-a-time approach. The result will be the placement of an advanced set of agile analytical tools in the hands of a cross-functional, virtual team comprised of customers, product designers, production planners, and process engineers.

During the great rush toward integration of corporate information systems of the 1980's, significant effort was expended to fully define business processes and their supporting integrated data structures. Relational databases were identified as the key to provide corporate access to information that would provide a competitive advantage. In the haste to model and implement information systems, little distinction was made between "pure" business processes and those that form the product design and production planning cycle. As a result, even though data redundancy was minimized and data integrity was improved, the 1980's manufacturing information systems that were built rigidly encoded business rules for all processes and virtually eliminated any opportunity for flexibility in how processes were executed. Change required by business process re-engineering was even more difficult to promulgate through the enterprise due to these systems.

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Proposed Integration Activities to be Leveraged

There are several funded integration activities which address elements of agile information systems. The following list presents those activities that could be leveraged to benefit this project. ORNL staff participate in each of these activities. A more complete discussion of their inter-relationship will be provided at a later meeting.

National Industrial Information Infrastructure Protocol (NIIIP)

NIIIP is a DoD funded Technology Reinvestment Project. IBM is the lead organization. The NIIIP project intends to develop and deploy the concept of a virtual enterprise by creating a national computer infrastructure. A virtual enterprise is many small companies (or parts of large companies) joining together to work as a single enterprise on a specific project. NIIIP intends to consolidate, rationalize, and integrate a set of standards upon which applications will be built and virtual enterprises will be formed. The NIIIP consortium will incorporate the standards that government and industry have developed for object technology, product data, documents, and computer communications to create a seamless environment for virtual enterprises. This will help to reduce the confusion created by the profusion of standards that currently confronts American industry and consolidate these standards into a cohesive solution that can be used and deployed by the entire computer industry.

Technologies Enabling Agile Manufacturing (TEAM)

TEAM is an industry led consortia of government, academia, and industry developing and deploying agile, pre-competitive technologies via vertically integrated demonstrations. Funding comes from the DOE. Currently, the three planned demonstrations are sheet metal forming, material removal, and electromechanical assembly. TEAM is working a piece of the virtual and distributed enterprise in an agile environment. TEAM has developed a "Product Realization Model" to help explain their activities. TEAM is addressing those parts of the model that are a match with DOE national laboratory capabilities. A technology toolbox is being developed that contains technologies necessary to implement the Product Realization Model. The five thrust areas of TEAM are Enterprise Integration, Virtual Manufacturing, Product Design and

Enterprise Concurrency, Manufacturing Planning and Control, and Intelligent Closed-Loop Processing.

Continuous Acquisition and Life Cycle Support (CALS)

CALS is an industry and government strategy intended to enable the more effective generation, exchange, management, and use of digital data supporting the life cycle of a product, through the use of international standards, business process change, and advanced technology application. The CALS vision is a shared data environment created by applying the best technologies, processes, ad standards for the development, exchange, and use of business and technical information among government and industrial enterprises. Basic CALS provides the ability to exchange digital information in standard formats and the ability to process information in digital form. Data bases are not integrated in basic CALS. Advanced CALS is a project to build upon basic CALS to provide data base integration. Engineering, manufacturing, and logistics data bases are integrated into a single logical data base including appropriate inter communications to provide concurrent engineering throughout a product's life cycle.

Agility Forum's Agile Information Technology Working Group

The Agility Forum, located at Lehigh University, is the Nation's clearing house for information on all aspects of Agile Manufacturing research and application. Its purpose is to assist American organizations to become more competitive in the global marketplace by researching, developing, and disseminating an understanding of "Agility" and facilitating its deployment. With input and support from industry, government, and academia, the forum is the leader in agile research, education, and training. The Agility Forum addresses many of the "soft" issues in the formation of virtual enterprises that are not addressed by the NIIIP.

Manufacturing Exchange Specifications (MES) Project

The object of the MES project is to establish a National Institute of Standards and Technology (NIST) special publication series of information models, interface specifications, and integrated services that, taken together, will enable the creation of integrated distributed manufacturing software systems. This project will prove the viability of its specifications by establishing a reference implementation of an integrated distributed manufacturing software system. The project collaborates closely with partnering organizations (including NIIIP and TEAM) to maximize technical benefit while reducing development overhead.

Systems Integration Architecture (SIA) Project

The SIA Project (led by the Agile Aerospace Manufacturing Research Institute at the University of Texas, Arlington) is based on a new functional model that facilitates higher levels of integration and provides a migration strategy towards self-configuring, self-collecting, and self-organizing systems. This model, simply stated, recognizes that the product realization process consists of a series of transformations of data. The model has its basis in the software engineering and design theory and methodology domain theory. The transformations are effected by functional agents that initially have no intelligence but are structured so that intelligence can be added at a later date. In essence, these intelligent agents provide an integration service in which a specific set of data or information is transformed into the desired result.

Recommendations Made to Industrial Review Committee

ORNL staff recommended that the program continue after slightly recasting the approach into a methodology that would be accepted by the projects that we anticipated leveraging. During our presentation, we described nine steps that should be followed to ensure integration of the project. These steps are listed below:

- *Develop workflow scenario*
- *Create activity diagrams and information model*
- *Perform benchmarks of selected software*
- *Adopt standards-based architecture*
- *Demonstrate interconnected workflow*
- Perform gap analysis
- Develop application framework
- Create missing connections
- Demonstrate integrated workflow

The first five of these steps were proposed for the remainder of the project year ending June 1997.

NADCA/USAMP Response to Recommendations

The Industrial Review Committee considered the ORNL recommendations in the context of the overall program and decided to cancel this aspect of the rapid prototyping project to focus more effort and resources on the manufacturing implementation of the down selected technology to fabricate the metal mold tooling.

Inventions Developed under this Program

No inventions were declared through the limited research efforts on this program.

Commercialization Possibilities

Since this program was canceled prior to completion of the goals of this CRADA, no current commercialization possibilities exist.

Future Plans

None are under consideration at this time.

Conclusions

Although the original intent of developing a package that would provide for seamless transfer of data between different software applications was still deemed desirable within the context of the overall program, the Industrial Review Committee decided that the remaining resources and effort were too limited to provide for this extensive development effort while still having the ability to meet all of the other critical milestones of the CRADA. Therefore, this discrete aspect of the CRADA was canceled to devote the remaining resources to the manufacturing implementation tasks of the rapid tooling prototyping project.

Acknowledgment

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Appendix A

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System Integration Task

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Outline

- Introduction
- Situation Analysis
- Proposed Solution
- Leveraging Opportunities
- System Integration Task Summary
- Discussion

Introduction

- Project Goal
  - ⇨ To reduce the die development time for metal mold processes from twelve months to three months
- System Integration Task
  - ⇨ Seamless connectivity of all software tools from die design to component fabrication simulation

Rapid Tooling for Functional Prototyping of Metal Mold Processes

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Initial Strategy

- Initial Strategy
  - ⇨ Evaluate various stages in tooling design to determine common software packages that are used by all three automotive companies
  - ⇨ Design and implement a single integrated software package to bridge between product design and tool manufacture
- Initial Evaluation
  - ⇨ No single, common software package is used

Rapid Tooling for Functional Prototyping of Metal Mold Processes

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Evaluation

- Automotive companies are standardizing on different commercial software
  - ⇨ GM Unigraphics
  - ⇨ Ford IDEAS
  - ⇨ Chrysler CATIA
- Excellent, but not ideal, solution. Some disadvantages
  - ⇨ Requires company-wide acceptance
  - ⇨ Dependent on one vendor (software/hardware limitations)
  - ⇨ Specialty software (ProCAST) still needs to be interfaced
  - ⇨ Ignores supplier realities

Situation Analysis

- Current product definition and manufacturing information systems are
  - ⇨ huge investments in software, hardware, and training
  - ⇨ typically hardwired, inflexible systems
  - ⇨ demand rigid corporate commitment
  - ⇨ provide enormous inertia to change
- Many manufacturing information systems
  - ⇨ encode business rules for all processes
  - ⇨ eliminate flexibility in how processes are executed
  - ⇨ are obstacles to business process re-engineering

Situation Analysis (Con'd)

- Manufacturing information systems of the future will
  - ⇨ maximize process execution flexibility
  - ⇨ be based on "manufacturing feature-driven" product data models based on the STandard for the Exchange of Product Model Data (STEP)
  - ⇨ use knowledge repositories of product, process, and resource data to simultaneously optimize designs
  - ⇨ participate in virtual enterprises

Rapid Tooling for Functional Prototyping of Metal Mold Processes

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Proposed Solution

- Strongly align with the Technologies Enabling Agile Manufacturing (TEAM) program
  - ⇨ GM and Ford actively participate already
- Use STEP
  - ⇨ GM, Ford, and Chrysler actively participate already
- Use Internet and the World Wide Web
  - ⇨ create an open system architecture and framework
- Integrate the process, not a vendors product
- Maximize leverage of other related activities

Rapid Tooling for Functional Prototyping of Metal Mold Processes

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Leveraging Opportunities

- TEAM, Technologies Enabling Agile Manufacturing
- PDES, Product Data Exchange using STEP
- NIIIP, National Industrial Information Infrastructure Protocols
- NIIT, National Information Infrastructure Testbed
- Agility Forum's Agile Information Technology Initiative
- IMES, Initial Manufacturing Exchange Specifications
- CALS, Commerce At Light Speed

Technologies Enabling Agile Manufacturing (TEAM)

- Industry led consortia of government (DOE, DoD, and NIST), academia, and industry
- Developing and deploying agile, pre-competitive technologies
- Three year project (likely to be extended)
- Five thrust areas working three cross-cutting demonstrations in
  - ⇨ material removal
  - ⇨ metal forming
  - ⇨ electromechanical assembly

TEAM Mission

- TEAM will provide American industry with the critical, enabling technologies needed to implement Agile Manufacturing concepts that will enhance the global competitiveness of US industry and support the evolving weapons missions of the national defense complex.
- TEAM will develop and demonstrate solutions to high priority needs and bring the enabling technologies to the point of commercialization for widespread implementation in both commercial and defense applications.

TEAM Goals

- TEAM will develop, validate, and deploy technologies that enable an information-driven, agile industrial base. Key goals are to
  - ⇨ Integrate design and manufacturing processes to streamline product development, thus reducing costs, enhancing quality, and shortening time-to-market
  - ⇨ Provide robust, flexible, modular tools that are readily accessible and implementable
  - ⇨ Maximize near-term deployment of enabling technologies within the evolving framework of TEAM's long-term vision

TEAM Thrust Areas

- Product Design and Enterprise Concurrency
- Virtual Manufacturing
- Manufacturing Planning and Control
- Intelligent Closed-Loop Processing
- Enterprise Integration
  - ⇨ STEP is a key enabling technology for TEAM
  - ⇨ Product definition is distributed among TEAM Thrust Areas via STEP

Rapid Tooling for Functional Prototyping of Metal Mold Processes

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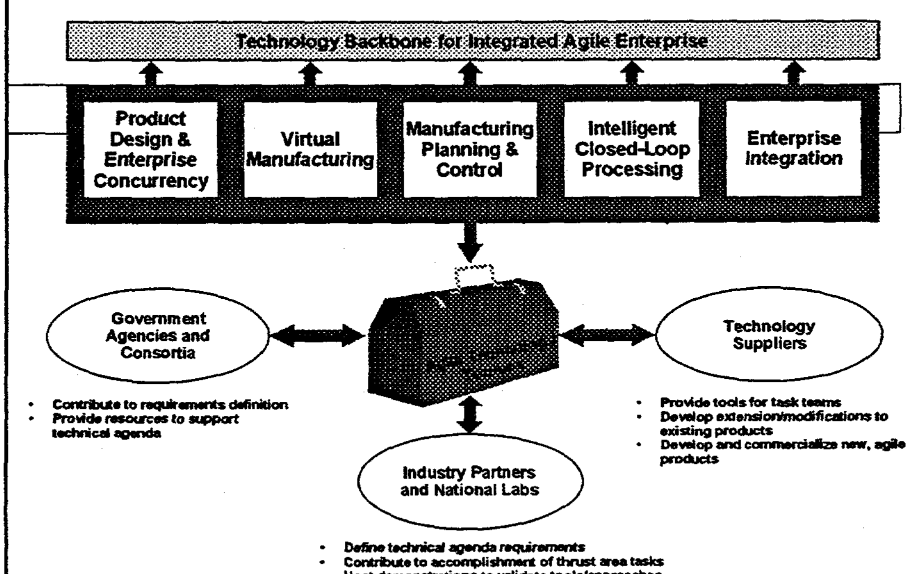
The TEAM Concept



Rapid Tooling for Functional Prototyping of Metal Mold Processes

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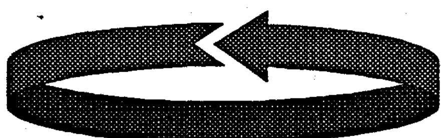
PDES, Inc.

- Purpose
  - ⇨ accelerate the development and implementation of product data exchange using STEP to improve product quality, increase flexibility, reduce product cycle time, and reduce costs
- STEP
  - ⇨ an emerging international standard, ISO 10303, which will provide for the complete, unambiguous, computer-interpretable definition of the physical and functional characteristics of a product throughout its life cycle

Product Data Exchange Using STEP

Product Life Cycle



Product Data

As Defined Configurations	As Planned Configurations	As Built Configurations	As Maintained Configurations

Current Environment

- Digital information is stored in heterogeneous systems
- Transition from one product life cycle to another is often accompanied by a loss of valuable information
- Paper is still common for product information exchange
- Same data may be inconsistent and stored in different places for different purposes
- Technical data packages are often incomplete

PDES 1997 Vision

- STEP will be an international standard
- STEP will be the state-of-practice file exchange mechanism for selected business processes
- Adoption of STEP into new systems procurements
- Emergence of shared database implementations in industry and government
- STEP translators for multiple applications
- Reduced product development time
- Real cost savings for technical data management

Rapid Tooling for Functional Prototyping of Metal Mold Processes

PDES 2000 Vision

- Technology to support integrated product development partnerships
- Shared database implementations
- Emergence of prototype knowledgebase environments
- STEP driven manufacturing will be a practice

National Industrial Information Infrastructure Protocols (NIIIP)

- ARPA Technology Reinvestment Project
- Started in fourth quarter of 1994
- The vision of the NIIIP consortium is to make US industrial enterprises more globally competitive through a new form of collaborative computing that supports the formation of virtual enterprises
- Key technologies include
  - ⇨ STEP (Information)
  - ⇨ Internet (Communication)
  - ⇨ Object Management Group (Object)

NIIIP Objectives

- Establish an open, standards-based software infrastructure protocol that will integrate heterogeneous and distributed computing environments
- Develop and distribute the NIIIP reference architecture, interface specification, and validation suites via public access
- Demonstrate NIIIP via pilot projects
- Commercialize NIIIP components and tools
- Enable incorporation of legacy manufacturing in order to preserve existing investments

National Information Infrastructure Testbed (NIIT)

- Membership includes companies that want to participate in testing to further the emerging national information infrastructure
- Agile Manufacturing is a recently formed working group
  - ⇨ Goal is to test product realization processes over a NII testbed
- Very focused on security issues
- Soliciting proposals for prototype demonstrations

Agility Forum

- Formed in 1991 at Lehigh University
- Nation's resource for information on all aspects of Agile research
- Agile Information Technology working group
  - ⇨ relatively new working group
  - ⇨ research and develop agile information systems
  - ⇨ promote an understanding of agile systems
  - ⇨ facilitate agile systems deployment

Initial Manufacturing Exchange Specifications

- A new National Institute of Standards and Technology (NIST) led project involving TEAM, NIIIP, Sematech, and others
- Objective
  - ⇨ establish a series of information models, interface specifications, and integration services that taken together will enable the creation of integrated, distributed manufacturing software systems.
- EXPRESS, the language of STEP, will be used
- A reference implementation will be built

Commerce At Light Speed (CALS)

- Origins come from the defense industry and the DoD
  - ⇨ initially targeted integrating systems development, production, and support
  - ⇨ now expanded to encompass all aspects of a virtual enterprise
- Basic tenets include
  - ⇨ open systems environments
  - ⇨ early adoption of commercial standards, STEP
  - ⇨ international coordination of standards for data exchange
  - ⇨ electronic commerce

CALS Vision

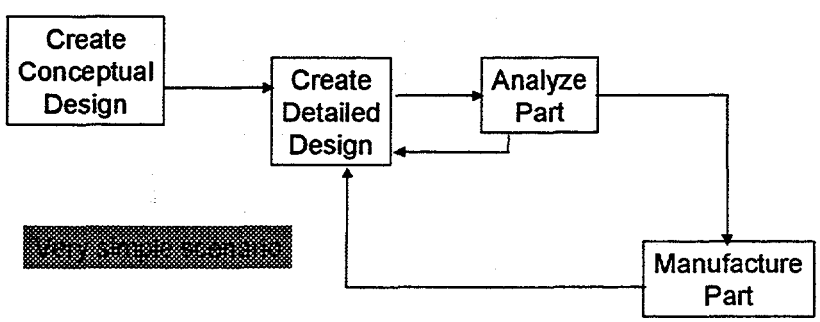
- All or part of a single enterprise (e.g., an original equipment manufacturer and its suppliers, or a consortium of public and private groups and academia) will be able to work from a common digital data base, in real time, on the design, development, manufacturing, distribution, and servicing of products. Direct benefits will come through substantial reductions in product-to-market time and costs, along with significant enhancements in quality and performance.

System Integration Task Summary

- Develop workflow scenario
- Create activity diagrams and information model
- Perform benchmarks of selected software
- Adopt standards-based architecture
- Demonstrate interconnected workflow
- Perform gap analysis
- Develop application framework
- Create missing connections
- Demonstrate integrated workflow

System Integration Task: Develop Workflow Scenario

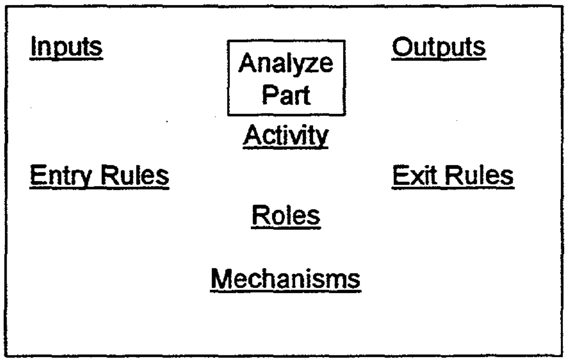
- Profile the activities by producing a "Day-in-the-Life" walk through



Very Simple Scenario

System Integration Task: Create Activity Diagrams

- Document activity details



Activity Diagram

System Integration Task: Perform Benchmarks

- Determine software for each activity
- Verify Inputs and Outputs
- Examine capabilities with respect to standard data formats
- Is STEP an option?
- What other standard technologies can be used?

System Integration Task: Demonstrate Interconnected Workflow

- Prototype entire system
- Interconnected means
  - ⇨ not integrated at this point
  - ⇨ may have redundant data
  - ⇨ may have to enter data twice
- Focus on finding the integration gaps

System Integration Task: The Rest of the Story

- ☑ *Develop workflow scenario*
- ☑ *Create activity diagrams and information model*
- ☑ *Perform benchmarks of selected software*
- ☑ *Adopt standards-based architecture*
- ☑ *Demonstrate interconnected workflow*
- Perform gap analysis
- Develop application framework
- Create missing connections
- Demonstrate integrated workflow

Discussion

- PDES Video
- Suggestions
- Further ideas

Software Integration Task Proposal

- Revisit integration tasks at next meeting in February
- Develop a new integration task plan based on
  - Developing a metal molding product scenario from the previous interviews
  - Leveraging activities with appropriate projects
  - Developing an information model for metal molding
  - Creating a standards-based architecture and application framework for metal molding
- Agree on a phased set of demonstrations to deliver the capability

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Leveraging of Other Integration Activities

- National Industrial Information Infrastructure Protocol
- Technologies Enabling Agile Manufacturing
- Continuous Acquisition and Life Cycle Support
- Agility Forum's Agile Information Technology Group
- Manufacturing Exchange Specifications Project
- Systems Integration Architecture Project

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