Programming Models and Environments

Exascale Computing Initiative (ECI)

March 12, 2015

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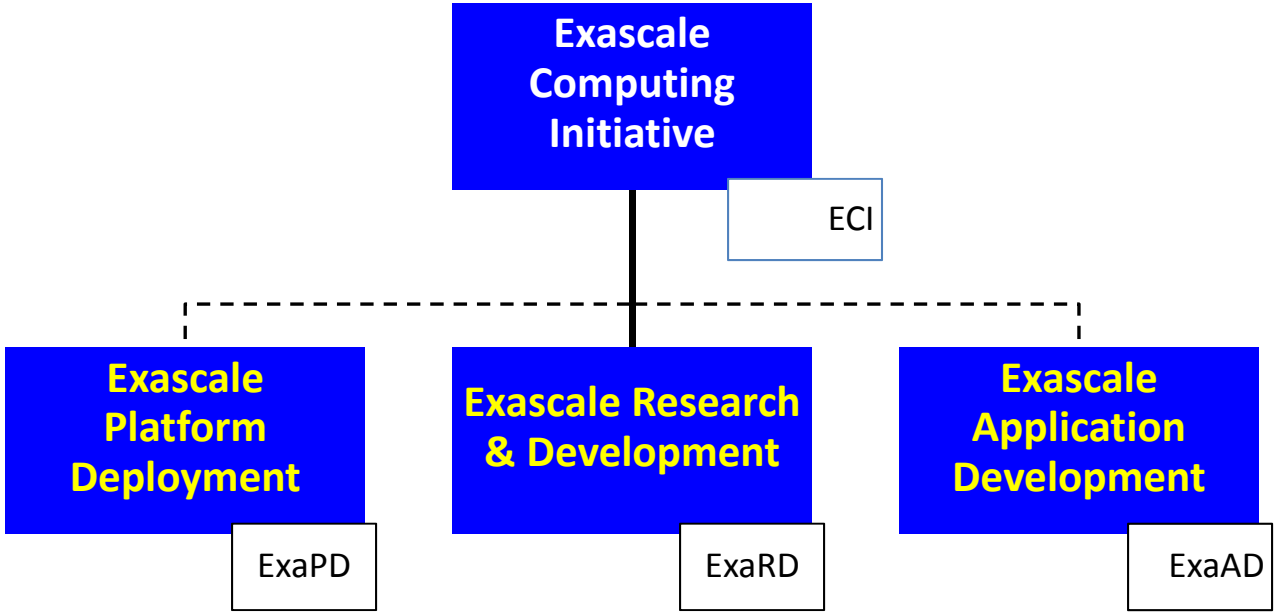
DOE Exascale Computing Initiative (ECI)

R&D Goals

- **Create dramatically more productive systems**
  - Usable by a wide variety of scientists and engineers for more problem areas
  - Simplifies efficiency and scalability for shorter time to solution and science result

Exascale Computing Initiative

High Level Program Structure



- Exascale technologies will offer new opportunities for pioneering scientific progress, and must be closely coordinated with exascale application development and acquisitions.
- Base funding for applications and acquisitions are provided by the appropriate DOE office.

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DOE Progress Towards Exascale

FY2011:

- MOU between the SC and NNSA for the Coordination of Exascale Activities
- Exascale Co-Design Centers Funded
- Request for Information: Critical and Platform Technologies

FY2012:

- Programming Environments (X-Stack)
- FastFoward: Vendor Critical / Cross Cutting technologies

FY2013:

- Exascale Strategy Plan to Congress
- Operating System / Runtime (OS/R)
- **Meeting with Secretary Moniz, "go get a solid plan with defendable cost"**

FY2014:

- Meetings with HPC vendors to validate ECI timeline, update on exascale plans and costs
- Established Nexus / Plexus lab structure – determine software plans and costs
- FastForward 2: Exascale Node designs
- DesignForward 2: Conceptual Designs of Exascale Systems
- External Review of "Exascale Preliminary Project Design Document (EPPDD)"

FY2015:

- **Release to ASCAC "Preliminary Conceptual Design for an Exascale Computing Initiative"**
- ***Generate requirements for exascale systems to be developed ECI and deployed in FY-2023***
- ***Complete next version of the ECI Project Plan***

FY2016:

- **Initiate the Exascale Computing Initiative (ECI)**
- ***Develop and release FOAs and RFPs, for funding in FY-2016***

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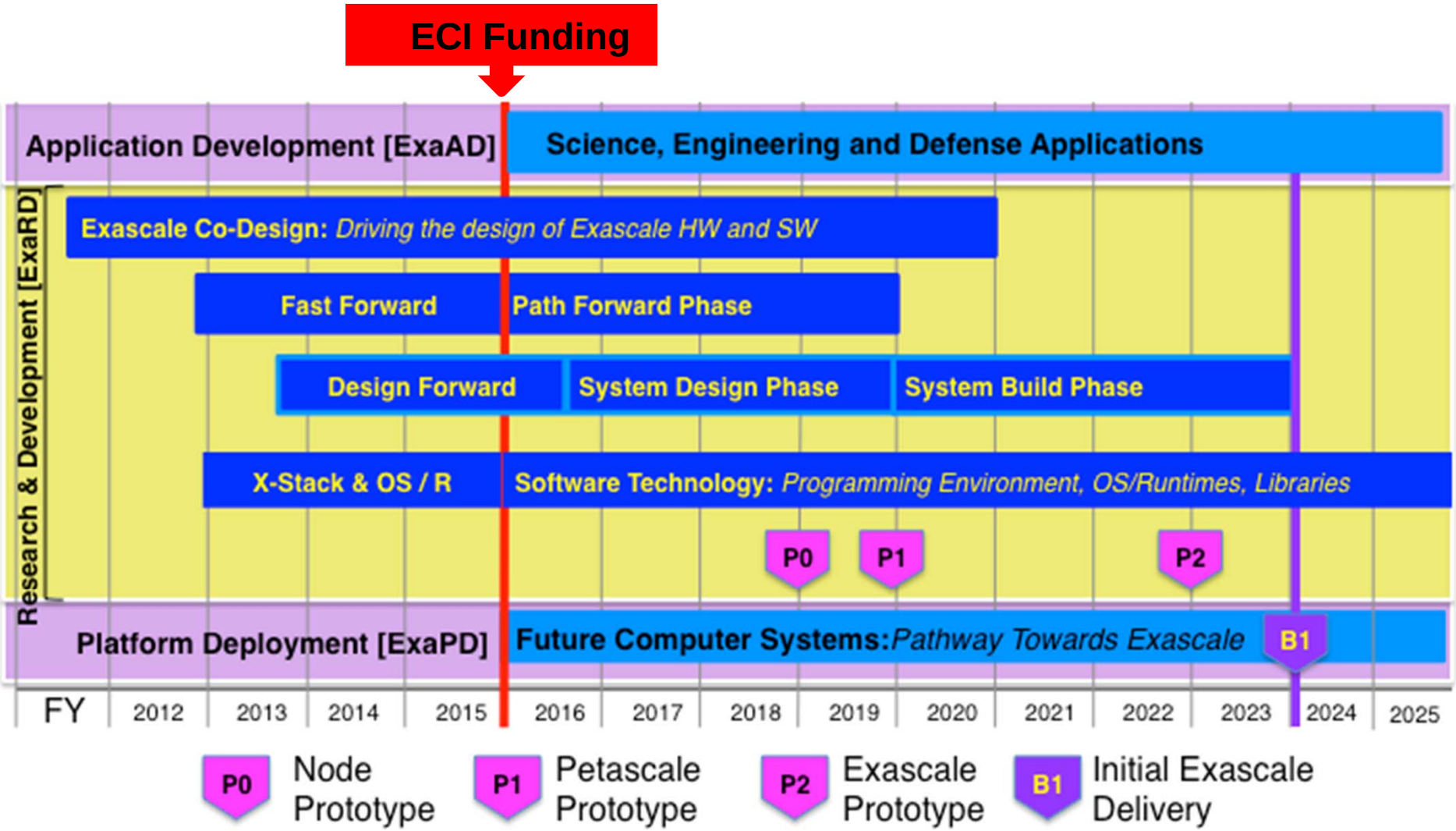
Exascale Challenges

- 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
  - Efficiency
  - Time to solution
  - Dependability (security and reliability) must be integrated at all levels of the design

ECI Project Schedule



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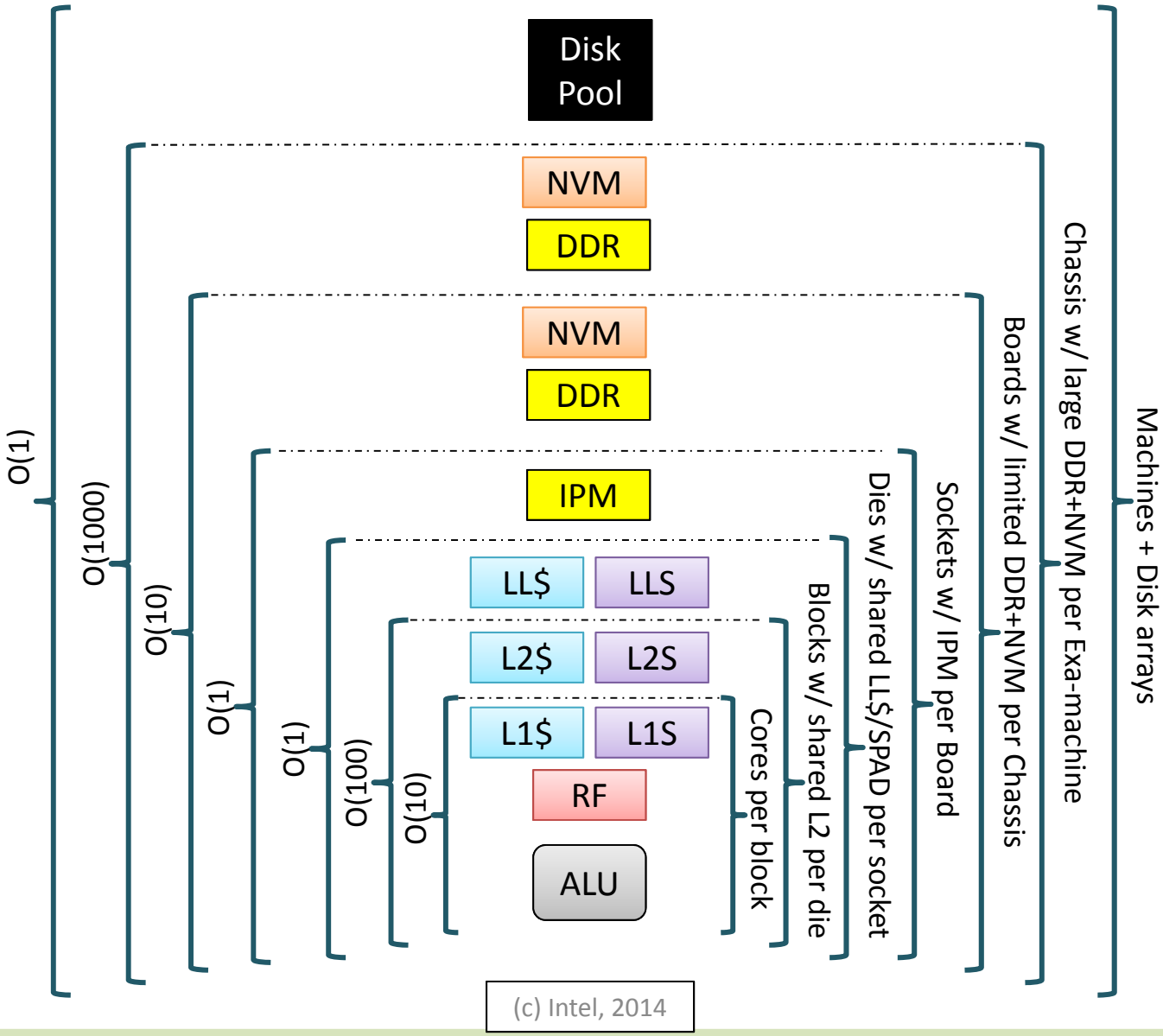
10 Levels of Memory Hierarchy



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ECI Project Scope

1 ExaAD -- Application Development

1.1 Integra
1.1.1 NNSA
1.1.2 Materi
1.1.3 Climat
1.1.4 *Code 3*
1.1.5 *Code 4*

2 ExaRD -- Research & Development

2.4 Software Technologies
2.4.1 Software Stack (SS)
2.4.2 Applied Math (AM)
2.4.3 Data Management (DM)
2.4.4 Data Analytics and Visualization (DV)
2.4.5 Collaborative Environments (CE)
2.4.6 Productivity (PR)
2.4.7 Performance Execution (PE)
2.5 Integrity Technologies
2.5.1 Cybersecurity (SR)
2.5.2 Resiliency (SR)
2.5.3 Program verification and validation (SS)

2.6.1 System Design
2.6.2 System Build
2.7 Transition to Production
2.7.1 System Engineering (SE)
2.8 Prototypes and Testbeds
2.8.1 Testbeds
2.8.2 Prototypes
2.9 Researcher Training
2.9.1 Outreach and Training

3 ExaPD -- Platform Development and Delivery

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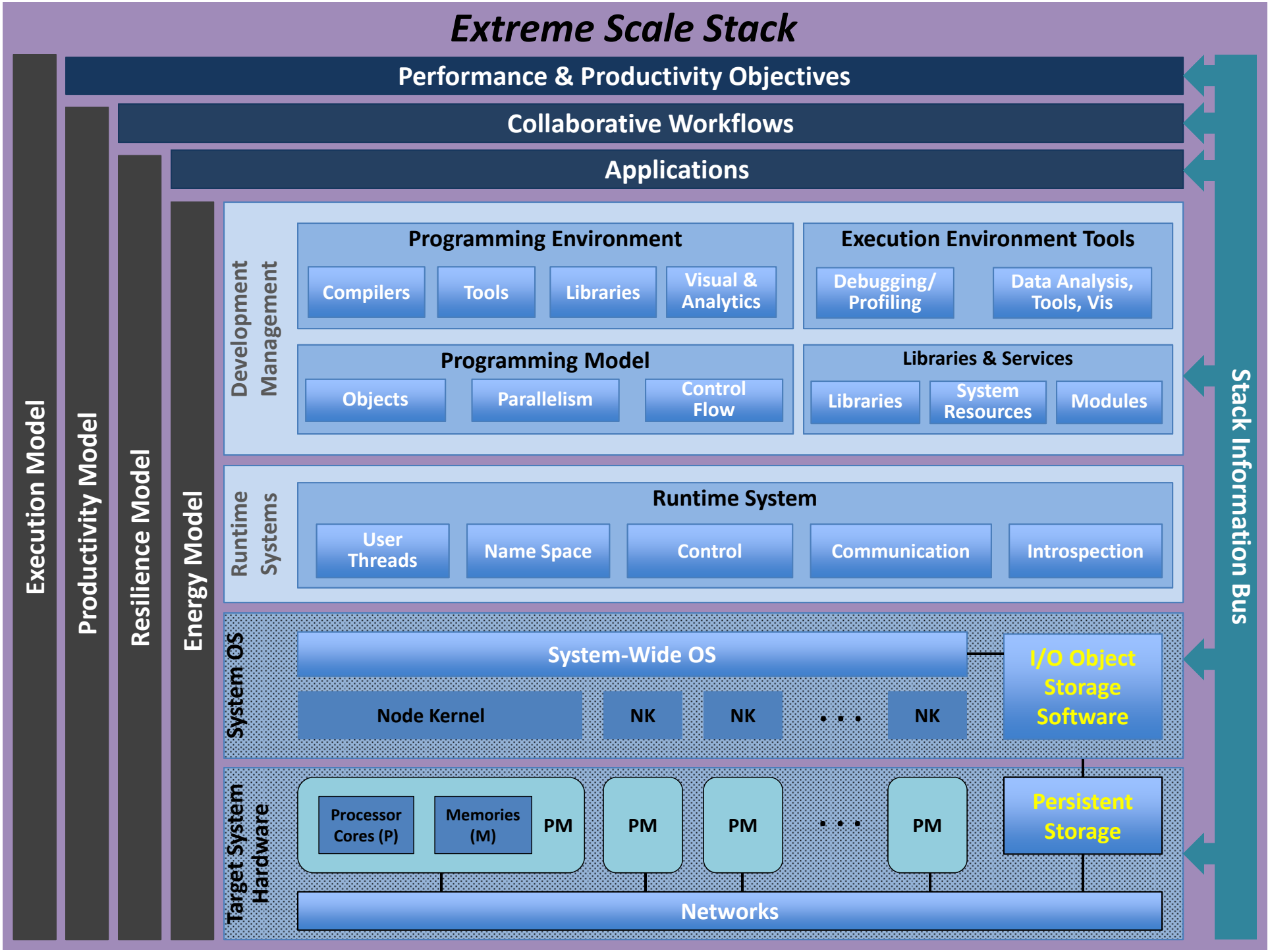
Extreme Scale Stack
Performance & Productivity Objectives
Collaborative Workflows
Applications
Execution Model
Productivity Model
Resilience Model
Energy Model
Development Management
Programming Environment
Compilers
Tools
Libraries
Visual & Analytics
Execution Environment Tools
Debugging/ Profiling
Data Analysis, Tools, Vis
Programming Model
Objects
Parallelism
Control Flow
Libraries & Services
Libraries
System Resources
Modules
Runtime Systems
Runtime System
User Threads
Name Space
Control
Communication
Introspection
System OS
System-Wide OS
Node Kernel
NK
NK
NK
I/O Object Storage Software
Target System Hardware
Processor Cores (P)
Memories (M)
PM
PM
PM
PM
Persistent Storage
Networks
Stack Information Bus

PM/E Vision

- The ECI PM/E vision will support a two-pronged approach with one short-term maintaining (and supporting) continuation of extended conventional practices. The second is one that is a "full break" with the past so as to maximize opportunity potentially available through full innovation (not yet proven).
  - We will refer to this as the extreme scale PM/E vision.
- An extreme scale PM/E vision needs to be grounded on applications requirements of relevance to DOE.
  - Performance
  - Parallelism
  - Execution Model
  - Performance portability
  - Invariants
  - Programmability

PM/E Workshop Objectives

1. Review the application requirements for ECI PM/E(s)
2. Propose, discuss, and determine the required characteristics or properties of future *programming models*
3. Identify the key capabilities and elements of future *programming environments*
4. Propose the methods for evaluating PM/E(s) research results
5. Determine the research questions that need to be addressed

Detailed Objectives and Driver Topics

1. **Workshop Drivers**
2. **Mission Drivers**
3. **Programming Model**
   - Discuss abstractions and their semantics
4. **Programming Environment**
   - Understand invariants of program characterization
   - Explore performance models and productivity models
   - Investigate debugging strategies for correctness and performance
   - Understand the needs for storage abstractions
   - Establish needs and means for application interoperability
5. **Software Stack**
   - Determine roles of programming models and programming environments within the system stack
   - Characterize nature and coupling of runtime system with programming model

Parallel Session Breakouts

- **Session I:** Application Requirements for Exascale PM/E(s)
- **Session II:** Methods for Evaluating PM/E(s)
- **Sessions III:** Characteristics of Programming Models and Environments
- **Session IV :** Characteristics of Programming Models and Environments
- **Session V**: Research Questions for Programming Models
- **Session VI:** Research Questions for Programming Environments

What's Next?

- Secure the proposed FY-2016 budget
  - **REP Funds -> ECI Funds**
- Prepare for the FY-2017 Budget request
- Complete a detailed ECI plan, with defendable budget
- Generate ECI requirements for FY16 FOAs & RFPs
  - research/development
  - applications
  - Facilities
- Prepare the FOAs and RFPs