What is STEP

- An International Standard for technical data about products including
  - Geometry and topology
  - Assembly and configuration information
  - Manufacturing attributes
- Move to STEP initiated by CAD users in 1984
  - More interoperability in design and manufacturing
  - Reduce costs for supply chain
  - Replace IGES, SET and VDAFS
- Two hundred product data specialists meeting three times per year.
  - Experts from Europe, Far East and USA
  - Most of the world's major engineering companies represented
  - >$500M investment by aerospace, shipbuilding and automotive industries
- More than one million CAD stations use STEP
  - All major CAD systems have STEP interfaces
  - Grown in IBM supply chain from 0% in 1998 to 17% in 1999 to 30% in 2000
- STEP-NC extends STEP for CAM and CNC control
• Direct control of machine tools from 3D data
  – STEP-NC under development in Europe and Far East for 4 years
  – Milling, Turning, Wire EDM, CMM others anticipated

• Benefits
  – 35% reduction in CAM planning time
  – 75% reduction in number of drawings sent from CAD to CAM
  – 50% reduction in machining time for small to mid sized job lots
  – Elimination of 4,500+ post processors
  – Safer, more adaptable machine tools


Industrial Review Board
– GE Fanuc
– CNC Data (MASTERCAM)
– CADKEY
– Alibre
– Boeing
– General Electric
– General Motors
– Gibbs and Associates
– Hurco Companies Inc.
– Lockheed Martin
– IBM
– Monarch Machine Tools
– NASA (GSFC)
– NASA (JPL)
– NCMS
– Northrop Grumman
– Unigraphics Solutions
– NIST Intelligent Systems
– Caterpillar
– Lawrence Livermore Laboratories
– Chrysler
– Watervliet Arsenal (Benet)
– General Dynamics Land Systems
– Cincinnati Machine
– The Design Edge
– RMC Associates
– Fala Technologies
– Cambridge Valley Machining
– Honeywell
– Electro Mechanical Integrators
– Liberty Consulting
– RPI
AS-IS Process

Integrated CAD/CAM for OEM’s

- CAD
- CAM Macro Planning
- CAM Micro Planning
- Post Processor
- RS274D
- NC Controller

IGES Data Exchange for supply chain

- CAD
- IGES
- CAM Macro Planning
- CAM Micro Planning
- Post Processor
- RS274D
- NC Controller

Macro planning is stock definition, feature selection, process ordering and tool requirements.
Micro planning is tool path generation with tools that meet the requirements.

TO-BE Process

Integrated CAD/CAM for OEM’s

- CAD
- CAM Macro Planning
- AP-203
- AP-238
- CAM Micro Planning
- NC Controller

Supply chain

- CAD
- AP-203
- CAM Macro Planning
- e.g. FB Mach
- AP-238
- CAM Micro Planning
- NC Controller

Post Processor is invisible to the user.
Micro planning (tool path generation) is automatic using a CAM system embedded into the NC Controller.
CNC Implementation

- Make part on the shop floor from AP-238 data
  - Minimal user input necessary
  - “Run” to make the part
  - “Verify” to check tool paths for collisions
  - “Document” to create spreadsheet of operations

CAM Benefit

The supplier creates the CAM plan from a 3D product model instead of paper drawings

Estimated by Lockheed Martin

<table>
<thead>
<tr>
<th></th>
<th>Without STEP</th>
<th></th>
<th>With STEP Saving</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Max</td>
<td>Min</td>
<td>Average</td>
<td></td>
</tr>
<tr>
<td>Hours to make a process plan</td>
<td>100</td>
<td>4</td>
<td>16</td>
<td>12</td>
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<td>Hours to replan a process plan</td>
<td>20</td>
<td>1</td>
<td>4</td>
<td>3</td>
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<td>Number of iterations</td>
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<td>2</td>
<td></td>
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<tr>
<td>Total Hours</td>
<td>28</td>
<td></td>
<td>18</td>
<td></td>
</tr>
</tbody>
</table>

Of 13M engineering hours on Boeing 777 project an estimated 8M spent on data correction and administration

CAD 75% faster

STEP (AP-203) 35% faster

STEP-NC (AP-238) 50% faster

Same geometry
CAM Benefit assumptions

- **AS-IS process**
  - CAM user receives drawing
  - CAM user converts drawing into CAM model
  - CAM user generates RS274D from CAM model

- **TO-BE process**
  - CAM user receives 3D model
  - Feature recognition used to initialize CAM model
  - CAM user generates AP-238 from CAM model

- **Accelerants**
  - Feature recognition
  - Features sent to CNC instead of M and G codes

- **Risks/Unknowns**
  - Reliability of feature recognition

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PDM Benefit

A 3D model is sent to the supplier instead of paper drawings

*Estimated by Raytheon*

<table>
<thead>
<tr>
<th>Using Drawing</th>
<th>Using STEP</th>
<th>Saving</th>
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</thead>
<tbody>
<tr>
<td>Max</td>
<td>Min</td>
<td>Average</td>
</tr>
<tr>
<td>Number of Drawings per design</td>
<td>100</td>
<td>10</td>
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<tr>
<td>Number of hours to make drawing</td>
<td>80</td>
<td>1</td>
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<tr>
<td>Total Hours</td>
<td>320</td>
<td>80</td>
</tr>
</tbody>
</table>

For each 1 file made by design 100 are made by manufacturing – Ford Motor

---

**Diagram:**
- **CAD**
- **STEP** (AP-203)
- **CAM**
- **STEP-NC** (AP-238)
- **CNC**

- 75% faster
- 35% faster
- Same geometry
- 50% faster
PDM Benefit Assumptions

- **AS-IS Process**
  - Make drawings for each stage of manufacturing from 3D models
  - Annotate drawings with product specifications as text
  - Send drawings to manufacturing

- **TO-BE Process**
  - Send STEP-NC data containing AS-IS and TO-BE model for each manufacturing stage

- **Accelerants**
  - No need to make so many drawings
  - Manufacturing gets an electronic product specification

- **Risks/Unknowns**
  - How to communicate tolerances between design and manufacturing?
    - Via a drawing
    - By annotating design (AP-203/214) data
    - By annotating manufacturing (AP-224/238) data

CNC Benefit

The machine computes optimum speeds and feeds from full fidelity geometry information

By value, 75% of manufacturing is for lots of 50 or less – Manufacturing Roadmap

<table>
<thead>
<tr>
<th>Part name</th>
<th>s05</th>
<th>s06</th>
<th>s09</th>
<th>s25</th>
<th>w2005</th>
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</thead>
<tbody>
<tr>
<td>Old Mach</td>
<td>3-axis</td>
<td>4-axis</td>
<td>4-axis</td>
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<tr>
<td></td>
<td>4.13hrs</td>
<td>2.3hrs</td>
<td>1.18hrs</td>
<td>?</td>
<td>?</td>
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<tr>
<td>New Mach</td>
<td>5-axis</td>
<td>5-axis</td>
<td>5-axis</td>
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<td>5-axis</td>
</tr>
<tr>
<td></td>
<td>1.09hrs</td>
<td>0.36hrs</td>
<td>?</td>
<td>0.59hrs</td>
<td>0.59hrs</td>
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<tr>
<td></td>
<td>73.61%</td>
<td>84.35%</td>
<td></td>
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</tbody>
</table>

CAD  
75% faster

STEP (AP-203)  
35% faster

Same geometry

CAM

STEP-NC (AP-238)  
50% faster

CNC
CNC Benefit assumptions

- **AS-IS process**
  - Machine executes RS274D codes with as much accuracy as possible

- **TO-BE process**
  - Machine gets complete manufacturing specification
    - Geometry, tolerances, tool requirements, fixtures, material
  - Machine computes optimal speeds and feeds
    - Algorithms + tool database + geometry/tolerances

- **Accelerants**
  - 5 axis machining and high speed machining become easier and safer to use so they are used more often for small and medium lot manufacturing

- **Risks/Unknowns**
  - How long until the new algorithms are available in the controller?

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STEP-NC Deployment

- **Phase 0**
  - Pace of development is slow
  - Technology is proven
  - Business benefits demonstrated
  - Draft standards published
  - Small number of test sites

- **Phase 1**
  - Pace of development quickens
  - Technology made reliable
  - Business usage parameters set
  - Final standards published
  - Deployment by Industry leaders

- **Phase 2**
  - Pace of development is frantic
  - Costs are reduced
  - Functionality is increased
  - Wide spread implementation
  - Deployment by supply chain

<table>
<thead>
<tr>
<th>Process</th>
<th>Phase 0</th>
<th>Phase 1</th>
<th>Phase 2</th>
</tr>
</thead>
</table>
Considerations

- **If current trends continue**
  - Most machine tools will be made in the Far East, many in China
  - (Today GDLS can buy US for $1.2M or Korean for $0.25M)
  - The CAM vendors will expand their Post libraries from 4,500 to ???
  - In the event of an emergency 10,000 people may be trying to port 10,000 G-code files to 10,000 machines with 10,000 posts

- **STEP-NC**
  - Eliminates the post
  - Defines a higher level interface
  - Maximizes flexibility of the Part Programs
  - Maximizes independence from the machine tool vendor

Basic Implementation

- **Apply software implemented by ATP program**
  - Create AP-238 data from AP-203 using ST-CAM (FB Mach)
  - Read AP-238 into the STEP-NC plug-in
  - Create manufacturing database in GibbsCAM or MasterCAM
  - Use GibbsCAM or MasterCAM to verify and post data to a CNC
• Find out how to
  – Make maximum use of existing machines
  – Make maximum use of existing CAD/CAM systems

What do we need to do in Phase 1

• Proved basic concept using NIST ATP funds
  – $2M over three years
  – 50 companies on IRB

• Next task (Phase 1) is to harden
  – STEP-NC output for the major CAD/CAM systems
  – Internet translation services
  – Test in factories of the future using typical machines
  – Work with International projects in the STEP-NC IMS program

• Then Deploy
  – Easy to believe savings will exceed $100 billion
  – Need to decide priorities