Creating an ecosystem to support US manufacturing adoption of High Performance Computing

IDC HPC User Forum 2016

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US Manufacturing has been slow to adopt technology

Industries need to leverage modern technology to survive
HPC has been shown to have a positive impact on innovation in manufacturing.
The Advanced Manufacturing Office’s HPC4Mfg Program partners the national labs and the manufacturing industry

Increase energy efficiency and advanced clean energy technology

- LLNL leads the program, with LBNL and ORNL partnership
- Phase 1 projects: HPC impact demonstration
  - AMO funds < $300K to laboratories; industry 20% in-kind
  - Project duration < one year
- Phase 2 projects: HPC adoption
  - Some mix of industry, consortium, government funding
  - Project duration: multiple year
- Streamlined private-public partnership execution
- Share what is learned
- Build HPC Manufacturing community

Lower the barrier of entry to HPC
Energy Intensive Example: Paper Manufacturing
Reducing energy in paper-making could save 80 trillion BTUs per year

- Industry partner: Agenda 2020—paper-manufacturing consortium

- Rewetting of paper pulp after pressing: widely considered leading contributor—3rd largest—to energy intensity of paper making

- LLNL and LBNL developing coupled-physics simulations
  - Determine how water flows through porous paper pulp during, after pressing process
  - The two approaches are continuum and pore-based models

- New press designs could reduce energy consumption by up to 20% (80 trillion BTU, in $240M—400M annually)
Initial modeling results show deformation and dryness of paper as it traverses rollers in continuum model. Zoomed in mesh (deformed) shows deformed paper/felt in the press nip. Models of deformation and dryness of compressed paper/felt can be used to optimize drying.
Energy Intensive Example: Steel Manufacturing
Reducing coke usage in steel-making could save $80 million per year

- Industry partner: Purdue Calumet (steel-manufacturing consortium)

- Carbon – rich natural gas and coke used in large quantities in steel production

- Molten iron production optimization will reduce carbon loads to environment and process costs

- LLNL improves blast furnace models:
  - Runs complex reactive flow simulations through coke, iron ore particles
  - Simulations identify furnace conditions with reduced coke utilization

- Optimized blast furnace processes could save $80 million/year industry-wide by reducing coke consumption
1000X improvement in computational speed, parametric studies to reduce coke consumption

StarCCM models decrease computational time 1000X for ladle mixing showing pure molten steel on bottom and slag on top

Parametric studies of blast furnace will help reduce coke usage, especially in partial-capacity production runs
Example: Energy-efficient Lighting
Scaling up a new GaN process could yield 20% cheaper LED lighting and new power electronics

- Industry partner: SORAA

- Scale-up of GaN crystal growth technology could
  - Reduce production costs of highly efficient, high-brightness LED lighting by 20%
  - Enable development of next-generation power electronics for renewables

- LLNL is modeling chemistry of ammo-no-thermal crystal growth to assist process scale-up

- New high-fidelity model will save years of trial-and-error experimentation typically needed to facilitate large-scale commercial production
Models have been developed to determine the flow within the ammono-thermal reactor

- Recent higher-fidelity simulations show more complicated flow structure compared to previous work
- Result is improved predictions of local temperatures and flow velocities within reactor
- Now optimizing uniform growth of GaN with these new results
How HPC4mfg Operates
Projects awarded by 2-step peer-reviewed solicitation

Communication is key

- Seek out potential partners
- Broadcast solicitation to industry
- Link lab PI to submitter to co-develop proposal
- Feedback to all submitters

Technical Merit Review Committee

- Partner labs and AMO representatives
- Heavy focus on nation-wide impact to energy efficiency and clean energy technology industry-wide
- Diverse portfolio of projects

Industry feedback: “... assignment of PI for co-development of full proposals demystifies national lab engagement...”
The HPC4Mfg Program stood up quickly

March–September 2015
Launch program with seedling projects

- LLNL established the program
- $1.5M – 5 seedlings projects
- Industry outreach
  - Energy intensive focus
  - NIST AMTech Roadmap

September 2015–March 2016
Inaugural solicitation

- LBNL, ORNL join as partner labs
- $3M solicitation: 10 projects to 8 companies
  - 34% of submissions went to full proposals
  - 23% of submissions were selected for awards
The HPC4Mfg Program is now running at steady state

Status after 1 year
- Selected 5 seedlings
- Awarded $3M from inaugural solicitation
- Issued current $3M solicitation
- Established summer internships at labs
- Identified first Phase II project

Future
- Solicitation twice a year
- Industry Day
- Building community
  - Continued lab outreach to industry
  - Students, professors, industry interns
  - Other lab partners as program grows
Recent projects address diverse challenges

Process Optimization
• Energy reduction of industry spray drying technology
• Highly scalable multi-scale FEA simulation for efficient paper fiber structure
• Tailoring microstructure in laser powder bed fusion manufacturing process
• Numerical simulation of fiberglass drawing process
• Development of reduced glass furnace model to optimize process operation
• High-fidelity model of coupled flow and mechanical deformation of porous paper web
• Modeling the E-Iron nugget process
• The virtual blast furnace

Design Improvement
• Computation design and optimization of ultra-low power device architectures
• Massively parallel multi-physics multi-scale large eddy simulations of a fully integrated aircraft engine combustor and high-pressure vane
• Microstructural modeling and control in laser-powder bed additive manufacturing
• Study Fluid Behavior Inside an ammono-thermal gallium nitride reactor using CFD

New Computational Tools
• Materials engineering tools for optimizing strength of forged Al-Li turbine blades
• Integrated predictive tools for customizing microstructure and material properties of AM aerospace components
• Open-source tools for weld prediction
Challenges remain

- Target outreach to industries not yet at the table
- Ensure HPC becomes part of the fabric of manufacturing after the one-year project
- Build the ecosystem that supports HPC in manufacturing
  - Access to cycles
  - Access to talent
- Leverage infrastructure to other areas of Energy and other labs
Questions?

Additional information at HPC4Mfg.org

Questions can be sent to

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peg@llnl.gov

HPC4Mfg brings value to Industry

National laboratory experts in advanced modeling, simulation and data analysis collaborate with industrial partners on project teams to address manufacturing challenges that will aid in decision making, optimize processes and design, improve quality, predict performance and failure, quickly or eliminate testing, and/or shorten the time of adoption of new technologies.

Infusion of advanced computing expertise and technology into the manufacturing industry is aimed at advancing innovative new clean energy technologies and reducing energy and resource consumption to be competitive in the worldwide market. Successful projects will enable significant nation-wide impact to
HPC4Mfg infrastructure was designed for expansion

Other DOE offices are interested in leveraging the program for their missions

- Execute projects under current infrastructure or stand up “franchise” programs to support other offices
- Expand DOE partner labs

Leverage established infrastructure for savings and industry recognition

Execute within industry sector on behalf of DOE office mission

New methods of transportation, new fuels, tech explosion…

Systems integration: many smaller companies provide solution pieces
## Program metrics

<table>
<thead>
<tr>
<th>Project</th>
<th>Core hours (M)</th>
</tr>
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<tbody>
<tr>
<td>SORAA</td>
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<tr>
<td>PUC</td>
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<tr>
<td>Agenda 2020</td>
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<tr>
<td>Carbontec</td>
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<td>Eaton</td>
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<td>The Procter &amp; Gamble Company</td>
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<td>PUC Phase II</td>
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### Primary HPC Systems

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<thead>
<tr>
<th>Lab</th>
<th>System</th>
<th>Nodes</th>
<th>Cores</th>
<th>Description</th>
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<tbody>
<tr>
<td>LLNL</td>
<td>Vulcan</td>
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<td>IBM Blue Gene/Q; PPC A2</td>
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<td>Cab</td>
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<td>11,776</td>
<td>Cray XC30; Intel Xeon E5-2670</td>
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<tr>
<td>LBNL</td>
<td>Edison</td>
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<td>Cori 1</td>
<td>1,630</td>
<td>52,160</td>
<td>Cray XC; Intel Haswell</td>
</tr>
</tbody>
</table>

### Industry Distribution

- Aerospace
- Automotive
- Materials
- Metals
- Power/Utilities
- Metrology
- Chemicals
- Ceramics
- Defense
- Composites
- Consumer Goods
- Semiconductors

### Discipline Distribution

- CFD
- Chemical reaction
- Electrolysis
- Materials-solids
- Materials-micro
- Particle-interactions
- Statics
- Structural
- Thermo-fluid-structural
- Thermo-fluids

### Process Distribution

- AM
- Power/heat
- Annealing
- Heating
- Composite
- Stamp
- Laser cutting
- Forging
- Liquid separations
- Machine
- Materials
- Powder-spray
- Public, tool/center
- Sintering
- Welding
Agenda2020 Consortium: Models of deformation and dryness of compressed paper/felt can be used to optimize drying

• Rewetting of paper pulp following pressing is widely considered to be a leading contributor to the energy intensity of paper making (3rd largest).

• LLNL and LBNL researchers are developing coupled-physics models to simulate paper dewatering and rewet at the pressing section.

• New press designs could reduce energy consumption by up to 20% (80 trillion BTU, in $240M - $400M annually).