Institute for Advanced Architectures and Algorithms: Overview and Projects

Presented by

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Impediments to useful exascale computing

- Data Movement
  - Local
    - Cache architectures
    - Main memory architectures
  - Remote
    - Topology
    - Link BW
    - Messaging Rate
  - File I/O
    - Network Architectures
    - Parallel File Systems
    - Latency and Bandwidth
- Power Consumption
  - Do Nothing: 100 to 140 MW
- Scalability
  - 10,000,000 nodes
  - 1,000,000,000 cores
  - 10,000,000,000 threads
- Resilience
  - Perhaps a harder problem than all the others
  - Do Nothing: an MTBI of 10's of minutes
- Programming Environment
  - Data movement will drive new paradigms

IAA strategy

- Focused R&D on key impediments to high performance in partnership with industry and academia
- Foster the integrated co-design of architectures and algorithms to enable more efficient and timely solutions to mission critical problems
- Partner with other agencies (e.g., DARPA, NSA …) to leverage our R&D and broaden our impact
- Impact vendor roadmaps by committing National Lab staff and funding
- Train future generations of computer engineers, computer scientists, and computational scientists, thus enhancing American competitiveness

Industry support

"We fully support the IAA as we believe it is truly critical to do joint research and develop key leading-edge technologies in order to optimize ultra-scale systems to advance the mission of the Department of Energy and U.S. leadership in supercomputing. Having the IAA jointly run by Sandia and ORNL will ensure that future peta and exascale systems will be viable across the wide breadth of applications in NNSA and the Office of Science. We are looking forward to working with the Institute leveraging this R&D into our future products, just as we have successfully done with the NNSA's Red Storm program which enabled a new line of Cray Supercomputers (the XT) and enabling it for the Leadership Computing program at the Office of Science." **— Pete Ungaro, President and CEO, Cray Inc.**

"The USDOE has long invested in R&D for High Performance Computing and in systems that build on that R&D. With the creation of the IAA, the USDOE has the opportunity to explore, foster, and sponsor needed advances in hardware and software architectures that will serve companies like Intel well as we strive to maintain US intellectual and business leadership in computing and information." **— Pat Gelsinger, Senior Vice President, Intel**

"Micron Technology supports the efforts of the IAA. Micron recognizes that advanced memory and system architecture will be required to meet upcoming high-performance computing needs and further believes that such architectural solutions will find broad commercial application. Micron looks forward to continuing advanced memory and system architecture work with Sandia and Oak Ridge." **— Dean Klein, VP of Memory System Development, Micron Technology**

"SGI and the entire industry recognize the innovation and leadership Sandia National Laboratories and Oak Ridge National Laboratory have provided to the HPC industry in computation, storage and visualization. We are very pleased to support the proposal for an Institute for Advanced Architectures and Algorithms and believe that it will be a benefit to both the industry and the nation." **— Bo Ewald, CEO, SGI**

"Given the massive changes underway in the development of computer systems, IBM is pleased that DOE has identified several key areas of concern and launched the IAA. The initial focus areas agree with the challenges we see and we believe there is value in having participation from industry to complement the expertise present in the DOE labs and academia." **— David Turek, Vice-President, IBM**

Uniqueness

- Partnerships with industry, as opposed to contract management
- Cuts across DOE and other government agencies and laboratories
- A focus on impacting commercial product lines
  - National competitiveness
  - Impact on a broad spectrum of platform acquisitions
- A focus on problems of interest to DOE
  - National security
  - Science
- Sandia and Oak Ridge have unique capabilities across a broad and deep range of disciplines
  - Computer architectures
  - System software
  - Application performance modeling
  - System performance modeling and simulation

Execution plan

- Project planning
  - Joint SNL/ORNL meetings
- Workshops*
  - Work with industry and academia to define and prioritize thrust areas
- Call for Initial Project proposals
  - Interconnects
  - Memory subsystems
  - Algorithms
- IAA Algoritms project funded

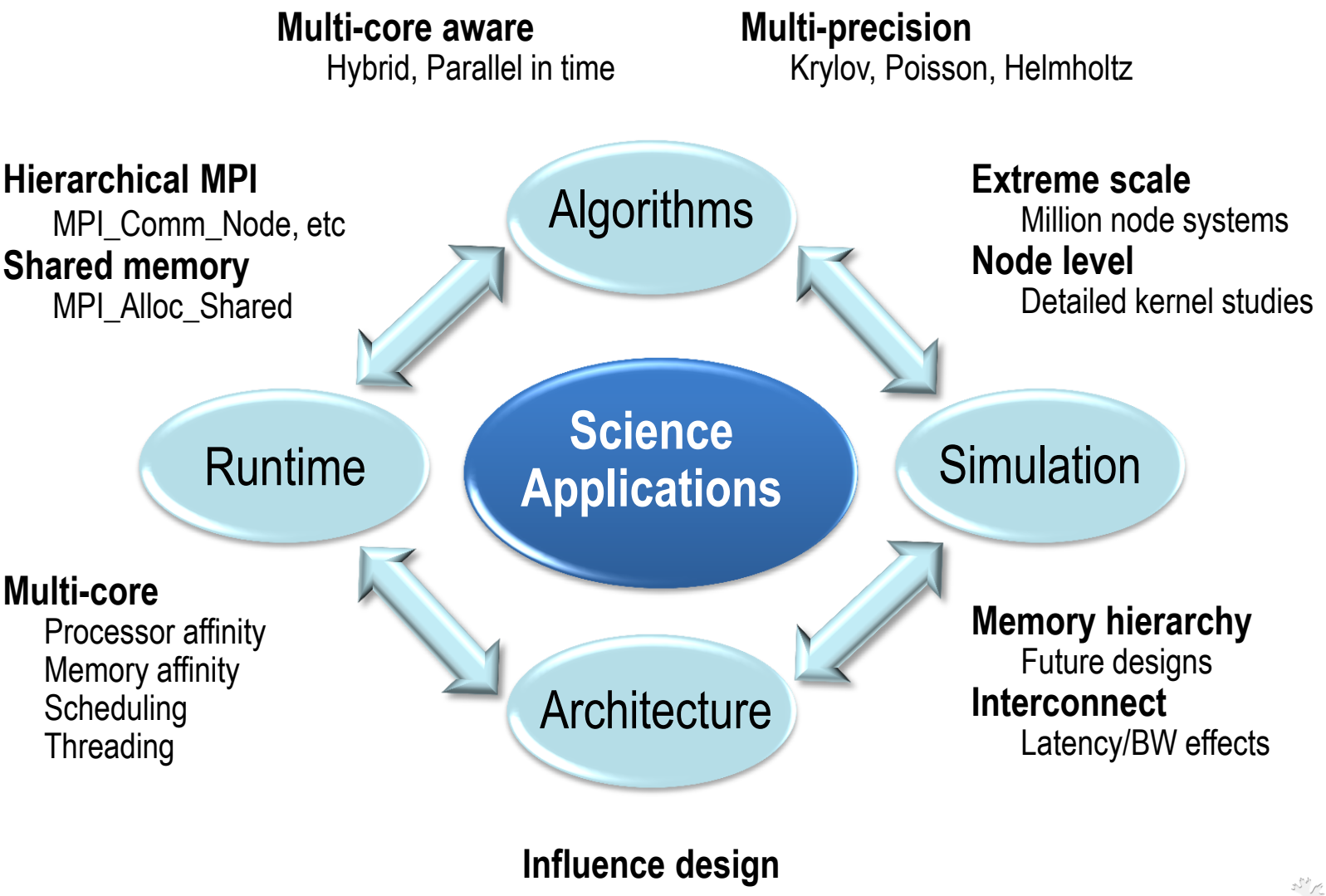
Potential thrust areas

* High-speed interconnects
* Memory subsystems
- Power
- Processor microarchitecture
- RAS/Resiliency
- System Software
- Scalable I/O
* Hierarchical algorithms
* System simulators
- Application performance modeling
- Programming models
- Tools

Algorithms project goals

- The Algorithms project goal is closing the "application-architecture performance gap" by developing:
  - Architecture-aware algorithms and runtime that will enable many science applications to better exploit the architectural features of DOE's petascale systems. Near-term high impact on science
  - Simulation to identify existing and future application-architecture performance bottlenecks. Disseminate this information to apps teams and vendors to influence future designs. Longer-term impact on supercomputer design

Algorithms project overview:
It all revolves around the science



Algorithms project team: Mix of math, computer science, and application experts

Project team includes key application developers

Climate (HOMME)

SNL
- Mike Heroux
- **Mark Taylor**
- Chris Baker

ORNL
- George Fann
- Jun Jia
- Kate Evans

Materials and Chemistry (MADNESS)

ORNL
- George Fann
- Judith Hill
- **Robert Harrison**

SNL
- Mike Heroux
- Curt Janssen

Semiconductor device physics (Charon)

ORNL
- George Fann
- John Turner

SNL
- Mike Heroux
- John Shadid
- **Paul Lin**

Excellent cross site teaming

Runtime and Affinity

SNL
- Ron Brightwell
- Kevin Pedretti
- Brian Barrett

ORNL
- Al Geist
- Geoffroy Vallee
- Gregg Koenig

Simulation

SNL
- Arun Roddrigues
- Scott Hemmert

ORNL
- Christian Engelmann
- Phil Roth

U Minnesota
- Bob Numrich

U Maryland
- Bruce Jacobs

GaTech
- Sudhakar

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