### Development of Industrial Assessment Metrics and Procedures

#### Motivation
- Manufacturing processes are resource intensive
  - 31% of total U.S. energy usage is due to industrial activities (U.S. EIA)
  - 19% of total world global warming potential (GWP) emissions (Herzog 2009)
- Growing environmental concern has made it important for manufacturers to fully understand and characterize their processes, tools, and equipment to meet increasing regulations and customer demands

#### Introduction
- The goal of this project was to develop a standardized methodology to assess manufacturing facilities at the cell and process level
- Three sustainability assessments of various manufacturing facilities were performed in order to inform the development of the standardized methodology

### Resource Flows in Machining

<table>
<thead>
<tr>
<th>Flow</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy</td>
<td>Used for machining processes</td>
</tr>
<tr>
<td>Water</td>
<td>Used for cooling and cleaning</td>
</tr>
<tr>
<td>Cutting Fluid</td>
<td>Used in machining processes</td>
</tr>
<tr>
<td>Fixtures, Tool Holders, etc.</td>
<td>Used in machining processes</td>
</tr>
<tr>
<td>Raw Stock</td>
<td>Used as input for machining processes</td>
</tr>
<tr>
<td>Contaminated Cutting Fluid</td>
<td>Produced as waste from machining processes</td>
</tr>
<tr>
<td>Spent Fluid</td>
<td>Produced as waste from machining processes</td>
</tr>
<tr>
<td>Compressors, Bulbs, etc.</td>
<td>Used in facility operations</td>
</tr>
<tr>
<td>Lighting, HVAC, Equipment, etc.</td>
<td>Used in facility operations</td>
</tr>
</tbody>
</table>

### Metrics Development
- The metrics were defined around the functional unit of the production of a part
- Facility data, when available, was amortized over the number of machine tools and parts produced
- The metrics fell into the following categories:
  - Power demand and energy consumption (e.g. idle power demand, processing energy consumption per year, etc.)
  - Production efficiency/OEE (e.g. availability, efficiency, etc.)
  - Process consumables and facility overhead charges (e.g. coolant consumption, water consumption, tool life, etc.)
  - Process waste (e.g. rework rate, scrap rate, etc.)
  - Return on investment (e.g. ROI)
  - Human safety (e.g. max noise level, injuries per year, etc.)

### Remmele Engineering

- **Site:** Remmele Engineering, Big Lake, MN
- **Date:** November 18-19, 2010
- **Process(es) Studied:** Two machine tools performing similar machining operations
  - Hydromat Rotary Transfer Machine Tool
  - Citizen Swiss Machine Tool
- **Key Goals:**
  - Baseline resource usage of machines to create gripper component
  - Comparative analysis of resource usage between machine tools
  - Compare older and newer machines

### GKN Aerospace

- **Site:** GKN Aerospace, St. Louis, MO
- **Date:** December 15-16, 2010
- **Process(es) Studied:** The resource consumption for the production of a test piece
  - Cincinnati H5-1000 Machine Tool
- **Key Goals:**
  - Assess the sustainability of the Magnum test cell
  - Establish a baseline of the resource usage of the cell for future assessments

### General Electric (GE) Aviation

- **Site:** GE Aviation, Madisonville, KY
- **Date:** February 8-10, 2011
- **Process(es) Studied:** Turbine airfoil hole drilling line
  - Grinding
  - Smear electrical discharge machining
  - Current electrical discharge machining
- **Key goals:**
  - Baseline resource usage of machines to create finished airfoil
  - Compare older and newer machines

### Conclusions & Future Work
- Results from the assessments can be used to identify savings opportunities in existing processes
- The data collected in these assessments can be used to establish a baseline/standard to which manufacturing or machining processes can be compared against
- Using this baseline, process level improvements can be explored to increase the resource efficiency of the machine tools and processes
- More assessments are needed to establish a baseline and further refine the methodology