High Performance Computing for Manufacturing at the US-DOE Advanced Manufacturing Office

*HPC4Materials Industry Day*

*Pittsburgh, PA*

October 12, 2017
Energy and Manufacturing Innovation Today

- Energy independence
- Stable, diverse energy supply
- Competitiveness by energy productivity
- Domestic jobs
- Clean Air
- Clean Water
- Stable, diverse energy supply

Technology Innovation through Early-Stage Research and Development In Manufacturing and Energy is a Foundation for Economic Growth & Jobs
A little history: The Start of a pair of Revolutions

Lexington & Concord
1775

Watt, Boulton & Co.
1775
(intelligence: steam regulation for external combustion engines)
“... the encouragement of manufactures is the interest of all parts of the Union.”

“Not only the wealth; but the independence and security of a country, appear to be materially connected with the prosperity of manufactures.”

“... it is the interest of a community with a view to eventual and permanent economy, to encourage the growth of manufactures.”

- Alexander Hamilton
US Treasury Secretary (1789-1795)

Reports to Congress
First Report on the Public Credit - 1790
Second Report on Public Credit - 1791
Report on the Subject of Manufactures - 1791
Second Industrial Revolution

Electrification

Process Scaling
Energy & Materials

Standardization &
Assembly Line

U.S. DEPARTMENT OF
Energy Efficiency &
Renewable Energy
<table>
<thead>
<tr>
<th>Industry</th>
<th>TBTU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary Metals</td>
<td>1608</td>
</tr>
<tr>
<td>Petroleum Refining</td>
<td>6137</td>
</tr>
<tr>
<td>Chemicals</td>
<td>4995</td>
</tr>
<tr>
<td>Wood Pulp &amp; Paper</td>
<td>2109</td>
</tr>
<tr>
<td>Glass &amp; Cement</td>
<td>716</td>
</tr>
<tr>
<td>Food Processing</td>
<td>1162</td>
</tr>
<tr>
<td>Other Manufacturing</td>
<td>~1600</td>
</tr>
</tbody>
</table>
How will Manufacturing, Economy and Security of the Nation depend on Information, Computation, Actuation and Communication Technologies in the 21st Century?
Processes for Energy Materials & Technologies
Energy Dependence: Energy Cost Considered in Competitive Manufacturing

Solar PV Cell
Carbon Fibers
Light Emitting Diodes
Electro-Chromic Coatings
Membranes
EV Batteries
Multi-Material Joining
Water Desalination
Powerful multiplier effects mean every new advanced industry job supports more than two others.
Advanced Manufacturing are Great Jobs!

![Bar chart showing average wages in thousands for different educational levels in Advanced and Non-Advanced Industries.](chart.png)
US Workforce is Highly Productive

Advanced Industries GDP per Worker (2010)

United States
Norway
Belgium
Netherlands
Italy
Austria
Sweden
France
Germany
Finland
Denmark
Czech Republic
Hungary
Slovenia

Annualized Growth in Advanced Industries GDP per Worker (2000-2010)

GDP per Worker
Growth in GDP per Worker

U.S. DEPARTMENT OF ENERGY
Energy Efficiency & Renewable Energy
Manufacturing Innovation is Important to the Nation
Advanced Manufacturing -- Opportunity

Technology Innovation through Applied Research and Development in Advanced Manufacturing and Energy is a Foundation for Economic Growth and Jobs in the US

$2T Manufacturing GDP
12.4M Manufacturing Direct Employment Jobs
0.8 / 1.0 – Indirect / Direct Jobs - All Manufacturing
2.2 / 1.0 – Indirect / Direct Jobs - Advanced Sub-Sectors

24 QBTU (25% of National Total) – Manufacturing
2/3 Manufacturing Energy is in Intensive Sectors
Current opportunities represent energy savings that could be achieved by deploying the most energy-efficient commercial technologies available worldwide. R&D opportunities represent potential savings that could be attained through successful deployment of applied R&D technologies under development worldwide.
AMO Technical Focus Areas (FY16/17 MYPP draft published)
## Impact Areas of Cross-Cutting Efficiency Technology Technology R&D for Energy Intensive Industry Sectors

### Sector Specific Roadmaps For Each Industry Sector Have Common / Shared Technology Challenges
AMO: Three complimentary strategies

**Technical Assistance: Direct engagement with Industry**

Driving a corporate culture of continuous improvement and wide scale adoption of proven technologies, such as CHP, to reduce energy use in the industrial sector.

**R&D Facilities: Public-Private consortia model**

Shared R&D Facilities offer affordable access to physical and virtual tools, and expertise, to foster innovation and adoption of promising technologies.

**R&D Projects: Bridging the innovation gap**

Research and Development Projects to support innovative manufacturing processes and next-generation materials.
HPC4Mfg leverages global leading HPC capabilities at the national labs to partner with industry and address critical technical challenges in manufacturing

- DOE labs possess 5 of the top 12 HPC systems worldwide and broad expertise in their application: 2 of top 3 in Top500

- Catalyzes Industry / National Lab partnerships

### Top500 / June 2017

<table>
<thead>
<tr>
<th>Rank</th>
<th>System Name</th>
<th>Country</th>
<th>Rmax (TF/s)</th>
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<tbody>
<tr>
<td>1.</td>
<td>Sunway TaihuLight (China)</td>
<td>China</td>
<td>93,015</td>
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<tr>
<td>2.</td>
<td>MilkyWay-2 (China)</td>
<td>China</td>
<td>33,863</td>
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<td>3.</td>
<td>Piz Daint – CSCS (Switzerland)</td>
<td>Switzerland</td>
<td>19,600</td>
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<tr>
<td>4.</td>
<td>Titan (Oak Ridge)</td>
<td>Oak Ridge</td>
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<td>5.</td>
<td>Sequoia (Livermore)</td>
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<td>6.</td>
<td>Cori (LBL)</td>
<td>Lawrence Berkeley</td>
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<td>7.</td>
<td>Oakforest – JCAHPC (Japan)</td>
<td>Japan</td>
<td>13,555</td>
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<td>8.</td>
<td>K Computer – Riken (Japan)</td>
<td>Japan</td>
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<td>9.</td>
<td>Mira (Argonne)</td>
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<td>8,587</td>
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<tr>
<td>10.</td>
<td>Trinity (Las Alamos)</td>
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<td>8,101</td>
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</table>
R&D Projects: HPC for Manufacturing

• Program teams manufacturers with DOE’s network of National Labs
• Applying High Performance Computing to face critical manufacturing challenges
Benefits of HPC to US Manufacturers

- Science-based innovation
- Lower energy costs and dependence
- Reduce testing cycles
- Reduce waste/reduce rejected parts
- Quality processes and pre-qualify processes
- Optimize design - Shorten the time to market
- New IT enabled process technologies

National Labs

- Lawrence Livermore (Coordination Lead)
- Oak Ridge
- Lawrence Berkeley
- Argonne (new – Round 3)
- LANL, PNNL, NREL (new – Round 4)
High Performance Computing for Manufacturing

Apply modeling and simulation capabilities to manufacturing challenges

- Industry defined challenges
- Businesses Partner with National labs
- Business-friendly terms and streamlined partnering process

A computer simulation of the virtual blast furnace. *Image courtesy of Purdue University – Calumet.*
Creating new lightweight alloys

**Goal:** Predict the strength of lightweight aluminum-lithium alloys produced under different process conditions; could save millions of fuels costs if used in aircraft design

**Results to date:** Developed new dislocation mobility laws for Al-Li alloys; examining influence of different precipitate density; predicting yield strength for differing particle sizes

**Team:** LIFT with LLNL

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Dendritic Growth in AM Parts

**Goal:** Use HPC to multi-scale morphology of solidification microstructure of Nickel base 718

**Results to date:** Predicting crystal growth over large domains from multi-component alloys using the Caliphad approach; moving to new alloy systems

**Team:** UTRC with ORNL/LLNL
HPC has been used to design better processes in a variety of industries

**Paper Towel Manufacturing**

**Goal:** Use HPC to evaluate different microfiber configurations to optimize drying time while maintaining user experience

**Results to date:** New mesh tool reduces product design cycle by 2X cycle; additional cores by another 8X; largest non benchmark run of Paradyn code at LLNL

**Team:** Proctor and Gamble with LLNL

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**Reducing Coke Usage in Steel**

**Goal:** Use models of complex reacting flows HPC to optimize blast furnace processes to reduce carbon loads and coke usage; savings up to $80M/yr if successful

**Results to date:** 1000X improvement in computational speed of parametric studies to examine factors such as CO2 enrichment, wind rate. Scaling code up to 2000 cores

**Team:** Purdue Calumet with LLNL
HPC4Mfg Program: Advancing Innovation

Framework:
• Business-friendly terms and streamlined partnering process
• Leverage decades of investment in platforms, codes, and expertise
• Emphasis on open sharing of successes benefits entire sector

U.S. Manufacturers, Industry Partners, and Consortia
• Identify industry challenge
• Industry partners contribute 20% “in kind” funding
• Share success

National laboratories provide
• HPC capabilities and modeling/simulation expertise
• Assistance to industry to develop full proposal
• Develop standard CRADA to protect industry IP
• DOE funding < $300K
• Application opportunity every 6 months
• More information at www.hpc4mfg.org
Applied R&D for Materials Genome Initiative (MGI)

Coordinated resource network with a suite of capabilities for advanced materials R&D

Materials Design & Synthesis  Functional Design  Process Scale-Up & Qualification

New Material Innovations for Clean Energy 2X Faster and 2X Cheaper
Focus on Real-Time For Energy Management

Institute Goals

- >50% improvement in energy productivity
- >50% reduction in installation cost of Smart Manufacturing hardware and software
- 15% Improvement in Energy Efficiency at systems level
- Increase productivity and competitiveness across all manufacturing sectors
What does Success Look Like?

Energy Products
Invented Here...

...And Competitively
Made Here!
Thank You

Questions?