Beckermann, C., and Fischer, G.W., "Vehicle and Heavy Equipment Integrated Product and Process Development (IPPD) Technology Development: Casting Process Simulation," in Proceedings of the 47th SFSA Technical and Operating Conference, Paper No. 3.6, Steel Founders' Society of America, Chicago, IL, 1993.

Vehicle and Heavy Equipment

Integrated Product & Process Development (IPPD)

Technology Development:

Casting Process Simulation

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Abstract

An overview is presented of the recently proposed Vehicle and Heavy Equipment Integrated Product and Process Development (IPPD) Technology Development project under the Technology Reinvestment Project (TRP) of ARPA. The goals of the tasks proposed in the manufacturing process simulation area are discussed in detail, with particular emphasis on casting. An important aspect envisioned is the integration of OEM's and suppliers within the IPPD environment. It is hoped that the proposed work will significantly benefit steel foundries, and a close collaboration with the SFSA is planned.

1. SUMMARY OF IPPD PROJECT

The strategic importance of achieving an Integrated Product and Process Development (IPPD) capability for a broad spectrum of commercial and defense products has been acknowledged. Technological and implementation challenges, however, differ greatly in product sectors such as ground vehicles and equipment, aircraft, microelectronics, and ships. This project focuses specifically on vehicles and heavy equipment, the latter defined broadly as "high capacity self propelled machinery used in military, construction, cargo hauling, material handling, agricultural, and related applications." The simulation based design approach proposed for vehicle and heavy equipment IPPD is shown schematically in Figure 1.1, with a summary of its benefits. The technology to be developed will be integrated with currently isolated CAD, CAE, CAM, and simulation tools to create a revolutionary new development process that uses simulation to rapidly carry out design iterations involving all product and process characteristics.

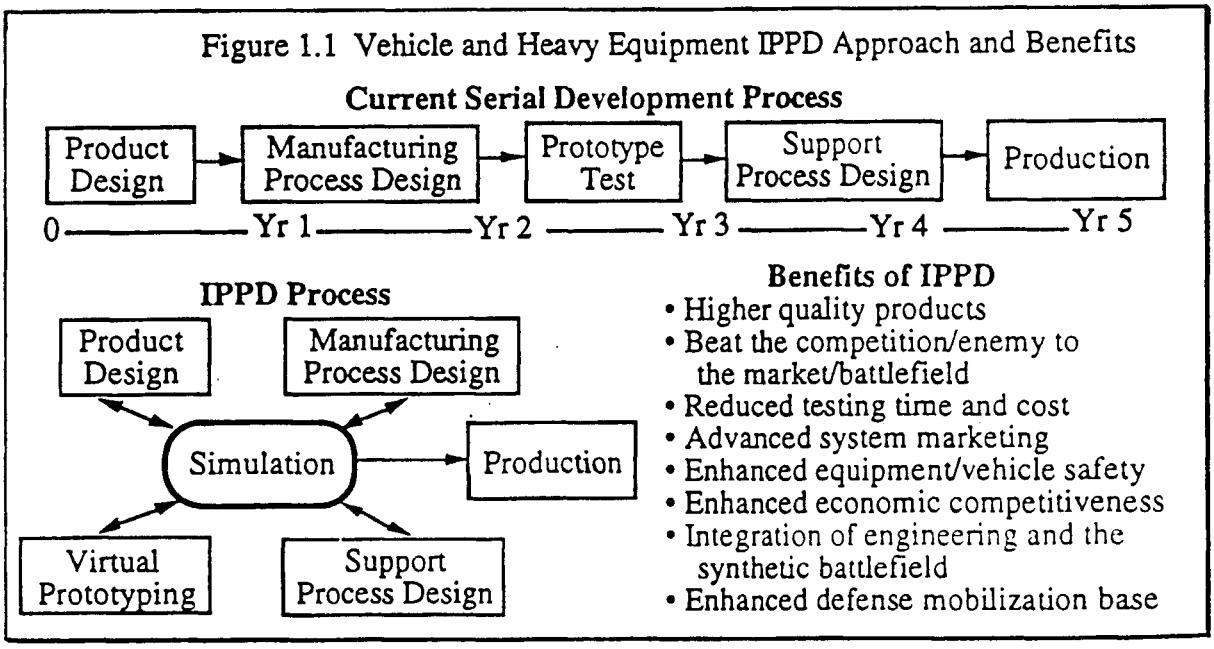

Figure 1.1 Vehicle and Heavy Equipment IPPD Approach and Benefits

Vision

Figure 1.2 Vision for Vehicle and Heavy Equipment IPPD

- Time to Develop and Introduce Products to the Market is Reduced by 50%
- Number of Test Cycles and Testing Cost are Reduced by 75%, Using Simulation
- Total Development Cost is Reduced by 50%
- Operator-Machine Performance Is Optimized, Using Virtual Prototyping
- Advanced Systems are Introduced, Using Customer-in-the-Loop Simulation
- Distributed Interactive Battlefield Simulation and Virtual Prototyping Simulations are Integrated to Develop Operationally Effective Military Vehicles
- IPPD Tools and Technologies are Accessible to Journeyman Engineers
- OEMs and Suppliers are Integrated Throughout the Development Process

Impact

Figure 1.3 Impact of Vehicle and Heavy Equipment IPPD Technology

- Heavy Vehicle and Equipment (HVE) Manufacturers; $44 billion US industry
  * $5.4 billion increase in sales; 12% of current sales
  * $650 million increase in profits; from increased sales and reduced costs
  * 110,000 new jobs; 22,000 direct and 88,000 indirect
  * Survival of small OEMs and suppliers; 4,100 US establishments
  * Pervasive impact on upper Midwest economy; 33% of all such jobs nationally
- Car and Light Truck Manufacturers; $130 billion US industry
  * Reduced test cost and time-to-market; current 60 months to 30 months
  * Enhanced product quality and international competitiveness
  * Recreate jobs lost; numbers comparable to HVE subsector
- Department of Defense
  * Reduced cost of high quality equipment; over 50% reduction in development cost
  * Reduced time to field new systems to meet contingencies; 50% of current cycle
  * Enhancement of defense vehicle and equipment mobilization base

Participants

INDUSTRY

BMY
Computer Aided Design Software, Inc.
CAEtechnology
Caterpillar
Deneb Robotics
Drexel Industries
Engineering Software Research and Development, Inc.
Evans & Sutherland
FMC Ground Systems Division
Ford Motor Company

General Motors
Integrated Systems, Inc.
Center for Nondestructive Evaluation
PDA Engineering
Quantum Consultants, Inc.
Rasna Corporation
Step Tools, Inc.
Steward & Stevenson Services, Inc.
Swanson Analysis Systems, Inc.
Turtle Mountain Manufacturing Co.
Universal Analytics, Inc.

ACADEMIC

The University of Iowa
University of Illinois
University of Michigan
University of Northern Iowa
University of Pennsylvania
Lehigh University
Eastern Iowa Community College District
Kirkwood Community College

GOVERNMENT

Armstrong Laboratory
Rock Island Arsenal
US Army Industrial Engineering Activity
US Army Material Systems Analysis Activity
US Army Tank-Automotive Command
Warner Robins Air Logistics Center
Waterways Experiment Station

Three Associated Proposals

1. Vehicle and Heavy Equipment IPPD Technology Development
2. Iowa Vehicle and Heavy Equipment IPPD Pilot Projects
3. Manufacturing Engineering Training in IPPD

Statement of Work (Headings)

1. Project Management and Infrastructure Support
2. IPPD Tool, Method, and Organization Test & Evaluation
3. Enterprise and Engineering Information Infrastructure Design & Development
4. Concurrent Engineering and Business Planning Tool Development and Integration

5. CAE/CAM Tool Development and Integration
6. Virtual Prototyping Tool Development and Integration
7. Manufacturing Process Simulation Development and Integration
8. Subsystem Model and Simulation Tool Development

2. OVERVIEW OF IPPD TESTBED

The Integrated Product and Manufacturing Process Design (IPPD) Testbed will establish an integrated computer hardware and software environment to evaluate existing mechanical system product and manufacturing process designs and provide simulation-based solutions to fill technology voids that are identified. The IPPD Testbed takes full advantage of software tools developed through on-going ARPA projects and available manufacturing process planning and simulation tools.

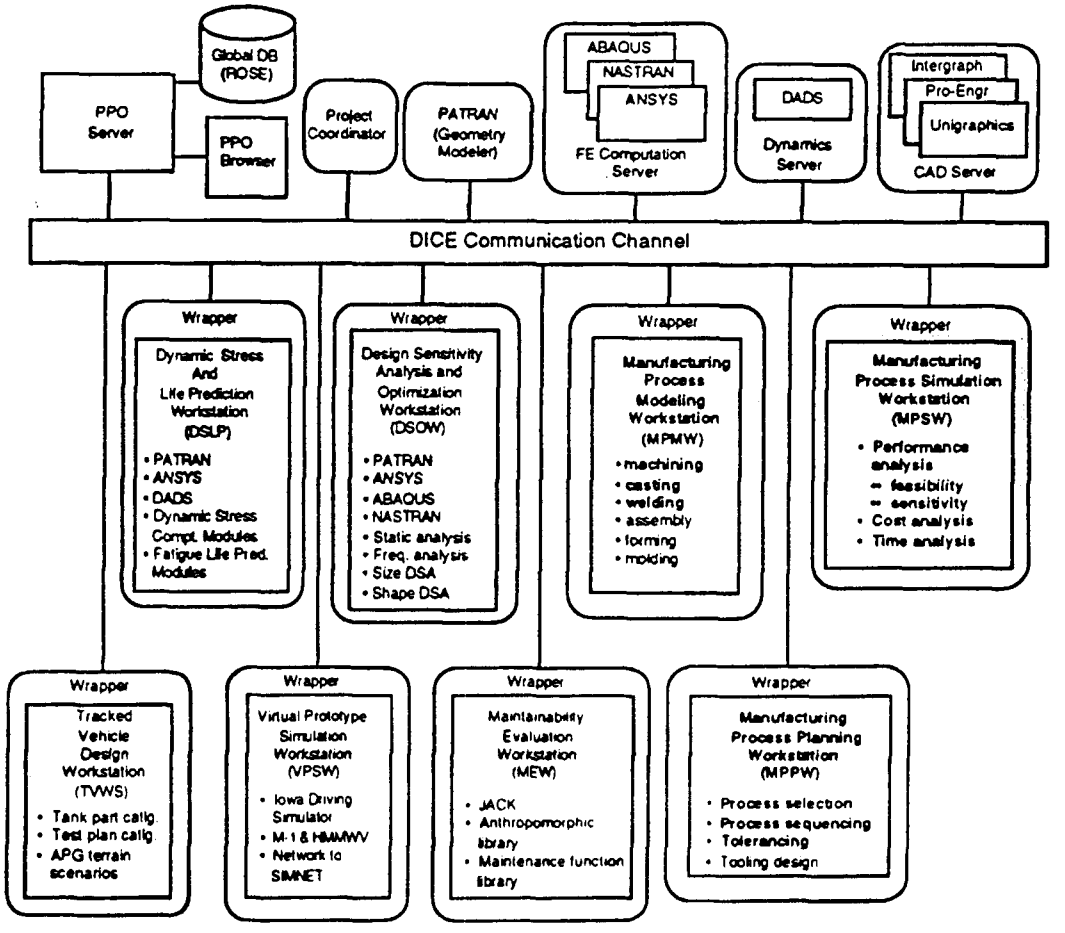

Figure 2.1 Integrated Product and Manufacturing Process Design (IPPD) Testbed

The approach taken follows three guidelines:

* Integrated product and manufacturing process data models will be shared by all parties involved throughout the entire life cycle of a product. The data model will be PDES/STEP-compatible, where possible.

* Networking capabilities will allow remote, instant access of product design models/data and manufacturing process models/data. The structure will baseline an agile design/manufacturing enterprise environment.

* An open system architecture will enable defense and commercial OEM's, OEM suppliers, and technology vendors to enhance their systems and freely share in the results.

The IPPD Testbed (pictured in Figure 2.1) extends the suite of integrated design simulation tools to examine key producibility issues.
The process planning module selects the best process, exercises the selected process model(s), and determines optimal process plan(s). The process modeling module represents the design of the manufacturing processes. The process models use input variable sets to determine the level of performance and quality that can be expected from the selected process. The process simulation module determines estimates of performance for a selected process, performs sensitivity analysis, and determines estimates of production cost and time.

A typical planning exercise starts with the specification of a part design and production requirements. The manufacturing modules of the IPPD Testbed are then used to select the best process(es), evaluate the manufacturability of the design concept for the selected process(es), and plan the manufacturing operations for the part. The IPPD project coordinator accesses databases and passes information and data to each of the appropriate functional modules.

3. CASTING PROCESS SIMULATION
(C. Beckermann and G.W. Fischer, U of Iowa)

Overview

The casting process simulation system is envisioned to consist of several closely linked software tools, as shown in the bold boxes in Figure 3.1. A number of commercial software packages exist for casting design and filling/solidification simulation, which is indicated below the dashed lines. Additional simulation-based tools are for casting tooling development, manufacturability analysis, and production control. All casting simulation tools will be connected to the IPPD communication channel and make use of the CAD/CAE services and the global database. Three organizations, namely the UI, UIUC, and UNI, are participating in the casting process simulation tool development. Their proposed tasks are identified in Fig. 3.1, with the arrows showing the connections to the overall tool structure.

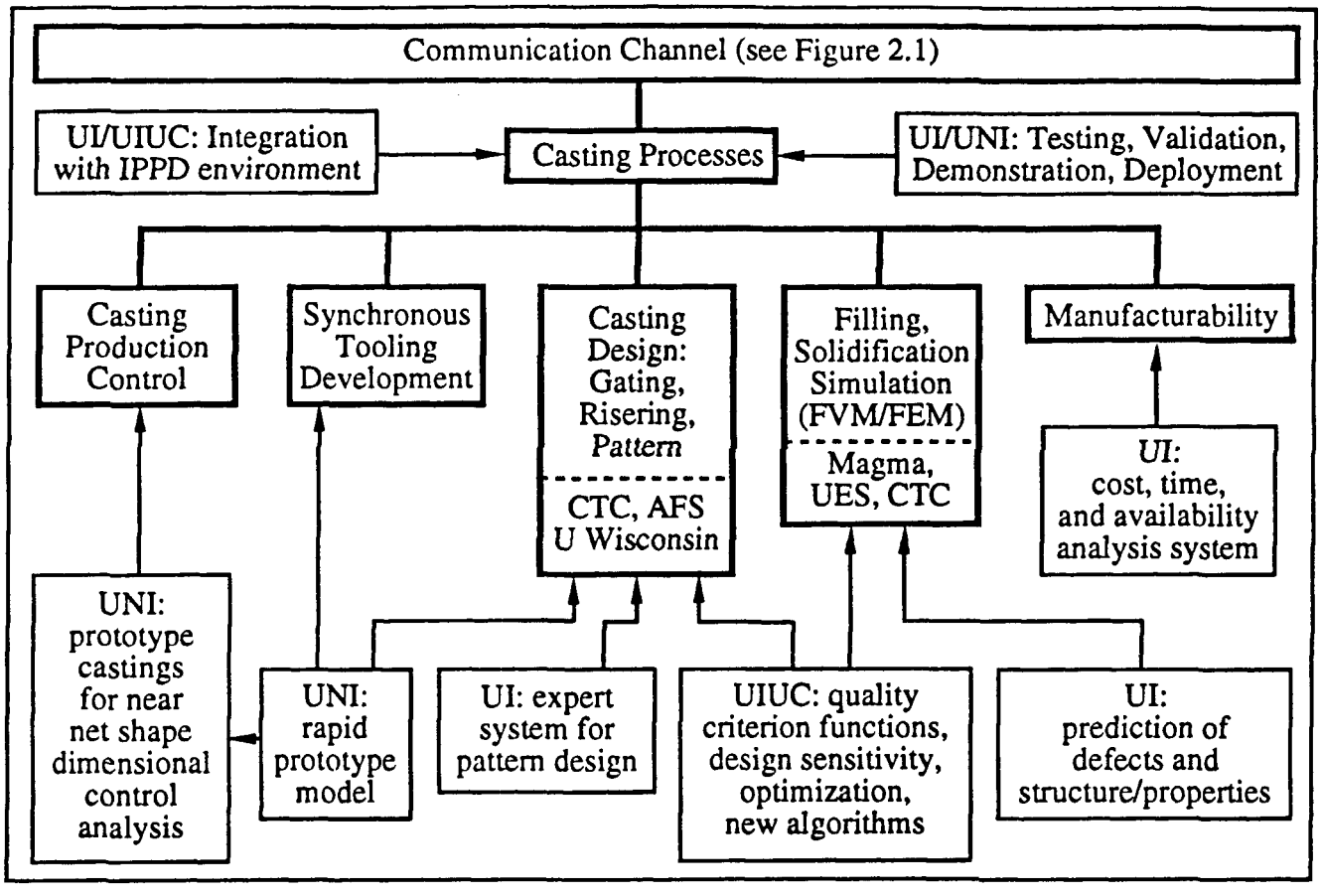

Figure 3.1: Casting Process Simulation Tool Structure and Proposed Tasks.

The University of Iowa project will focus on implementation of existing casting simulation tools and integration in the IPPD environment, refinement of existing and development of new capabilities in critical areas, and testing and demonstration of new casting simulation capabilities in collaboration with foundries. The integration with other manufacturing process sirnulation and product design tools within the IPPD environment will allow the trade-offs and economics of different casting and manufacturing processes and designs to be examined. The project will not only advance present casting simulation technology, but will more importantly lead to reductions in casting development time and testing cost that are comparable to the goals stated in the IPPDI proposal (i.e., 50 to 75%). Productization/commercialization will be achieved through agreements with established casting software vendors, use of a deployment system, and the establishment of service units to support the use of the integrated casting simulation system in industry.

Plans for Years 1 and 2

Work Package 1: Establish framework for integrated casting process simulation

Objectives: Select existing casting process design and simulation software, that supports integration in the IPPD environment. The focus will be on software with capabilities in sand, die, and/or investment casting of cast iron and steel vehicle and heavy equipment component parts. Establish connections with CAD system and basic services of Figure 2.1.

Technical Plans: A number of commercial software packages presently exist for casting design and simulation. The selection will be done in collaboration with industry and software vendors. If necessary, software will be developed to permit communication with the basic services shown at the top of Figure 2.1. In particular, the casting software must accept a CAD model of a typical component part and, in later stages of the project, adhere to STEP standards. The new simulation framework will be demonstrated using a representative casting. This initial task will establish the basic casting process simulation framework and will serve as the basis for all future casting tool developments.

Work Package 2: Develop expert system for pattern design

Obiectives: Develop a knowledge-based expert system for foundry casting pattern design for use in the casting simulation system.

Technical Plans: This task is based on previous work by one of the PIs (G.W.F.) sponsored by RIA. Although some casting design software is available for gating and risering, there is a lack in the area of foundry casting pattern design. It is planned to first develop an appropriate knowledge base for pattern design of representative vehicle and heavy equipment parts. The expert system will be constructed using the NEXPERT software from Neuron Data, Inc. The expert system will be coupled with the CAD system and the other casting design and simulation tools.

Work Package 3: Enhance casting simulation capabilities

Objectives: Enhance casting simulation capabilities by incorporating advanced tools for the prediction of solidification defects, microstructures, segregation, and mechanical properties.

Technical Plans: This task is based on previous work by one of the PIs (C.B.) sponsored by NSF, NASA, IDED, and various companies, as well as on recent studies by other investigators. The goal is to incorporate the research results into existing casting simulation software and make them available to industry. The task is important because the enhanced software will fully reflect the coupling between material, alloy composition, casting conditions, the occurrence of certain defects, and the resulting microstructure and segregation of alloying elements at various locations in the solidified casting. This will, in turn, allow for the prediction of mechanical properties and, thus, establish the processing-property relationship. The properties are needed in other design steps (e.g., structural analysis) as well as to determine the casting's performance during subsequent manufacturing operations (e.g., machining, welding, heat treatment). This task will be critical for giving IPPD the level of fidelity needed to achieve the target of a 75% reduction in testing cost. The work is expected to continue through the first four project years. The enhanced capabilities will be validated and tested using representative component parts.

Work Package 4: Develop casting manufacturability analysis tool

Objectives: Develop a manufacturability analysis tool for predicting the cost, time, and availability of casting processes.

Technical Plans: This work is part of the development of the process simulation module of Figure 2.1. It is intended to mesh with the Concurrent Engineering and Business Planning Tool Development and Integration tasks of in the Statement of Work. It is also mentioned in the proposal as one of the critical technologies to be advanced. It is proposed to develop a manufacturability analysis tool specific to casting processes. This

task will be based on work performed by one of the PIs (G.W.F.) on developing a similar tool for welding and machining processes. Integration of the casting rnanufacturabili ty analysis tool in the IPPD environment will allow the economics of different casting processes and trade-offs between different component part designs and manufacturing processes to be examined. This will be demonstrated using representative vehicle and heavy equipment parts.

Plans for years 3 through 6

During years 3 and 4 work will be completed on work packages 1 through 4. Long-term objectives involve (i) full validation and demonstration of the integrated casting process simulation system within IPPD, including the casting of representative validation parts by participating foundries, revision of casting simulation tools, and documentation of casting development time and testing cost savings, and (ii) integration of the casting process simulation tools within the IPPD environment, including the establishment of connections among the various casting tools and with other manufacturing process and product design tools. In addition, the plans for productization and commercialization described below will be realized. The casting industry impact will be further enhanced through close collaboration with the Steel Founders' Society of America (SFSA) throughout the course of this project.

Plan for Productization/Commercialization

The project will make extensive use of existing commercial software products. The main software vendors in the casting design and simulation area are Magma, UES, and CTC. Collaborative agreements will be reached with selected vendors to (i) enable integration of the existing software with the IPPD environment and (ii) add refinements and new capabilities developed under this project. An agreement will also be reached to share any profits derived from IPPD project related activities and the sale of added software modules.

In addition, the results of the proposed project will constitute important parts of the overall casting process simulation system (see Fig. 3.1). Therefore, productization will be achieved through the deployment system proposed by UNI, involving the use of communication networks and satellite uplinks.

Finally, a service will be established to provide support to vehicle and heavy equipment casting manufacturers in the use of the integrated casting process simulation system. This will be done through the establishment of special service units in existing casting software companies or as a part of the associated Technology Deployment Project.