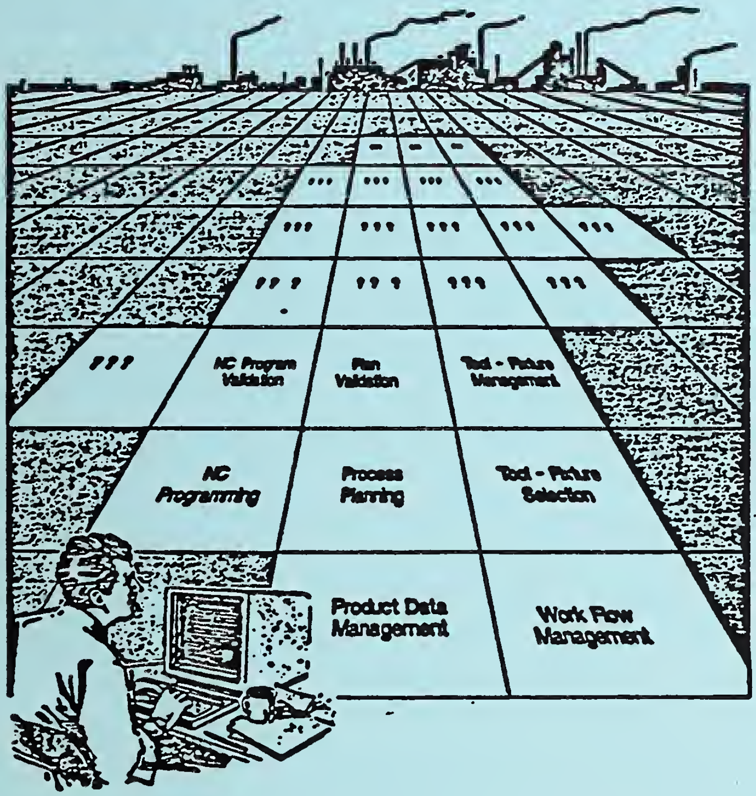
NISTIR 5699

Computer-Aided Manufacturing Engineering Forum

First Technical Meeting Proceedings



Mike Smith
Swee Leong

Sponsored by the

U.S. DEPARTMENT OF COMMERCE
Technology Administration
National Institute of Standards
and Technology
Manufacturing Systems Integration Division
Gaithersburg, MD 20899

and

U.S. Navy Manufacturing Technology Program

Gaithersburg, Hilton Head
March 21-22, 1995

March 1995

U.S. DEPARTMENT OF COMMERCE
Ronald H. Brown, Secretary

TECHNOLOGY ADMINISTRATION
Mary L. Good, Under Secretary for Technology

NATIONAL INSTITUTE OF STANDARDS
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Arati Prabhakar, Director

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CAME Forum Overview and Objectives

The first technical meeting of the Computer-Aided Manufacturing Engineering (CAME) Forum convened March 21-22, 1995 in Gaithersburg, Maryland to consider issues relevant to development of the Manufacturing Engineering Tool Kit (METK). The tool kit project is jointly sponsored by the U.S. Navy Manufacturing Technology Program and the National Institute of Standards and Technology.

The CAME Forum was attended by nearly 30 representatives from industry, government, and academia including manufacturing engineers, application software vendors, manufacturing technology developers, senior manufacturing managers, and government program managers. A list of forum participants is provided in Appendix A as is the agenda that guided meeting activities. Attendees were invited to participate actively yet be willing to reach a consensus on METK characteristics and requirements that all could endorse and support.

The primary objectives of this first technical meeting of the CAME Forum were:

1. *To obtain consensus on the initial context for developing the Manufacturing Engineering Tool Kit (e.g., parts, processes, data).*
2. *To identify the validation requirements for the engineering data package in the agreed context.*
3. *To identify appropriate engineering data package validation methods.*

This first technical meeting was organized into three major segments. These segments were designed to provide the information participants needed to fully understand what an METK is intended to do and then to solicit their input regarding the METK development context and the type of information the METK should validate to ensure that a part is produced correctly the first time. Specifically, the three forum segments and the topics addressed within each segment were:

1. *Setting the Context*
   - Manufacturing Engineering Tool Kit Overview
   - Plan of Attack (Program Plan)
   - Engineering Data Package Integration
   - Data Package Validation
   - Vendor System Presentations

2. *Identifying Requirements*
   - Review of the METK Development Context
   - Identification of Manufacturing Engineering Data Validation Requirements

3. *Discovering How*
   - Identification of Manufacturing Engineering Data Validation Methods
   - Open Forum to Discuss Technical and Programmatic Issues
   - Review of Action Items and Responsibilities

The Preliminary Draft Specification for the Manufacturing Engineering Took Kit was discussed during the first segment and is provided in Appendix B. Appendix C contains briefing slides used during the first segment of the technical meeting for setting the context (Manufacturing Engineering Tool Kit Overview, Plan of Attack, Engineering Data Package Integration, and Manufacturing Engineering Data Package Validation). In addition to this context setting information, three application software vendors described and demonstrated products currently available that will support the initial METK development effort. Appendix D contains descriptions of the three application software product. ICEM Technologies' PART is a generative process planning system; Deneb's products, IGRIP, QUEST, and Virtual NC provide a suite of simulation environments that can be used to plan and/or evaluate systems and system components from the machine tool to the shop floor level; and Matrix's product, also called Matrix, is a product data management system that provides an object-oriented data management structure that can be used to manage all of the data needed to support business and manufacturing processes.

Context for Manufacturing Engineering Tool Kit Development

An initial context for developing a Manufacturing Engineering Tool Kit (METK) was proposed by NIST as a strawman for discussion among meeting participants. The context addressed candidate part characteristics, manufacturing processes to be included, and the engineering data package elements to be validated before initial production is begun. These context parameters, provided in detail in the Draft METK requirements paper prepared by NIST, are presented in abreviated form here:

Candidate Part Characteristics	*Candidate Manuacturing Processes*	*Engineering Data Package*
• Machinable metal alloys	• Metal cutting machines and systems	• Sequenced list of operations
• ≤ 24 inch (60 cm) cube	• Tooling, workholding	• Data required for each operation
• ≤ 250 lbs (100 kgs)	• Workhandling	• Tooling lists
• Holes, pockets, cylindrical features, threads, bores, counterbores, flats, chamfers, grooves, slots, etc.	• Metal forming	• Machine control programs
• Mechanical fasteners, force fits, shrink fits	• Metal joining, assembly	• Operator instructions
• Deburring, heat treatment, painting	• Metal cleaning and finishing	• Quality control parameters
• Tolerances up to 0.0002 in.	• Controls, computers, and software	• Administrative documents
	• Inspection and quality control	

Forum participants were asked to review the METK development context in terms of the following questions:

(1) Are the part types and features and manufacturing processes meaningful in your organization? (Does your organization make parts with these characteristics?)

(2) *Are they adequate to demonstrate a prototype METK that is both significant and extensible? (Would an METK that deals with these part types and processes address a significant portion of your production and do you believe that an METK developed in this context could be expanded or enhanced to address other part types and processes?)*

(3) *Is the suggested set of Engineering Data Package (EDP) elements sufficiently complete to release a part to the machine shop?*

After reviewing the "strawman" METK context, forum participants made the following recommendations:

1. Add plastic parts.
2. Start with raw castings (including near net shape castings).
3. Include heat treating and plating processes.
4. Consider environmental impact (esp., legal requirements for handling hazardous materials).
5. Include machining of composites.
6. Include turned parts.
7. Include conveyors (vertical and horizontal part movement).
8. Include tumbling and powder coating.
9. Include process data derived from design specifications.
10. Include quality control (both destructive and non-destructive testing requirements).
11. Include some assembly operations (subassemblies).
12. Define tooling/fixtures/gauges/cutting tools.
13. Consider production lot size.

In addition to reviewing the context parameters, forum participants, working in three separate teams, reviewed a detailed list of manufacturing processes and indicated how important each process is to successful development of a meaningful METK. Teams rated each process on a "high, medium, low" scale in terms of its importance to the METK development process. Every team did not rate all of the processes. Table 1 shows how the processes were rated.

Table 1. Relative Importance of Selected Processes to METK Development Environment

Notes for Table Entries:
[1]All processes with average scores of 1.5 or less were labeled "High" importance for purposes of this table.
[2]Underlined entries were added to the original list by one or more of the breakout groups.
[3]Ratings were assigned as follow: 1=High, 2=Medium, 3=Low importance to initial METK development.
[4]Scores were calculated using the ratings from breakout groups that provided ratings; blank cells were not included.

Relative Importance[1]	Manufacturing Processes[2] (Grouped by Process Category)	Breakout Group Rating[3]			Average Score[4]
		BLUE	GREEN	RED	
	METAL CUTTING MACHINES AND SYSTEMS				
High	NC 3-axis horizontal milling	1	1	1.25	1.08
High	2-4 Machine Cell with Pallet Handling System	1	1	1.5	1.17
High	Tapping, threading	1	1	1.5	1.17
High	NC 2-axis turning	1	1	1.75	1.25

Relative Importance[1]	Manufacturing Processes[2] (Grouped by Process Category)	Breakout Group Rating[3]			Average Score[4]
		BLUE	GREEN	RED	
High	Machining center with pallet handling system	1	1	1.75	1.25
High	HN 4-axis Milling	1	1	2	1.33
High	NC 3-axis vertical milling	1	1	2	1.33
High	NC 2-axis grinding	1	1	2.25	1.42
	5-axis milling	1	3	1.75	1.92
	High-Speed Machining	1	3	2	2.00
	Drilling Machines	3	1	2	2.00
	Honing and lapping system			2	2.00
	Sawing Machines	3	1	2.25	2.08
	EDM	3	2	1.5	2.17
	Turning Machines	3	2	1.5	2.17
	Milling Machines	3	1.50	2.25	2.25
	Broaching	2	3	1.75	2.25
	Gear Cutting Machine	2	3	2	2.33
	Multi-spindle NC turning machine	3	2	2.25	2.42
	Screw Machine	2	4	2	2.67
	Laser		4	1.5	2.75
	Metal Cutting Machines and Systems		4	1.75	2.88
	NC Turning (Hi Speed)	3			3.00
	Plasma ARC	3			3.00
	Gear Rolling (Cold Forming)	3			3.00
	Sheet Metal Plate Stock	3			3.00
	TOOLING, WORKHOLDING				
High	Modular tooling systems		1	1	1.00
High	Modular fixturing systems		1	1	1.00
High	Tool presetting system		1	1.25	1.13
High	Jigs and Fixtures		1	1.75	1.38
High	Tool Room		1	2	1.50
	WORKHANDLING				
High	Pallets		1	2	1.50
High	Multi-pallet work handling for machining center		1	2	1.50
High	Marking, bar coding		1	2	1.50
High	Controlled storage area		1	2	1.50
High	Fixturing station (manual)		1	2	1.50
	Multi-machine pallet handling system		3	1.75	2.38
	METALFORMING				
	Investment Casting		3	1.75	2.38
	Die Molding		3	1.75	2.38
	METAL JOINING, ASSEMBLY				

Relative Importance[1]	Manufacturing Processes[2] (Grouped by Process Category)	Breakout Group Rating[3]			Average Score[4]
		BLUE	GREEN	RED	
	Adhesives		2	2	2.00
	Mechanical Fastening Systems		2	2.25	2.13
	Assembly Station		2	2.25	2.13
	Welding, Brazing		2	2.5	2.25
	METAL CLEANING AND FINISHING				
High	Parts Washing, Degreasing		1	1.5	1.25
High	Painting		1	1.5	1.25
High	Deburring system		1	1.75	1.38
High	Heat treating, hardening		1	2	1.50
	Abrasive finishing		1	2.25	1.63
	CONTROLS, COMPUTERS, AND SOFTWARE				
High	Shop floor data collection		1	1.25	1.13
High	Inventory tracking and reordering system		1	1.75	1.38
High	Tooling and workpiece tracking		1	1.75	1.38
High	SPC		1	2	1.50
	Cutting tool condition monitoring		3	1.75	2.38
	INSPECTION AND QUALITY CONTROL				
High	Optical measurement system		1	1.5	1.25
High	CMM		1	1.75	1.38
High	Inspection stations (manual gauging)		1	2	1.50
High	SPC data collection and analysis system		1	2	1.50
	Gear measurement		3	1.75	2.38
	OUT-OF-SCOPE PROCESSES				
High	Limited Object Manufacturing (LOM)			1	1.00
High	Stereo Lithography (SLA)			1	1.00
	Chemical treatment		1	2.25	1.63
	Plastics		1	2.25	1.63
	Waterjet/abrasive jet		3	1.25	2.13
	Sheet Metal		3	1.5	2.25
	Foundry		3	1.75	2.38
	Scheduling		3	1.75	2.38
	Automated part handling between stations (e.g., AGV)		3	2	2.50
	Composite materials processes		3	2	2.50
	Chemical Machining		3	2.25	2.63

Manufacturing Engineering Data Validation Needs

After reviewing, discussing and refining the METK development context and draft specification, participants were asked to respond to the following question:

What manufacturing engineering data should be validated?

Participants, again working in three groups, recorded ideas independently and then shared ideas within and among small groups. Appendix E contains the initial lists of data validation needs. Note that many ideas in the initial lists overlap considerably or are identical. Each of the three groups combined the ideas generated by individual group members into a single list; each group's list was then reviewed during a plenary session where similar items were combined so that they appear on at most one list. After compiling this consolidated list, participants rated each idea in two ways: first, each participant selected the five validation needs that are *most important* to producing a part correctly the first time; second, each participant selected the five ideas that are *most problematic* in the data validation process. The resulting consolidated list is shown in Table 2. Note that the two selection criteria resulted in very different ratings of validation needs. The *most important* validation needs were clearly G15 (Verify machine control programs, tool offsets, locator reference points) and B08 (Data are from the latest/correct version); participants exhibited less agreement about data validation needs that are *most problematic*. Items B12 (Shop floor feedback captured by PDM), B11(Material and processes are environmentally compliant), and B08 ranked highest, yet two of the three (B12 and B11) were not among the most important validation needs.

Table 2. Consolidated List of Data Validation Needs

Idea Label	Most Important	Most Problematic	Engineering Data Validation Need
Blue Breakout Group Responses:			
B01	0	3	Appropriate Material substitution
B05	0	0	No fixture damage to part
B07	0	0	Lifting device and fixture able to support part
B08	13	7	Data are from latest/correct version
B10	4	2	That package is complete
B11	0	7	That material and process are environmentally compliant
B12	1	9	That shop floor feedback is captured by PDM
Green Breakout Group Responses:			
G01	5	4	Check all ECOs posted against prod. & process data (No pending ECOs)
G02	8	5	Check process capability data against tolerance of product
G04	1	3	Validate regulatory compliance
G05	6	3	Validate QA steps in each operation (CMM program, etc.)
G06	1	0	Process data for all features/steps
G07	2	2	All required process parameters for each process
G08	0	2	Approvals correct
G10	1	3	Operator certifications
G11	1	0	If alternatives are possible, make sure a single selection is identified
G12	6	3	Validation sequence of operations
G14	4	5	Check resource availability
G15	19	5	Verify machine control programs, tool offsets, locator reference points
G16	2	2	Calibration and maintenance requirements
Red Breakout Group Responses:			
R02	3	1	Tool list

Idea Label	Most Important	Most Problematic	Engineering Data Validation Need
R03	5	2	Ops sheet/process plan
R04	3	2	Setups/teardown instructions
R05	0	0	Capture of up/down load time
R06	1	0	Capture of resource dead time
R07	0	2	Comparison with other parts within families
R09	1	0	Dynamic cutting forces
R10	0	0	Track number of parts produced versus time
R11	1	0	Gauge dimensions
R12	0	3	Setup optimization within or between products
R13	1	2	Overspec/overtolerance
R14	0	1	Availability of shop drawings
R18	4	0	Validation of tool ids
R19	1	1	As designed = as simulated
R20	0	3	Identification of Standard tooling or already built tools
R21	0	2	Validation of raw materials
R22	1	2	Flagging expensive operations
R23	1	0	Use of less expensive machine tools

After developing the consolidated list of data validation needs, participants organized them into "similarity" categories. Participants compared items two at a time, answering the question, "Is *Validation Need A* in the same category as *Validation Need B*?" After an initial group of comparisons were made and several groups of validation needs were formed, participants placed the remaining ideas in categories where they best fit, given the ideas already in that category. Attendees then labeled each category based on the common characteristics of the items contained in each category. The resulting list of validation needs classified into similarity categories is shown in Table 3. Within each category, validation needs are listed beginning with the need that was judged *most problematic* by participants.

Table 3. Classified Engineering Data Validation Needs

Idea Label	Most Important	Most Problematic	Engineering Data Validation Needs
Category A: Technical Data Validation			
B08	13	7	Data are from latest/correct version
G01	5	4	Check all ECOs posted against prod. & process data (No pending ECOs)
B01	0	3	Appropriate Material substitution
B10	4	2	That package is complete
G08	0	2	Approvals correct
R14	0	1	Availability of shop drawings
G06	1	0	Process data for all features/steps
Category B: Feedback			
B12	1	9	That shop floor feedback is captured by PDM
Category C: Resource Capability			
B11	0	7	That material and process are environmentally compliant

Idea Label	Most Important	Most Problematic	Engineering Data Validation Needs
G02	8	5	Check process capability data against tolerance of product
G04	1	3	Validate regulatory compliance
B07	0	0	Lifting device and fixture able to support part
Category D: Resource Availability			
G14	4	5	Check resource availability
G10	1	3	Operator certifications
R12	0	3	Setup optimization within or between products
R20	0	3	Identification of Standard tooling or already built tools
G16	2	2	Calibration and maintenance requirements
R07	0	2	Comparison with other parts within families
R21	0	2	Validation of raw materials
G11	1	0	If alternatives are possible, make sure a single selection is identified
R11	1	0	Gauge dimensions
Category E: Process Validation			
G15	19	5	Verify machine control programs, tool offsets, locator reference points
G05	6	3	Validate QA steps in each operation (CMM program, etc.)
G12	6	3	Validation sequence of operations
G07	2	2	All required process parameters for each process
R03	5	2	Ops sheet/process plan
R04	3	2	Setups/teardown instructions
R13	1	2	Overspec/overtolerance
R02	3	1	Tool list
R19	1	1	As designed = as simulated
B05	0	0	No fixture damage to part
R09	1	0	Dynamic cutting forces
R18	4	0	Validation of tool ids
Category F: Cost/Performance Metrics			
R22	1	2	Flagging expensive operations
R06	1	0	Capture of resource dead time
R23	1	0	Use of less expensive machine tools
R05	0	0	Capture of up/down load time
R10	0	0	Track number of parts produced versus time

The categories that resulted from this activity span the range of validation requirements. The categories address the availability and accuracy of engineering data (Category A), the capability and availability of resources needed to produce parts (Categories C and D, respectively), the validity and accuracy of process and machine instructions (Category E), the economic impacts of process and production plans (Category F), and feedback from shop floor activities that could affect process planning (Category B).

Manufacturing Engineering Validation Methods

The third segment of the technical meeting focused on identifying methods that could (and should) be used to validate the types of data listed above. The validation methods were to be considered in the context of the evolving METK requirements and specifications so that they could be reasonably included in METK development. Specifically, participants were asked to consider the following questions in light of the manufacturing engineering data validation needs previously identified:

- What methods are currently used to accomplish this type of validation?
- How successful are these methods in validating manufacturing engineering data?
- What are the primary advantages and disadvantages of these methods?
- What alternative methods do you propose and what is their value added over current methods?

Participants considered these questions in breakout groups with each group focusing on four of the six categories of data validation requirements. Two of the three groups reported results in terms of the data validation categories and these results are provided in Table F-1 in Appendix F and summarized in Table 4; the third group organized results around methods used to accomplish the validation and these results are shown in Table 5.

Table 4. Recommended Engineering Data Validation Methods (by Validation Needs)

Idea Label	Engineering Data Validation Needs	Recommended Validation Approaches
Category A: Technical Data Validation		
B08	Data are from latest/correct version	• Workflow/PDM system
G01	Check all ECOs posted against prod. & process data (No pending ECOs)	
B01	Appropriate Material substitution	
B10	That package is complete	
G08	Approvals correct	
R14	Availability of shop drawings	
G06	Process data for all features/steps	
Category B: Feedback		
B12	That shop floor feedback is captured by PDM	• On-line teleconferencing between staff on-site • Review terminal on shop floor as part of workflow process, on-line flagging, instant review, concurrent review meetings • Operator electronic feedback system • Everyone in process has electronic feedback/feedforward • Capture/retain/react to all feedback issues --required response! (Knowledge-based system)
Category C: Resource Capability		

Idea Label	Engineering Data Validation Needs	Recommended Validation Approaches
B11	That material and process are environmentally compliant	• Virtual factory • Knowledge-based system with cautions, warnings, process completion (for hazardous materials disposal)
G02	Check process capability data against tolerance of product	
G04	Validate regulatory compliance	
B07	Lifting device and fixture able to support part	

Idea Label	Engineering Data Validation Needs	Recommended Validation Approaches
Category D: Resource Availability		
G14	Check resource availability	• Manufacturing engineering needs on-line check of resource availability • Work around procedures identified in system • Database of resources • Scheduling system • Library of parts and fixture models • Tooling design and manufacturing system
G10	Operator certifications	
R12	Setup optimization within or between products	
R20	Identification of Standard tooling or already built tools	
G16	Calibration and maintenance requirements	
R07	Comparison with other parts within families	
R21	Validation of raw materials	
G11	If alternatives are possible, make sure a single selection is identified	
R11	Gauge dimensions	
Category E: Process Validation		
G15	Verify machine control programs, tool offsets, locator reference points	• Better simulations, more complex simulation • Use simulation to visually check operations are correct before cutting • Data base of lessons learned -- rule-based plan generation • Manufacturing guidelines at design level
G05	Validate QA steps in each operation (CMM program, etc.)	
G12	Validation sequence of operations	
G07	All required process parameters for each process	
R03	Ops sheet/process plan	
R04	Setups/teardown instructions	
R13	Overspec/overtolerance	
R02	Tool list	
R19	As designed = as simulated	
B05	No fixture damage to part	
R09	Dynamic cutting forces	
R18	Validation of tool ids	
Category F: Cost/Performance Metrics		
R22	Flagging expensive operations	• Generate process/resource utilization spreadsheet/Gantt chart for each process plan • Maintain on-line database of guidelines
R06	Capture of resource dead time	
R23	Use of less expensive machine tools	
R05	Capture of up/down load time	
R10	Track number of parts produced versus time	

Table 5: Recommended Data Validation Methods (by Approach)

Manufacturing Engineering Validation Need	Idea Labels (from Table 2)	Recommended Validation Approach
Tooling	R20/G16/R11/ R12/R18/R2	Tooling Design and management system
Change Control	B8/G1/G8/B10	Product Data Management System
Process Capability	G2/B11/G4/ G14/G6/G7	Real-time process capabilities database
Product Performance	B1/G8	Product model and simulation
Standard Parts	R12/R7/G11	Expert and knowledge-based system
Resources	B7	Factory model
Process	G12/G15/R3/B5	Process simulation
Procedure	G5	{No response}
Operator Instructions	R4	Tooling data base
Verify simulation	R19/R9	Tests

CAME Forum Summary and Action Plan

The final session of the CAME Forum's First Technical Meeting concluded with a review of what had been accomplished during the meeting and the action items to be addressed prior to the next meeting, scheduled for June/July 1995. In general, participants felt that the meeting had been successful in scoping the manufacturing engineering data validation needs and in beginning to identify appropriate manufacturing engineering data validation methods. Significant results of the meeting included substantial agreement on the need for the following:

1) a product/process data management system that can capture, store, update, and make available all product and process (including tooling) data that affect manufacturing engineering decisions,

2) knowledge-based systems for generative process planning that can use product data to develop and verify process plans, and

3) virtual factory models that simulate and visualize manufacturing processes at a level of complexity that will surface resource capability/capacity problems, tooling/fixture design problems, and other process-related issues.

Action items agreed to by participants include review of draft METK requirements and specifications and the proposed METK development context and further coordination and clarification of their roles in this program. Action items include:

All Participants:
- Review and revise METK system specification document
- Execute CRDAs and/or Letters of Agreement as required for participation in the program
- Review, comment and recommend test parts and part models
- Review, comment and recommend process and tooling data

Industry and Government-Owned Industrial Organization:
- Provide the names of participating technical staff from each organization

NIST METK Development Program:
- Revise the model production processes
  - a typical machine shop tools/processes is not practical for initial development
  - include heat treating/plating
  - include non-destructive inspection and testing
- Include design specifications/data along with process plans/data
- Include environmental specifications.

Open Forum Comments

At the close of the meeting, participants were invited to offer any ideas, suggestions, concerns, or questions about any technical or programmatic issue relevant to the CAME program. The following items were mentioned by forum attendees:

1. The METK operational environment must be user friendly -- to be used by operators. Inputs should be through wanding or icons. Consider human factors -- make the system intuitive so that it makes the job easier. Leverage operator skills.

2. A long-term goal should be to migrate systems to commodity-type platforms.

3. Include a representative from the Society of Manufacturing Engineering (SME) in next meeting (suggest Sharon Ballor of SME be invited).

4. Forum attendees are invited to provide comments on the draft requirements document provided in the forum notebook (and as Appendix B of this document).

5. Software demonstrations of the products currently involved in this program are available (contact representatives from Deneb, Matrix, and ICEM if interested).

6. Consider cultural acceptability of Manufacturing Engineering Tool Kits to achieve effective implementation.

7. Need to communicate that the visualization of the product *is* the design and includes parameters that are relevant to manufacturing engineering.

8. Note the importance of a team/participative approach to design and implementation of Manufacturing Engineering Took Kits.

9. Consider how to deal with control, especially on shop floor.

10. Will METK be modular in design?

11. Will lack of portability of SGI applications be a problem?

12. Consider incorporating concurrency into METK validation.

Appendices

Appendix A: CAME Forum First Technical Meeting Agenda and List of Participants
Appendix B: Preliminary Draft Specifications for the Manufacturing Engineering Tool Kit
Appendix C: METK Development Context Briefings
- » METK Overview
- » Plan of Action
- » Engineering Data Package Integration
- » Manufacturing Engineering Data Package Validation

Appendix D: Application Software Descriptions
- » ICEM Process Planning System
- » Deneb Simulation Systems
- » Matrix Product Data Management System

Appendix E: Initial Lists of Data Validation Needs
Appendix F: Engineering Data Validation Methods Review

Appendix A: CAME Forum First Technical Meeting Agenda and List of Participants

Computer-Aided Manufacturing Engineering Forum

Technical Meeting Agenda
Tuesday, March 21, 1995

7:45 a.m.	Continental Breakfast	
8:30 a.m.	Welcome and Introductions	C.McLean and M.Smith
8:45 a.m.	Manufacturing Engineering Tool Kit Overview ..... - Goals and objectives - Assumptions, scope, and constraints - System overview	C.McLean
9:10 a.m.	Plan of Attack .... - Development plan - Mode of operation, roles, test data, etc.	S.Leong
9:35 a.m.	Engineering Data Package Integration .... - Process planning function - Data formats and integration issues	S.Ray
9:55 a.m.	Data Package Validation .... - What can be validated? - Validation and error checking mechanisms - Part mix and shop simulation model	S.Frechette
10:15 a.m.	Break	
10:30 a.m.	Vendor System Presentations - Process Planning System .... ICEM Technologies - Simulation Systems .... Deneb Robotics - Product Data Management System .... Matrix	
12:00 p.m.	Lunch	
1:00 p.m.	Breakout Sessions .... - Product mix characterization - Process-machine selection and prioritization - Required data package elements - Types of errors - Validation requirements	All
3:00-3:15 p.m.	Break	
4:30-5:00 p.m.	Wrap up and Adjourn for the Day	

Computer-Aided Manufacturing Engineering Forum

Technical Meeting Agenda
Wednesday, March 22, 1995

7:45 a.m.	Continental breakfast	
8:30 a.m.	Breakout Sessions - How do we detect the errors? - Summary preparation	All
10:00 a.m.	Break	
10:15 a.m.	Breakout Session Reports	Working Group Leaders
11:15 a.m.	Discussion and Open Forum	M.Smith
11:45 a.m.	Action Items and Next Meeting Plan	S.Leong
12:00 p.m.	Meeting Wrap up	

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Appendix B: Preliminary Draft Specifications for the Manufacturing Engineering Tool Kit

Revised: July 31, 1995

PRELIMINARY DRAFT

SPECIFICATION FOR THE MANUFACTURING ENGINEERING TOOL KIT (METK)

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1. SCOPE

The Manufacturing Engineering Tool Kit (METK) is a software system that provides an integrated set of tools for generating and validating process plans in a machine shop environment. This functional specification document defines the objectives of METK. It also describes its operational environment, functions, and characteristics. This section identifies the tool kit, its major modules, and provides an overview of the contents of this document.

The tool kit will integrate commercial off-the-shelf software (COTS) modules which can be used to help: 1) plan part production, i.e., generate manufacturing engineering data packages, 2) validate the contents of the engineering data package before a job is released to the shop floor. Engineering data packages contain the information needed to perform the manufacturing operations required to produce a single part or many parts. A data package may contain a sequence of operations, data required for each operation, tooling lists, machine control programs, operator instructions, quality control parameters, and administrative documentation. The data in the data package may be the actual data, e.g., oven temperature = 1200F, or it may be a pointer to the actual data, e.g., the name and location of an NC program file.

Although individual production processes can be proved out and validated prior to production start up, data packages may still contain many errors that must be worked out during the initial production run. Fine tuning the data package in this way is costly and time consuming. On low lot size jobs, the potential cost per part could be quite high. One possible solution to this problem would be to use simulation to validate the entire data package prior to production. Many data errors could be eliminated prior to production by simulating the production processes and using the data as inputs to the simulation models. An example of this type of process validation is NC program simulation. Simulation systems are used to visualize the NC cutting process to determine if there are any problems such as cutting a fixture component. The actual NC program, fixture design, and machine tool configuration are used as inputs.

The tool kit will integrate manufacturing process planning and simulation capabilities. It will enable plan validation through the use of accurate simulation models and manual checklists. Other functions may also be included in the environment at a later time, e.g., design, cost estimating, tool and fixture design, and time standards.

The scope of functionality for the tool kit is limited to:

- planning and validation of data for the production of a family of machined parts which must precisely fit together to form mechanical or electromechanical assemblies (planning of assembly operations themselves is currently not in scope),

- variant process planning (development of expert process planning capabilities for the selected family of parts is not within scope),

- selected machining and support processes, e.g., cutoff sawing, milling, drilling, boring, reaming, tapping, turning, grinding, heat treatment, surface finishing, setup, cleaning, and inspection (out-of-scope processes include: sheet metal operations, foundry, chemical treatment , automated guided vehicles and other automated part handling systems, scheduling, plastic and composite fabrication, waterjet/abrasive jet cutting operations),

- validation of critical elements of the manufacturing process through simulation and checklists, e.g., work piece setups - tool, fixture, work piece interactions; metal cutting operations - access to reference surfaces, removal of proper volumes; tolerance variations and stack ups, and assembly of machined parts (production scheduling is not within scope).

Project collaborators will participate in finalizing project objectives, scope, and the selection of part families, processes, equipment, tooling, etc.

1.1 System Identification

The software defined within this document is identified as the CAME Manufacturing Engineering Tool Kit (METK). The abbreviation "METK" will be used where the reference to the system is clear from the context of the document. Other acronyms used to describe modules in the tool kit are as follows:

PDM - product data manager,
PPS - process planning system,
EDV - engineering data validation,
MRA - manufacturing resources administrator,
DBMS - data base management system(s), and
GUI - graphical user interface.

1.2 Purpose and Benefits

One of the major problems faced by manufacturing today is the lack of integration between engineering tools (software). Engineers need integrated tool kits which are comprised of software packages capable of sharing data. Unfortunately, the interface and database standards do not exist which would enable the construction of integrated tool kits. Furthermore, data generated by current engineering tools is not guaranteed to produce a correct part the first time. The METK project will assess industry needs, with respect to manufacturing engineering tools and tool integration, and develop solutions.

The METK will integrate several commercial off-the-shelf (COTS) software tools that are designed to help manufacturing engineers and other staff perform their jobs.
The environment will provide capabilities which will allow a skilled user to develop manufacturing plans and evaluate those plans through simulation. Integrated databases will be developed to maintain required data. The environment will run on one or more computer work stations.

Three key components of the integrated environment will include: a process planning system, a validation system based upon simulation and checklists, and a database management system. Other stand-alone manufacturing engineering tools are also being considered for inclusion in the environment.

Some of the functions that METK will support include:

- loading of product design data from several CAD file formats,
- management of product data, process data, and engineering change orders,
- work flow management for the planning and validation processes,
- planning of routings and operations for machine parts,
- selection of material stock, tools, and fixtures, as a part of the process planning process,
- validation of engineering data through simulation and checklists,
- management of resource data required for planning and plan validation,
- preparation of hard copy reports, e.g., plans, tool lists, inventory status,
- recording of plan simulations on videotape.

METK also will provide functions and interfaces for:

- generating reports,
- recording simulation runs,
- system administration and user access control,
- importing and exporting data in external formats, and
- development of system extensions, i.e., new machine models for the simulated shop and checklists for manual data validation.

The benefits realized from the METK will be applicable to Defense as well as civilian manufacturing. The METK may be installed at internal DoD manufacturing sites, primes and subcontractors, and non-defense commercial manufacturing facilities. It can be assembled by procuring its component modules from system vendors participating in this project. Virtually all manufacturing facilities would benefit from improved capabilities in the areas addressed by this project.

METK technology will help manufacturing engineers identify errors, make better decisions and more quickly evaluate the effects of those decisions. By improving process planning and simulation capabilities, a much greater percentage of products will be produced correctly the first time. Furthermore, the overall time to perform the engineering function will also be reduced if fewer changes to plans and programs are required once a job hits the shop floor. These improvements will result in fewer scrapped parts and less re-work. The integration of software packages and common databases will ensure that less time is wasted re-entering the same data into multiple engineering tools.

A number of broad benefits will be seen as a result of improvements in the manufacturing engineering function:

- Better utilization of shop floor equipment.
- The best equipment for the job will be selected more often.
- Less equipment time will be consumed by non-productive work, e.g., producing scrap and performing rework.
- Shops will be able to respond quicker to rush orders if their resources are used more efficiently.
- More energy can be devoted to producing higher quality products.
- Better response times are needed to obtain spare/repair parts for existing weapon systems as well as to shorten the development time of new systems.

1.3 Document Organization

Section 2 describes project goals and objectives of the METK system. The section introduces general capabilities, basic requirements, and the intended operational environment. Section 3 specifies tool kit requirements in terms of engineering functions, the data base management systems, user interface, computer system hardware and software. Section 4 provides a glossary of terms used in this document.

For readability, all statements about the METK and its component modules are made in present rather than future tense.

2. OBJECTIVES

The purpose of this section is to define the overall objectives of METK project and the tool kit environment. It also describes the operational environment for the intended application of the METK system.

The overall goal of Computer-Aided Manufacturing Engineering (CAME) is to lower manufacturing costs, reduce delivery times, and improve product quality through the coordinated development and use of advanced software tools. The METK Project supports this goal by achieving integration between at least two important CAME systems, i.e., process planning and manufacturing data validation. Objectives of the tool kit project include:

- Development of architectures, database structures, and techniques for integrating manufacturing engineering tools, e.g., process planning, and manufacturing simulation systems,

- Integration of at least three major elements of a tool kit environment:

    - a process planning system,
    - a manufacturing simulation system, and
    - a database management system.

- Development of common databases for maintaining the following types of data: process resources and capabilities, tools and fixtures, process plans, and simulation models of selected manufacturing equipment,

- Testing and validation of the integrated system using real world data,

- Development of solutions that could be used by large and small shops alike,

- Recommendation of potential standards based upon project results, e.g.,

    - information models for the relevant data,
    - database structures for common databases,
    - functionality of software tools,
    - interfaces between tools and other system elements.

2.1 General Capabilities

METK is designed to be used by manufacturing engineering and machine shop personnel in a small batch machined-parts production environment. The METK provides integrated tools to plan production parts and to ensure that plans are correct before the first piece goes into production on the shop floor. Some examples of required tool functions include:

- load part design and specification data prepared using commercial CAD systems,
- identify initial work piece materials, e.g., sheet and bar stock,
- prepare process plans including part routings and operation sequences,
- select cutting tools and fixtures,
- validate plans using simulation and checklists,
- manage work flow within the engineering process, and
- track product and process data.

This list provides examples of typical functions. A more complete list of required capabilities is provided in the individual module descriptions in Section 3 of this document.

In addition to engineering functions, METK provides tools for producing reports, recording simulation runs, loading and administering various types of engineering and manufacturing resource data, and a graphical user interface.

2.2 Basic Requirements

Requirements for the tool kit can be decomposed into the following major groups of functions:

- process planning,
- engineering data validation,
- manufacturing resource data administration,
- work flow management, and
- product and process data management.

A process planning system is used to develop plans for the machining and assembly of precision components. The process planning system is also used to select cutting tools and fixtures. Process planning will initially focus on a limited set of test parts. Test parts will be used during initial system development and configuration to analyze tool kit performance. Test parts will be used as inputs into process planning and engineering data validation modules. Part data includes design data, CAD files, and performance requirements. Initial test parts must be simple enough to be processed, but complex enough to provide meaningful input. Tentative test part characteristics are as follows:

- Material: machinable metal alloys
- Work volume: Up to 24 inch (60 cm) cube

- Weight: Up to 250 lb (100 Kgm)
- Machinable features: holes, pockets, cylindrical features, threads, bores, c-bores, flats, chamfers, grooves, slots, etc.
- Assembly operations: mechanical fasteners, force fits, shrink fits
- Finishing operations: deburring, heat treatment, painting
- Tolerances: up to 0.002 inch

A simulation system and an interactive set of checklists provide the tools for validating the engineering data package. A process plan interpreter is required in the process planning system to run and validate plans. A generic machine shop is modeled in the simulation environment. Processes and machines which are required or are under consideration for the simulated shop include:

- Metal cutting machines and systems:
  - NC 3-axis vertical milling
  - NC 3-axis horizontal milling
  - NC 2-axis turning
  - NC 2-axis grinding
  - Machining center w/pallet handling system
  - Tapping, threading
  - Sawing machines (manual)
  - Drilling machines (manual)
  - Milling machines (manual)
  - Turning machines (manual)

- Tool and workholding devices
  - Cutting tools and tool assemblies
  - Tool presetting system
  - Jigs and fixtures

- Material handling
  - Pallets
  - Multi-pallet work handling for machining center
  - Marking, bar coding
  - Storage area
  - Tool room and tool racks

- Metal joining and assembly
  - Mechanical fastening systems
  - Assembly station

- Metal cleaning and finishing
  - Manual and vibratory deburring system
  - Parts washing, degreasing
  - Painting
  - Heat treating, hardening
  - Abrasive finishing

- Controls, computers, and software
  - Inventory tracking and reordering system
  - Distributed numerical control

- Inspection and quality control
  - Inspection stations (manual gaging)
  - Coordinate measuring machine

Other capabilities which may be included in the validation system are to demonstrate the effects of variations in tolerances on piece parts, cutting tools, fixtures, and assemblies.

Databases will be used to maintain common data, i.e., data that is relevant to multiple engineering tools (or possibly other tools in future CAME tool kits). In this context, the product data management module represents a part of the database system. Information maintained in the database(s) includes: product specification and design data, process plans, tool and fixture data, machine capabilities data, simulation results, and simulation models.

Other METK requirements are to provide tools for managing, accessing, editing, viewing, printing, and recording the data associated with the planning and production of machined parts. Associated support functions include software installation, backups, and system security, i.e., controlling which users may access and update which information. Additional objectives are to provide an import/export capability to handle external data formats and an interface for developing user-specific shop models and validation checklists.

2.3 Operational Environment

The first version of METK is a single workstation system which is intended for use by process engineers working in an engineering office area. The workstation will not be hardened for shop floor use. The workstation will run the UNIX operating system and will be networked to other NIST computing systems. The UNIX environment was chosen because it is widely accepted by the "commercial off-the-shelf" (COTS) software market for workstation-based applications. It is the only operating system common to the baseline software selected for this tool kit. In the long term, UNIX provides an open architecture that can run on platforms varying in size and having different hardware architectures.

The core of the METK is a data repository which is based on both relational and object-oriented database technologies. Two of the selected engineering tools include run-time database licenses: Objectivity (Matrix) and Oracle (ICEM Technologies PART). Whether different database products will be used for the METK database management system remains to be determined.

The graphical user interface (GUI) of METK provides windows for displaying part geometry, workstation setups, process plans, tooling lists, machine capabilities, simulation graphics, validation checklists. A commercial window management package has not yet been selected. See section 3.3 for more information on the user interface. Remote operation of the METK using an X-windows interface is being investigated.

Two peripheral devices are supported for the generation of reports and videotape recordings of simulation runs. All reports are generated in black and white Postscript format. Paper size is 8 1/2 by 11 inches or the metric A4 format. A Postscript laser printer is required. All recordings will be generated in NTSC video format. A video recorder supporting either 3/4" or VHS formats is required.

METK development platform is the Silicon Graphics Onyx Extreme workstation. The UNIX operating system version used is IRIX 5.3. The system will be designed to be ported to a Silicon Graphics Indigo Extreme workstation for industrial testing. It is likely that Indigo Extreme workstation will not support the running of large simulation models. Further information on the hardware configuration of the development environment is contained in Section 3.

3. TOOL KIT FUNCTIONS AND CHARACTERISTICS

This section divides the functional capabilities of METK into three major categories. The data required to support each function is also briefly introduced. The topics covered in the remainder of Section 3 are briefly outlined below:

3.1 Tool Kit Functions - The principal engineering and support functions are described: process planning, engineering data validation, product data and work flow management, manufacturing resources administration, reporting, videotape recording, system administration, external data format support, and user-specific application development.

3.2 Database Management System and Databases - The database management system(s) and required databases are identified.

3.3 Graphical User Interface - The major component elements and functions of graphical user interfaces are described.

3.4 Computer System Characteristics - The computer hardware, peripheral devices, operating system, and supporting software products are identified.

This section not only identifies the functions of METK in each of these areas, it also provides background information on the significance of these capabilities.

3.1 Tool Kit Functions

This section identifies and describes each of the specific functions of METK. The section is divided into subsections which address the following functions:

3.1.1 Process Planning
3.1.2 Engineering Data Validation
3.1.3 Product Data and Work Flow Management
3.1.4 Manufacturing Resources Administration
3.1.5 Report Generation
3.1.6 Videotape Recordings
3.1.7 System Administration
3.1.8 Support for External Data Formats

Subject to industry inputs, other functions may be included in the environment. Some examples of important functions which may be added at a later time are: computer- aided design of parts, tool and fixture design, other types of simulation, time standards, and cost estimating.

3.1.1 Process Planning

Process planning is one of the key functions involved in the development of the engineering data package. Some of the functions that the Process Planning System (PPS) performs include:

a) provide capabilities to import product model files such as Pro-Engineer, CATIA, PDES/STEP, ACIS, etc.,

b) provide capabilities to change or define the geometric tolerances for the imported models as required,

c) provide capabilities for featured-based analysis of products,

d) support group technology classification and coding of products,

e) provide capabilities to define specific machining methods for individual parts that contain a classification of manufacturing features, cutting tools, materials and machining motions required for production,

f) provide capabilities to generate setups including selecting jigs and fixtures per setup,

g) provide capabilities to select specific machine tool per setup including toolset selection,

h) provide capabilities to define machining operations and to optimize machining sequences,

i) provide capabilities to generate machining tool path including the cutting conditions,

j) analyze tradeoffs for different processing options,

k) generate reports for production, e.g., process plans, tooling, setup sheets, material requirements list, NC programs,

l) manage process engineering data.

The software package used to implement the process planning function is ICEM Technologies PART Version 1.2.100.

3.1.2 Engineering Data Validation

Simulation systems have been used on a limited basis to analyze manufacturing system designs and predict their performance. The Engineering Data Validation (EDV) module uses simulation and interactive checklists to aid the engineer in the validation process. A commercial manufacturing and mechanical simulation system is used to provide models of machines and fixtures, primitives for basic metal cutting operations, and process plan execution. Although NC programs are frequently verified using simulation capabilities, the same does not hold true for process plans. Industry needs good simulation, visualization, and analysis capabilities to ensure that process plans are complete and correct before jobs are released to the shop floor. Functions which tools must support include:

a) Provide mechanisms through simulation and checklists to detect a variety of engineering data package errors including:

- process problems,
- process incompatibility,
- resource availability,
- machine control program errors,
- tooling/fixture problems,
- invalid estimates,
- administrative errors.

b) provide editing capabilities to develop simulation models for manufacturing systems which are capable of precisely modeling mechanical systems,

c) provide functions for loading, interconnecting, and managing shop, machine, part, and planning data within the simulation environment,

d) provide functions for evaluating alternative system configurations, e.g., throughput, bottlenecks, equipment selections, operating procedures, effects of breakdowns, system kinematics, etc.,

e) provide time scaling options for accelerating or slowing down simulation runs,

f) provide display functions for presenting simulation data and checklists in tabular, iconic, 2D, and 3D graphical formats,

g) provide selective replay functions for portions of simulation runs,

h) generate reports for summarizing the results of simulations,

i) manage simulation archives including: building block models, catalog of systems, and saved runs,

j) provide an application programmer interface for incorporating: (1) database management system interface, (2) process plan interpreter, (3) pop up validation checklists, and (4) possibly other system extensions.

The software packages used to implement the engineering data validation function are Deneb Robotics QUEST Version X, ENVISION Version X, and VIRTUAL NC Version X. A separate software package may be selected to implement validation checklists.

Other functions under consideration for this module include tools for identifying and analyzing tolerance problems. A common cause of rejected parts is tolerance problems, e.g., tolerance stack up, dimensional interaction, poor choice of datum reference points/lines/planes, insufficient process capability data (i.e., can the process satisfy tolerance constraints), etc. Industry needs to help recognize tolerance problems and develop solutions.

3.1.3 Product Data and Work Flow Management

The METK accesses a number of different types of engineering and manufacturing resource data. Product data and work flow management functions are needed to handle this data. The Product Data Manager (PDM) provides these functions. Required capabilities for this module include:

a) provide mechanisms for defining user roles and controls to ensure that users cannot access product and process data without proper authorization,

b) provide embedded revision control mechanisms to maintain integrity and consistency of product and process document versions,

c) provide functions for graphically defining and managing work flow based on multiple engineering business models and on a per-product basis,

d) provide capabilities to launch engineering tool applications from the work flow manager and initialize the applications with the proper work context, i.e., data files to be reviewed, edited, etc.,

e) provide e-mail notifications to designated users when changes in statuses for product and process data,

f) support dynamic definition of product and process data structures,

g) provide a range of functions for managing product and process data in a multi-platform networked computing environment including: object creation, browsing, searching based on key attributes, document check-in and check-out, viewing based on object type, editing, annotation, and linking,

h) support the management of a variety of data object types including: drawings, text specifications, work orders, memos, electronic mail, spreadsheets, solid models, process plans, simulation models, checklists, work standards, video, change orders, layouts, and schematics,

i) provide a capability to establish user-defined classification systems for product data, and

j) maintain history data on the processing of individual products.

The implementation of this module is based upon the Matrix product data management system, Version X.

3.1.4 Manufacturing Resources Administration

The Process Planning and Engineering Data Validation modules require and need to share a number of different types of manufacturing resources data. Examples of this data includes: cutting tools, fixtures, job skill categories, machine capabilities, machine attributes, material handling device characteristics, shop and machine status, and operation times. The Manufacturing Resources Administration (MRA) module provides functions and window-based forms for loading, entering, editing, printing, and checking the various types of resource data required by the METK.

3.1.5 Report Generation

A number of METK functions produce hard copy reports or listings. A report is a form which organizes and tabulates text or numeric data from the database. Report specification screens are a part of the user interface. The user specifies the parameters required to select and complete a given report. The report generator accesses the database to retrieve data and provides a number of formatting functions for producing high quality report documents. All reports may be viewed on the screen, routed to a file, or produced as hard copy output on a printer. Hard copy reports are printed on a Postscript laser printer. The report generation functionality is likely to be implemented as an extension to one or more of the commercial database management system(s).

A summary of METK report types follows:

a) Process plan - specifies the steps required to produce a given machined part. The report provides a plan header, a resource requirements list, and a process specification.

b) Tool catalog - provides a listing of cutting tools and fixtures maintained in the tool kit environment.

c) Tool status list - provides a listing of the location and status of tooling within the simulated shop environment.

d) Tool setup specification - provides a component bill of materials and a setup drawing for a particular tool assembly.

e) Data package list - provides a structure listing of all product and process data elements contained within data packages maintained by the system.

f) Machine models list - provides a list of machines modeled in the engineering data validation system and their attributes.

g) Data validation results - provides a listing of simulation results, time estimates, errors and warnings resulting from validation of a selected engineering data package.

h) Shop layout plan - provides a layout drawing of a selected simulated shop floor configuration.

3.1.6 Videotape Recordings

The computer workstation contains a video interface for recording the graphical screen displays from simulation runs and tool kit sessions. Videotapes may be maintained as archive records to later demonstrate how specific parts are produced, train new users on the tool kit, provide video records of process plans for shop personnel, etc.

The video interface will generate NTSC video output. The signal will be compatible with normal 3/4", VHS, and Beta recorders used in the U.S. market.

Control windows provide for setting up work sessions, providing identification information at the beginning and end of recordings, and initiating simulations for recording. The videotape recorder itself is operated under manual control. Options for placing the recorder under computer control are being investigated.

3.1.7 System Administration

METK is designed to run in a single Unix workstation or multiple workstation environment. Normal system administrative procedures are used to maintain the tool kit environment, establish accounts for new users, etc.

This section describes some of the administration functions and capabilities that are required to support a METK environment. Functions covered include:

- 3.1.7.1 Installation
- 3.1.7.2 Backup and Restore
- 3.1.7.3 Access Control
- 3.1.7.4 Administrative Utilities

A brief summary of each of these functions follows.

3.1.7.1 Installation

Installation is the initial loading and setup of METK on a new workstation or at a new user site. Initially two tool kit installations are planned: 1) the Silicon Graphics Onyx workstation used for development and integration testing, and 2) the Silicon Graphics Indigo Extreme planned for industry "alpha" testing. Temporary licensing issues associated with the testing phase still must be addressed.

New installations will typically be performed by vendor representatives and/or NIST Global Systems Support staff. Script files are used wherever possible to automate the installation process. Manual intervention may be required to provide system specific installation data.

Loading of test data (e.g., parts and tooling data) is not considered part of the installation process. This subject is addressed in Section 3.1.8, Support for External Data Formats.

3.1.7.2 Backup and Restore

Backups are needed to restore a system after a disk crash, other system failures, or in the case of accidental file deletion. METK provides utilities for automatically backing up tool kit files to a designated Unix file server. Systems support staff perform full backups of the METK software and data using their normal utilities. Functions are also provided within METK to backup and restore databases separately.

3.1.7.3 Access Control

Access control is implemented through capabilities provided in the Unix operating system and the product data manager. Users will be divided into classes based upon their job function. File access privileges will be afforded based upon their assigned user group and job function.

3.1.7.4 Administration

METK is intended to be a low maintenance system. METK maintenance duties will be performed by regular systems support staff. System administration functions which must be performed include: setting up user accounts (initial passwords, privileges, directories, default login files), handling networking problems, performing system backups, managing disk allocation, installation of system upgrades, new user training, correction of hardware problems, etc.

3.1.8 Support for External Data Formats

The METK provides a set of import/export capabilities which may be used to transfer data to and from the system. The external formats which may be used to import product design and/or machine model data into the tool kit include:

a) Pro-Engineer
b) CATIA
c) ACIS
d) STEP
e) IGES
f) Autocad DXF

A standard delimited file format will be used to import other types of manufacturing resource data into the databases. Standard delimited file formats are export options on many database management systems. Other import and export data capabilities are yet to be determined.

3.2 Database Management System and Databases

The management of data is a major function of METK. Currently, data is typically maintained in the proprietary file formats of the software vendors. Some software packages may employ a commercial database management system for data storage. Commercial database management systems provide capabilities which make large amounts of data more accessible, manageable, and useful. Although conventional database management systems provide better opportunities for interoperable software tools, they do have limitations. A more flexible approach to data management in the future will probably be based upon object-oriented programming techniques. In object-oriented systems, the line between programs and data is blurred. This approach also tends to result in the develop of more modular systems. Commercial database management systems with relation and object-oriented data management capabilities are required within the METK.

Engineering data has different representations within different tools. There is no common conceptual model for the data required by the COTS software within METK.
There is also no agreement on the physical file formats for most of the data used by engineering tools. Without a common data model and standard data formats, it is virtually impossible to develop plug-compatible COTS software systems in the future.

The METK database will be based on developing a common data model for a subset of the engineering data that is within the scope of the tool kit. The common data model identifies the types of data that are required, the meaning of each data element, and the relationships that exist between the different types of data. Common data models for part specification data (geometry, materials, tolerances) has been developed as part of the ISO STEP effort. Some of the other types of engineering data under consideration for the common METK data model and databases includes:

- Process resources/capabilities,
- Tool and fixture specifications,
- Tolerance allocations,
- Setup specifications,
- Process plans,
- Simulation models of equipment, processes, tooling, setups, and parts.

Other functions required of the DBMS include: automatic generation of data dictionary entries from information models, programming and subroutine access interfaces, and a report generator.

3.3 Graphical User Interface

The graphical user interface (GUI) functions include: 1) window management, 2) special purpose display generation software (e.g., graphics rendering), 3) application windows (e.g., part display, setups, tools, fixtures, list of stations, process taxonomy and capabilities, process plan steps and resources), and 4) system administration windows (version control, environment initiation, backups, database loading and purging, user account management).

METK has two principal modes of operator/user interaction: engineering and administration (updating system data). A consistent user interface is required for both modes of operation. It is assumed that system administration will only be performed by a skilled computer user.

A window management system is required to provide a consistent interface to display windows and their component elements, open multiple windows, change the size of windows, iconify windows, select items from lists, select items from menus. Windows, panes (sub-portions of windows that can be independently sized), sashes (for sizing panes), pull down and pull up menus, dimmed menu selections (unavailable or inapplicable options), cascade menus, option menus, list boxes, dialogue boxes, push buttons, check boxes, radio buttons, text entry boxes, and pop-ups are supported.

METK provides context-sensitive help as contained within baseline COTS tools. The embedded help capabilities offer the user advice or guidance depending upon the function that is currently being performed or based upon the error which may have just occurred.

3.4 Computer System Characteristics

This section identifies and describes the key characteristics of the computer system hardware and software on which the METK system runs. It describes how the system relates to peripherals and other computer systems.

3.4.1 Hardware

METK's hardware architecture is initially based on a single UNIX-based Silicon Graphics workstation. The workstation will be used to develop, integrate and test the METK module. The configuration of the workstation is as follows:

Onyx Extreme Deskside workstation
- 200 mhz dual R4400 processor,

- 128 megabyte RAM,
- 4 megabyte secondary cache,
- 2 gigabyte internal DAT tape drive,
- 2 gigabyte SCSI-2 internal disk drive,
- internal CD ROM,
- dials and buttons box, and
- 21 inch Multisync Granite monitor.

The workstation is networked to other computer platforms located within the Advanced Manufacturing Systems and Networking Testbed (AMSANT) facility and elsewhere at NIST. As such, it is connected to the Internet. File transfer protocol (FTP) may be used to transfer data files and software from collaborator sites.

A Postscript-capable laser printer is required to output reports. A video interface card and videotape recorder is required to log simulation runs.

3.4.2 Required Support Applications

Application support packages that are required to run the METK include:

IRIS Development System for IRIX 5.3 operating system including C++ 4.0 and Viewkit 1.1,
Oracle - relational data base management system,
Objectivity - object-oriented database management system,
GUI window manager, and
other applications yet to be determined.

Software development, system build, and configuration management utilities are required to maintain and extend the tool kit. These are software tools which support the software development process, building of system versions from the correct source code modules, and management of source code and link libraries. Software development tools will include: information modeling systems, general Computer-Aided Software Engineering (CASE) tools, compilers, linkers, debuggers, code generators, etc.

4. GLOSSARY OF TERMS

CAME - Computer-Aided Manufacturing Engineering.

COTS - commercial off-the-shelf software.

Engineering data package - Engineering data packages contain the information needed to perform the manufacturing operations required to produce a single part or a lot of parts. A data package may contain a sequence of operations, data required for each operation, tooling lists, machine control programs, operator instructions, quality control parameters, and administrative documentation.

Generative process planning - A process planning system which uses expert rule-based systems to generate process plans from part descriptions.

METK - Manufacturing Engineering Tool Kit.

System architecture - A technical specification for a system which identifies its major modules, functions of the modules, types of data used by the modules, and interfaces between the modules.

Tool Kit - A set of software packages that provide an integrated set of functions and share data to serve a common business purpose, e.g., manufacturing engineering.

Variant process planning - A process planning system which new process plans are created by searching for existing plans for similar parts and modifying the plans to accomodate variations in the new part.

Appendix C: METK Development Context Briefings

- » METK Overview
- » Plan of Action
- » Engineering Data Package Integration
- » Manufacturing Engineering Data Package Validation

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Manufacturing Engineering Tool Kit Overview

Chuck McLean
Leader
Manufacturing Systems Engineering Group

CAME Industry Meeting
March 1995

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Outline

* CAME Program Background
* Manufacturing Engineering Tool Kit (METK)
  - Abstract
  - Goal and Scope
  - Candidate Part Mix
  - Technical Focus
  - Requirements Synopsis
  - System Concept
  - Project Deliverables
* Issues and Questions

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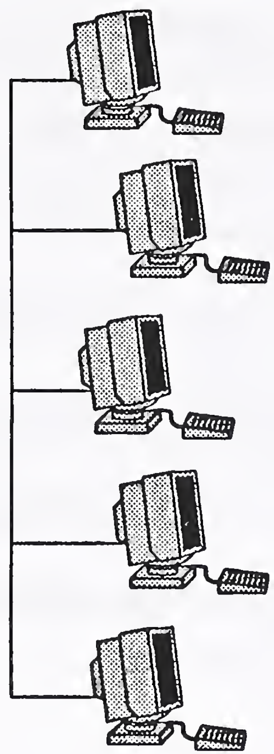
Computing Environments in the Manufacturing Enterprise



- Business Management
- Design and Product Data Management
- Manufacturing Engineering
- Production Planning and Control
- Distribution and Logistic Support

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Industry Needs

* Integrated engineering tool kits and databases
* Capabilities to reliably predict manufacturing system behavior
* Standard manufacturing engineering databases
* Improved tools for performing a number of engineering functions, for example: producibility analysis, tolerance analysis, process planning, system simulation, tool and fixture design
* Plug-compatibility between commercial engineering tools

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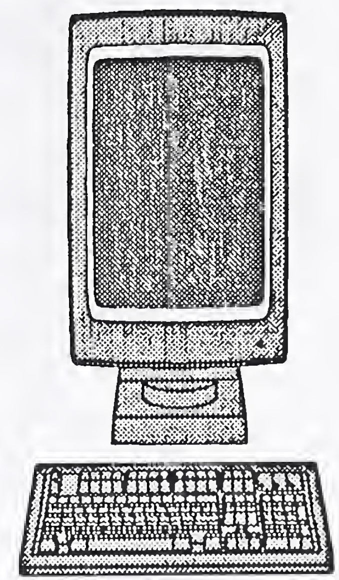
Manufacturing Engineering Tools

– Limited number of tools are available

– Some problems with existing tools include:

- *Not widely used*
- *May be difficult to learn*
- *Per site costs are high*
- *Many capabilities have not been computerized*
- *Many techniques are not well-defined*



– The most significant problem is that existing tools are not integratable, i.e., they do not work together!

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Tool Kit Integration Problems

- Difficulties in sharing data among engineering tools
- Cryptic, proprietary data file formats
- Inconsistent tool launching mechanisms
- Conflicts in system configuration requirements
- Different sets of peripheral devices are supported
- Integration is at the lowest common denominator (text)
- Lack of synergy between commercial products
- Inconsistent user interface designs
- Annoying security mechanisms
- Intrusive copyright and licensing notice screens
- Limited flexibility in report formats

Advertisement for Commodore Multimedia products.
— PC Week, 5 October1992

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The CAME Solution

Computer-Aided Manufacturing Engineering (CAME) is broadly defined as:

the use of computerized tools in the application of scientific and engineering methods to the design and implementation of manufacturing systems, subsystems, processes, and equipment.

The overall goal of CAME is to lower manufacturing costs, reduce delivery times, and improve product quality through the coordinated development and use of advanced tools.

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The "Vision"

An integrated computing environment for manufacturing engineering which includes:

- engineering tools
- other application software
- databases and reference libraries
- operating systems
- computer and communications hardware

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Typical CAME Applications

System Level	Product Concept	Product Development	Production Planning	Production
Equipment	- Equipment concepts	- Tolerance studies	- Tool design - Equipment selection	- Capability analyses - SPC
Process	- Process concepts	- Producibility analyses - Design for X	- Process planning - Inspection procedures	- Process mapping - Time and motion
Cell / Department	- Cell concepts	- Cell design	- Assembly line design - Equipment selection - Cell layout	- Performance studies - Quality standards
Factory	- Capacity analysis - Factory concepts	- Site location	- Plant layout - Make-or-buy - Material handling	- Performance studies - Incentive programs
Enterprise	- Production strategy	- Cost estimating - Teaming	- Outsourcing - Quality management	- Benchmarking - Supplier tracking

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Who will use CAME?

Current users:
- Manufacturing Engineers
- Design Engineers
- Quality Engineers
- Industrial Engineers
- System Engineers
- Process Planners
- Tool Designers
- Etc.

Additional future users:
- Manufacturing Strategists
- Producibility Engineers
- Enterprise Designers
- Benchmarkers
- Etc.

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CAME Program Focus

The CAME Program will place an emphasis upon providing:

- an integrated framework,
- operating environment,
- common databases, and
- interface standards

for a wide variety of emerging tools and techniques for designing manufacturing processes, equipment, and enterprises, as well as tools for evaluating the producibility of product designs.

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Why is ManTech focusing on CAME?

- Manufacturing Systems Committee Strategic Plan estimates DOD spends $24.7 billion annually on mfg. support costs--mfg. engineering represents roughly $3.2 billion of these costs. It recommends investment in: 1) integration methodologies, 2) simulation and modeling, and 3) manufacturing/industrial engineering support tools to reduce these costs.

- Engineering tools increase the productivity of engineers performing producibility analyses, design of manufacturing processes and systems, determining production and quality costs, and design trade-off studies. CAME focuses specifically on improving the productivity of manufacturing engineers through the development of integrated tool kits.

- It is reasonable to expect that as project results are widely implemented engineering costs could be reduced 10% annually with a potential savings of $320 million/year.

- The cost of this program is small in comparison to expected benefits. DOD investment is being leveraged by internal NIST investment in related efforts.

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Long Term Strategy

- Identify and refine the required engineering methods and tools
- Specify architectures and designs for integrated environments
- Select target computing platforms for project implementations
- Develop prototype manufacturing engineering tool kits
- Validate specifications and establish industry standards
- Provide conformance testing mechanisms and support activities
- Promote commercialization of tool kit technology
- Implement tool kit environments on manufacturing programs

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Key Issues

* Collaboration with industry users, system vendors, researchers, and other government agencies
* System implementations based upon commercial software tools
* Development of architectures, integration techniques, and common databases for engineering tool kits
* Applicability of results to large and small businesses alike
* Public demonstration of new tool kit capabilities
* Industrial testing of prototype tool kit environments
* Establishment of rapid commercialization paths for new technologies

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METK Project Abstract

- Construct an integrated manufacturing engineering tool kit and common databases that provide: 1) product data and work flow management, 2) process planning, 3) engineering data validation through simulation, and 3) possibly other capabilities for a family of machined parts.

- Functionality will be based upon extensions to the capabilities of commercial off-the-shelf software and hardware.

- Conduct the project as a collaborative effort by users, vendors, academic researchers, and representatives other government agencies in project planning, requirements definition, system design, development, testing, and evaluation.

- Perform "alpha" testing and evaluation of the tool kit environment at industry and government manufacturing sites.

- Recommend new industry standards based upon project results.

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METK Project Goal

- To develop an integrated engineering tool kit from commercial software products that will enable a manufacturer to produce machined parts correctly the first time.

- To initiate the development of standards for manufacturing engineering tool integration based upon interface specifications defined for the tool kit.

METK Project Scope

* A family of precision machined parts that must fit together
* Process planning and NC programming capabilities
* A selected set of machining and support processes, for example:
    - work station setup
    - milling, drilling, boring, turning, grinding
    - cleaning and inspection
* Validation of critical aspects of the manufacturing process, such as:
    - setup
    - metal cutting operations
    - tolerance variations and stackups

Candidate Part Mix

- Material: machinable metal alloys
- Work volume: Up to 24 inch (60cm) cube
- Weight: Up to 250 lbs (100 kgms)
- Machinable features: holes, pockets, cylindrical features, threads, bores, counterbores, flats, chamfers, grooves, slots, etc.
- Assembly operations: mechanical fasteners, force fits, shrink fits
- Finishing operations: deburring, heat treatment, painting
- Tolerances: Up to 0.0002 inch

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METK Technical Focus

- Integration of commercial software into a tool kit environment
- Development of information models and common databases for required manufacturing engineering data
- Extension of process planning system to include the use of: process capabilities databases, common manufacturing work element definitions, and generic report formats
- Extension of simulation system(s) to include: process plan verification and tolerance analysis capabilities
- Development of a common tool shell which provides standard mechanisms for handling interaction between a software tool and: 1) the database management system, 2) the graphical user interface, 3) other tools, and 4) the computer operating system

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Requirements Synopsis

- Loading of product design data from several CAD formats
- Management of product, process, and engineering change order data
- Workflow management for planning and validation processes
- Planning of routings and operations for machined parts
- Selection of resources, e.g. material stock, tools, fixtures
- Validation of engineering data through simulation, checklists, etc.
- Management of resource data required for planning and plan validation
- Preparation of hard copy reports, e.g., plans, tool lists, inventory status
- Recording of simulation runs on video tape

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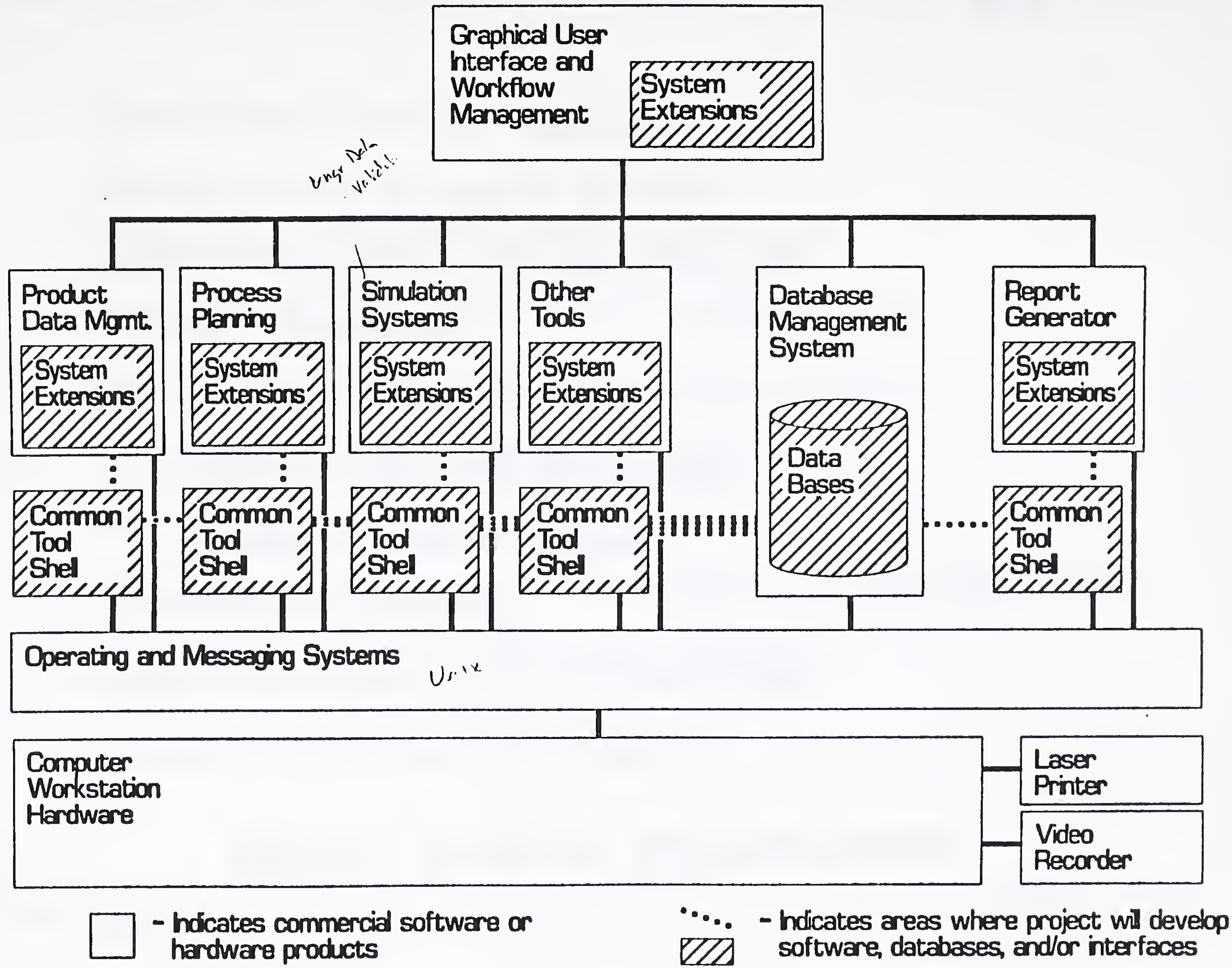
System Concept for the Manufacturing Engineering Tool Kit



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METK Project Deliverables

* Manufacturing Engineering Tool Kit (METK)
* Public demonstrations of the tool kit environment
* Various technical documents:
    - Requirements / needs analyses
    - Architecture and design specifications
    - Test and demonstration plans
    - User documentation
* Installation and testing of tool kit at "alpha" sites
* Information models for common databases
* Recommended standards

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Issues

- Specification of relevant engineering methodologies
- Identification of required functionality of engineering tools
- Definition of data models and data management schemes
- Development of on-line reference and test data sets
- Selection of graphical user interface management systems
- Identification of mechanisms for tool connectivity and information sharing
- Establishment of standards for system integration

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Plan of Attack

Swee Leong
Manufacturing Engineer

CAME Industry Meeting
March 1995

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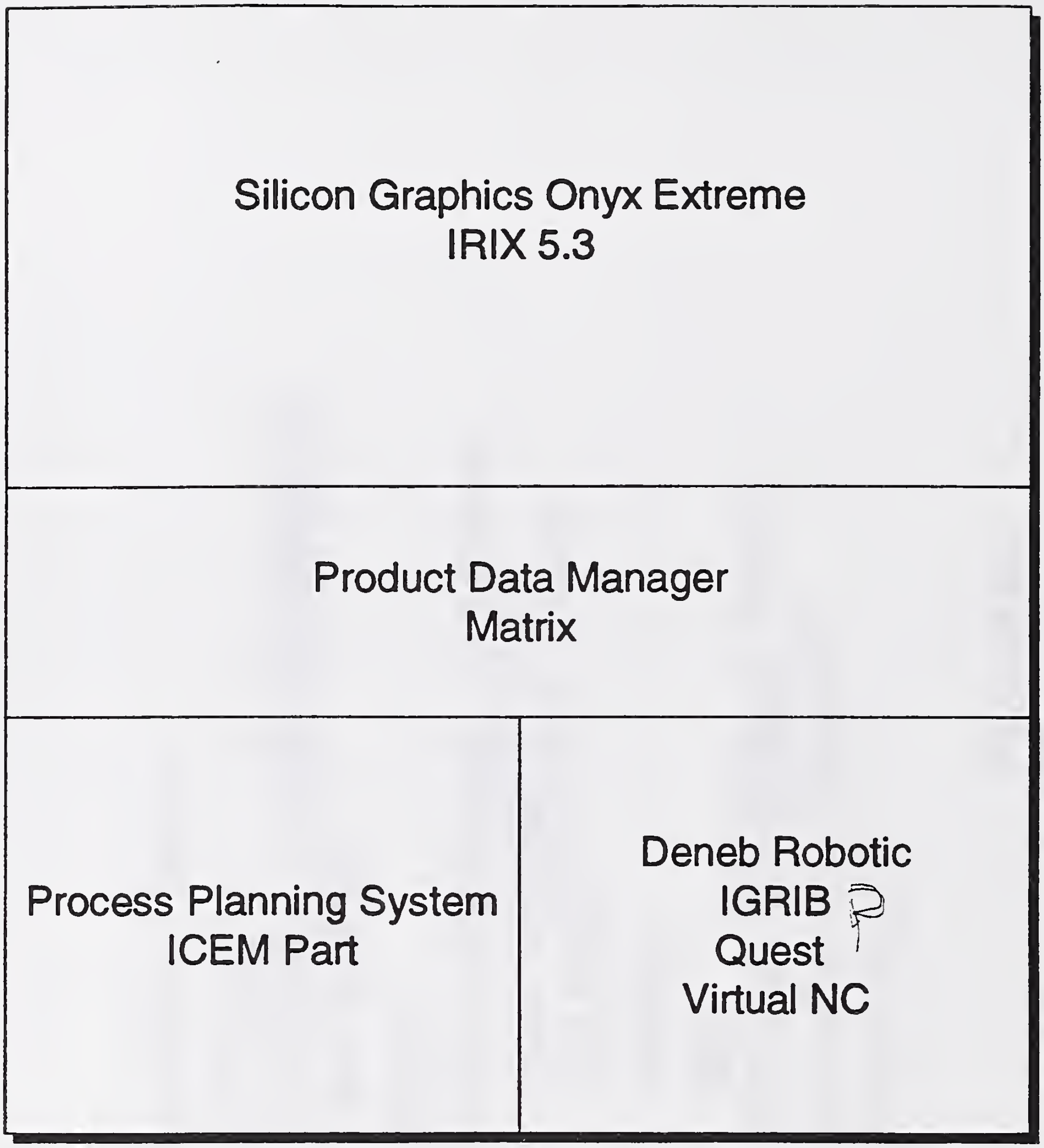
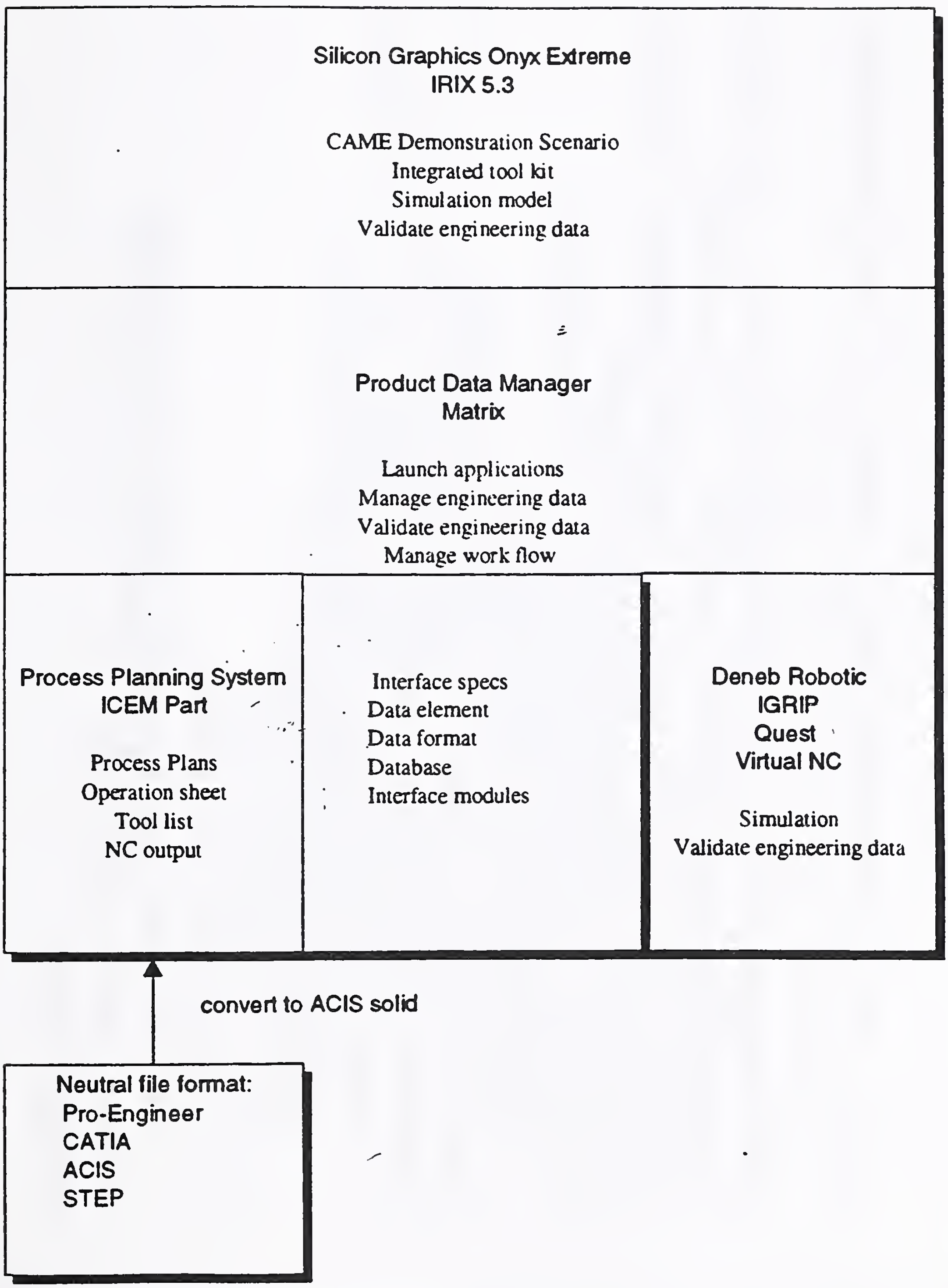
Outline

* Baseline system
* What needs to be done
* Participant responsibilities
  - NIST
  - Vendors
  - End users
  - Other participants
* Levels of collaboration - participation
* Benefits
* Project schedule
* Project status - progress to date
* Project issues
* Discussion questions

Baseline system



What needs to be done



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NIST Responsibilities

* Identify project participants (software vendors, end users, universities, researchers, subcontractors, DOD agencies)
* Obtain sponsor funding and various in-kind contributions from participants
* Organize CAME Forum technical meetings - 4 times a year
* Organize CAME Executive Advisory Committee meetings - 2 times a year
* Identify baseline software and hardware products
* Provide Advanced Manufacturing Systems and Networking Testbed (AMSANT) laboratory facilities
* Obtain and install hardware and software in AMSANT
* Coordinate participation in development efforts
    - requirements and system design specification
    - systems and database development
    - unit and integration testing
    - documentation and training
    - pilot and alpha site installation, testing, and evaluations
* Develop generic shop models
* Manage project

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Vendor Responsibilities

* Provide baseline software
  - ICEM Technologies - PART process planning
  - Deneb Robotics - Quest / Envision / Virtual NC simulation
  - ADRA Systems - Matrix product data management
* Participate in developing interface specifications
* Install systems in AMSANT Facility
* Train users and developers
* Develop interface module and system extensions
* Support applications
* Participate in tests and demonstrations

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End User Responsibilities

* Participants involved in production: Black & Decker, Texas Instruments, Hughes Missile Systems, Litton Amecom, Naval warfare centers, Army arsenals, . . .
* Review technical approach, specifications, designs, data, etc.
* Select and provide test parts and data
* Provide engineering process model, part routing, operation, and tooling data
* Help build own operating scenario
* Commit technical staff
* Participate in testing and demonstrations
* Identify executive champion
* Cover own expenses

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Other Participant Responsibilities

* Army TARDEC
  - Provide machine simulation models
  - Build new models

* Defense Systems Management College
  - Develop educational program
  - provide training facilities over Internet

* Universities and other Research Institutions
  - Software Engineering Institute - tool kit architectures
  - University of Kansas - process capabilities
  - Brigham Young University - production engineering tools

* Subcontractors
  - Create process models
  - Build machine shop models and checklists
  - Develop common database

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Levels of Collaboration · Participation

* NIST provides development and testing environment
  - hardware
  - software: ICEM Part, Deneb Quest/Envision/VNC, Matrix
  - test and demonstration system, scenarios, models, data

* Participant's technical staff works at NIST for several days to several weeks at a time to develop their specific operating scenarios

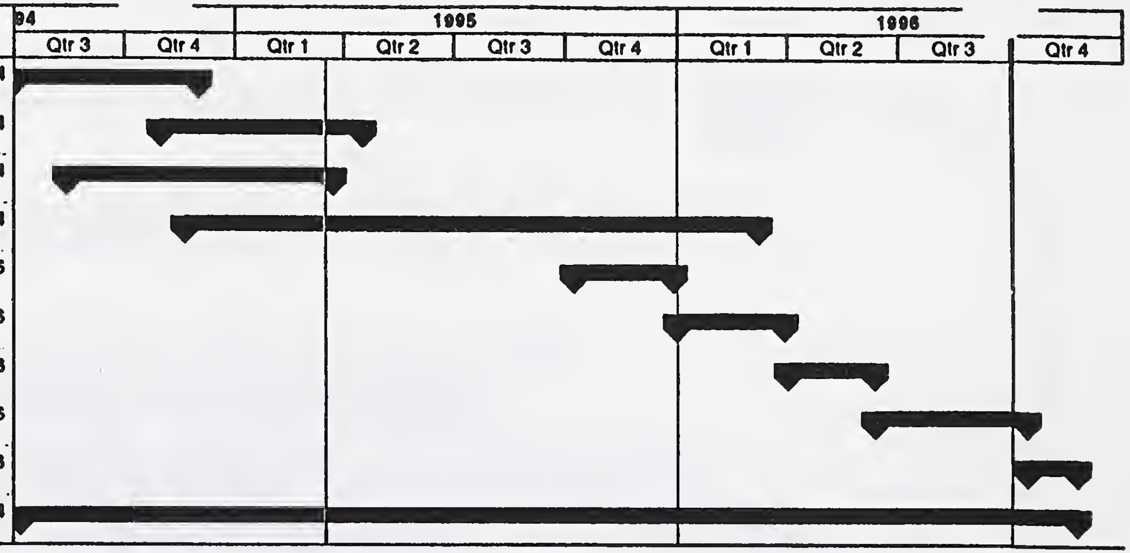
* Participant obtains SGI Indigo workstation and software licenses for co-development and testing

* Participant site establishes remote network link to access NIST development system over Internet (after obtaining appropriate local workstation hardware and required software licenses)

Benefits

* Introduction to new tools
* Use of integrated tool kit
  - common data formats
  - common database
  - avoid wasted time re-entering same data into multiple tools
  - reduce cycle time to generate error free process plans
  - improve quality, less scrap and rework
* Improve interoperability - standard interfaces between tools
* Improve demand and market share
* Reduce risks in introducing new technologies

ID	Task Name	Group	Duration	Start
1	T1. Prepare & maintain technical development p		111d	7/1/94
5	T2. Initiate industrial collaborations		120d	11/1/94
10	T3. Select, acquire, and install baseline systems		160d	8/15/94
20	T4. Prepare specifications and contracts		340d	11/21/94
33	T5. Develop individual tool modules & database		60d	10/9/95
35	T6. Integrate and test tool modules and databas		65d	1/1/96
38	T7. Demonstrate system		51d	4/1/96
41	T8. Conduct "alpha" testing at other sites		90d	6/11/96
45	T9. Prepare final documentation package		30d	10/15/96
47	T10. Manage tool kit environment project		622d	7/8/94



Project: Manufacturing Engineering Tool Ki
Date: 3/16/95

Task		Summary		Rolled Up Progress	
Progress		Rolled Up Task			
Milestone	◆	Rolled Up Milestone	◇		

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Project Status - Progress To Date

* Identified initial industrial participants
* Identified Industrial Advisory Committee members
* Purchased and installed development hardware (SGI Onyx Extreme)
* Purchased and installed baseline software
  - ICEM Technologies Part
  - Deneb Quest, Envision and Virtual NC
  - Matrix Product Data Manager
* Leveraging other NIST resources
* Developed manufacturing engineering functional model
* Developed preliminary tool kit specification
* Organized first technical meeting of CAME Forum - March 95

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Project Issues

* CAD systems and data formats (ACIS, CATIA, Pro-Engineer, STEP, Intergraph, Unigraphics)
* Letter of agreement and/or CRDAs
* Handling of proprietary data
* Operating scenario
* Individual facility models
* Staffing needs
* Project schedule
* In-kind contributions
* Demo systems usage and loan
* Selection of pilot sites and alpha test sites
* Hardware requirements
* Software license requirements
* Training on hardware, software and integrated system

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Action Items

- CRDAs and/or Letter of Agreement
- Test parts and part models
- Process data
- Tooling data
- Names of participating technical staff

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Next Meeting Plan

* Scheduled for June/July time frame
* Discuss engineering models and user scenario
* Review plans and technical specifications:
  - System design document
  - System architecture
  - Interface specifications
  - Database specifications

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Computer Aided Manufacturing Engineering

Engineering Data Package Integration

March 21, 1995

Steven Ray

Outline

- Objective
- Engineering Data Package definition
- Approach
- Other representation efforts and approaches
- Data exchange with the ICEM PART system
- Example data
- Process plan data issues

Integration Objective

To identify the data package needed to support integration of the manufacturing process planning function with other engineering functions.

Engineering Data Package Contents

Process plan: routing and operation sheet*†

NC program†

Tool, fixture, machine, materials lists*†

Quality plans*†

Product data

---

*. Formats are needed

†. Data that we need to validate

Approach

Select commercial process planning technology

Analyze and document functional and communication requirements of the system

Implement a reusable integration solution for identified data

International Organization for Standardization
Subcommittee 4
Industrial Data and Global
Manufacturing Programming Languages

TC 184/SC4 N259

Source: Secretariat
Date: 7 June 1994

ISO CD 10303 - 213

Product Data Representation and Exchange - Part 213: Application Protocol: Numerical Control Process Plans for Machined Parts

Attached is STEP Part 213 which specifies an application protocol (AP) for the exchange, archiving and sharing of computer-interpretable numerical control process plans for machined parts. The intent of this AP is to enable the sharing of data among dissimilar computer aided process planning systems. The AP specifies the data contained within a process plan as opposed to the data necessary to perform process planning functions. Included are the relationships that exist between the different process plan data elements as well as the relationships that exist between these data elements and the product definition data. Product definition data includes data elements such as geometry, surface finish and tolerance.

This document is the same as SC4/WG3 N303 10 May 1994 and has been reviewed and approved for CD ballot by the following:

Qualification	Mary Mitchell	11 May 94
Integration	Yuhwei Yang	10 May 94
Project Leader	Larry Parker	7 Jun 94
Working Group	Barbara Warthen	7 Jun 94
PMAG	Neal Laurance	7 Jun 94

CD BALLOT CLOSING DATE - 7 OCTOBER 1994

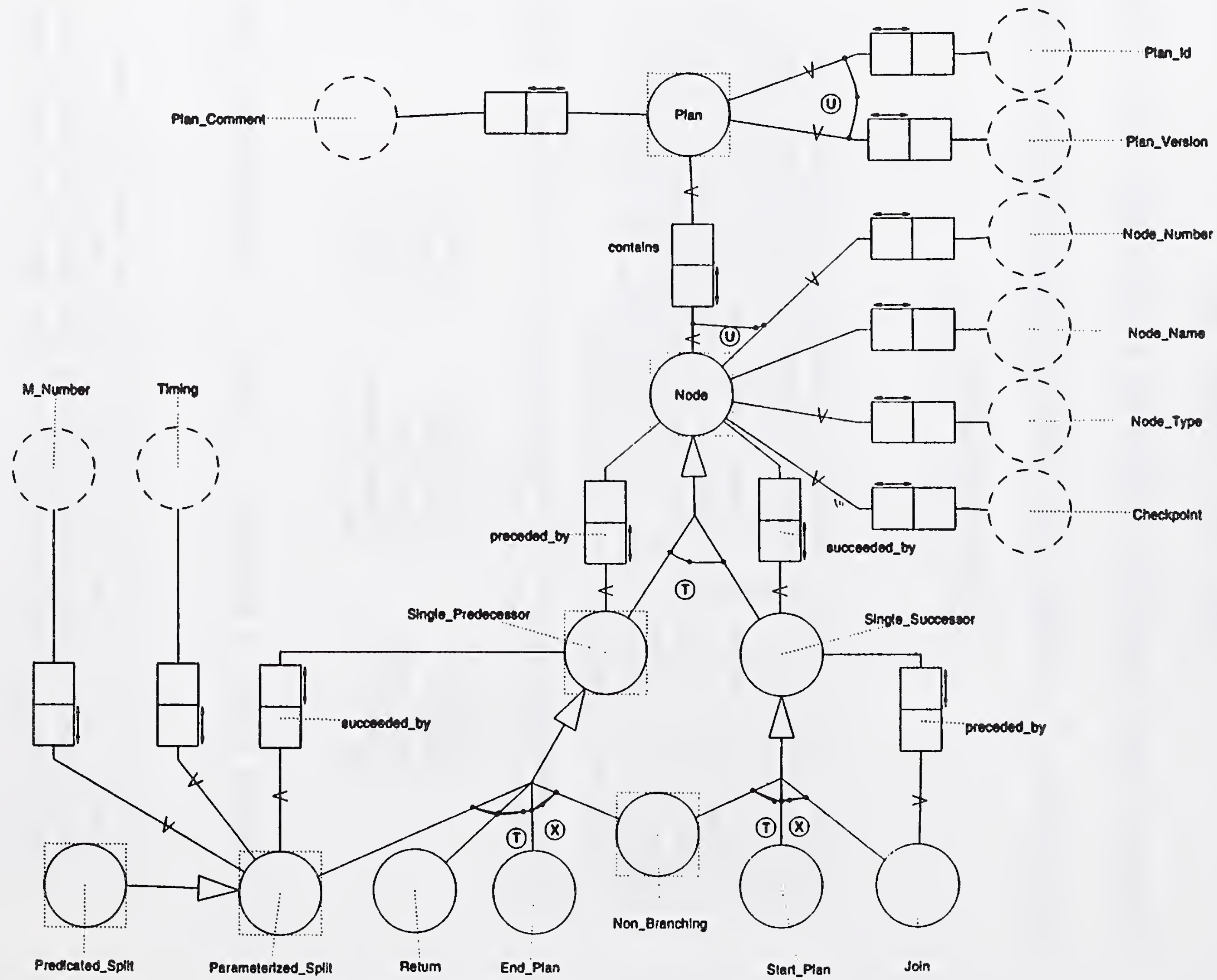
CD ballots are required by all SC4 "P" Members by the due date shown above. Commentors are asked to send their material in electronic form to speed the summarization and reporting of results. Email has been found to be most effective, although comments in ASCII form on PC format floppy disks are acceptable if they are sent via overnight mail.

Secretariat: National Institute of Standards and Technology
A127 Building 220
Gaithersburg, MD 20899 USA

Phone 301 975-3558
FAX 301 258-9749
Email smithb@cme.nist.gov

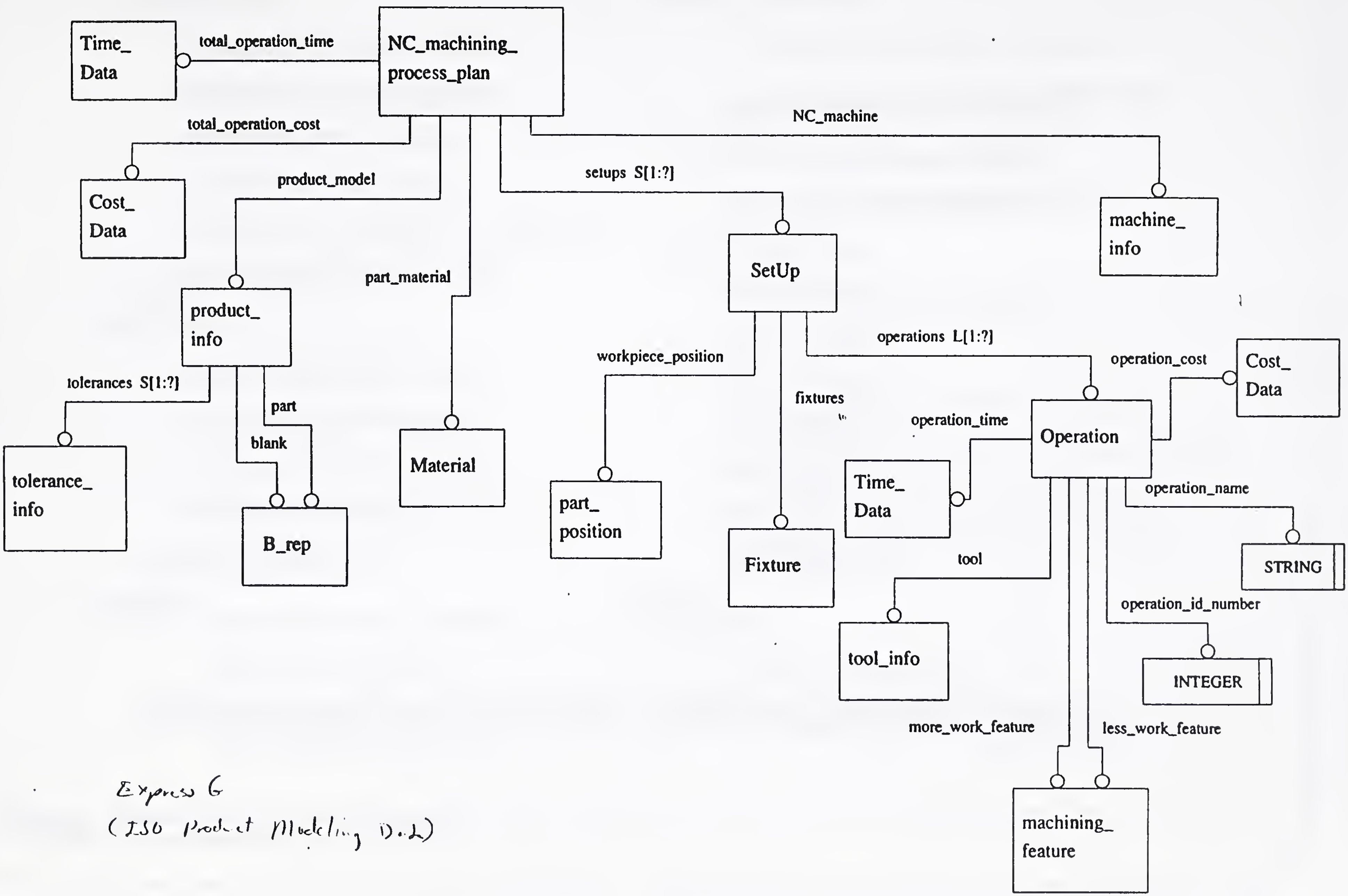
United States Department of Commerce
National Institute of Standards and Technology

ALPS - A Language for Process Specification



A Process Plan Model for PART

Working Draft (3/11/95)



Express G
(ISO Product Modeling D..L)

Machining Features Supported by PART

Holes:

- Hole round straight
- Hole obround straight
- Hole rectangular straight
- Hole free-shaped straight
- Hole round straight thread

Pockets:

- Pocket free shaped straight
- Pocket round straight
- Pocket round tapered
- Pocket obround straight
- Pocket rectangular straight
- Pocket round straight thread

Slots:

- Slot rectangular
- Slot round
- Slot obround
- Slot U-shaped
- Slot V-shaped
- Slot T-shaped
- Slot 90 degree
- Slot dovetail
- Slot upside down dovetail
- Slot rectangular free shaped
- Slot rectangular non-symmetric

Partial slots:

- Partial slot round
- Partial slot U-shaped
- Partial slot obround
- Partial slot rectangular
- Partial slot U-shaped free-shaped

Corner notches:

- Corner notch straight
- Corner notch round
- Corner notch U-shaped
- Corner notch rectangular
- Corner notch round convex

Side notches:

- Side notch round concave
- Side notch U-shaped
- Side notch rectangular
- Side notch round convex

Axial grooves:

- Axial groove circular rectangular
- Axial groove free-shaped rectangular

Inside grooves:

- Groove inside radial rectangular

Surfaces:

- Planar surface rectangular

Profiles:

- Inside profile round tapered convex
- Inside profile free-shaped tapered convex
- Outside profile round tapered convex
- Outside profile free-shaped tapered convex

Bosses:

- Boss round straight
- Boss free-shaped straight

OPERATION SHEET

product : dmprod_04
material : AlMgSi1 — **machine** : MAHO MC 400 - PT — date : 02/28/95 11:01
setup : 1 — **toolset** : TOOL_SET_1 — programmer : JMC

coordinate extremes	X	Y	Z
MIN :	-100.000	-100.000	-50.000
MAX :	100.000	100.000	100.000

total time : 04:02:21
machine costs : 42.6 USD
tooling costs : 23.3 USD
total costs : 65.9 USD

NR	OPERATION	TOOLNO	TOOL	DIAMETER	TIME	COSTS (USD)
1	Mill_Pock_Rect_Drill_Sprl_Out	18	AL_SHANK_END_MILL_3_FL	20.0 mm	00:01:10	1.00
2	Mill_Pocket_Free_Shaped	18	AL_SHANK_END_MILL_3_FL	20.0 mm	00:02:02	1.00
	TABLE ROTATION -- A-axis, 90.0, INCR, CCLW --					
3	Mill_Corner_Notch_Straight_New	18	AL_SHANK_END_MILL_3_FL	20.0 mm	00:02:54	1.00
4	Mill_Slot_Part_Rect	79	SHANK_END_MILL	6.00 mm	01:07:22	8.00
5	Mill_Slot_Part_Rect	79	SHANK_END_MILL	6.00 mm	01:07:24	8.00
	TABLE ROTATION -- A-axis, 90.0, INCR, CLW --					
6	Finish_Pocket_Free_Shaped	79	SHANK_END_MILL	6.00 mm	01:23:25	1.00
7	Mill_Pocket_Profile_Contour	1	AL_SHANK_END_MILL_3_FL	16.0 mm	00:00:45	0.50
8	Centering	46	NC_CENTRE_DRILL	16 mm	00:00:01	0.10
9	Centering	46	NC_CENTRE_DRILL	16 mm	00:00:01	0.10
	TABLE ROTATION -- A-axis, 90.0, INCR, CCLW --					
10	Centering	46	NC_CENTRE_DRILL	16 mm	00:00:01	0.10
11	Centering	46	NC_CENTRE_DRILL	16 mm	00:00:01	0.10
12	Centering	46	NC_CENTRE_DRILL	16 mm	00:00:01	0.10
13	Drill_Small_Hole_Brkchp	21	AL_TWIST_DRILL	6.0 mm	00:00:14	0.10
14	Drill_Big_Hole	22	TWIST_DRILL	12.0 mm	00:00:18	0.10
15	Drill_Big_Hole	20	TWIST_DRILL	18.0 mm	00:00:23	0.10
16	Plunge_Mill_Pre_Drilled_Pocket	18	AL_SHANK_END_MILL_3_FL	20.0 mm	00:00:30	0.10
17	Finish_Pocket_Round_Straight	1	AL_SHANK_END_MILL_3_FL	16.0 mm	00:05:41	1.00
18	CM_Stepped_Pocket	18	AL_SHANK_END_MILL_3_FL	20.0 mm	00:01:12	1.00

NR	OPERATION	TOOLNO	TOOL	DIAMETER	TIME	COSTS (USD)
19	Centering	46	NC_CENTRE_DRILL	16 mm	00:00:01	0.10
20	Centering	46	NC_CENTRE_DRILL	16 mm	00:00:01	0.10
21	Centering	46	NC_CENTRE_DRILL	16 mm	00:00:01	0.10
22	Centering	46	NC_CENTRE_DRILL	16 mm	00:00:01	0.10
23	Centering	46	NC_CENTRE_DRILL	16 mm	00:00:01	0.10
24	Centering	46	NC_CENTRE_DRILL	16 mm	00:00:01	0.10
25	Centering	46	NC_CENTRE_DRILL	16 mm	00:00:01	0.10
26	Centering	46	NC_CENTRE_DRILL	16 mm	00:00:00	0.10
27	Drill_Small_Hole_Brkchp	31	AL_TWIST_DRILL	5.0 mm	00:00:10	0.60
28	Drill_Small_Hole	31	AL_TWIST_DRILL	5.0 mm	00:00:05	0.60
29	Drill_Small_Hole_Brkchp	31	AL_TWIST_DRILL	5.0 mm	00:00:10	0.60
30	Drill_Small_Hole	31	AL_TWIST_DRILL	5.0 mm	00:00:05	0.60
31	Drill_Small_Hole_Brkchp	31	AL_TWIST_DRILL	5.0 mm	00:00:10	0.60
32	Drill_Small_Hole	31	AL_TWIST_DRILL	5.0 mm	00:00:05	0.60
33	Drill_Small_Hole_Brkchp	31	AL_TWIST_DRILL	5.0 mm	00:00:10	0.60
34	Drill_Small_Hole	31	AL_TWIST_DRILL	5.0 mm	00:00:06	0.60
TABLE ROTATION -- A-axis, 90.0, INCR, CLW --						
35	Drill_Small_Hole	31	AL_TWIST_DRILL	5.0 mm	00:00:08	0.20
36	Drill_Small_Hole	31	AL_TWIST_DRILL	5.0 mm	00:00:09	0.20
TABLE ROTATION -- A-axis, 90.0, INCR, CCLW --						
37	Drill_Small_Hole_Brkchp	61	TWIST_DRILL	5.5 mm	00:00:11	0.20
38	Drill_Small_Hole_Brkchp	61	TWIST_DRILL	5.5 mm	00:00:12	0.20
39	Drill_Big_Hole	51	AL_TWIST_DRILL	7.5 mm	00:00:10	0.10
40	Drill_Big_Hole	51	AL_TWIST_DRILL	7.5 mm	00:00:11	0.10
41	Drill_Big_Hole	51	AL_TWIST_DRILL	7.5 mm	00:00:11	0.10
42	Drill_Big_Hole	51	AL_TWIST_DRILL	7.5 mm	00:00:11	0.10
43	Plunge_Mill_Pre_Drilled_Pocket	13	AL_SHANK_END_MILL_3_FL	8.0 mm	00:00:16	0.20
44	Plunge_Mill_Pre_Drilled_Pocket	13	AL_SHANK_END_MILL_3_FL	8.0 mm	00:00:16	0.20
45	Plunge_Mill_Pre_Drilled_Pocket	13	AL_SHANK_END_MILL_3_FL	8.0 mm	00:00:16	0.20
46	Plunge_Mill_Pre_Drilled_Pocket	13	AL_SHANK_END_MILL_3_FL	8.0 mm	00:00:17	0.20
TABLE ROTATION -- A-axis, 90.0, INCR, CLW --						
47	Mill_Pocket_Profile_Contour	13	AL_SHANK_END_MILL_3_FL	8.0 mm	00:00:26	4.00
TABLE ROTATION -- A-axis, 90.0, INCR, CCLW --						
48	Plunge_Mill_Pre_Drilled_Pocket	79	SHANK_END_MILL	6mm	00:00:14	0.50
49	Plunge_Mill_Pre_Drilled_Pocket	79	SHANK_END_MILL	6mm	00:00:14	0.50

NR	OPERATION	TOOLNO	TOOL	DIAMETER	TIME	COSTS (USD)
50	Plunge_Mill_Pre_Drilled_Pocket	79	SHANK_END_MILL	6mm	00:00:14	0.50
51	Plunge_Mill_Pre_Drilled_Pocket	79	SHANK_END_MILL	6mm	00:00:14	0.50
52	CM_Stepped_Pocket_Plunge_Mill	62	SHANK_END_MILL	10mm	00:00:15	0.50
53	CM_Stepped_Pocket_Plunge_Mill	62	SHANK_END_MILL	10mm	00:00:16	0.50
54	CM_Stepped_Pocket_Plunge_Mill	62	SHANK_END_MILL	10mm	00:00:16	0.50
55	CM_Stepped_Pocket_Plunge_Mill	62	SHANK_END_MILL	10mm	00:00:17	0.50
TABLE ROTATION -- A-axis, 90.0, INCR, CLW --						
56	Drill_Big_Hole	26	AL_TWIST_DRILL	8.0 mm	00:00:08	1.00
57	Drill_Big_Hole	26	AL_TWIST_DRILL	8.0 mm	00:00:09	1.00
TABLE ROTATION -- A-axis, 90.0, INCR, CCLW --						
58	Drill_Big_Hole	44	TWIST_DRILL	10.0 mm	00:00:13	1.00
59	Drill_Big_Hole	44	TWIST_DRILL	10.0 mm	00:00:14	1.00

TOTAL NUMBER OF TOOL CHANGES : 19
TOTAL NUMBER OF TABLE ROTATIONS : 9

TOOL SHEET

product : dmprod_04		
material : AlMgSi1	machine : MAHO MC 400 - PT	date : 02/28/95 11:01
setup : 1	toolset : TOOL_SET_1	programmer : JMC

TOOLNO	ASSEMBLY_ID	TOOL_ID HOLDER_ID ADAPTER_ID	TOOL HOLDER ADAPTER	Length (offset) TIME	DIAMETER (offset)
18	15	410 1	AL_SHANK_END_MILL_3_FL 20.0 mm COLLET 3-30 mm ISO40	147.00 mm (0.00) 00:07:50	20.00 mm (0.00)
79	80	477 11	SHANK_END_MILL 8mm COLLET DIN1835D 6-16 mm ISO40	180.00 mm (0.00) 03:39:10	8.00 mm (0.00)
1	32	409 1	AL_SHANK_END_MILL_3_FL 16.0 mm COLLET 3-30 mm ISO40	134.00 mm (0.00) 00:06:26	16.00 mm (0.00)
46	39	3 41 13	NC_CENTRE_DRILL 16 mm HOLDER WHISTLE-NOTCH 32 ISO40 COLLET ADAPTER 3-16 mm	248.00 mm (0.00) 00:00:13	16.00 mm (0.00)
21	12	80 31 12	AL_TWIST_DRILL 6.0 mm HOLDER B16 DRILL_CHUCK ISO40 DRILL_CHUCK ADAPTER 1-13 mm	179.00 mm (0.00) 00:00:14	6.00 mm (0.00)
22	11	52 31 12	TWIST_DRILL 12.0 mm HOLDER B16 DRILL_CHUCK ISO40 DRILL_CHUCK ADAPTER 1-13 mm	237.00 mm (0.00) 00:00:18	12.00 mm (0.00)
20	13	427 1	TWIST_DRILL 18.0 mm COLLET 3-30 mm ISO40	211.00 mm (0.00) 00:00:23	18.00 mm (0.00)

TOOLNO	ASSEMBLY_ID	TOOL_ID HOLDER_ID ADAPTER_ID	TOOL HOLDER ADAPTER	LENGTH (offset) TIME	DIAMETER (offset)
31	2	77 31 12	AL_TWIST_DRILL 5.0 mm HOLDER B16 DRILL_CHUCK ISO40 DRILL_CHUCK ADAPTER 1-13 mm	172.00 mm (0.00) 00:01:23	5.00 mm (0.00)
61	65	32 1	TWIST_DRILL 5.5 mm COLLET 3-30 mm ISO40	27.00 mm (0.00) 00:00:24	5.50 mm (0.00)
51	48	86 31 12	AL_TWIST_DRILL 7.5 mm HOLDER B16 DRILL_CHUCK ISO40 DRILL_CHUCK ADAPTER 1-13 mm	184.00 mm (0.00) 00:00:44	7.50 mm (0.00)
13	52	405 1	AL_SHANK_END_MILL_3_FL 8.0 mm COLLET 3-30 mm ISO40	10.00 mm (0.00) 00:01:33	8.00 mm (0.00)
62	64	460 1	SHANK_END_MILL_10mm COLLET 3-30 mm ISO40	106.00 mm (0.00) 00:01:06	10.00 mm (0.00)
26	7	87 31 12	AL_TWIST_DRILL 8.0 mm HOLDER B16 DRILL_CHUCK ISO40 DRILL_CHUCK ADAPTER 1-13 mm	190.00 mm (0.00) 00:00:18	8.00 mm (0.00)
44	33	46 41 11 12	TWIST_DRILL 10.0 mm HOLDER WHISTLE-NOTCH 32 ISO40 DRILL_CHUCK ADAPTER 0-6.5 mm DRILL_CHUCK ADAPTER 1-13 mm	220.00 mm (0.00) 00:00:28	10.00 mm (0.00)

Process Plan Data Issues

- Product identifier – good enough for plan identifier?
- How much approval information should be present?
  - Should that be handled by the PDM system?
- What other information would you want present?
  - Cost estimates
  - Part family identifiers
  - Facility requirements
  - Setup definitions
  - Special tooling or other resource constraints
  - Notes and annotations

Manufacturing Engineering Data Package Validation

Simon Frechette
NIST

Outline

-- Manufacturing Engineering Data Packages

-- Potential Data Package Errors

-- Possible Methods for Data Package Validation

-- Model Production Facility Concept and Scoping

-- Model Production Facility Candidate Processes

-- Issues

-- Questions

NIST

Manufacturing Engineering Data Packages

Manufacturing Engineering Data Package:

Set of information necessary to perform the manufacturing operations required to produce a single part or lot of parts. Includes a sequenced list of operations, data required for each operation, tooling lists, machine control programs, operator instructions, quality control parameters, and administrative documents. The data package may contain the actual data, e.g., oven temperature, or it may point to the actual data, e.g., the name and location of an NC program file.

-- Individual production processes can be proved out prior to production start up

-- Data packages may still contain many errors that must be worked out during the initial production run

-- Fine tuning is costly and time consuming

-- Use simulation to validate the entire data package prior to production

-- Use the actual data as inputs to the simulation models

-- An example is NC program simulation where the actual NC program, fixture design, and machine tool configuration are used as inputs

MEL

Potential Data Package Errors

-- Process Problems

Fixture does not adequately hold part

Adhesive takes too long to cure

Welds are cracking

-- Process incompatibility (i.e., process inadvertently affects subsequent processes)

Welding makes part too hard to mill

Finish interferes with adhesive

-- Resource Availability

Tooling order not verified

Wrong tool number specified

Not enough of a consumable called out

Potential Data Package Errors (cont.)

-- Machine Control Program Errors

- Program is incorrect
- NC program post-processed for wrong machine

-- Tooling/Fixture Problems

- Fixture interferes with cutter
- Fixture does not fit on machine
- Fixture damages part in some way

-- Administrative

- Missing approvals
- Missing forms
- Not latest revision

Possible Methods for Data Package Validation

-- Process simulation (e.g., NC)

-- Check lists

-- Workflow simulation

-- Resource verification

Model Production Facility Concept

Model:
A simplified for idealized description of system or process, often in mathematical terms, devised to facilitate/verify predictions.

-- Define a closed world

-- Create meaningful set of processes

-- Simulate individual processes (e.g., NC verification)

-- Validate data requirements

-- Verify work flow

-- Could take several forms (e.g., check lists, dynamic process simulation, workflow models)

-- Not intended for use as a scheduling tool

Model Production Facility Process Scoping

-- Metal Cutting Machines and Systems

-- Workholding

-- Workhandling

-- Metalforming

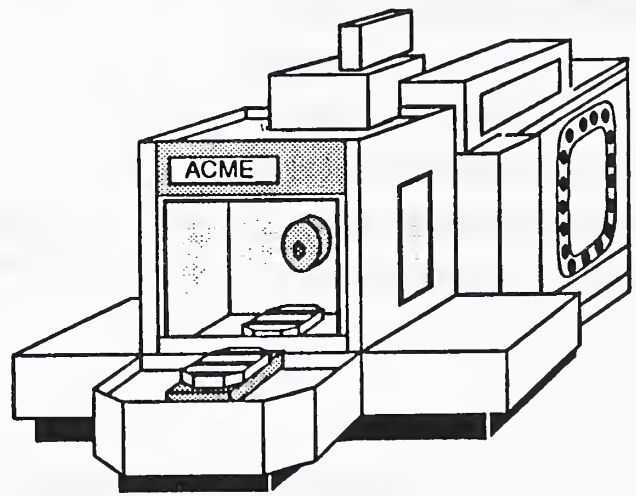
-- Metal Joining, Assembly

-- Metal Cleaning and Finishing

-- Controls, Computers, and Software

-- Inspection and Quality Control

-- Out-of-Scope Processes



Model Production Facility Candidate Processes

-- Metal Cutting Machines and Systems

- Metal Cutting Machines and Systems
- 2-4 NC machine cell w/pallet handling system
- High-speed machining
- NC 4-axis milling
- EDM
- Multi-spindle NC turning machine
- NC 3-axis vertical milling
- NC 3-axis horizontal milling
- NC 2-axis turning
- NC 2-axis grinding
- Machining center w/pallet handling system

- Sawing machines (manual
- Drilling machines (manual)
- Milling machines (manual)
- Tapping, threading
- Broaching
- Turning machines (manual)
- Screw machine
- Gear cutting machine
- 5-axis milling
- laser

Model Production Facility Candidate Processes (cont.)

-- Tooling, Workholding

- Jigs and fixtures
- Tool presetting system
- Modular tooling systems
- Modular fixturing systems
- Tool room

-- Workhandling

- Pallets
- Multi-pallet work handling for machining center
- Marking, bar coding
- Controlled storage area
- Multi-machine pallet handling system
- Fixturing station (manual)

NIST

Model Production Facility Candidate Processes (cont.)

-- Metalforming

- Investment casting
- Die molding

-- Metal Joining, Assembly

- Mechanical fastening systems
- Assembly station
- Welding, brazing
- Adhesives

-- Metal Cleaning and Finishing

- Deburring system
- Parts washing, degreasing
- Painting
- Heat treating, hardening
- Abrasive finishing

MEL

Model Production Facility Candidate Processes (cont.)

-- Controls, Computers, and Software

- Inventory tracking and reordering system
- Cutting tool condition monitoring
- Tooling and workpiece tracking
- Shop floor data collection
- Honing and lapping system
- SPC

-- Inspection and Quality Control

- Inspection stations (manual gaging)
- CMM
- SPC data collection and analysis system
- Optical measurement system
- Gear measurement

Model Production Facility Candidate Processes (cont.)

-- Out-of-Scope Processes

- **Sheet metal**
- **Foundry**
- **Chemical machining**
- **Chemical treatment**
- **Automated part handling between stations (e.g., AGV)**
- **Scheduling**
- **Plastics**
- **Composite materials processes**
- **Waterjet/abrasive jet**

Issues

-- Acquisition of data required to create a model facility and processes

-- Intra-package data compatibility (e.g., PART-Deneb)

-- Use of evolving standards (e.g., STEP APs)

-- Application of results of data validation process

Questions

-- What data elements are commonly included in manufacturing engineering data packages?

-- What data should be validated?

-- How should data be validated?

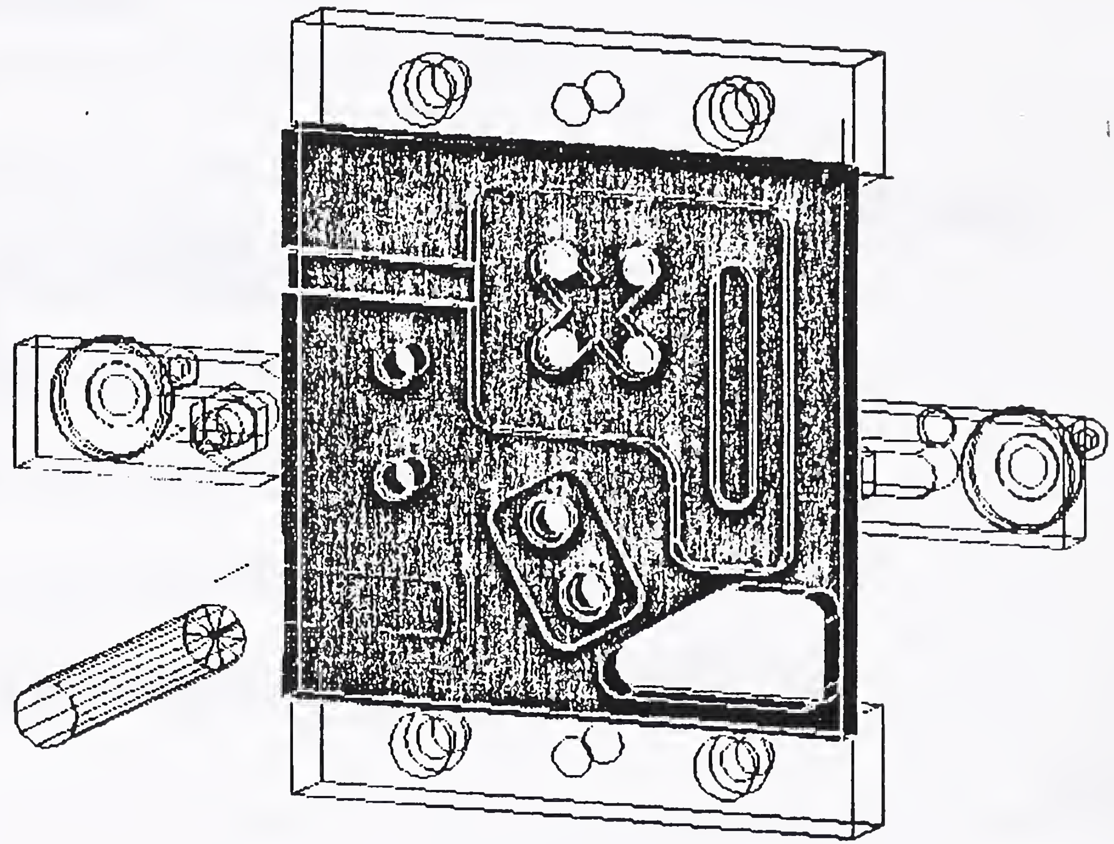
-- What processes, machines, and activities should be included in the modeled facility?

-- What types of simulation / modeling would be most effective?

Appendix D: Application Software Descriptions

- » ICEM Process Planning System
- » Deneb Simulation Systems
- » Matrix Product Data Management System

PART
A Fresh Start For Manufacturing

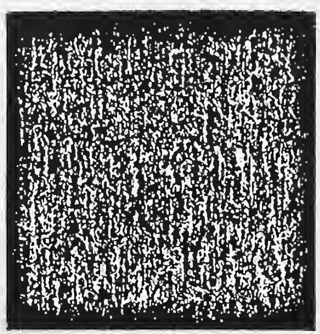


ICE Technologies

Partners in Advanced Technologies

ICEM Technologies

CONTROL DATA

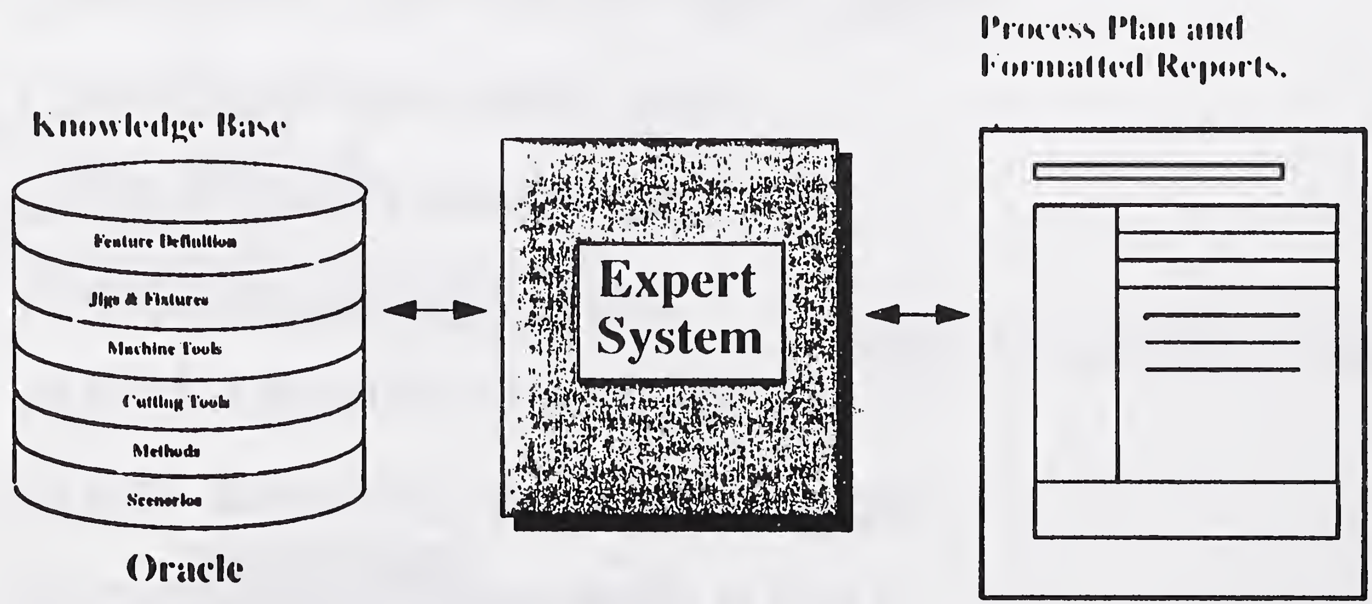


C3 Manufacturing System Software

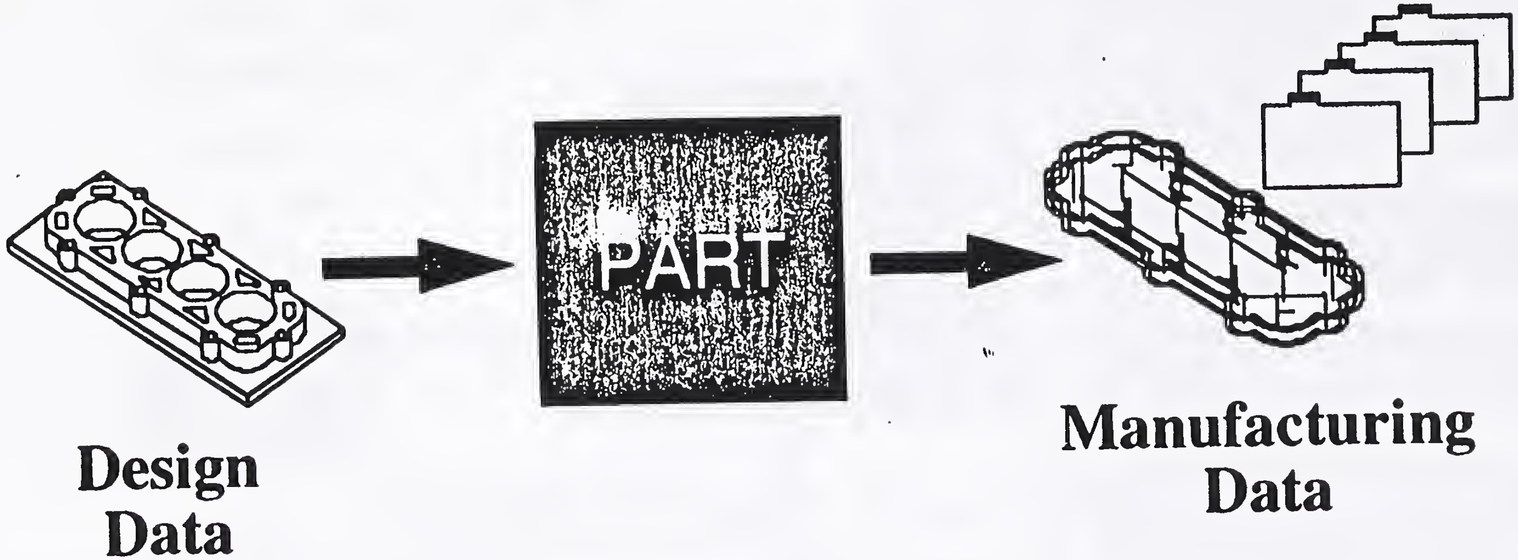
Process Planning

- Decide how to machine a part
- What material to remove first
- Which cutting tools to use
- Machine tool selection
- Find optimal methods
- Calculate costs and time
- Distribute jobs on the shop floor

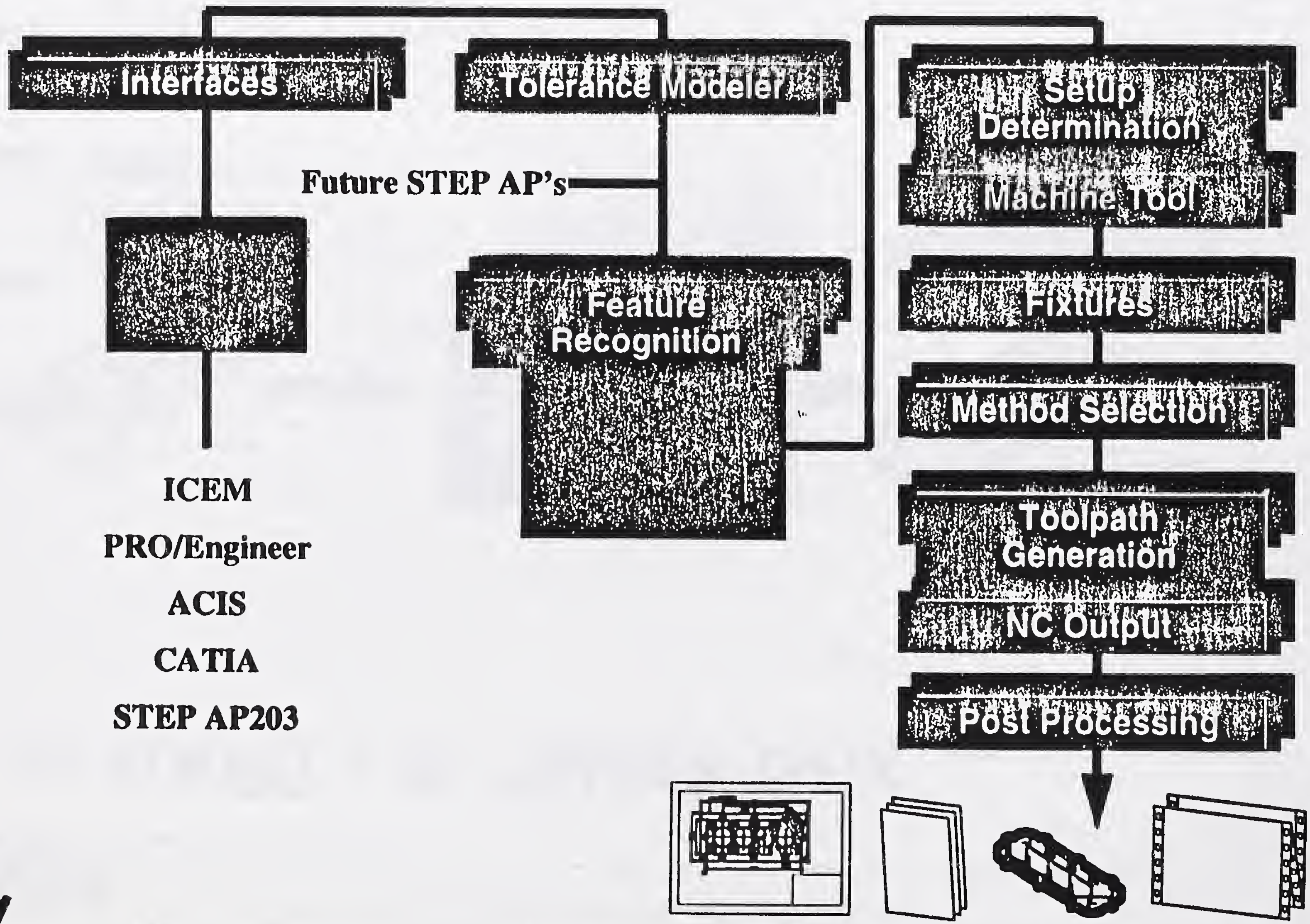
Generative Process Planning in an Expert System



PART - A "Black Box"...

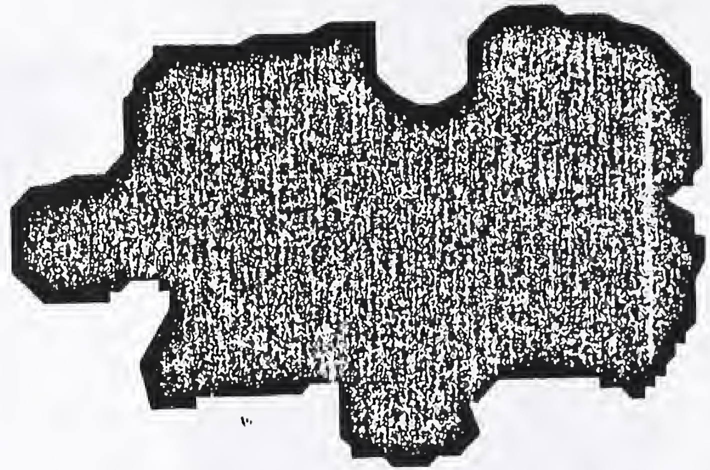


The PART Main Module



PART Interfaces

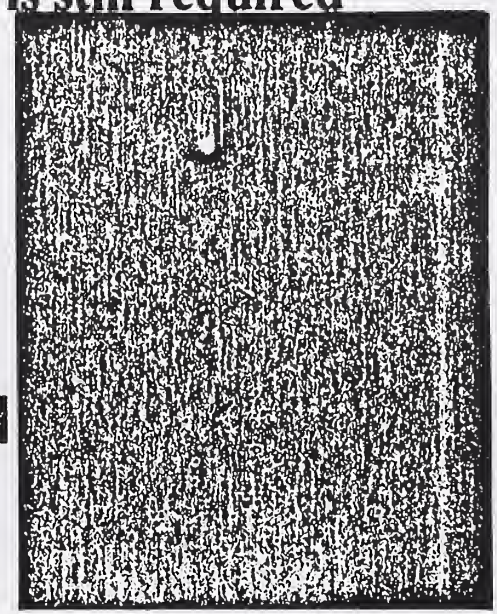
- **Direct Interface to**
  - PRO/Engineer
  - Catia
  - ICEM
  - Autocad Designer
  - HP Solid Designer



- **General Interface Strategy Based On Step (AP203)**
  - Bi -directional interface
  - Interchange of CSG and B-Rep Solids

Tolerance Module - WHY ?

- Today, CAD databases only supply the shape information
- Tolerance and attribute information is still required
  - –Methods selection
  - –Machine tools selection
  - –Cutting tool selection
  - –Toolpath generation

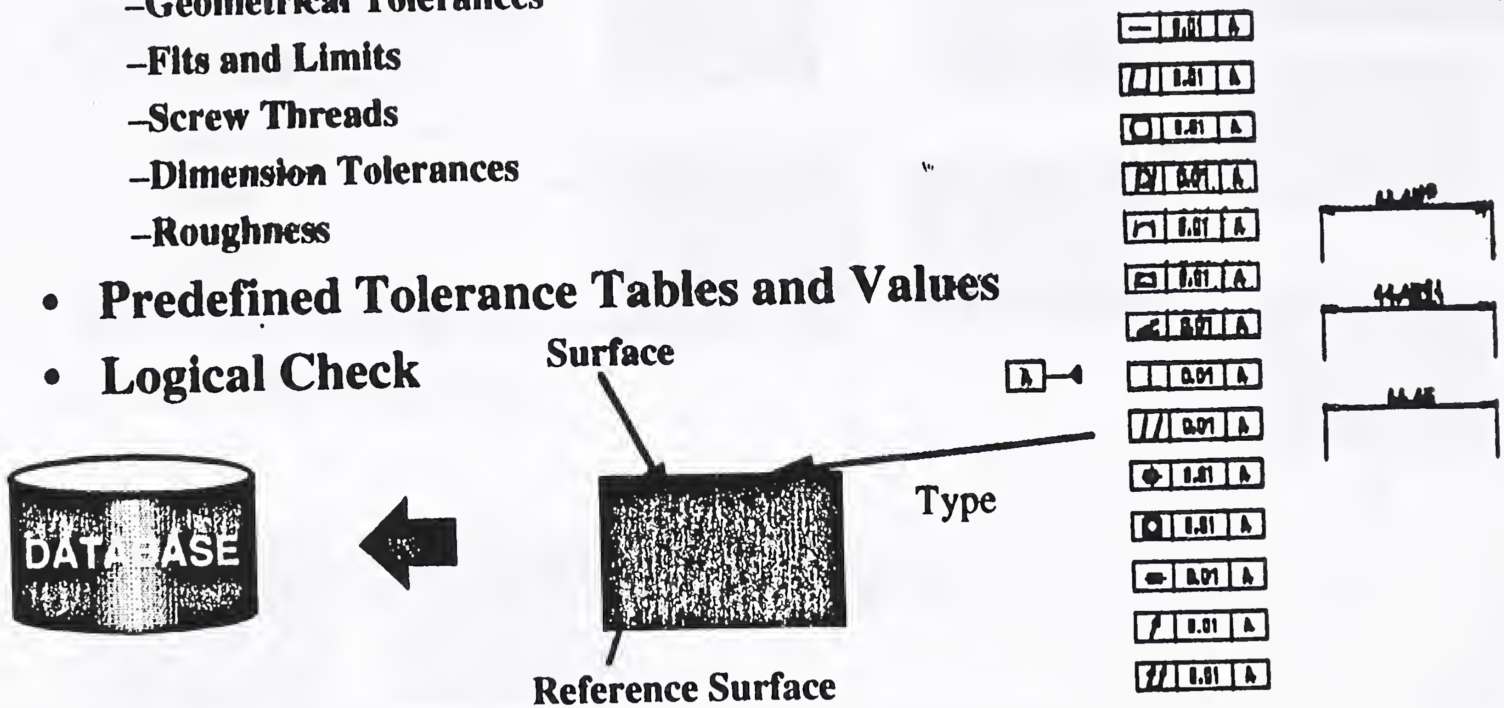


[illegible]	CAD Dimensions	[illegible]
Shaft	20	[illegible]
Hole	20	20.003

- CAD databases will evolve to include this information
- PART is positioned to accept it automatically

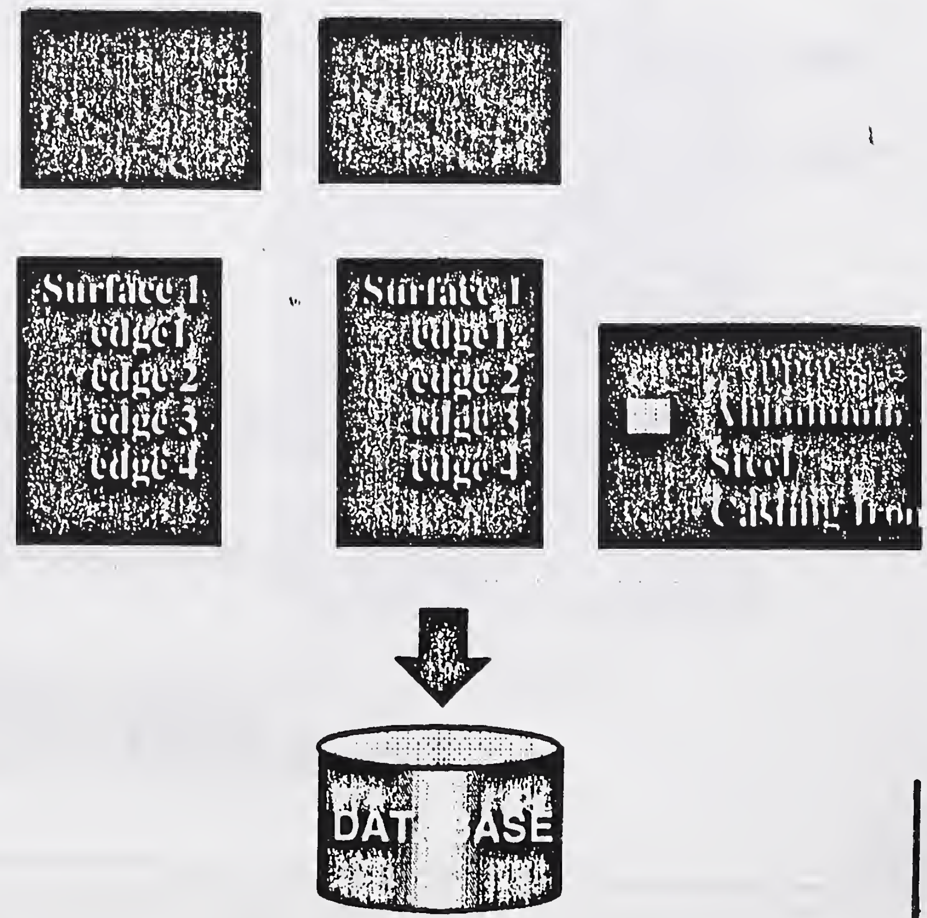
Tolerance Modelling - How !

- Assigns Tolerance Information to Surfaces
  - Follows STEP methodology
- Tolerance Support
  - –Geometrical Tolerances
  - –Fits and Limits
  - –Screw Threads
  - –Dimension Tolerances
  - –Roughness
- Predefined Tolerance Tables and Values
- Logical Check



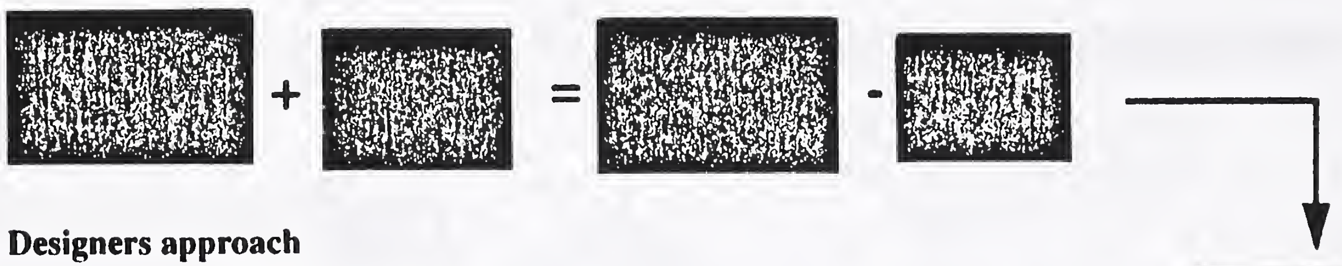
Product Definition in PART

- **Organized in Oracle**
- **Product Consists of:**
  - Model
  - Blank
  - Material
- **Model and Blank Represented as Solids**
- **Optional Automatic Blank creation**
  - Cubic
  - Cylindric
- **Alignment**



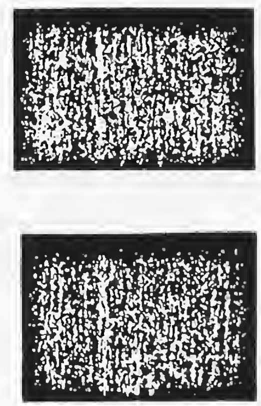
ICEM Technologies

Feature Recognition - Why ?



Designers approach

- **Looking for functionality**
- **Using proven techniques during design process**
- **Different approaches lead to the same model**

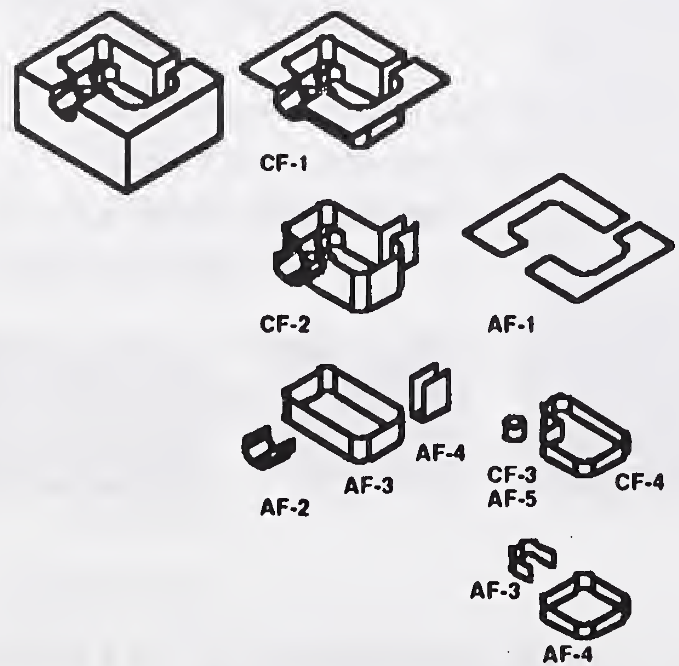


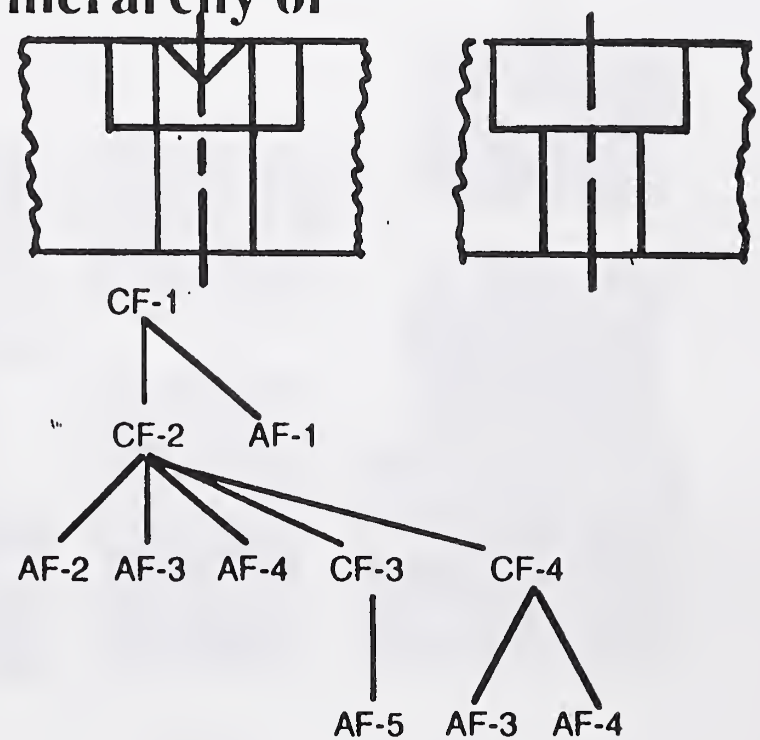
Manufacturing approach

- **Looking at the material to be removed**
- **Order critical**

Feature Recognition

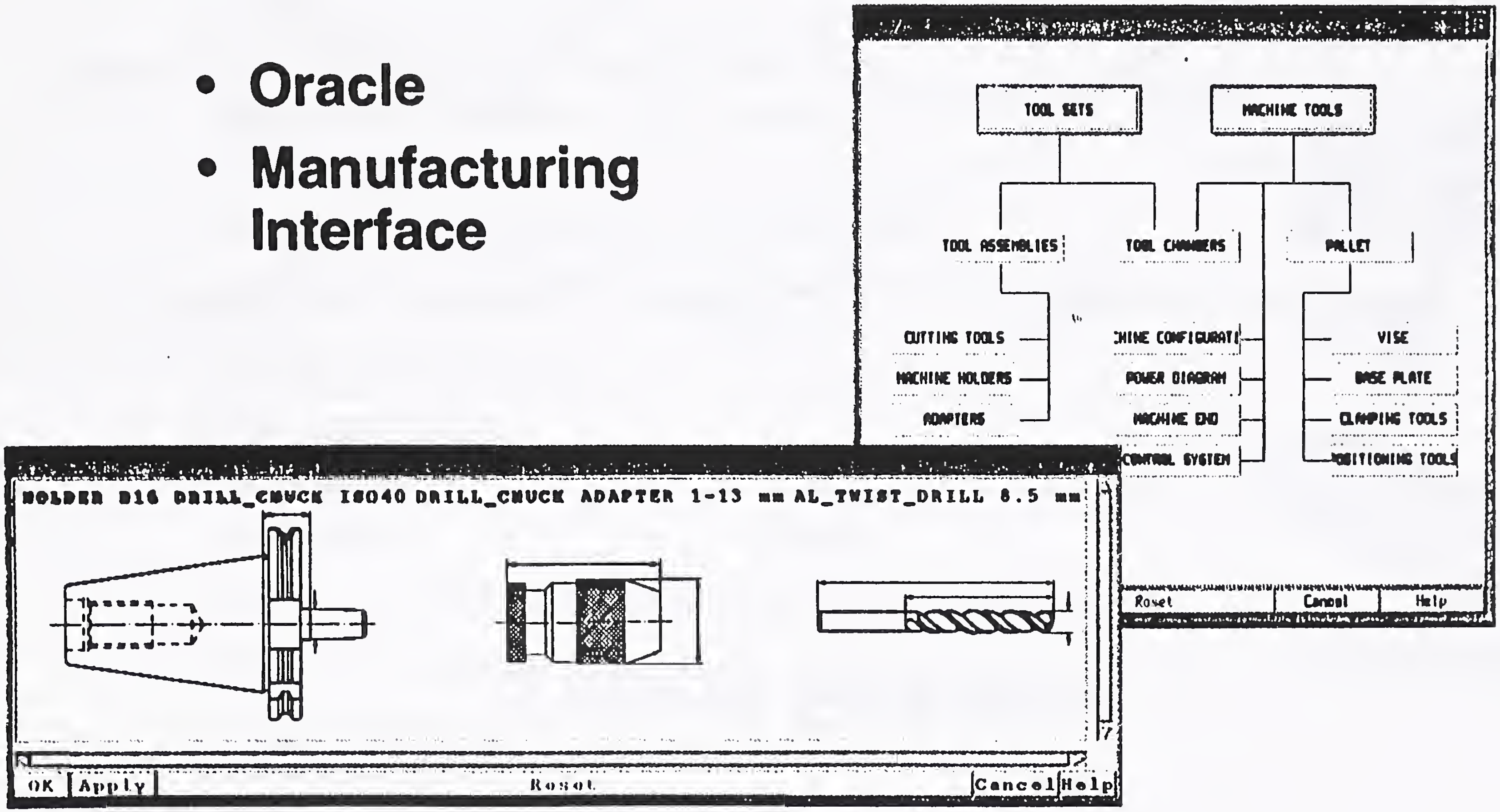
Automatic feature recognition converts the volume to be removed into a hierarchy of manufacturing features.



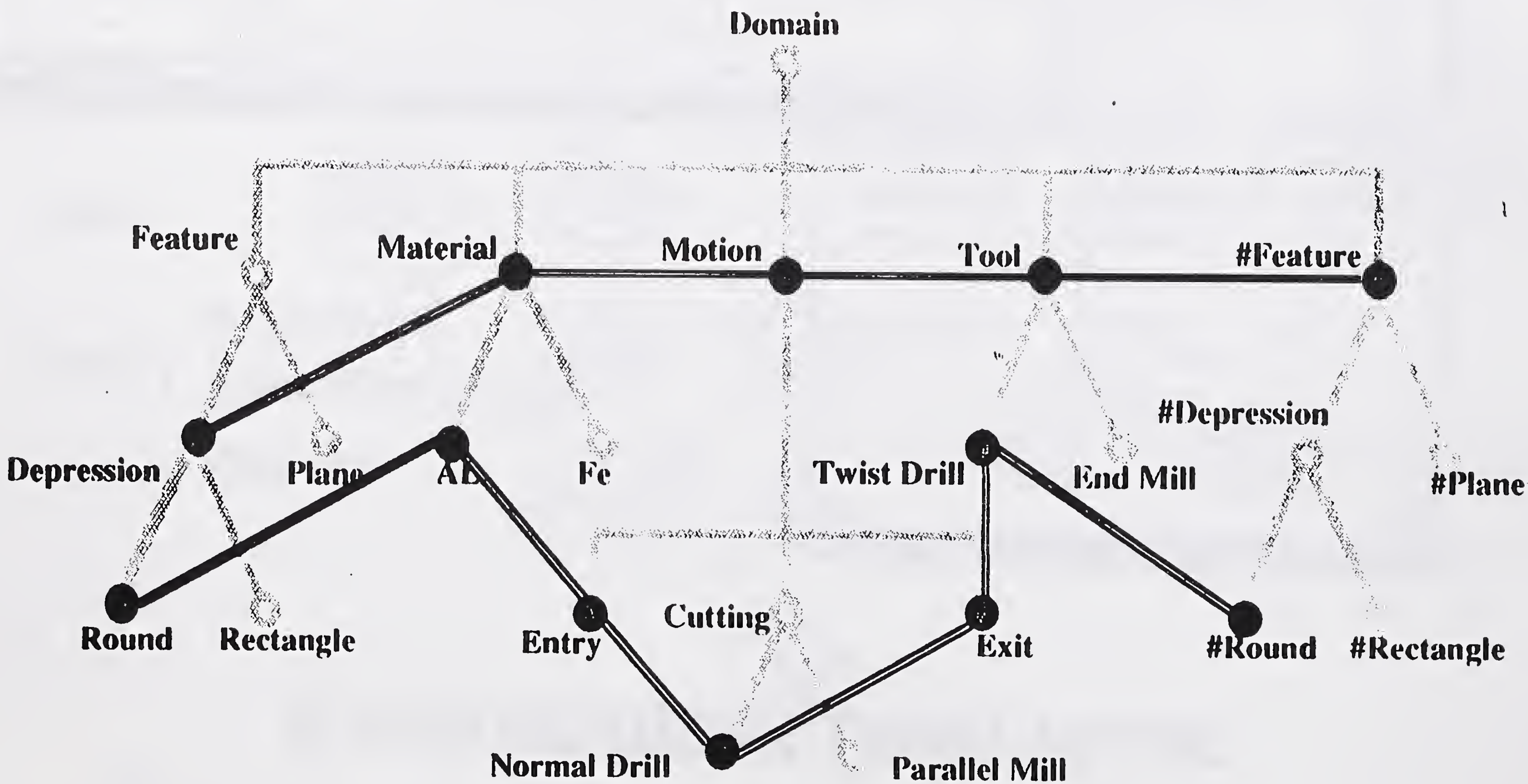


Environment Data Base

- Oracle
- Manufacturing Interface



Expert System



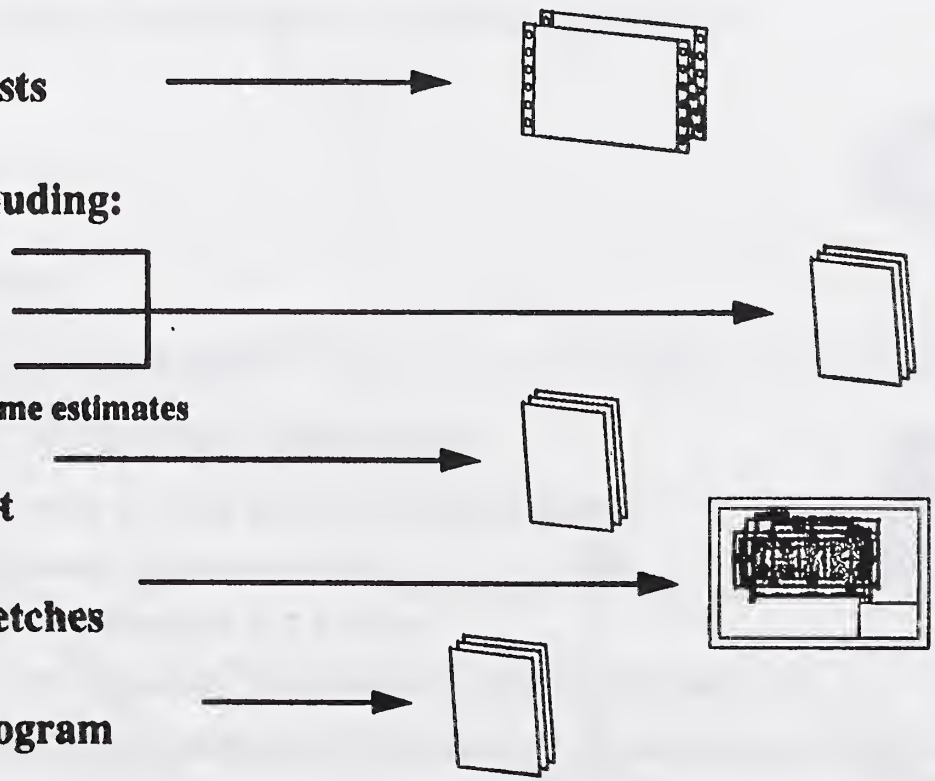
Toolpath Generation

- All the necessary information to generate a toolpath exists
  - –Tools and motions have already been selected during methods
  - –Features (Faces) to be machined are known
  - –Part material has already been indicated
  - –Cutting technology such as feed &speeds exists in Oracle
- Toolpath are automatically generated
- APT source code is created
- History is recorded
- Edit capabilities
  - –Strategies
  - –APT Source
- Interactive toolpath generation and modification
- Collision checking
- Gouge checking

Toolpath Data

Harvesting Data - NC Output

- **Operation Lists**
- **Tool lists including:**
  - **Holder**
  - **Adapter**
  - **Tools**
  - **Cost and time estimates**
- **Fixturing List**
- **Fixturing Sketches**
- **APT Part Program**

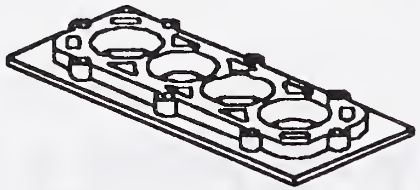


Post Processing

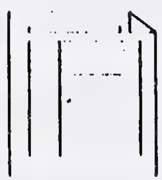
- Control system data is stored in the database
- Generalized PP can be adapted to specific machine tools
- Automatic PP execution
- Complete APT part program available

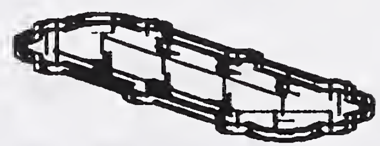
OPEN . . .OPEN . . .OPEN . . .

Open Input - Direct use of solid models from any popular Solid Modeler



Open Output - NC tool paths in CLDATA and APT formats along with custom manufacturing reports





Open Design - UNIX based systems

ACIS solid modeling kernal

C & C++ programming language

SQL for ORACLE database communications

X & OSF/Motif user interface

Keeping The Right Balance

- Automated Process Planning
- Automated Toolpath Generation
- Variant Process Plans
- Flexible Scenarios

- Modifiable Output at Each Step
- Steps Are Easily Reverted
- Full Edit and Undo
- Interactive CAM

Automation

Interactive Control

Corporate Profile

- Founded in 1985
  - To Develop Simulation Software for Process Verification and Off-line Robot Programming
- First Product Introduced in 1986
  - IGRIP
    (Interactive Graphic Robot Instruction Program)
- Consistent Profits
- Steady Growth
- No Debt

Deneb

Corporate Profile

- Mission Statement
  - Provide the Most Productive and Accurate Simulation Software
  - Provide the Enabling Technology for Concurrent Engineering, Simulation-based Design, and the Virtual Manufacturing Enterprise
  - Provide Comprehensive Support Services to Allow Users to Maximize Their Effective Usage Of the Software

Deneb

Corporate Profile

- Product Overview for Manufacturing
  - IGRIP
    - Process Simulation and Off-line Robot Programming
    - Application-specific Ultra's Based on IGRIP Technology
      - UltraArc for Arc Welding Applications
      - UltraFinish for Finishing Applications
      - UltraPaint for Painting Applications
      - UltraSpot for Spot Welding Applications
  - QUEST
    - Discrete Event Simulation
  - Virtual NC
    - Verification Simulation

Deneb

Corporate Profile

- The Deneb Product Offering Features
  - Customer Driven Development
  - Vertical Packages
  - Seamless Migration Between All Products
  - Productivity Tools
  - Inverse Kinematic Solutions, Not Matrices or Tables
  - Worldwide Support

Deneb

Corporate Profile

Worldwide Support

Deneb Robotics, Inc.
World Headquarters
Auburn Hills, MI

Subsidiaries

- *United States* — Deneb Robotics, Inc., Auburn Hills, MI
- *Japan* — Deneb Japan, Inc., Tokyo
- *Germany* — Deneb Deutschland GmbH, Neuss
- *France* — Deneb France S.A., Paris
- *India* — Deneb Hitech India Pvt., Ltd., Bangalore

Distributors

- *United Kingdom* — Intelligent System Solutions, Ltd., Salford
- *Scandinavia* — Tehdasmallit Oy, Espoo, Finland
- *Korea* — KoreaCADD Engineering, Seoul
- *Australia* — Sydney

Deneb

Corporate Profile

- Commitment
  - 75% of Personnel Dedicated to:
    - Software Development
    - Customer Support
  - 25% of Personnel Work in:
    - Sales
    - Marketing
    - Administration
  - All Profits are Reinvested in the Company

Deneb

Corporate Profile

- The Deneb Product Offering is Built Upon Universal Compliance
  - Direct Translators
  - RRS Compliant
  - STEP Translators
  - All UNIX Hardware Platforms Supported
  - DOS-based PC Hardware Platforms Supported

Deneb

IGRIP®

Deneb

Product Overview

- IGRIP®
  - Interactive 3D Graphic Simulation Tool for Designing, Evaluating, and Off-line Programming Robotic Workcells
    - Modelling
    - Workcell Design
    - Robot Models and Kinematics
    - Analysis
    - Simulation
    - Off-line Programming
    - Application Tool Kits

Deneb

Product Overview

- IGRIP (cont.)
  - Modelling
    - Create Geometry for Workcell Components Using Geometric Primitives and B-spline Surfaces
    - Automatically Convert 2D Data to a 3D Model
    - Apply Surfaces to Wireframe Parts
    - Full Part Drawing Support Including Dimensioning and Plotting
    - Automatic Data Filtering and Reduction
  - Data Translators
    - IGES, DXF, CATIA, ProENGINEER, Unigraphics, CGS, and others

Deneb

Product Overview

- IGRIP (cont.)
  - Analysis
    - Accurate Cycle Time Prediction for Individual Robots and Multiple Robots
    - Real-time Display and Plotting of Robot Performance Attributes (Joint Values, Speeds, Accelerations, Tool Center Point Location)
    - Full Dynamic Analysis Predicts Joint Torques, Motor Loads, and Resultant Trajectory
    - Graphical Robot Work Envelop Generation With Tool Offsets and Joint Limits
    - Graphical 3D Traces for Trajectory Analysis

Deneb

Product Overview

- IGRIP (cont.)
  - Simulation
    - Powerful, Intuitive Simulation Programming Capability
    - Automatic Time Coordinated Multiple Device Motion
    - Automatic Collision and Near-miss Detection
    - Realistic Cable Simulation Based on Cable Dynamic Properties
    - I/O Communication Between Devices
    - Replay Recorded Simulations at Different Speeds or In Reverse

Deneb

Product Overview

- IGRIP (cont.)
  - Off-line Programming
    - Native Language Programming
    - Download/Upload Robot Programs Directly To/From Robot Controller
    - Calibrate the Entire Process to Within Fractions of a Millimeter
      - Measure Exact Tool Point Offsets
      - Accurately Locate Workpieces and Positioning Tables with Respect to the Robot
      - Identify Complete Signature Parameters for Robot and Auxiliary Axes
      - Utilize the Robot as the Measuring Device
    - Create Custom Translators Using the Translator Tool Kit

Deneb

Product Overview

- IGRIP (cont.)
  - Other Product Features
    - Intuitive Easy-to-use Patented Graphical Interface
    - User Definable Menu Pages
    - Command Line Interpreter (CLI) for Batch Mode Operation
    - Sophisticated Camera Model for Vision Simulation and Calibration
    - Advanced Graphics with Support for Multiple Lights and Texture Maps
    - Inter-process Communication Tools

Deneb

Product Overview

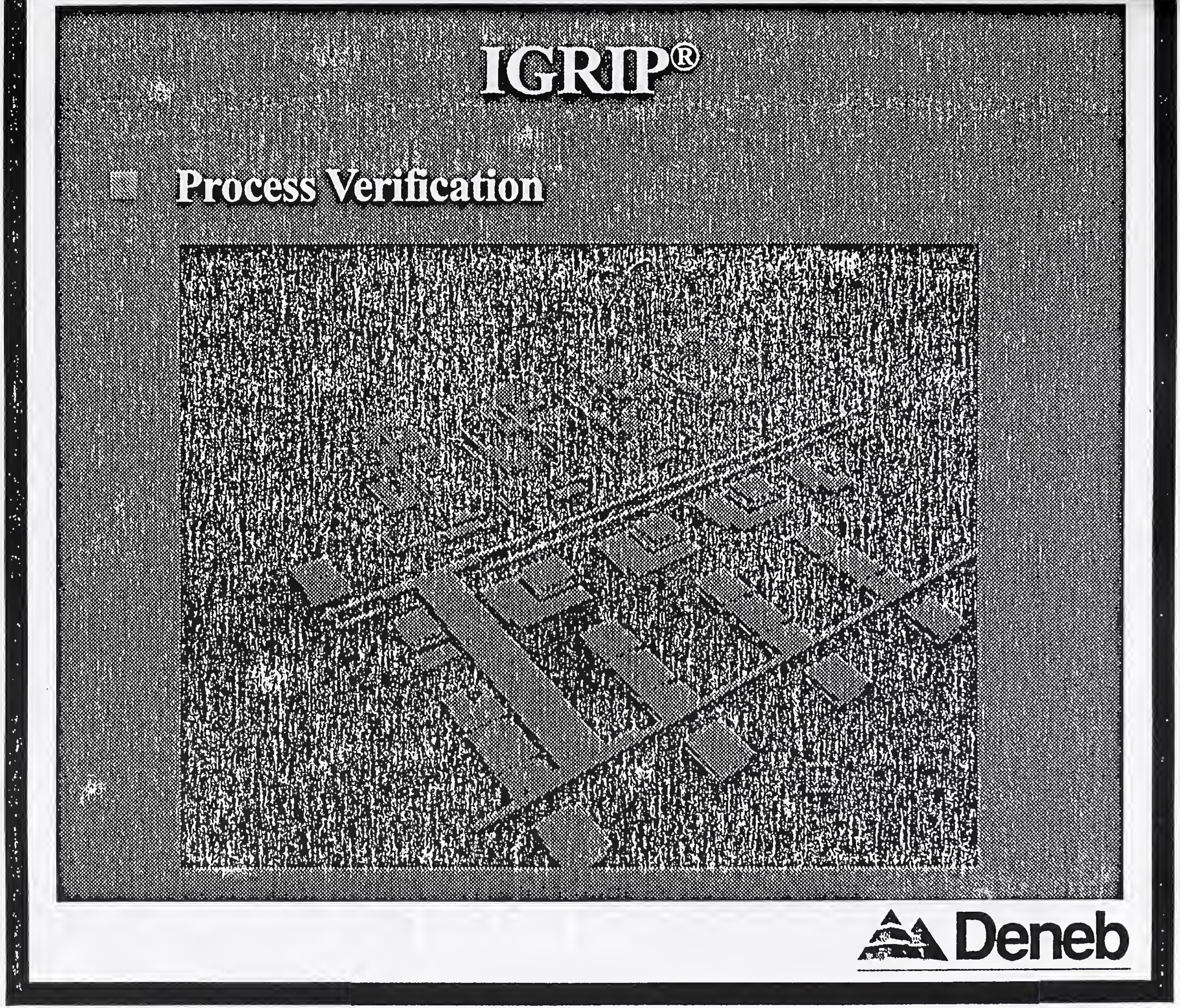
- IGRIP (cont.)
  - Application Tool Kits
    - Paint Processing
    - Spot Welding
    - Arc Welding
    - Sheet Metal Bending
    - Telerobotics
    - Grinding/Polishing/Deburring

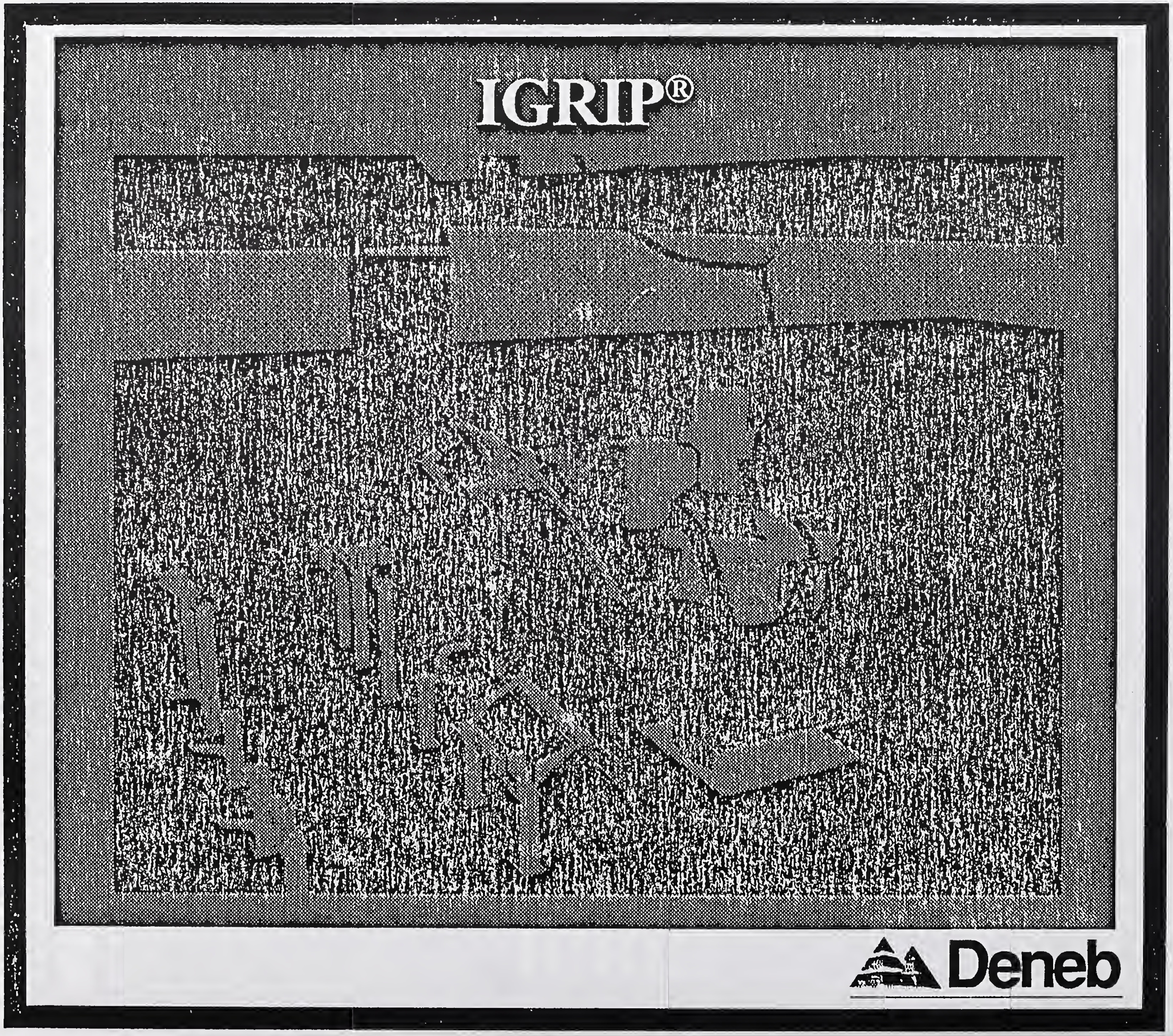
Deneb

IGRIP®

- Robotic Workcell Concept Design and Validation

Deneb


IGRIP®
Process Verification
Deneb


IGRIP®
Deneb

QUEST®

Deneb

Product Overview

- QUEST®
  - Analyze Discrete Event Processes
    - Bottlenecks, Machine Failures and Scheduling Alternatives
    - Cycle Time, Throughput, Product Mix and Utilization
  - Improve
    - Cycle Time
    - Material Flow
    - Machine and Labor Utilization
    - System Design
    - Production Costs
    - Inventory Management

Deneb

Product Overview

- QUEST (cont.)
  - Built-in Functionality
    - Accumulating and Non-accumulating Conveyors
    - Power & Free Systems
    - AS/RS and Buffers
    - AGVs
    - Labor
    - Library of Processing Workcells
    - Hierarchical and Distributed Modelling
    - Activity-based Costing
    - Push and Pull Production Methods
    - Real-time Bi-directional Communication to Shop Floor
    - Built-in, Full Logic Source Code

Deneb

Product Overview

- QUEST (cont.)
  - Analyze Costs
    - Capital Equipment Justification
    - Cost Verification and Output
    - Work In Process Valuation
  - Control Costs
    - Operating, Production, Work In Process Costs
    - Product and Inventory Costs
    - Capital Costs
    - Repair and Scrap Costs
    - Transportation Costs
    - Busy/Idle Labor Cost
    - Total Overhead Costs

Deneb

Product Overview

- QUEST (cont.)
  - Import Process Workcells
    - IGRIP
    - UltraArc
    - UltraFinish
    - Virtual NC
    - UltraSpot
    - UltraPaint
  - Decision-making Support
    - Real-time Visualization of System Bottlenecks
    - On-screen Popup Displays
    - Tabular Results
    - Comparative Graphs and Histograms
    - Dynamic Graphs
    - Language Support for Design of Experiments
    - Support for Direct Shop Floor Monitoring

Deneb

Product Overview

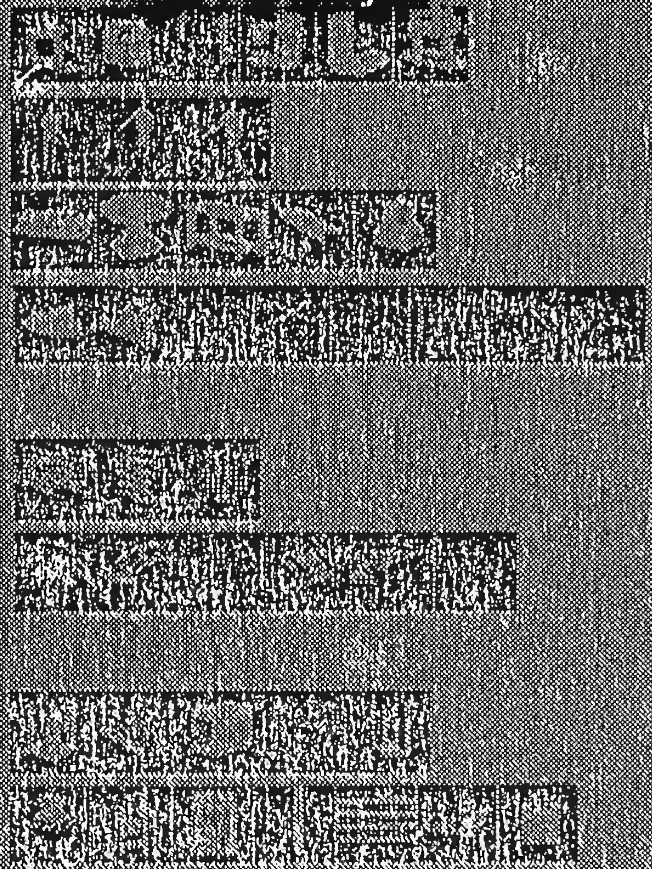
- QUEST (cont.)
  - Supporting Functionality
    - Full-function 3D CAD world
    - IGES, DXF, CATIA, ProENGINEER, Unigraphics, CGS, and Other Data Translators
    - Integrated Animation Scripting and Facility Walk-through
    - Video Output Capability
    - Dynamic Dimensioning
    - User-customizable Menus
    - Multiple Languages Supported

Deneb

QUEST®

- Resource List
  - Workcells
  - Labor
  - Buffers
  - AGVs, Control Points, Paths
  - AS/RS
  - Conveyor Systems, Power & Free
  - Sources, Sinks
  - Accessories

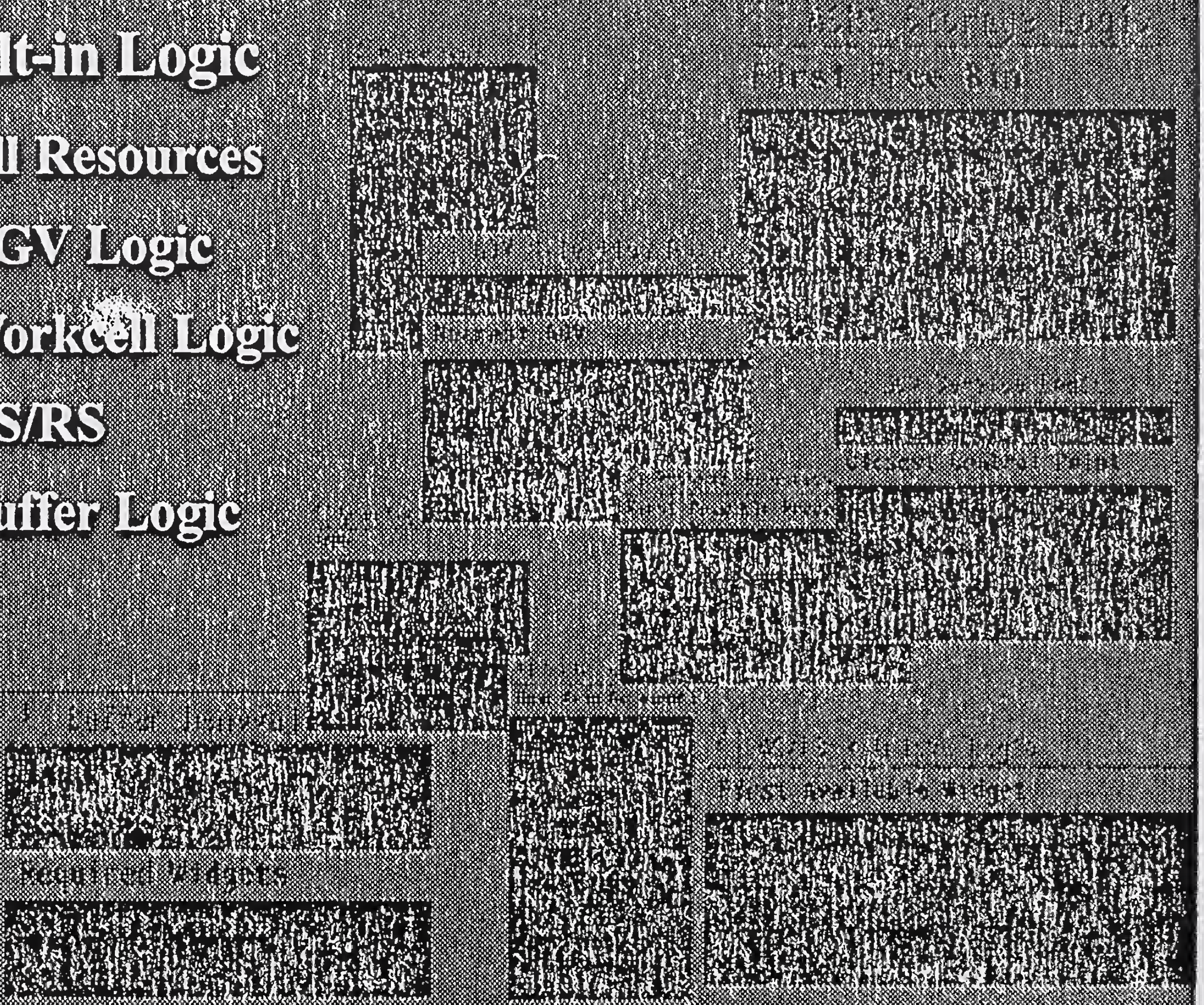
Visual File Interface



Deneb

QUEST®

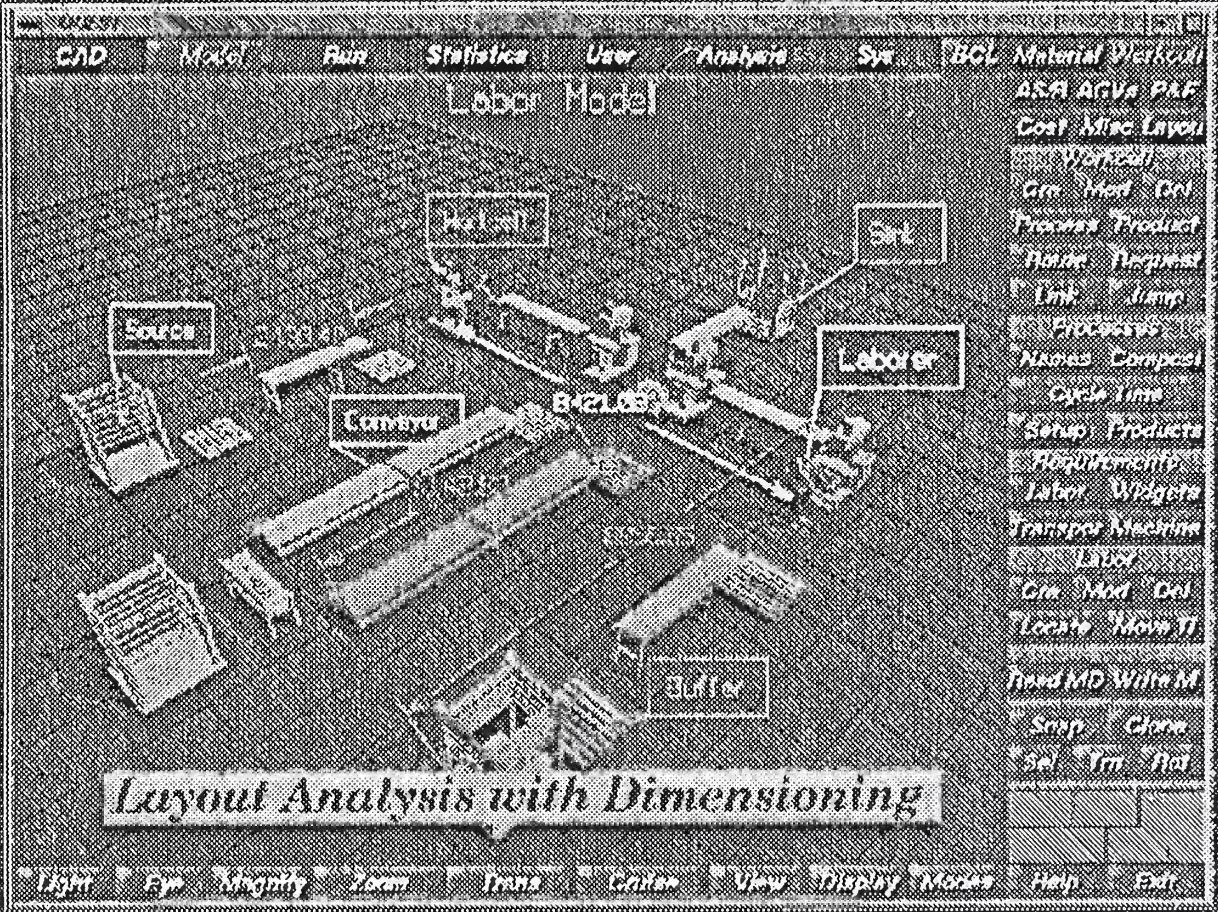
- Built-in Logic
  - All Resources
  - AGV Logic
  - Workcell Logic
  - AS/RS
  - Buffer Logic



Deneb

QUEST®

- Layout Analysis with Dimensioning



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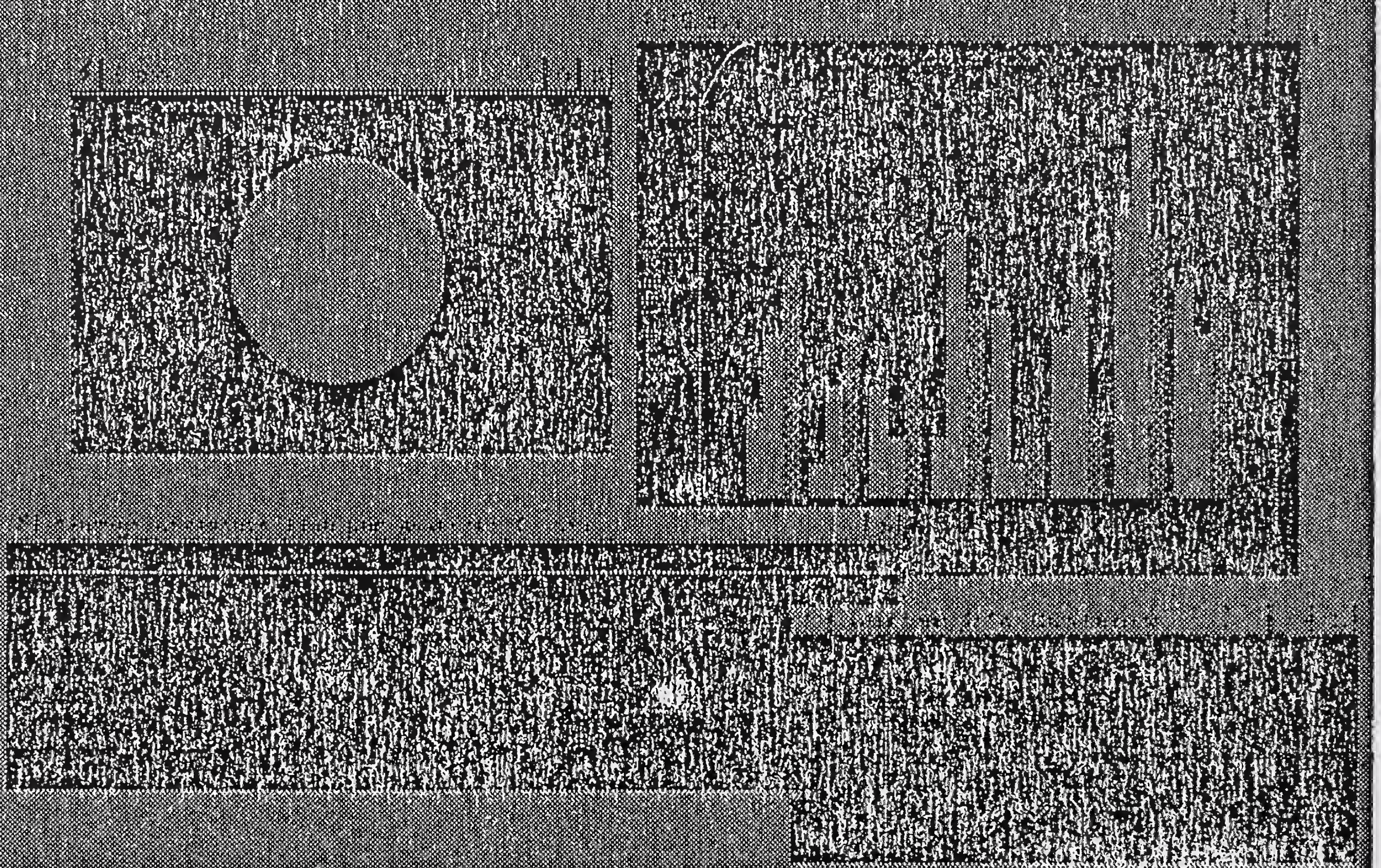
QUEST®

- Rich Statistical Capability



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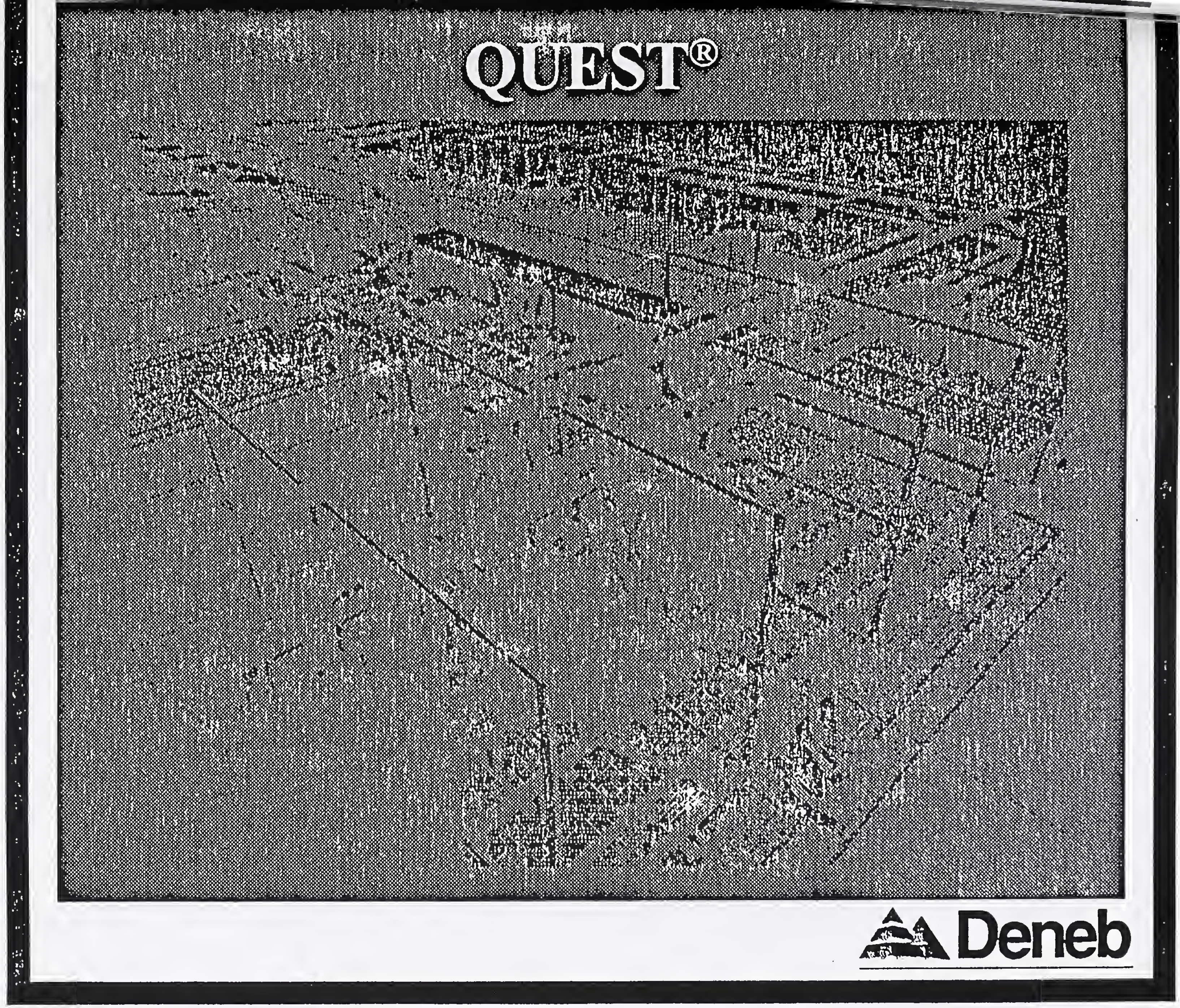

QUEST®
Deneb

Virtual NC®

Deneb

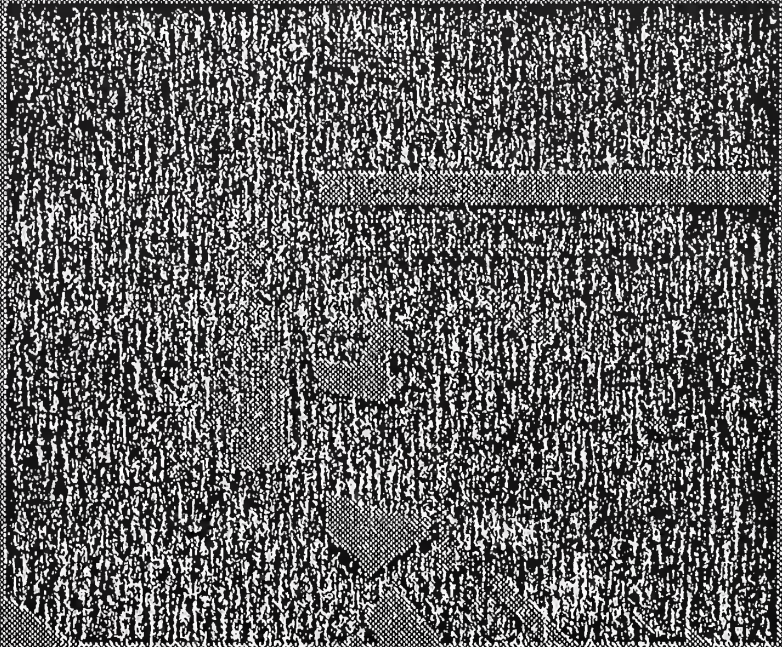
Product Overview

- Virtual NC®
  - Visualize and Analyze the Functionality of a Machine Tool, its CNC Controller, and the Material Removal Process
    - Simulate the Entire Machine Tool
    - Execute the Actual NC Program Utilizing MIMIC, the Built-in, Configurable Virtual NC Controller
    - Display the Material Removal Process
  - Data Translators
    - IGES, DXF, CATIA, ProENGINEER, Unigraphics, CGS, and others

Deneb

Product Overview

- Virtual NC (cont.)
  - Improve Machine Tool Uptime
    - Detect Near Collisions, Prevent Expensive Crashes
    - Perform Program Prove-outs Off-line, Without Sacrificing Valuable Machine Time



Deneb

Product Overview

- Virtual NC (cont.)
  - Increase Productivity
    - Optimize NC Programs to Increase Productivity
      - Identify Wasted Tool Motion
      - Optimize Tool Paths
    - Model Tool Changers, Pallet Loaders and Other Peripheral Devices to Accurately Predict Cycle Time
  - Visualize and Verify
    - Display Unlimited Machine Tool Axes and Geometry
    - View the Model From Any Perspective, Display up to Four (4) Views Concurrently, Using Dynamic Viewing
    - Verify Machinability through Workpiece and Fixture Placement Evaluation

Deneb

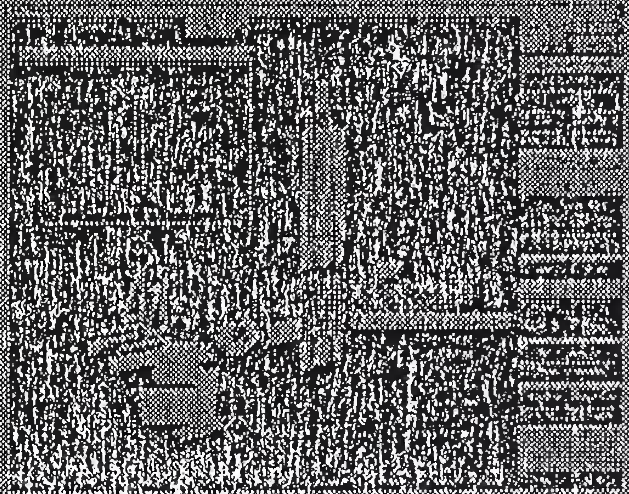
Product Overview

- Virtual NC (cont.)
  - Physics-based Simulation
    - Machine Cycle Times maintained Separately from Simulation Time
    - Simulation Step Size Can Be Varied at Any Time During the Machining Cycle
    - Simulation Can Be Run in Real Time, to Give a Visual Representation of Actual Velocities
    - Machine Accelerations Profiles Simulated
    - Over Travel Limits Monitored

Deneb

Product Overview

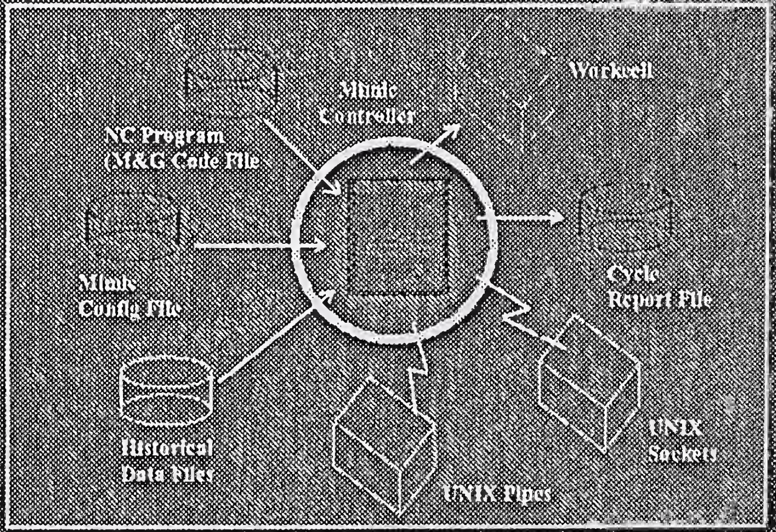
- Virtual NC (cont.)
  - Machining Cycle Information
    - Depth of Cut
    - Volumetric Rate of Material Removal
    - Cycle Time
      - For the Entire Machining Process
      - For the Current Move
    - Tool and Workpiece Time
      - Spent Cutting Material
      - Spent in Feed Mode
    - Axis Speeds, Feedrates, Positions, and Accelerations
    - Distance to Go (for Current Move)



Deneb

Product Overview

- Virtual NC (cont.)
  - Easily Customized
    - Communicate With Other Processes via UNIX Sockets, Pipes, or Direct Files
    - Create Custom Button Layouts
    - Define Button Macros to Simplify Commonly Used Sequence of Operations or To Reproduce Buttons Found on a Specific NC Controller



Deneb

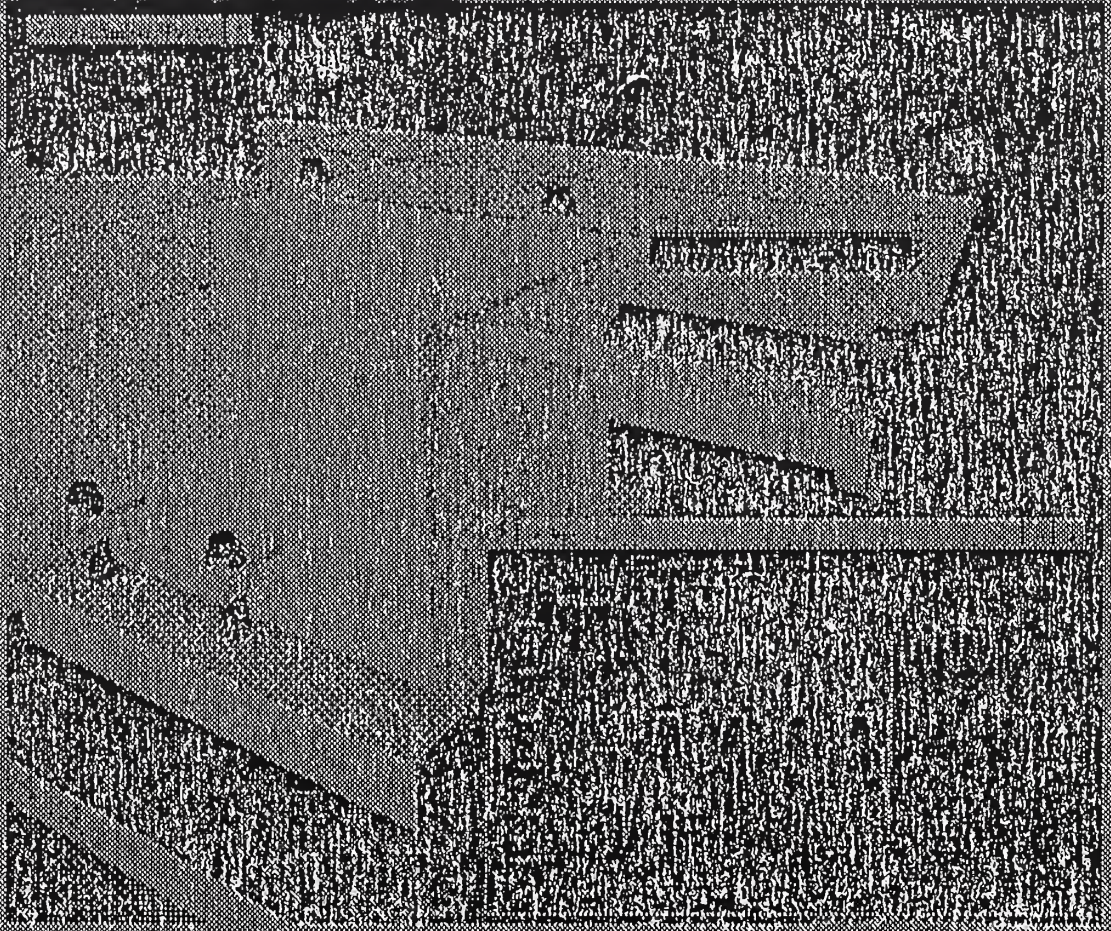
Product Overview

- Virtual NC (cont.)
  - Simulation-based Training
    - Train New Machine Operators
    - Enhance NC Programmer Skills
      - Prove-out Previously Unused NC Controller Functions
      - Experiment with and Evaluate New Programming Techniques
    - Increase Process Awareness
    - Communicate Ideas More Effectively

Deneb

Virtual NC®

- Material Removal



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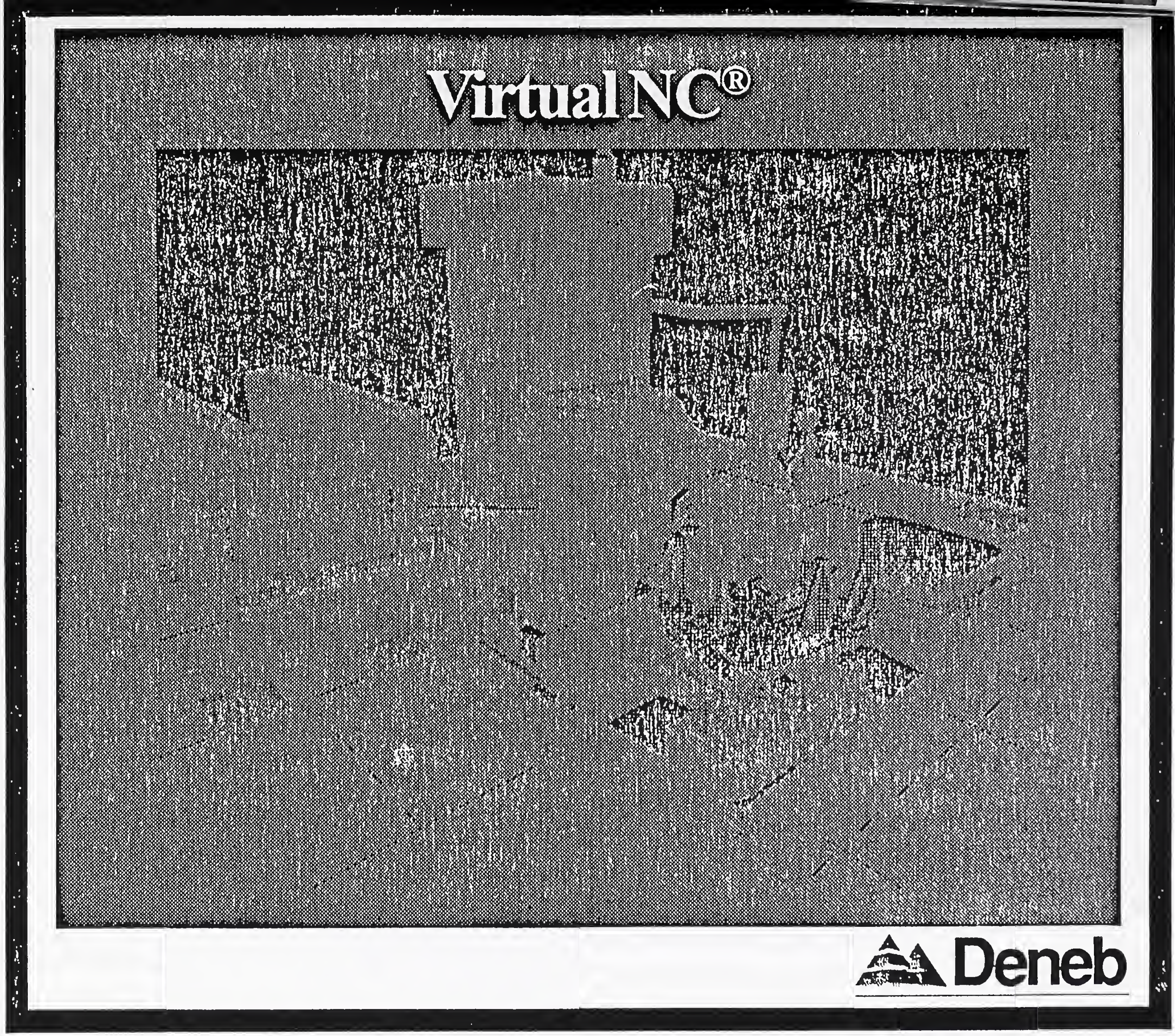

Virtual NC®
Deneb

MATRIX

The New Force

in

Information Management

Presentation

NOTES

Introducing MATRIX

The Company

- Independent Business Unit
- Industry Recognized Staff
- Customer-Driven Organization

The Product

- New "Clean Slate" Approach
- Next Generation Environment
- Built by Users for Users

MATRIX

• *If asked* -> Matrix is an independent division of Adra Systems, with a mission to equally support customer choice in CAD and other application tools

• It is staffed from industry (Sikorsky, system integrators, etc.) with personnel who specialize in product process automation; users and implementers who were frustrated with "technological dead-ends" and the limitations of current technology

• They have formulated and lead major changes in engineering processes

• They bring an understanding of customer needs - for they believe systems should behave the way users want them to and accommodate the customers' way of doing business

• The Matrix product builds upon advanced 90's technology:

- object-oriented databases and coding structures,

- flexible user interface development kits, and

- multimedia tools

all on standard hardware platforms

• This commitment to advancing the user's perspective for information tools was the basis for the totally new approaches and design choices used in the development of the Matrix System

Customer Challenges

- Increasing
  - Product Complexity
  - Volume of Change
  - Rates of Change
- Dynamic, Project-Oriented Organizations
- Fluid Applications Usage

MATRIX

- Customers are facing ever increasing challenges:

- products are continually becoming more complex

- the name of the game today is time-to-market, dictating find and revise previous work - not reinvent the wheel

- increasing derivative products creates more versions to manage

- increasing collaboration with other divisions, suppliers, customers, and partners generates more sources of design impact which leads to more change

- time-to-market pressure requires that design iterations occur in less time (shorter cycles), leading to higher rates of change

- traditional line organizations are being restructured as cross-functional project teams to achieve their objectives

- these teams are very fluid to better adapt to the project at-hand; people can belong to several teams and have differing roles in each one; this mandates that the information management environment needs to be flexible and dynamic to support changing priorities and assignments

- the applications in use today at a customer are not necessarily those that will be used tomorrow; customers want to use the best tools for each job which results in an ever-chaging applications mix

State of the Market

- Unfriendly Systems
- Limited User Control
- High Costs of Ownership
- Fixed Functionality
- Imposed Architectures
- Poor Performance
- Complex Integration

MATRIX

• **Then why has data management technology been adopted by approximately only 3% of the companies it is intended to benefit?**

• Recent studies by Andersen Consulting and Coopers & Lybrand identify the reasons limiting adoption:

- **the number one reason cited by 70% of respondents is ease of use**; since people buy tools they can use, ease-of-use is critical to both user and management acceptance

- **many current offerings are difficult to implement** and/or require a high dependence on the vendor or specialized resources to make changes; users want control over their environments and migration

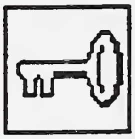
- **beyond price, all of this translates to many hidden lifecycle costs** including consulting, installation, customization, administration overhead, maintenance, and platform penalties to support growth that's not scalable; of note is the hidden cost of server hardware that must grow with the number of users in a relational-based system

- **many systems remain "bounded" to specific tasks** that force users to modify their way of doing business or are "unbalanced" in their support of data, workflow, and integration management; and that can create new bottlenecks on top of the ones you're trying to solve

- **inflexible configurations for platforms, databases, networks, and topology can force structural tradeoffs** of architectural objectives for things like performance, redundancy, or remote support; moreover, with relational systems, performance is much worse for similar-size databases compared to object-based systems, and performance degrades as users are added to a relational system

- **and you shouldn't be restricted in choosing third-party applications** or having to mutilate target applications and legacy file systems to interoperate or exchange data with them

The MATRIX Mission



- Improving Control of Information
- Understanding & ReEngineering Processes
- Integrating Existing & New System Tools
- Facilitating Collaboration
- Providing Intuitive Work Environments

MATRIX

• **Matrix is targeted at helping companies realize business benefits from information management technolcgy. Critical elements of the Matrix mission are:**

- **keeping pace with the increasing variability/rate-of-change** with today's products and the technology in them by consolidating information and providing fast/easy access;

- **giving visibility to process and workflow** by supporting the user to dynamically design, model, and change processes to achieve and enforce "best practices"; best of all, with an object-based system you can implement it to model today's environment to see current processes before deciding to make changes; relational systems are so complex to start-up, that the process re-engineering must be done in advance because you can only afford one implementation cycle - Matrix lets you change dynamically, continually adapting to your evolving environment

- **enabling the user to choose and introduce the best tools** such as applications and platforms to do the job;

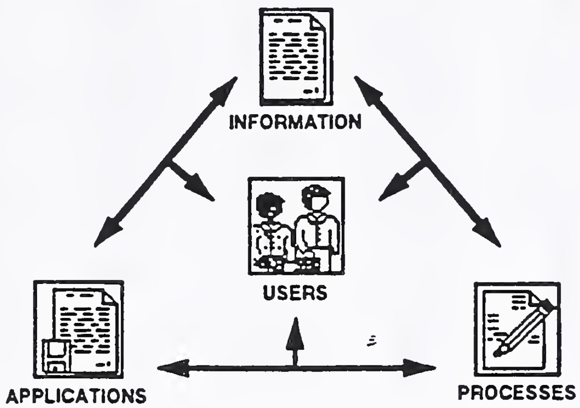
- **increasing the speed and quality of communications** among users, teams, departments, divisions, and customers/suppliers; and

- **providing consistent and natural means of managing information** independent of source or function in a way that compels adoption and usage

• *If you want to go further with this* -> Time, cost, and quality returns are not ends in themselves, but the means to gain and sustain competitiveness which results from the growth of user capabilities -- not point "solutions" from vendors -- and how those returns are internally applied

MATRIX Defined

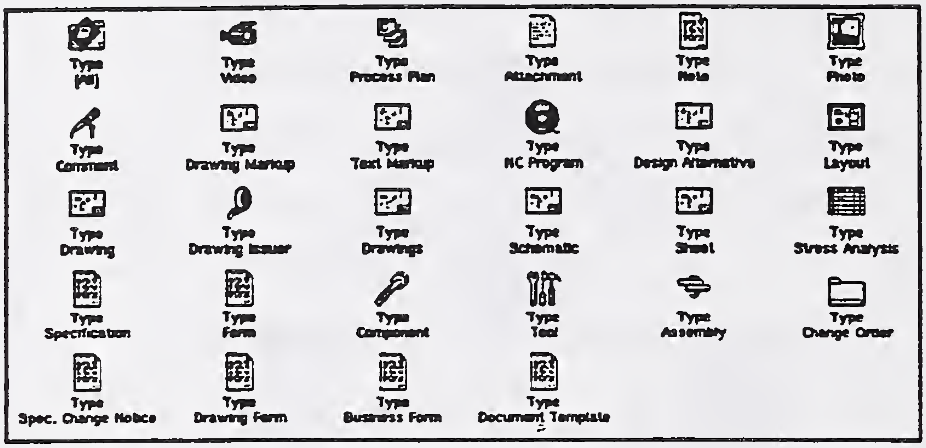
A Comprehensive Facility for Managing Any Type of Information in Any Business Process



- To accomplish this, Matrix was designed from the outset as a uniform environment to:
- consolidate information and make it easy to find,
- integrate and use the applications that create it, and
- provide visibility to, and control over, the processes that govern object lifecycles

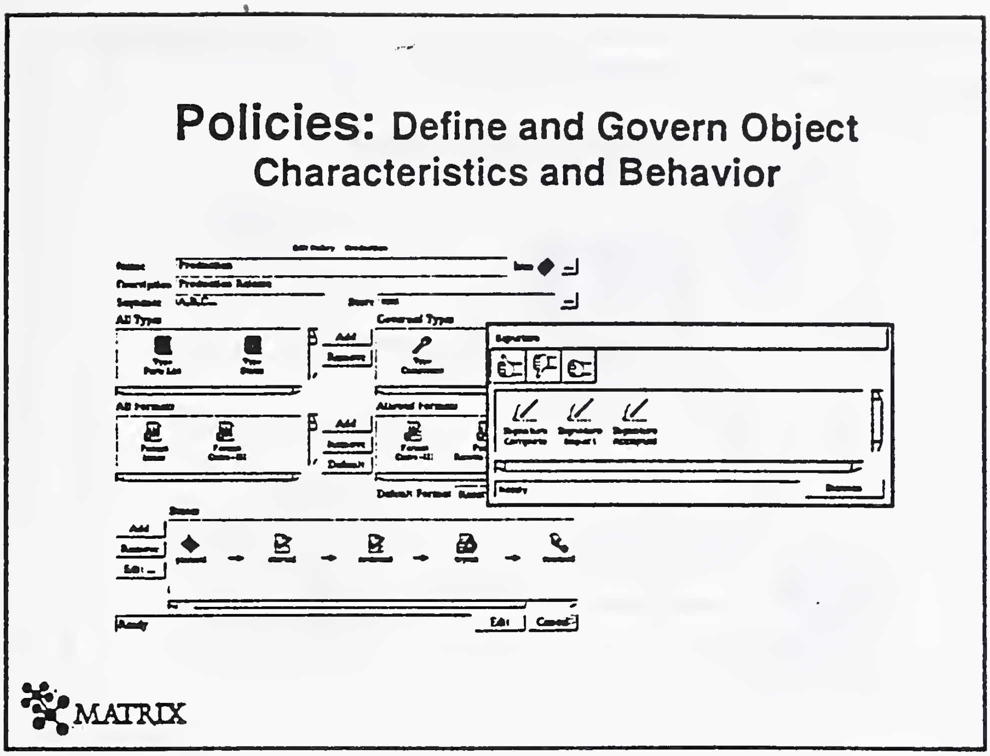
- In Matrix, information is managed as business objects, typically documents or files of any format (or multiple formats)
- Matrix interoperates with any application that shares its environment without requiring modification of, or complex integration with, target application(s); this is achieved by "encapsulation" which reduces barriers caused by platform differences and smoothes information flow from application to application
- The organization is described in human terms by identifying the people, groups, and their roles to accommodate today's reality of an individual supporting multiple roles or groups, and performing single or multiple functions
- It is the user-defined policies such as relationships and attributes for objects that form the basis of integral process control to direct the workflow, communication, and approvals among users, their information, and the respective applications
- All of this is easily installed, operated, maintained using intuitive and highly visual user interfaces that virtually eliminate programming; the system can be changed or expanded in any dimension, at any time, as a dynamic environment

Objects: Capable of Representing Anything



MATRIX

- **Objects typically contain documents or files** such as memos, POs, drawings, specs, test results, project schedules, machine control data, binary images, etc. in any media format (including things like voice and video)
- **Any number of object types (or classes) can be defined by the user** with familiar names and terminology and can be characterized by any number of attributes
- **There are no limits to the number of files in objects and no restrictions based on source application** or naming convention
- **Objects can be linked and navigated by various relationships** on the fly (in real-time)
- It is through these relationships that capabilities like check-in/out, workflow, revision and versioning, and third party application access become intrinsic functions available from a common framework
- For example, changes made to an object as it progresses through its lifecycle are automatically maintained in its history to support regulatory compliance
- Other examples of the versatility of objects include license management of software tools and master indexing of paper and microfilm/fiche drawing vault



• **Policies establish the workflow of an object** and the rules governing the originator, reviewers, approvers, and recipients of information as it moves through its lifecycle

• **Policies for objects are defined and maintained by an administrator without programming** and can be different for each object, object type, and group of objects

• **In addition, a single object can have multiple policies** for each related project with which it is involved

• **They can be applied to:**

- event or time-based **workflow states,**

- **routing and distribution** to reviewers, and

- **automatic storage** of file conversion processes

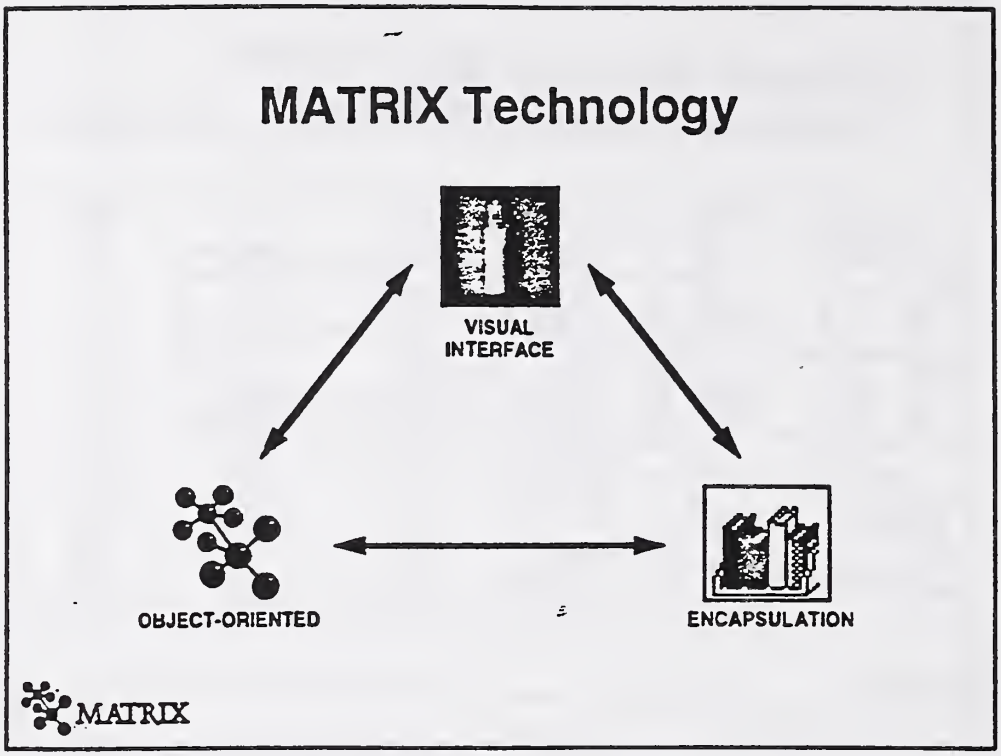
• **Typical applications** include:

- **providing change control and configuration management** to manage multiple versions and revisions,

- **controlling electronic signatures**, access, and modification rules, and

- **providing automatic notification** via IconMail or Email

• **This ability to graphically incorporate process control, combined with the power of object relationships, gives users maximum versatility to apply and architect a Matrix solution to virtually any information management problem**



• Matrix is built upon a modern architecture to give users control

• The System's visual user interfaces provide a completely graphical (and inviting) method of interacting with information, applications, and processes

• Users can select from Motif, Open-Look, or Windows GUIs with a click of the mouse

• Advanced capabilities only available due to the full implementation of object-oriented technology (data and code bases) include:

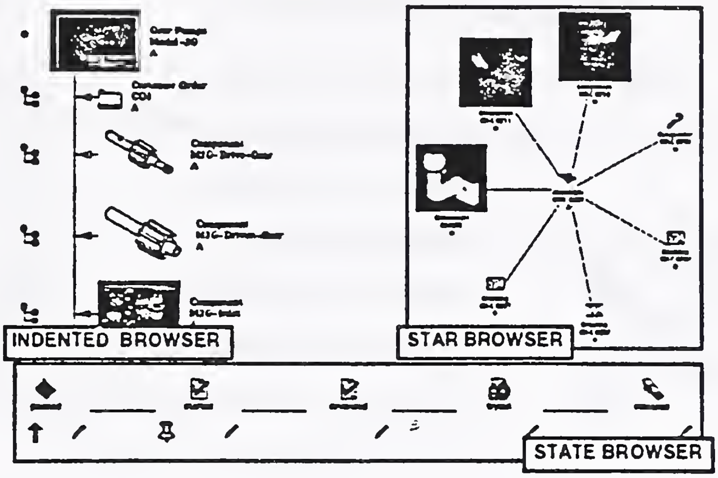
- scalable performance,

- full distribution of databases anywhere on the network, and

- automatic functions for the management of change, configuration, notification, file conversion, workflow, etc.

• Through encapsulation techniques, integration can be as simple as a single command line or shell script to access an application or exchanges files

Visual Interface



MATRIX

- **Every major function within Matrix is presented and operated visually**
- Matrix employs a **Windows paradigm throughout**, providing the lists of menu options with pull-down menus while a toolbar presents frequently used functions in icon form
- Only Matrix has **IconImages** that allow users to see snapshots of the data which eliminates having to interpret filenames
- **Dialogues and keyboard entry are reduced** by providing lists of selectable options and allowing users to set and save session preferences
- **The database is navigated with browsers** that instantly present multiple views of objects, their relationships, and workflow states; the user only needs to ask Matrix a query once, from then on all data can be located through intuitive exploration and browsing
- An intelligent addition to Email, called **IconMail, employs these visual techniques and reduces network traffic by sending the icon of an object** rather than duplicate copies of data to message recipients; IconMail is a powerful communications tool because it allows the sender to send a "string" to another Matrix user who can instantly browse for related or effected objects from within the mail tool instead of having to leave the mail system to respond
- **All of this saves time, compels user adoption (and acceptance), and provides a consistent means of managing information regardless of the user's particular role(s)**

Object-Oriented

- Manages Any Information
- High Performance Relationships
- Fully Distributable
- Multiple Storage Methods
- Interactive & Batch Modes
- Integral Process Control

MATRIX

- To get the full power of objects requires more than what others call being object-based -- written in C++ or object coding structures
- Matrix is based on fundamental change in root technology to provide advanced capabilities, and is the first system of its kind built upon ODB technology
- Object-oriented databases are achieving a high rate of adoption throughout the commercial software market -- from CAD companies using them in geometry engines to IS suppliers in transaction processing
- Even market leaders like Oracle have endorsed the advantages of object technology and committed to deliver their own ODB
- ODB technology provides a third dimension where relationships exist as an integral part of the data model -- both data elements and knowledge about their inter-relationships are available to speed creation, modification, navigation, and reporting
- The depth-of-function and efficiency found in object management is superior in flexibility and user-related functions because:

- any information can be stored independent of the source or application that created it and file format recognition is automatic,
- individual databases can be located anywhere and dynamically relocated,
- interactive and batch modes are available,
- multiple storage methods such as tracking, capturing, and ingesting can be used or combined, and
- process control is integral so automatic functions can be applied

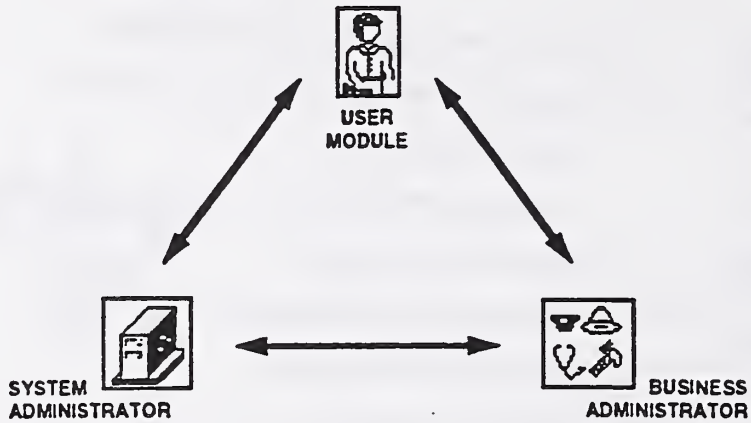
Encapsulation

- Transparent Application Services
  - Launch for View, Markup, and Edit
  - File Translation
  - Format Independent Printing/Plotting
- Coupled to Lifecycle
- Tools for Easy Integration
- Multiple Data Formats

MATRIX

- **Matrix is designed so that modifying the application tools with which it operates is not necessary;** this reduces sensitivity to (and the burden of maintaining) application revisions
- **Encapsulation allows third-party applications to be accessed, invoked, and data exchanged** within the same operating environment as Matrix
- For example, in other systems file operations must be added to a given application to move files in and out -- this is complex and requires specialized programming resources (not to mention cost)
- With Matrix, the only action the user must take is to describe the file format using the Business Administrator module
- **Matrix provides several unique integration functions that work for any application with a consistent interface;** these tools make operations such as launching (to perform any function from that application), printing, and translating transparent
- **Because of its ability to manage relationships, Matrix can actually achieve a deeper level of integration than other products;** the MQL programmatic interface allows users to develop their own unique application-based functions if they desire
- **Matrix supports customer choice in selecting and integrating the applications they want to do the job** and easily adapts to new tools over time

MATRIX Modules



MATRIX

∘ **All the power to operate and administrate the Matrix System is contained in three integrated modules that support all three major information management** functions: information vaulting, workflow processing, and application integration

• **The User Module is the primary work environment to access information and** support the workflow; through it, users can:

- browse and locate information,
- create, review, approve, and route objects,
- share application files and services, and
- view, markup, and print documents

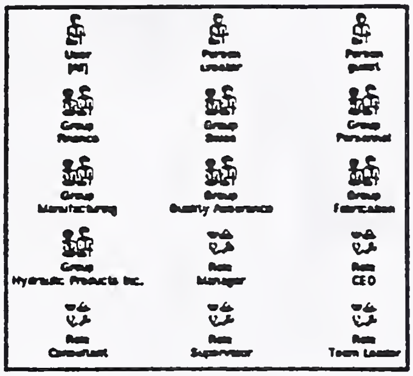
• **The Matrix Business Administrator is used to develop and control processes;** through it, administrators can:

- create organizations, roles, and groups
- define people, their roles, and assignments, and
- define object types, attributes, and associated policies
- define workflows, routing, and approval structures

• **The System Administrator is used to manage the systems environment** including the computers, networks, and applications; through it, operators can:

- define servers for meta data, files, and applications,
- set-up application independent services (such as viewing and printing), and
- perform backup, recovery, and system tuning

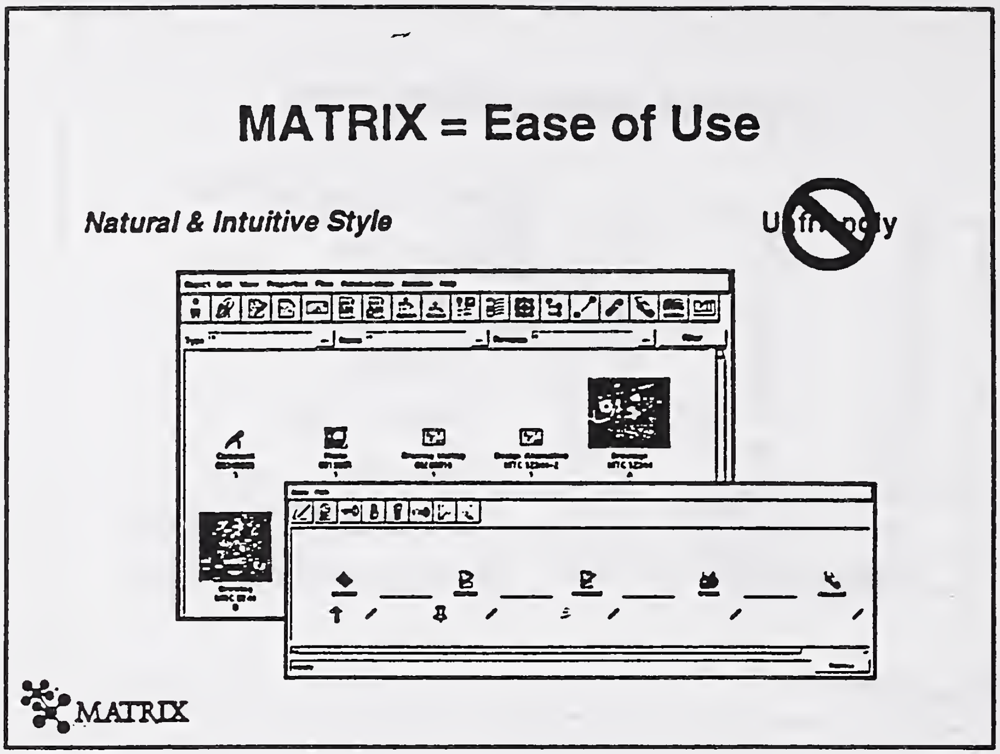
Organizational Features



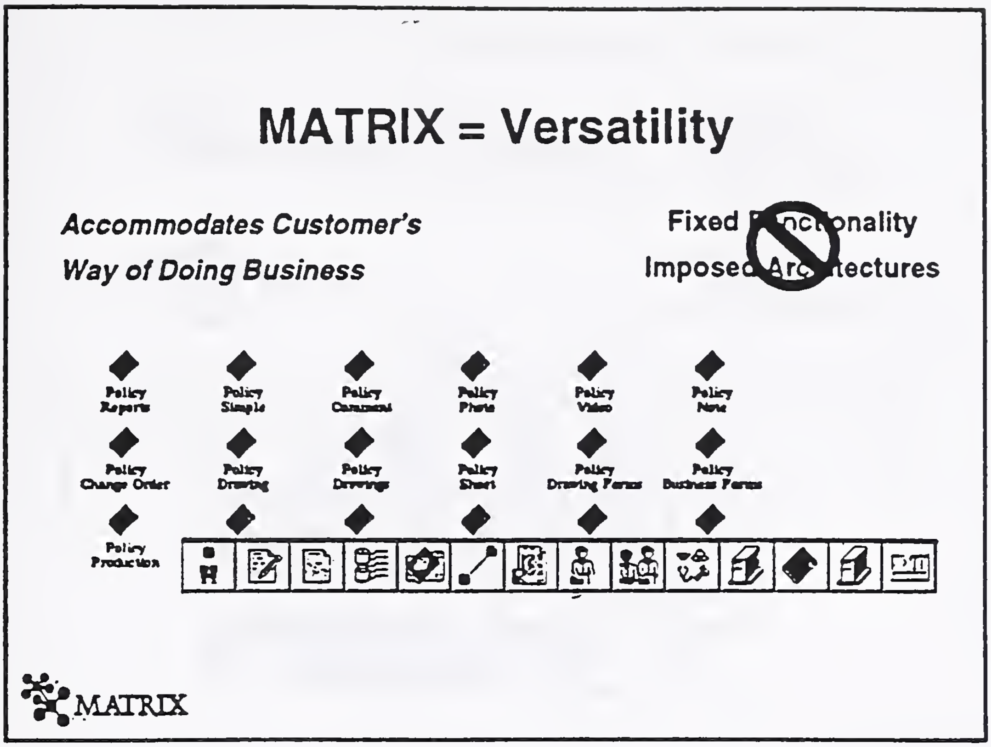
- Model Organizational Hierarchies
  - People
  - Groups
  - Roles
  - Projects
- Coupled to Access Rules
- Automatic Notification

MATRIX

- **In Matrix, operators can model people in a business in exactly the way they are organized** -- the individuals, the groups to which they belong, and their role(s)
- Groups and roles can be defined in hierarchies and persons assigned to them
- Each user can access the information that their assignment(s) control
- And, policy-based linkage controls access to, and notification about, objects and events throughout the user community
- **All the definitions needed are detailed graphically using the Business Administrator module, which does not require programming** or operating system experience
- **The only requirement is that the administrator developing the schema have a working knowledge about the company's operations**
- **Any change to the organizational schema (such as adding a new user, changing roles, or re-organizations) can be done anytime** during system operation
- *If you want to go further with this* -> This is equivalent to organizational concepts defined by STEP in ISO standard 10303-41

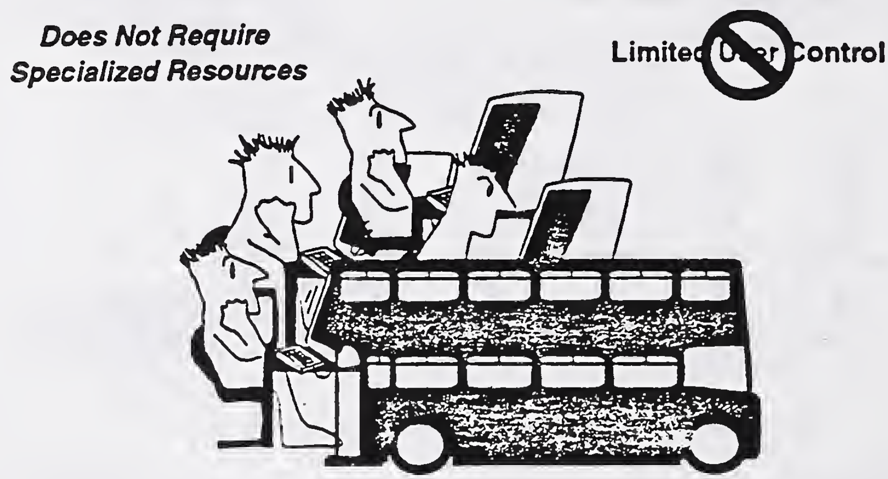


- Matrix supersedes traditional text, tabular, and even icon-based interfaces
- The click and browse approach is far more natural and appealing than formulating a query, and it also keeps typing to an absolute minimum
- Because users can intuitively navigate the actual information structure, they can quickly locate locate, identify, and access the information they seek rather than repeating shotgun searches
- By giving visibility to the process, users can understand, evaluate, and re-engineer their workflows
- These techniques are comprehensively applied to administration functions to virtually eliminate programming as the primary means of tailoring the system
- In effect -- Matrix enables the work to find the user



- With Matrix, installation and operation goes quickly and efficiently
- Users can implement in different departments and link them up to behave as one
- The user is free to architect the configuration (or variety of them) without restriction and can change or add objects, rules, and policies as business needs dictate
- Matrix accommodates user preferences for such items like network topology, redundancy, performance, etc.
- This structural flexibility is essential to facilitating and maintaining communication and collaboration

MATRIX = Reduced Overhead



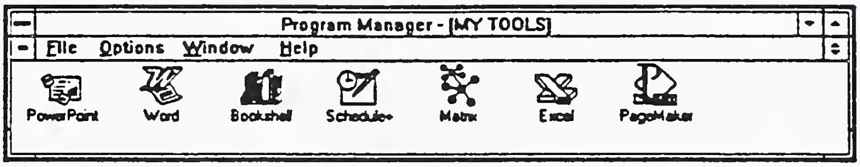
MATRIX

- **Because of product complexity, other systems penalize users** dictating that they either involve the vendor or invest in in-house programming expertise
- **Matrix eliminates the overhead associated with today's typical data management implementation** where the cost in associated services for custom programming can match or exceed the hardware/ software purchase price
- **There's no need for the busload of specialized technical staff** to install and maintain, which is a major contributor to the total cost of ownership of other systems
- Matrix reverses this overhead because it only requires someone who has a working understanding of how the organization operates to implement it
- **Matrix makes it even easier (and speeds system start-up) by providing templates** that contain pre-defined schema for organizational structure, objects, and workflow which can be applied to any business domain (such as the Drawing Manager and others that we are developing)

MATRIX = Freedom of Choice

Application-Friendly

Complex Integration



MATRIX

• Integrating with third-party applications and legacy systems is an increasingly large part of today's needs

• **With Matrix, information management takes a rightful place with other system-wide facilities, interoperates easily, and in a uniform manner;** Matrix operates at the same level as other applications, and does not "take over" the environment that can limit direct access to applications or external files

• **If needed, tools are available to achieve deep levels of integration that don't control the whole environment**

• **This allows rapid start-up, easy implementation, and quick success**

MATRIX = Customer Control

- Define Any Variety Of Business Objects & Relationships
- Select The Applications Of Choice
- Describe The Organization & Processes
- Visualize The Information & Workflow – In Real Time
- Changes Can Be Made *During The Lifecycle* – By The User!

MATRIX

• The new approaches and technologies in Matrix enables customers to install, implement, adapt, and grow the system themselves in their own terms -- without dependence on vendors or specialized (and expensive) resources

• For the first time, users have control over their information management environment and future direction

• Matrix gives users (both operators and management) the power to:

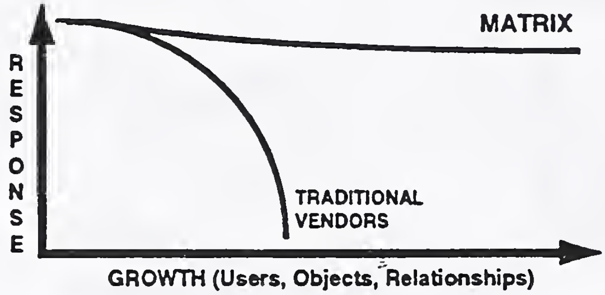
- consolidate, inter-relate, and manage any information,
- choose the best tools for the job,
- be able to "see" opportunities for efficiency,
- regulate approvals in human terms,
- model and change their operations, and
- grow their capabilities naturally

• Further, Matrix can dynamically adapt to environmental changes as the awareness of data structures and process needs is discovered after the database is first loaded

MATRIX = High Performance

Linear, Consistent Response

Poor Performance



MATRIX

- **Because Matrix is fully distributable, each user utilizes the needed processing and storage capacity resident in their own workstation or PC**
- **Performance scales with user count** without requiring exponential increases in data and file server horsepower
- **As the system expands in any or all dimensions, performance is kept constant at the desktop,** unlike other systems that hit limits in supportable bandwidth and volume
- *If you want to go further with this ->* ODB performance is less sensitive to typical installation factors that affect client/server-based systems such as the number of:

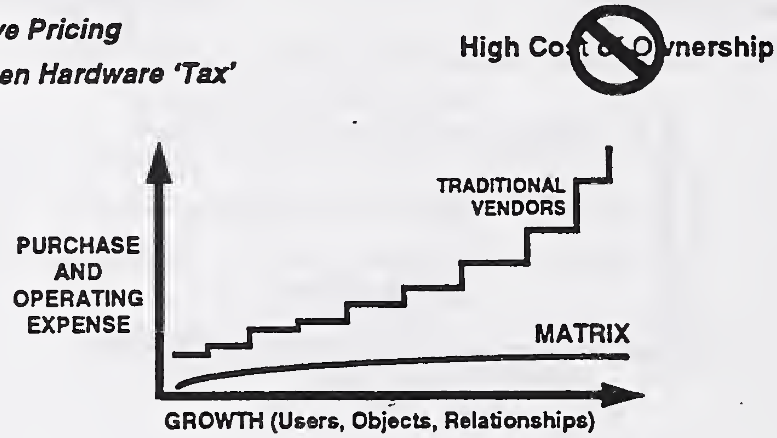
- concurrent users
- records in the database
- connections between objects
- files stored

- Relational databases are comprised of tables all of which must be fully traversed to respond to queries; object databases traverse the relationship "wires" that directly connect objects, resulting in huge performance advantages

MATRIX = Cost Advantage

Attractive Pricing

No Hidden Hardware 'Tax'



MATRIX

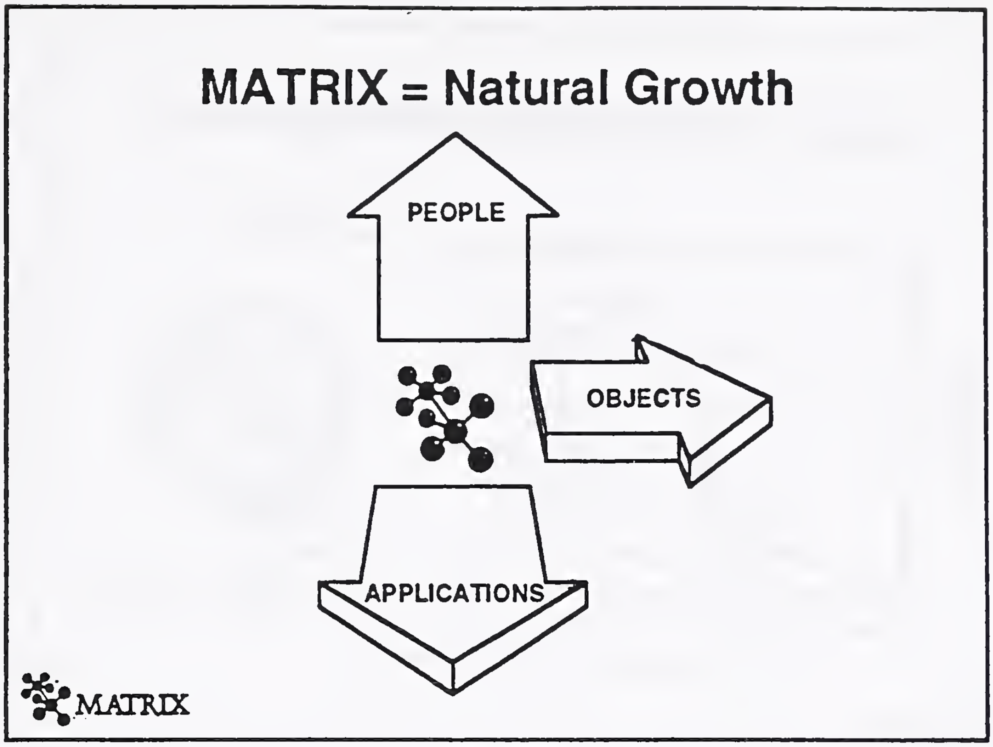
- Price is only one facet of the total cost of ownership
- **Matrix is inexpensive to purchase, install, and operate**
- **Because it is scalable, the cost to grow is scalable also** and not a function of subjective discounts based on size of purchase
- Remember, **Matrix does not require hidden costs** such as:

- **consultants** for "enterprise-wide" plans

- **specialized technical staffing** to customize or integrate

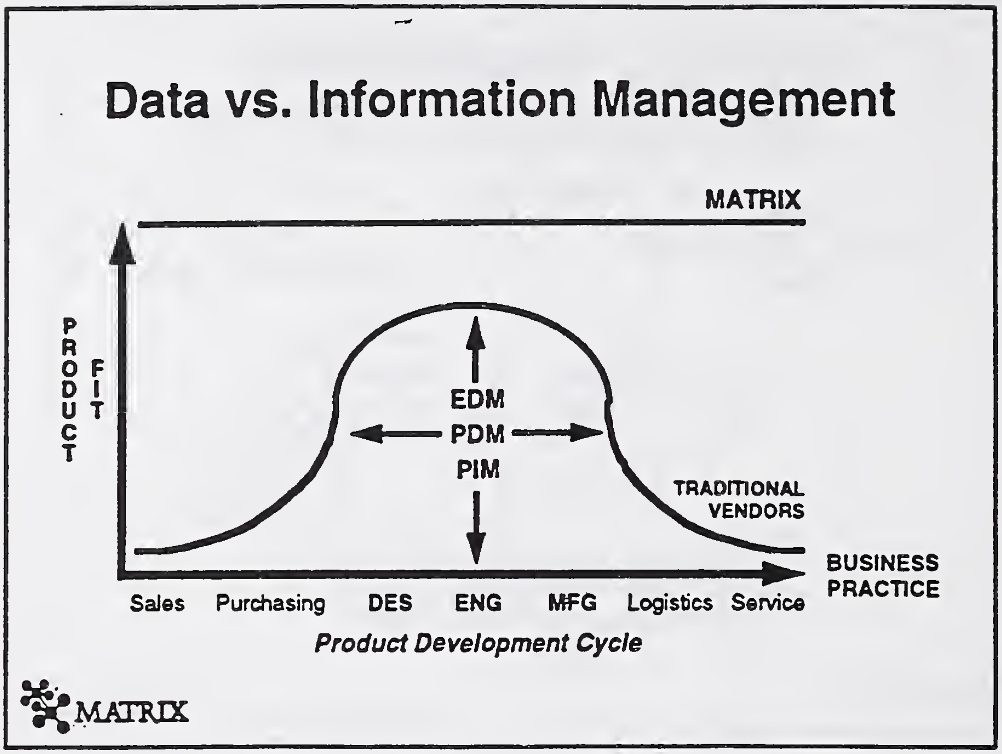
- **system upgrades** like large data or file servers to insure performance

- Because Matrix enables customers to implement and maintain the system themselves, **the costs of administration and maintenance are significantly reduced**



- As we have shown, Matrix is the only system to truly address all three major components of information management
- Matrix enables you to expand when, where, and how you want to in any dimension, without all of the obstacles, limitations, and expense of older generation systems
- The significant technology and architectural advantages that Matrix provides means that it is the only product available today that delivers optimum balance:

- **freedom to expand** and modify your environment,
- coupled with **excellent visibility, and**
- **complete control** over the information and work processes



• The differences between what was possible with older data management, versus new information management technology, are striking

• The distinction between data management and information management was recently addressed in an article in CAE Magazine, where today's data managers (EDMs, PDMs, and PIMs) were, to paraphrase, "defined by their specific contribution to the product development process"

• Information management, on the other hand, is a much more comprehensive concept displacing "data management" as users seek to support the complete business practice -- not just a subset of it

• The difference between data and information management is in its scope, versatility, and support of the entire organization or any part of it -- not just radiating data from or within the design, engineering, and manufacturing communities

• The gap between these two presents incremental opportunity for the customer -- to apply, and generate benefit from, information management technology anywhere or everywhere he/she chooses -- in product or service parts of their business

The MATRIX Difference

- Affordable
- Easy to Start
- Compelling to Use
- Inexpensive to Maintain
- Quick to Change
- Scalable Performance
- Environment-Friendly

MATRIX

- Matrix has broken through the barriers of traditional EDM/PDM/PIM approaches
- Matrix is changing the way people think about, interact with, and select information management tools
- Let's have a quick demonstration and see how Matrix opens a whole new spectrum of possibilities for you
- We'll show you how the Matrix User Module offers the most intuitive, flexible, and compelling method of locating and communicating product and business objects
- But we think that the real proof of the Matrix approach will become evident when you see the Business Administrator and how easy it is to set-up and dynamically change the information, applications, and workflow environment

Appendix E: Initial Lists of Data Validation Needs

Individual Responses to Triggering Question: "What Manufacturing Engineering Data Should Be Validated?"

BLUE TEAM RESPONSES:

Sheet 1
1. Dimensions
2. Finishing
3. Correct tool
4. DoD drawings need to be checked for errors; the notes need reviewing
5. Finishing- OK
6. Correct tools - OK
7. Processes selected (machining) will produce the desired part to the specified tolerance.

Sheet 2
1. Environment (Fixtures, Lifting, Conveying Means)
2. Quality Control (Inspection Criteria)
3. Dimensions - N.C. Cop
4. Finishing (Adhesives, Cleaning)
5. Sometimes the BOM calls out items that are no longer environmentally acceptable.
6. Fixtures (locating and clamping) will allow ready access to all details to be machined.
7. Fixturing does not damage critical areas or areas already machined.

Sheet 3
1. Validate the engineering data package created is based on the latest released version of the design specs and design model. (Not necessarily "latest", but "correct" version for spares and repairs. There will always be revisions made to the drawing; it will be difficult to keep it current.)
2. Verify that all the required engineering data package generated is complete. This is much easier to do with a product data model than paper.

Sheet 4
1. That process can meet engineering specification.
2. That operation can be performed in the time estimated.
3. That material meets engineering specification.
4. That process plan can satisfy the design specs.
5. NC program is generated for the correct machine controller.
6. That NC program is certified.
7. Critical parts are protected during handling.
8. That resources (material, tooling, machine, fixtures, etc.) are available as specified by the process plan.

Sheet 5
1. For DoD systems the material is outdated and no longer used, in some cases. It the needs a material substitution evaluation to modify the spare parts original requirement. This may require further redesign to ensure functionality of modified design.
2. Process data are frequently provided in place of design specifications. This results in an expensive and time consuming reverse engineering process to determine the design requirements that led to the processes called out. Concurrent engineering practices should overcome this in principle, but the links between design features and process requirements need to be adequately documented for archival purposes.

Sheet 6
1. NC machine tool output data. Can this be neutral, such as BCL?
2. Manufacturing input data (proper revision of solid model & are there any pending engineering changes)
3. That engineering specification is latest revision, or "correct version" for spares and repairs.
4. Shop floor revision and validation
5. Heat treatment processes properly interspersed to relieve stress.

Sheet 7
1. NC code (for gauging, unremoved material, etc.) -- Neutral format such as BCL?
2. Tolerance specs (to ensure functionality, replaceability)
3. Surface coating/finish specs (to ensure process satisfactorily performed)
4. Spec of process always produce parts within tolerance
5. Thin walls?

RED TEAM RESPONSES:

Sheet 1
1. Sequence of operations (process plan)
2. Tooling list (adequate?)
3. NC program
4. Fixturing plan
5. Machining efficiencies increased
6. Machines are not out of line dimensionally
7. Gauge list to validate gauge call outs
8. Use of less expensive machines?

Sheet 2
1. Correct raw material used
2. Correct component TDP (right dwg)
3. Correct dimensions/tolerance achieved!
4. Flagging of unusually expensive operations along with recommended change to less expensive one.
5. NC tape
6. Tool list
7. Correct version of process plans, inspection plans, NC programs for correct part design version.

Sheet 3
1. Tools in tooling lists have correct tool ID's and holders!
2. Part produced using simulated data matches part specified in design!
3. Possibility of standard tool/ holders/ adapters/ fixtures to reduce cost of custom tooling.

Sheet 4
1. Tool offset
2. NC program
3. Locator reference point
4. Dimensions of raw material
5. Tool dimensions
6. Proper tooling
7. Cutter lists for valid tooling part numbers
8. Process plan (routing) for valid machining controls, work controls, and fixture part numbers
9. Required signoffs for operation are in place.

Sheet 5
1. NC Program
2. QC inspection data (for SPC, in-process inspections, etc.)
3. Part tolerance trends
4. Changeover to new parts
5. Availability of shop drawings

Sheet 6
1. NC Programs
2. Process plan (op sequence, intermediate stock shapes, tool list)
3. Inspection plan
4. Gage dimensions
5. Setup optimization
6. Over specification/over-tolerancing

Sheet 7
1. NC program for geometry, rapid moves, interference and compliance with the inspection plan
2. CMM program for same as #1
3. NC program dynamic cutting forces
4. Tool lists
5. Feeds, speeds, cutter material type, raw material type
6. Track number of parts produced vs. time tracking

7. Parts/individual operator assessments

Sheet 8
1. NC tape
2. Tool list
3. Op sheet
4. Setup/teardown instructions
5. Time to upload/download captured?
6. Sit around time evaluated/reduced?
7. Comparison with previous part/process families (variant approach).

GREEN TEAM RESPONSES:

Sheet 1
1. Dimensions and tolerances (part configuration)
2. Process steps
3. Quality insurance steps
4. NC commands -- motions, speeds, feeds, etc.
5. Welding voltages, currents, purity, wire-feed
6. Heat treat temps, times
7. Secondary process steps and address
8. Special handling requirements (protect finish)

Sheet 2
1. Tolerances, dimensions
2. Surface conditions (roughness, hardness, coating)
3. Tooling data (cutter, fixture, jig)
4. Machine capability data
5. Add QA step
6. Are tools available in inventory
7. Tool offsets
8. Tolerance stackup from fixture reference surfaces
9. Machining commands -- speeds, feeds, etc.
10. Welding parameters -- amps, volts, wirefeeds, etc.
11. Heat treat parameters -- temps, times, etc.
12. Process parameters (speed)

Sheet 3
1. Check to see that all engineering change notices have been accounted for on the product and process data
2. Check that every feature on part is accounted for in process plan
3. Check for collisions between machine and workpiece
4. Machining speeds, feeds
5. Heat treat temps, times, quenchant
6. Welding amps, volts, feeds
7. Design/product information
8. Tolerances
9. QA steps
10. Check for correct match between design and related documentation (e.g., operator instructions)
11. Check for part/fixture drawing

Sheet 4
1. NC program commands/speeds/feeds
2. Heat treat temperature & times
3. Welding currents, voltages, polarities, feed rate
4. Other data (manual)
5. Process data (other)
6. Coolant on and off at current times
7. Special support requirements on heat treatment items
8. Cooling requirements on heat treatment
9. Ensure that 1st manufactured part is checked for validation against plan
10. Quality requirements note
11. If alternate process are possible, validate that “correct” on is specified (e.g., lot size may determine alternate processes)

Sheet 5
1. Verify machine control programs are correct and do not crash machine
2. Verify that the required process parameters are included for each process
3. Check to ensure that processes do not interfere with downstream processes
4. Cross-check and validation for availability of tooling, raw material, etc.
5. Process capability data

Sheet 6
1. The tolerances of the part should be checked against the machine capabilities.

2. The correct machine callouts should be validated (machine type, speeds, tools, etc.)
3. The correct routing of the product should be validated
4. Correct effectivity for assemblies
5. QA Steps
6. Machining commands - speeds, feeds, movements, etc.
7. Welding parameters - amps, volts, wirefeed, purity
8. Heat treat specs
9. Enough tool life is planned/allocated for cutting processes.
10. Operator certification

Sheet 7

1. Consistency and date of versions of engineering data being worked on
2. Conformance to appropriate company standards for product quality
3. All appropriate approvals and signoffs obtained
4. Routing include validation inspection
5. Authorization of access to design data -- ensure permission and access controls are appropriate
6. Traceability of materials accounted for aerospace parts

Sheet 8

1. Correct design revision level (all data) -- date, latest version
2. Regulatory compliance (process)
3. Environmental validation - what chemicals to use, how to dispose of waste material
4. Total chemicals required
5. Expected waste material generated
6. Temporary storage requirements of chemicals, e.g., paint
7. Surface conditions (hardness, roughness, coating)

Appendix F. Engineering Data Validation Method Review

Table F-1. Summary of Validation Methods by Validation Need Category

Validation Requirement	Current Methods	Advantages/ Disadvantages	Alternatives & Value Added
Category A: Technical Data Validation	Checklists, Configuration Management, PDM, paper, EDMS, Process Planning, Tool and Gauge Management System; Process Planner, Drawing #, Name, Drawing Revision, ECPS, NC Program, quantity	*Disadvantages*: Lack of concurrency, lack of control, serial delays	Provide workflow/PDM system
Category B: Feedback	Telephone, voice, paper, email		Operator/everyone electronic feedback system
That shop floor feedback is captured by PDM	1) Meet to discuss problems occurred on shop floor	*Advantage*: Timely Feedback. *Disadvantages*: Not always effective capture of information	
Concurrent Review and Input and Signoff Feedback)	2) Formal Committees (Process Action Teams)	Attempt to reach consensus, decisions not always good;	On line teleconference practices at site
	Process Sheet Change Request	Is documented slow unless prioritized	On line flagging; Instant Review
	Verbal Feedback	Forgotten, loss travels with individual	Review Terminal on shop floor as part of work flow process
	Update Database	Lag time	Real time shop floor data analysis and presentation
	Nonconformance Reports		Concurrent review meeting among design/ production/ QA teams
	SPC/QA Data Analysis	Not connected directly to the machine - validation is through inspecting	Real time SPC from the machine - problems (out of spec) would stop process
	Action Teams		

Validation Requirement	Current Methods	Advantages/ Disadvantages	Alternatives & Value Added
Category C: Resource Capability	Manual for requirements Actual trials	*Disadvantages*: Expensive and slow	Simulation plus knowledge based system (requirements)
Category D: Resource Availability	GT coding/manual for standard tooling; scheduling system; Tool Gauge Management system Database for G10		GT supported libraries of standardized parts/processes
	Machine Tool Maintenance Records, Maintain Procurement Records, Maintain Calibration Records, Maintain Inventory Data, Maintain Operator Certifications, Use GT Coding, Use MRP Tracking, Use Tracking Systems, Use Bar Coding, Manual (written) lists, Human Memory	*Disadvantages*: Procurements not on schedule, Not all information gets into system (matl. tracking), Resource not adequate in some way, Human Error	Manufacturing Engineer needs to check resource availability, but is not responsible for ultimate availability; Manufacturing Engineer needs more input from operators, managers, experts, schedulers, etc.; Capacity Planning
	Maintain Status levels (e.g., 4-Create BOM & PP, 3-Order Material, 2-Process Development, 1-Ready for Production)		
	Check Process Descriptions & Capabilities		
	Assume Resources are available because job has been done before	Status of shop has changed	Resource System Shows Status of Shop Resources at Planned Production Time
	Keep shop floor resource data on paper sheets	Difficult to update the data on the sheets	Develop Information System
			Work Around Procedures

Validation Requirement	Current Methods	Advantages/ Disadvantages	Alternatives & Value Added
Category E: Process Validation			
Verify control programs, tool offsets	NC Simulation, cutting air, cut wax, 1st piece; machine operator verifies all programs & machine settings during setup & step through -- validation is on 1st piece	*Disadvantages*: May not show all problems, costly, time consuming, collision risk; loss of material	Better, more complex simulation would eliminate most of the setup and 1st piece problems; 1st piece acceptance would be higher
	Quality Assurance Reviews	Time	Automatic insertion; standard inspection procedures
Dynamic cutting forces are correct	Operator observation; machinability guides	Costly; not optimum	Setup checklists of boundary conditions for each process
Required process parameters	Visual check of plans	Not necessarily complete or correct	Automatic syntax and content checking of process parameters by rules
Setup/ Teardown Instructions	Visual check, not specified, drawings, standard setup configuration	Subjective, not possible to validate; variations in process; drawings not always done	Knowledge-based checking tool; use graphic/simulation to show key aspect of setup with notes
Process/ operation sequence	Test part run, expert input; ME develop sequences; Quality Engineers check sequences for inspection and test	Time consuming, high setup, corrections may not be captured; sequence cannot be validated until 1st piece is completed	Simulation could ensure all sequences are correct before fabrication cycle is started
Ops sheets/ Process plan	ME's develop all ops sheets and process plans before the fab process begins -- accomplished via history, lessons learned, and manufacturing guidelines	No real way to validate process plan before fabrication	Rule based generative process plans; data base of lessons learned which could be highlighted to the ME as the process plan is being developed; simulation
Validate QA steps	Test run, expert input	Time consuming, scrap, collision risk	
Overspec/ overtolerance	ME's, QE's check engineering drawing for this condition	Oversights occur and not caught until fabrication process begun	Manufacturing guidelines in place at the design level; if engineering designed product overspec/ overtolerance the database would question why.

Validation Requirement	Current Methods	Advantages/ Disadvantages	Alternatives & Value Added
Category F: Cost/ Performance Metrics			
Setup time, down time, run time, idle time, etc.	Shop floor data collection system (job number, parts made/scrap, operator no., time, etc.)	*Disadvantages*: Not real-time; after the fact	On line from DNC data
Hourly rate for each resource			
Scrap/Success rates	Scrap rework and repair	After the fact	
Parts vs. Time	MRP system	Serial	Maintain on-line data base
Capture resource dead time	Observation	Not comprehensive	Process/resource utilization analysis; process/resource vs time Gantt chart