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

• Causing a data explosion – a natural component of exascale computing
  – Experimental facilities face exponentially burgeoning data caused by technology advances

• 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
# Mission: Extreme Scale Science

Data Explosion

<table>
<thead>
<tr>
<th>Genomics</th>
<th>Driven by exponential technology advances</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Volume increases to 10 PB in FY21</td>
<td>Data sources</td>
</tr>
<tr>
<td>High Energy Physics (Large Hadron Collider)</td>
<td>• Scientific Instruments</td>
</tr>
<tr>
<td>15 PB of data/year</td>
<td>• Scientific Computing Facilities</td>
</tr>
<tr>
<td>Light Sources</td>
<td>• Simulation Results</td>
</tr>
<tr>
<td>Approximately 300 TB/day</td>
<td>• Observational data</td>
</tr>
<tr>
<td>Climate</td>
<td>Big Data and Big Compute</td>
</tr>
</tbody>
</table>
| Data expected to be 100 EB | • Analyzing Big Data requires processing (e.g., search, transform, analyze, ...)
| | • Extreme scale computing will enable timely and more complex processing of increasingly large Big Data sets |

1 EB = 10^{18} bytes of storage
1 PB = 10^{15} bytes of storage
1 TB = 10^{12} bytes of storage

“Very few large scale applications of practical importance are NOT data intensive.” – Alok Choudhary, IESP, Kobe, Japan, April 2012
Exascale Challenges and Issues

• Four primary challenges must be overcome
  – Parallelism / concurrency
  – Reliability / resiliency
  – Energy efficiency
  – Memory / Storage

• Productivity issues
  – Managing system complexity
  – Portability / Generality

• System design issues
  – Scalability
  – Time to solution
  – Efficiency

• Extensive Exascale Studies
  – US(DOE, DARPA, ...), Europe, Japan, ...
## Key Performance Goals for an exascale computer (ECI)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance</td>
<td>Sustained 1 – 10 ExaOPS</td>
</tr>
<tr>
<td>Power</td>
<td>20 MW</td>
</tr>
<tr>
<td>Cabinets</td>
<td>200 - 300</td>
</tr>
<tr>
<td>System Memory</td>
<td>128 PB – 256 PB</td>
</tr>
<tr>
<td>Reliability</td>
<td>Consistent with current platforms</td>
</tr>
<tr>
<td>Productivity</td>
<td>Better than or consistent with current platforms</td>
</tr>
<tr>
<td><strong>Scalable benchmarks</strong></td>
<td>Target speedup over “current” systems</td>
</tr>
<tr>
<td><strong>Throughput benchmarks</strong></td>
<td>Target speedup over “current” systems</td>
</tr>
</tbody>
</table>

ExaOPS = \(10^{18}\) Operations / sec

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**Notes:**
- ExaOPS = \(10^{18}\) Operations / sec
- Big Data and Extreme-scale Computing (BDEC)
- 29 January 2015
Exascale Target System Characteristics

- 20 pJ per average operation
- Billion-way concurrency (current systems have Million-way)
- Ecosystem to support new application development and collaborative work, enable transparent portability, accommodate legacy applications
- High reliability and resilience through self-diagnostics and self-healing
- Programming environments (high-level languages, tools, ...) to increase scientific productivity
FY2011:

**Computer Science:** Execution Models  
**Computational Partnerships:** 3 Exascale Co-Design Centers Funded  
**Networking:** Terabit Networking for Extreme-Scale Science  
**Request for Information:** Critical and Platform Technologies

FY2012:

**Computer Science:** Programming Environments (X-Stack), Performance Modeling (BMS), HWArch, e.g. CAL  
**Applied Math:** Resilient Extreme-Scale Solvers (RX-Solvers)  
**Networking:** Scientific Collaborations at Extreme-Scale  
**FastForward:** Critical / Cross Cutting technologies (joint with NNSA)

FY2013:

**Exascale Strategy Plan to Congress**  
**Computer Science:** Operating System / Runtime (OS/R)  
**Applied Math:** Uncertainty Quantification  
**DesignForward:** Critical / Cross Cutting technologies (joint with NNSA)  
**FastForward:** Critical/Cross Cutting technologies (joint with NNSA)

FY2014:

**CORAL:** The joint Collaboration of Oak Ridge, Argonne, and Lawrence Livermore (CORAL)  
**Computer Science:** Scientific Data Management, Analysis and Visualization at Extreme Scale  
**Computer Science:** Software Productivity  
**Exploratory Research for Extreme-Scale Science (EXPRESS)**  
**Networking:** Analytical Modeling for Extreme-Scale Computing Environments  
**FastForward 2:** Critical/Cross Cutting technologies (joint with NNSA)  
**DesignForward 2:** Critical/Cross Cutting technologies (joint with NNSA)

FY2015:

**Preliminary Conceptual Design for an Exascale Computing Initiative:** Developed jointly with NNSA  
**Computer Science:** Resilience for Extreme-Scale Supercomputing Systems
Schedule Baseline

Exascale Co-Design: Driving the design of Exascale HW and SW

Fast Forward  Path Forward Phase

Design Forward  System Design Phase  System Build Phase

X-Stack & OS / R  Software Technology: Programming Environment, OS/Runtimes, Libraries


P0  Node Prototype  P1  Petascale Prototype  P2  Exascale Prototype  B1  Initial Exascale Delivery

Big Data and Extreme-scale Computing (BDEC)
29 January 2015
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.
Summary

- **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 FY-2023, two capable exascale computing systems.**
BACK-UP