EXECUTIVE ORDER

CREATING A NATIONAL STRATEGIC COMPUTING INITIATIVE

By the authority vested in me as President by the Constitution and the laws of the United States of America, and to maximize benefits of high-performance computing (HPC) research, development, and deployment, it is hereby ordered as follows:

The NSCI is a whole-of-government effort designed to create a cohesive, multi-agency strategic vision and Federal investment strategy, executed in collaboration with industry and academia, to maximize the benefits of HPC for the United States.

https://www.whitehouse.gov/sites/default/files/microsites/ostp/nsci_fact_sheet.pdf
NSCI Strategic Themes

• Create systems that can apply exaflops of computing power to exabytes of data.
• Keep the United States at the forefront of HPC capabilities
• Improve HPC application developer productivity.
• Make HPC readily available.
• Establish hardware technology for future HPC systems
Mission: Extreme Scale Science
Next Generation of Scientific Innovation

• DOE's mission is to push the frontiers of science and technology to:
  – Enable scientific discovery
  – Provide state-of-the-art scientific tools
  – Plan, implement, and operate user facilities

• The next generation of advancements will require Extreme Scale Computing
  – 100X capabilities of today's computers with a similar size and power footprint

• Extreme Scale Computing, however, cannot be achieved by a “business-as-usual” evolutionary approach

• Extreme Scale Computing will require major novel advances in computing technology – Exascale Computing

Exascale Computing Will Underpin Future Scientific Innovations
Exascale Applications Respond to DOE/NNSA Missions in Discovery, Design, and National Security

Scientific Discovery
- Mesoscale materials and chemical sciences
- Improved climate models with reduced uncertainty

Engineering Design
- Nuclear power reactors
- Advanced energy technologies
- Resilient power grid

National Security
- Stockpile stewardship
- Real-time cybersecurity and incident response
- Advanced manufacturing
Exascale Computing Initiative (ECI)
The Goals

• Initiate a new era of computing: exascale computers
  – Foster new generation of scientific, engineering, and large-data applications
  – Enable computing platforms with 100 times more computational power than today’s systems, within a similar size, cost, and power footprint
  – Must overcome challenges: parallelism, memory, resiliency and energy efficiency
  – Set the US on a new trajectory of progress – towards a broad spectrum of computing capabilities over the succeeding decade

• Create dramatically more productive systems
  – Usable by a wide variety of scientists and engineers for more problem areas

• Deploy two architecturally different systems in 2023
• Develop marketable technologies
• Prepare for “10 Year Exascale Era”
ECI Strategy

- SC & NNSA Partnership
- Develop next generation of applications
- Exploit co-design process, driven by the full application workflow
- Develop exascale software stacks
- **Partner with and fund vendors to transition research to product space**
- Integrate applications, acquisitions, and research and development
- Collaborate with other government agencies and other countries, as advantageous
Exploit Co-Design Process

Exascale Co-Design Center for Materials in Extreme Environments (ExMatEx)
  – Director: Timothy Germann (LANL)
  – http://www.exmatex.org

Center for Exascale Simulation of Advanced Reactors (CESAR)
  – Director: Andrew Siegel (ANL)
  – https://cesar.mcs.anl.gov

Center for Exascale Simulation of Combustion in Turbulence (ExaCT)
  – Director: Jacqueline Chen (SNL)
  – http://exactcodesign.org
Current partnerships with vendors
Fast and Design Forward Programs

Fast Forward Program — *node technologies*

- Jointly funded by SC & NNSA
- **Phase 1:** Two year contracts, started July 1, 2012, **Phase 2:** Two year contracts, starting Fall 2014: IBM, Cray, AMD, NVIDIA, Intel ($64M / $100M)

**Project Goals & Objectives**

- Initiate partnerships with multiple companies to accelerate the R&D of critical node technologies and designs needed for extreme-scale computing.
- Fund technologies targeted for productization in the 5–10 year timeframe.

Design Forward Program — *system technologies*

- Jointly funded by SC & NNSA
- **Phase 1:** Two year contracts, started Fall 2013, **Phase 2:** Two year contracts, starting Winter 2015: Cray, AMD, IBM, Intel ($23M / $10M)

**Project Goals & Objectives**

- Initiate partnerships with multiple companies to accelerate the R&D of interconnect architectures and conceptual designs for future extreme-scale computers.
- Fund technologies targeted for productization in the 5–10 year timeframe.
EXASCALE NODE ARCHITECTURE*
INTEGRATED PROCESSING AND MEMORY FOR PERFORMANCE AND EFFICIENCY

*CONCEPT ONLY: NOT AN ACTUAL DESIGN

Optical Link for Power Efficient Communication
Non-volatile Memory for High Memory Capacity
Heterogeneous Processor for Reliable, Power-Efficient Computing
Processing-in-Memory for Reduced Data Movement
Stacked Memory for High Memory Bandwidth

Public Information – EAR99
Intel Straw-man Processor Architecture

Control Function
- I$  RF
- D$  GP
- SP  Int

System SW

Block: 8 XE + Control
- XE  XE  XE  XE
- XE  XE  XE  XE

Large shared SRAM

Execution (XE) Function
- I$  RF
- D$  DP FP
- SP  FMA

Application specific

Cluster (~16 X)

Interconnect

Large Shared SRAM

Processor Chip (Clusters)

Hierarchical & Scalable
Abstract Machine Model (AMM)

3D Stacked Memory (Low Capacity, High Bandwidth)

Thin Cores / Accelerators

Fat Core

Fat Core

Integrated NIC for Off-Chip Communication

Coherence Domain

DRAM

NVRAM

http://www.cal-design.org/publications
10 Levels of Memory Hierarchy

- Disk Pool
- NVM
- DDR
- IPM
- LL$
- LLS
- L2$
- L2S
- L1$
- L1S
- RF
- ALU

Chassis w/ large DDR+NVM per Exa-machine
Boards w/ limited DDR+NVM per Chassis
Sockets w/ IPM per Board
Dies w/ shared L1$/SPAD per socket
Blocks w/ shared L2 per die
Cores per block
Blocks per socket
Sockets per board
Chips per block
Die(s) per chip

(c) Intel, 2014
Summary

Leadership in high-performance computing (HPC) and large-scale data analysis will advance national competitiveness in a wide array of strategic sectors, including basic science, national security, energy technology, and economic prosperity.

The U.S. semiconductor and HPC industries have the ability to develop the necessary technologies for an exascale computing capability early in the next decade.

An integrated approach to the development of hardware, software, and applications is required for the development of exascale computers.

ECI’s goal is to deploy, by 2023, two capable exascale computing systems.
BACKUP
Technical Approaches

The Top Ten Exascale Challenges, with Technical Approaches

1. Energy efficiency
2. Interconnect technology
3. Memory Technology
4. Scalable System Software
5. Programming systems
6. Data management
7. Exascale Algorithms
8. Algorithms for discovery, design, and decision
9. Resilience and correctness
10. Scientific productivity
Exascale Math

- **Applied Math for Exascale:**
  - Analyze potential gaps in current thinking about applied mathematics for the exascale;
  - Identify new algorithmic approaches that address exascale challenges;
  - Identify mathematics to address new scientific questions accessible at exascale, especially through integration across applied mathematics sub-disciplines;
  - Identify a holistic, co-design approach for applied mathematics exascale research that more directly involves a dialogue with application scientists and computer scientists.