Parametric Technology Corporation

Tools for the Engineer
Reshaping Tomorrow
Today’s Situation

The Problem
- Increasing competition
- Increasing product complexity
- Limited resources available
- Geographically dispersed operations

And yet you have to achieve conflicting goals of
- Reduced time-to-market
- Improved quality
- Lower product costs
Design Decisions Are Critical...

Design is a tiny piece of the development pie, but it locks in the bulk of later spending

<table>
<thead>
<tr>
<th></th>
<th>Percent of total costs*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Incurred</td>
</tr>
<tr>
<td>Conception</td>
<td>3% - 5%</td>
</tr>
<tr>
<td>Design Engineering</td>
<td>5 - 8</td>
</tr>
<tr>
<td>Testing</td>
<td>8 - 10</td>
</tr>
<tr>
<td>Process Planning</td>
<td>10 - 15</td>
</tr>
<tr>
<td>Production</td>
<td>15 - 100</td>
</tr>
</tbody>
</table>

*Cumulative

Source: Computer Aided Manufacturing International, Inc.
...And Traditional Engineering Is Expensive

The typical cost for each change made during the development of a major electronics product

<table>
<thead>
<tr>
<th>When design changes are made</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>During Design</td>
<td>$1,000</td>
</tr>
<tr>
<td>During Design Testing</td>
<td>$10,000</td>
</tr>
<tr>
<td>During Process Planning</td>
<td>$100,000</td>
</tr>
<tr>
<td>During Test Production</td>
<td>$1,000,000</td>
</tr>
<tr>
<td>During Final Production</td>
<td>$10,000,000</td>
</tr>
</tbody>
</table>

Source: Dataquest, Inc.
Sensitivity of Profits over Product Life Cycle

% Reduction in Life Cycle Profits

- 6 Month Delay: 33%
- 50% Expense Overrun: 3.5%
- Product Cost 9% High: 22%

Price-Eroding Market -- 5 Year Life

Financial Justification

How important is time to market?

A one-month savings in development time translates into one additional month of mature sales.
The Benefits of Early to Market

- Greater market share
- Early pricing premiums
- Greater profitability
- Earlier customer feedback for successive offerings
- Products that set industry standards
- Reputation as an innovator
- Pre-emption of distribution channels
The Process and the Players

- Complex, multi-disciplinary, time-based process
- Product definition evolves through time
- Each participant has functional set of engineering deliverables to produce

<table>
<thead>
<tr>
<th>Conceptual Design</th>
<th>Detailed Design</th>
<th>Drafting</th>
<th>Manufacturing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design Manager</td>
<td>Analysis Engineer</td>
<td>Project Manager</td>
<td>QA Engineer</td>
</tr>
<tr>
<td>2D &amp; 3D Design Layouts</td>
<td>Detailed Part &amp; Assembly Design</td>
<td>[Deliverables: Design Specification, Layouts]</td>
<td>[Inspection &amp; QA Specifications]</td>
</tr>
<tr>
<td>Design Engineer</td>
<td>Drafstman</td>
<td>Part Drawings</td>
<td>Tooling</td>
</tr>
<tr>
<td>Detailed Part &amp; Assembly Design</td>
<td>Manufacturing Engineer</td>
<td>Part Drawings</td>
<td>Process Plans</td>
</tr>
<tr>
<td>Production Drawing Creation</td>
<td>Manufacturing Process Definition</td>
<td>Assembly Drawings</td>
<td>In-Process Drawings</td>
</tr>
<tr>
<td>Tooling</td>
<td>Process Plans</td>
<td>Tool Paths</td>
<td>Cutter Location Files</td>
</tr>
</tbody>
</table>

Deliverables:
- Design Specification
- Layouts
- Part & Assembly Models
- Tolerance Analysis Models
- FEM/FEA Models
- Bill of Materials
- Part Drawings
- Installation Drawings
Multiple Perspectives of a Product

Design Engineer
Maps design specifications into model representation

Tooling Engineer
Overlays manufacturability onto design model

Design Manager
Manages process and establishes key global parameters

Manufacturing Engineer
Coordinates manufacturing process with design model

Draftsman
Documents design for all participants

Quality Engineer
Verifies quality adherence and establishes inspection criteria

The Challenge is Converging Multiple Perspectives on a Single Product Definition in Less Time
The Process

Traditional Sequential Engineering

<table>
<thead>
<tr>
<th>IDEA</th>
<th>CONCEPT</th>
<th>DETAIL DESIGN</th>
<th>ANALYSIS</th>
<th>DRAFTING</th>
<th>MANUFACTURING</th>
</tr>
</thead>
<tbody>
<tr>
<td>15%</td>
<td>25%</td>
<td>10%</td>
<td>20%</td>
<td>30%</td>
<td></td>
</tr>
</tbody>
</table>

Third Generation Approach

<table>
<thead>
<tr>
<th>IDEA</th>
<th>CONCEPT</th>
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<td>15%</td>
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</table>

- Shortened development cycle
- Increased analysis
- Increased optimization
- Drafting removed from critical path

30%
What is the Third Generation?

- A completely different modeling vision
- A “ground-up” new software architecture supporting the modeling vision
- An emphasis on automating the process, not just the individuals involved in the process
- The creation of a single product model

Design Intent + Manufacturing Process Priorities + Quality Guidelines
“Cognitive Features as Building Blocks”

- Can be defined simply and generically
- Natural mechanical objects containing knowledge of their environment
- Adapt “predictably” to changes in surrounding features
- All physical objects can be described by fewer than 22 cognitive design features
- Traditional systems use “Form-Features”
  - Macros for pre-programmed sequences of Boolean operations
  - No inherent knowledge of their relationships to each other
Cognitive Design Features

Example

- A rib can be described simply:
  - a cross-section
  - parameter specifies thickness
  - topological relation to surrounding geometry

- If the rib is relocated, it reconfigures itself automatically and dynamically to changes in the surrounding geometry
Design Feature Chain

Operation ➔ Cross Section ➔ Dimensioning Scheme ➔ Topological Relations


Part “A” ➔ Part “B” ➔ Part “C”

Assembly “A” ➔ Assembly “B” ➔ Assembly “C”

Product
Manufacturing Feature Chain

- A manufacturing feature is a discrete manufacturing operation
- A series of manufacturing features describes the machining process
- At all times the process definition is dynamically linked to the design definition
Cognitive Manufacturing Features

Example

- A mill feature can be described simply by:
  - manufacturing tools
  - machining parameters
  - boundary of the volume to mill
- As the design model changes the milling toolpath updates automatically and dynamically

![Toolpath for 4 Fins](image1)

![Toolpath for 8 Fins](image2)
Modeling Vision

- All disciplines can participate simultaneously throughout the product design
- Result includes a higher quality, lower cost product developed in less time
Engineering Data Reuse

- Most designs can be based heavily on previous design efforts
- The nature of cognitive features facilitates global interchangeability
- Generic product design contains multiple variations based on the presence of alternate features

Functional Alternatives Can be Captured Within a Single Generalized Product Model
Engineering Data Reuse

Example A

- The final design of an engine can change significantly
- The existing product model updates to accommodate these new requirements
- New deliverables include a complete set of design, documentation and manufacturing information

Engine Assembly Model X11

Engine Assembly Model X12
Engineering Data Reuse

Example B

- Next generation products can borrow heavily from existing products
- Cognitive features make it easy to reuse existing designs in new, sometimes significantly different designs

Existing Engine Design

Engine Assembly

- Muffler
- Block
- Head

Reuse with Next Generation

Next Generation Engine Design

New Engine Assembly

- Crankcase
- 4X Block
- 4X Head
Engineering Data Reuse

Existing Engine Design

Next Generation Engine Design
Engineering Data Reuse

Benefits

- Reduces product development time by orders of magnitude
- The complete product definition, including all deliverables “for free,” is created for each new design
- Improves product quality
- Shortens your response time to meet your customers’ needs

Past successes are leveraged for future products!
Concurrent Engineering Pays Big Dividends

Benefits from designing manufacturability, quality, and ease of maintenance into the product at the start

<table>
<thead>
<tr>
<th>Benefits</th>
<th>Percent Change</th>
</tr>
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<tbody>
<tr>
<td>Development Time</td>
<td>30 - 70 less</td>
</tr>
<tr>
<td>Engineering Changes</td>
<td>65 - 90 fewer</td>
</tr>
<tr>
<td>Time to Market</td>
<td>20 - 90 less</td>
</tr>
<tr>
<td>Overall Quality</td>
<td>200 - 600 higher</td>
</tr>
<tr>
<td>White-Collar Productivity</td>
<td>20 - 110 higher</td>
</tr>
<tr>
<td>Dollar Sales</td>
<td>5 - 50 higher</td>
</tr>
<tr>
<td>Return on Assets</td>
<td>20 - 120 higher</td>
</tr>
</tbody>
</table>

Source: National Institute of Standards & Technology, Thomas Group Inc., Institute for Defense Analysis
Project Examples

Honda
*Productivity gains of 15:1*

Whirlpool
*Time to market reduced by 60%*

J. I. Case
*Product development cycle reduced by 50%*

Baxter Healthcare
*Conceptual design and modeling time reduced by 50%*

Kohler
*Development and prototyping cycle reduced from 6 months to 2 weeks*
Project Examples

Three-Five Systems
*Lead times reduced up to 75%*

Precor
*Prototypes per product decreased by 30%*

Penn Fishing Tackle
*Design time reduced by 30%*

Genus, Inc.
“*Pro/ENGINEER practically regenerates drawings automatically.*”

Quest Engineering
*6-month project completed in 2 months; costs reduced by 40%*
Summary

Reduced Time-to-Market

Improved Quality

Lower Product Costs