High Performance Computing Systems

- Exascale Computing

Doug Shook

Exascale Computing

- How many flops?
- Why is this an important milestone?
- What challenges would you anticipate?

Challenges

- DOE has found 10 challenges to exascale computing
- What must we do to meet these challenges?
- When will these challenges be met?

- Lucas, et. Al, "Top Ten Exascale Research Challenges" 2014

#1 Energy Efficiency

- Current usage
  - Can we simply increase energy usage?
- What parts of the system are affected by energy efficiency?
- Evolutionary vs. revolutionary

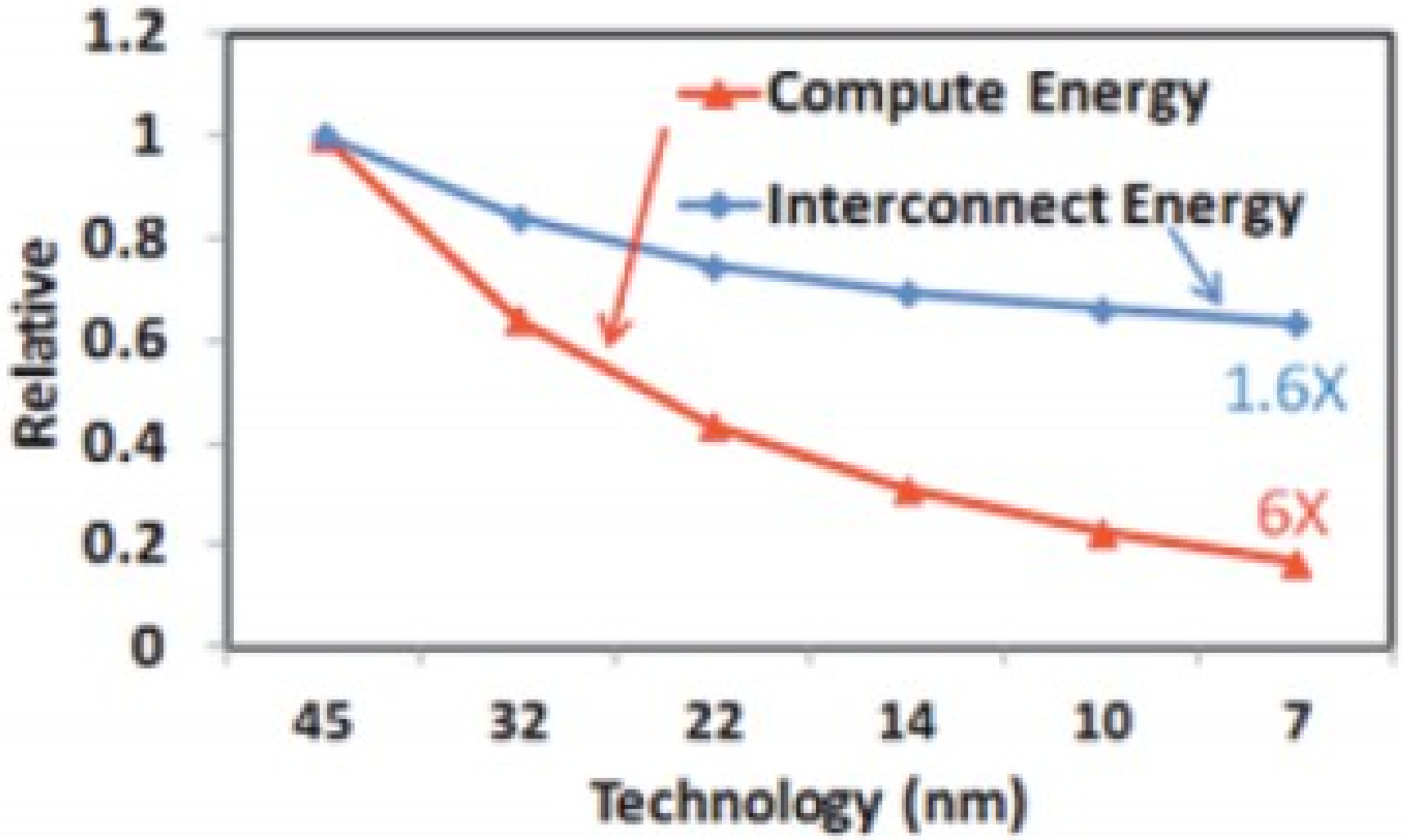
Near Threshold Voltage (NVT)

- What is the threshold voltage?
- Energy advantages of operating near threshold voltage
- Problems?

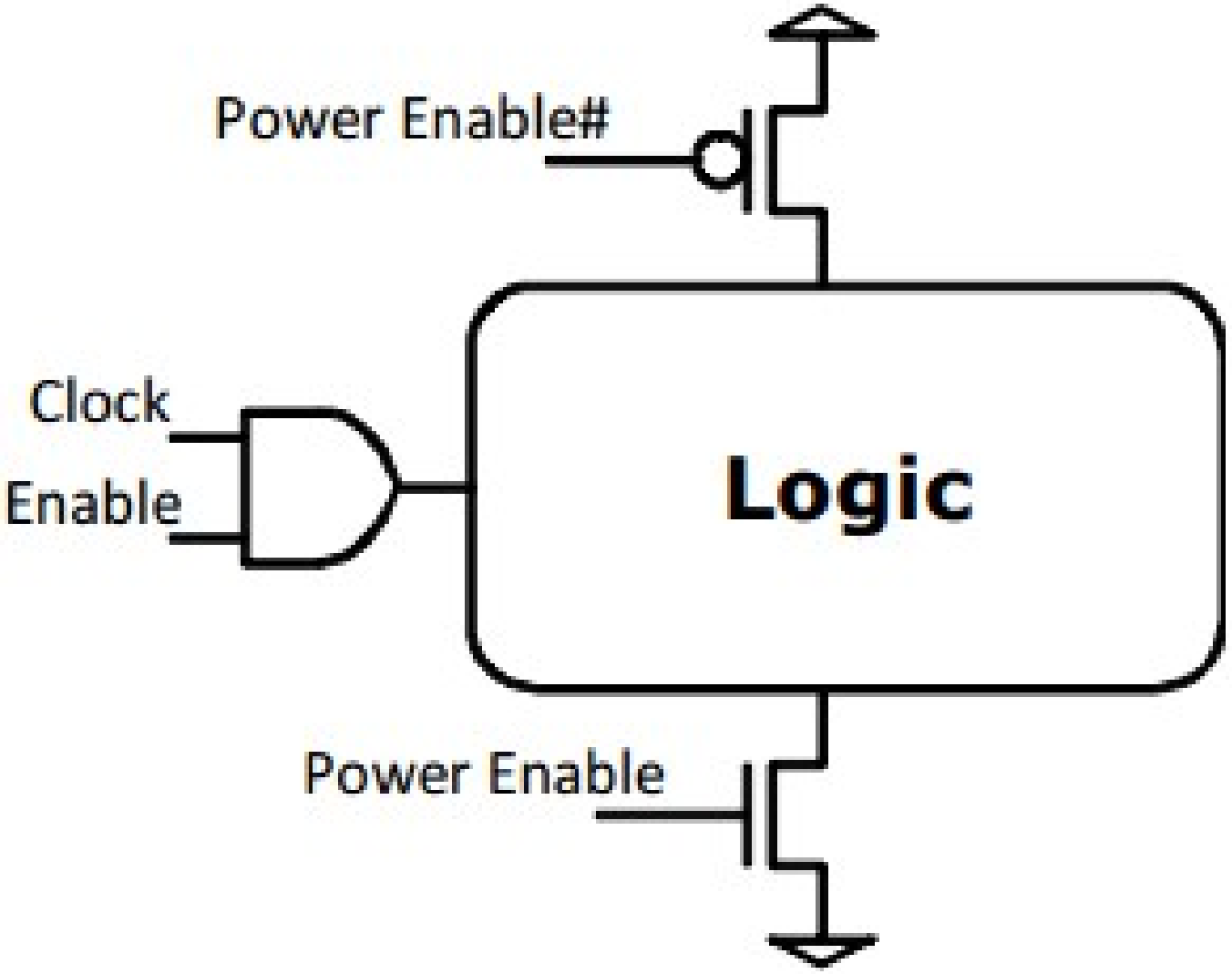
Energy Efficient Architecture

- How much energy does it take to perform 1 FP operation?

Energy Efficient Interconnects



On Chip Power Management

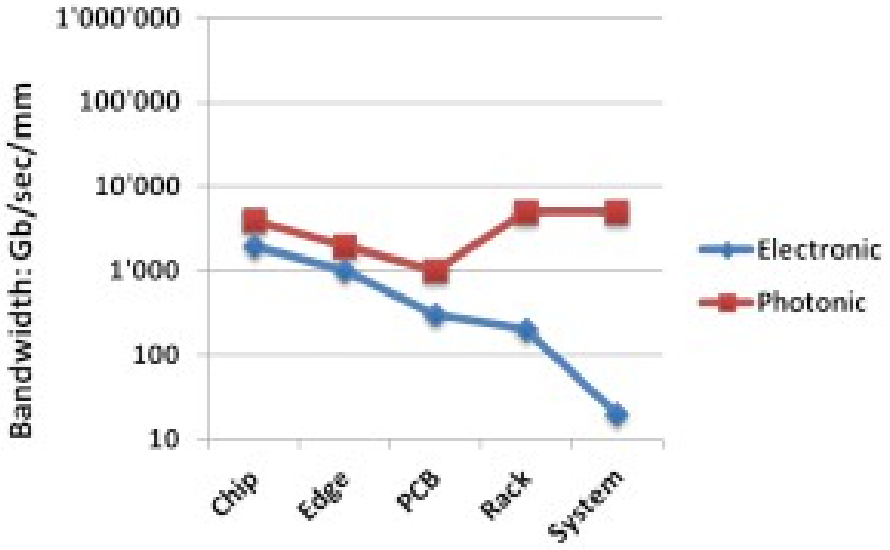


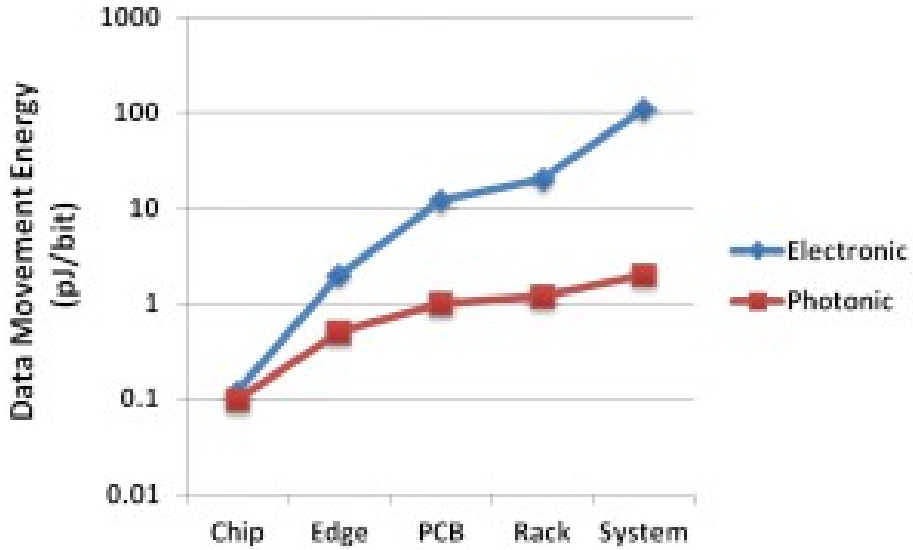
System Scale Power Management

- Power Distribution
- Cooling
- Packaging

#2 Interconnect Technology

- Data Movement Energy and Bandwidth



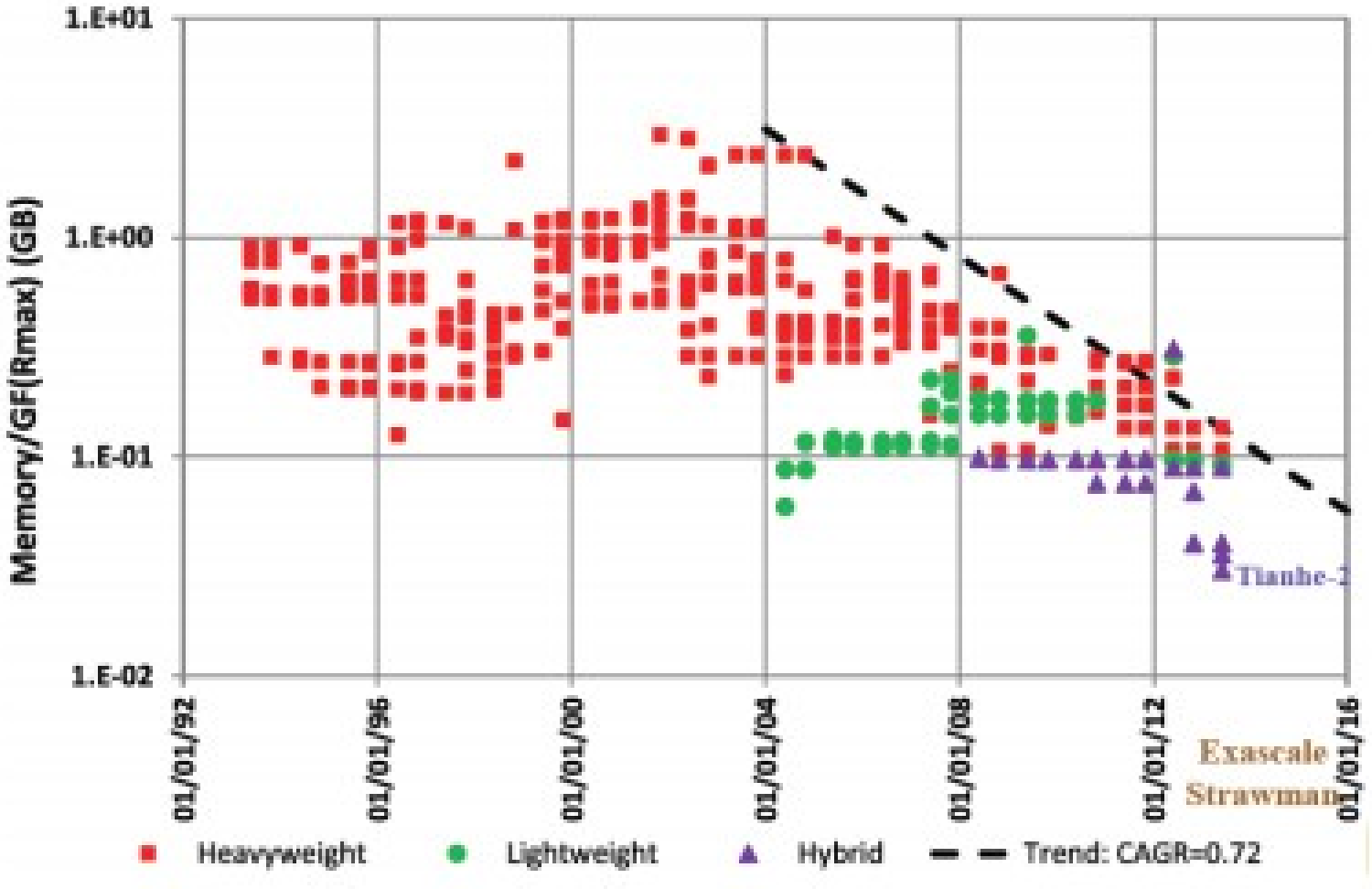


#2 Interconnect Technology

- On-die Interconnect Fabric
- Inter-chip Network Integration
- Photonics

#3 Memory Technology

- Memory Capacity



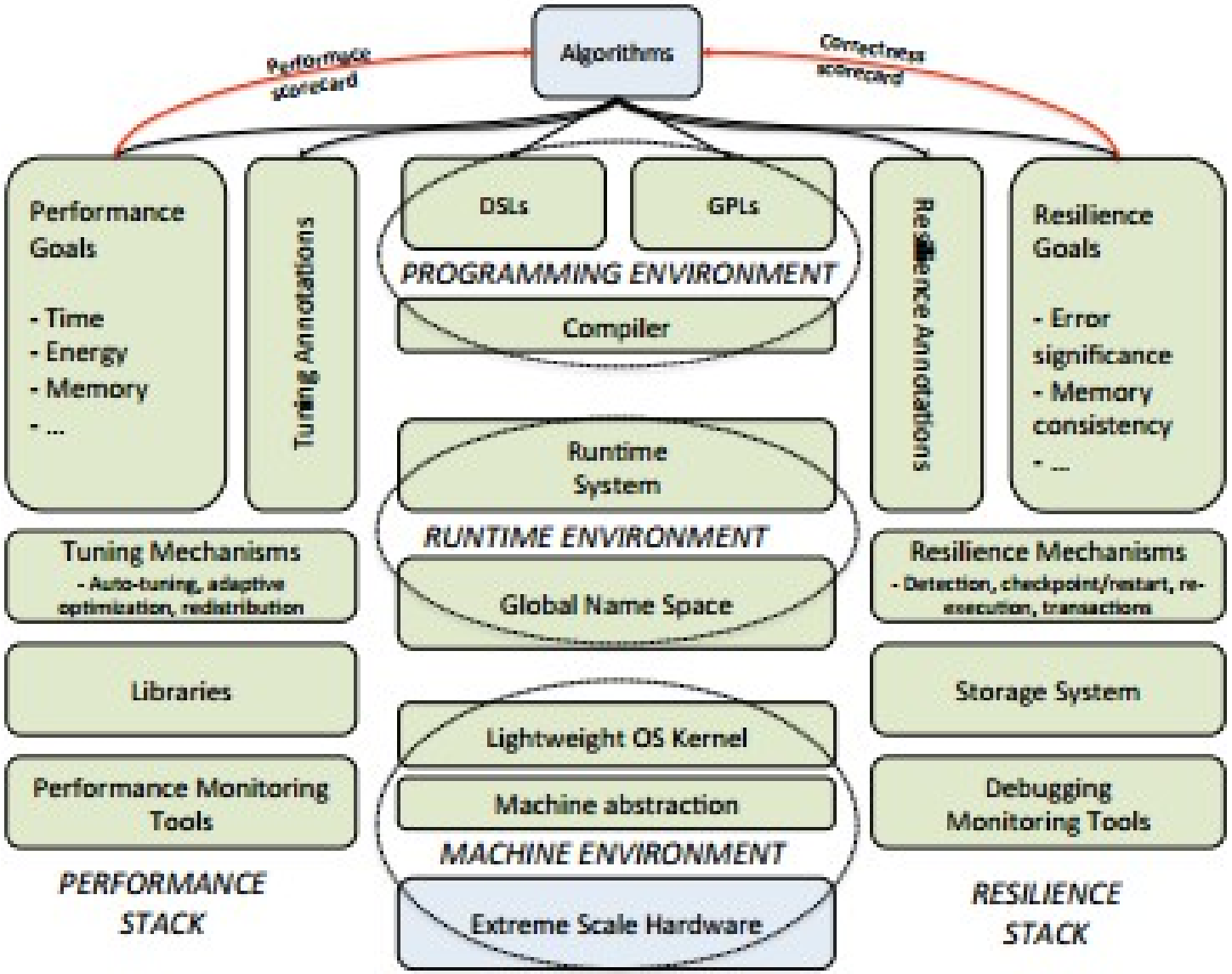
#3 Memory Technology

- Energy
- Scaling
- Resiliance

#4 Scalable System Software

- Research Directions
- Lightweight OS
- Runtime Systems
- Introspection
- Energy Management

#5 Programming Systems



#5 Programming Systems

- Programming Models
- Compilers

#6 Data Management

- Offensive vs. Defensive I/O
- General I/O Challenges
- Offensive I/O Challenges
- Defensive I/O Challenges

#7 Exascale Algorithms

- Multicore friendly vs. Multicore aware
- Communication Avoiding Algorithms
- Synchronization Reduction
- Multi-physics algorithms
- Multi-scale algorithms
- Energy Efficient Algorithms

#8 Algorithms for Discovery, Design, and Decision

- Uncertainty Quantification
- Optimization

#9 Resiliance and Correctness

- Hardware Support
- Programming Models
- Algorithmic based fault tolerance
- Correctness

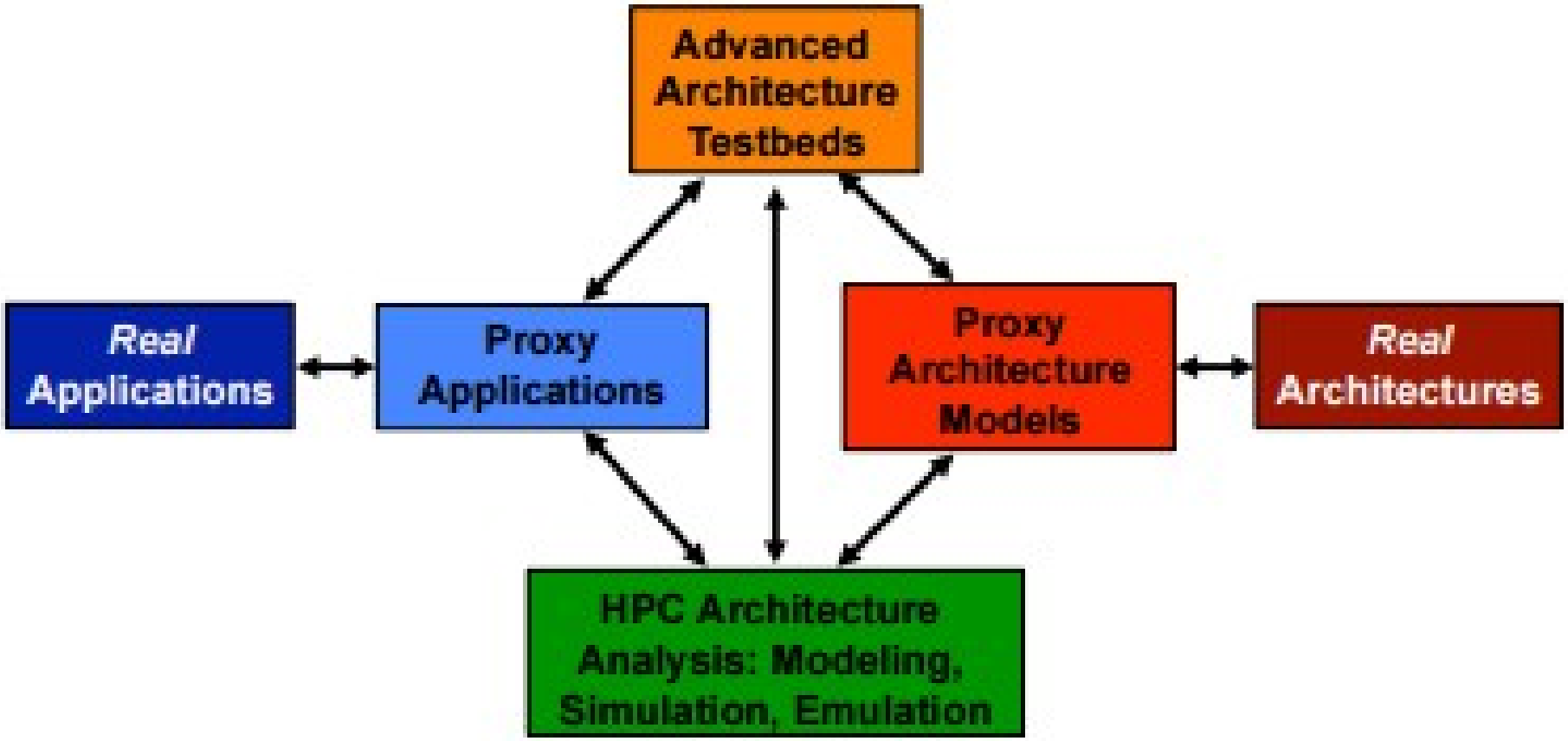
#10 Scientific Productivity

- Research Directions

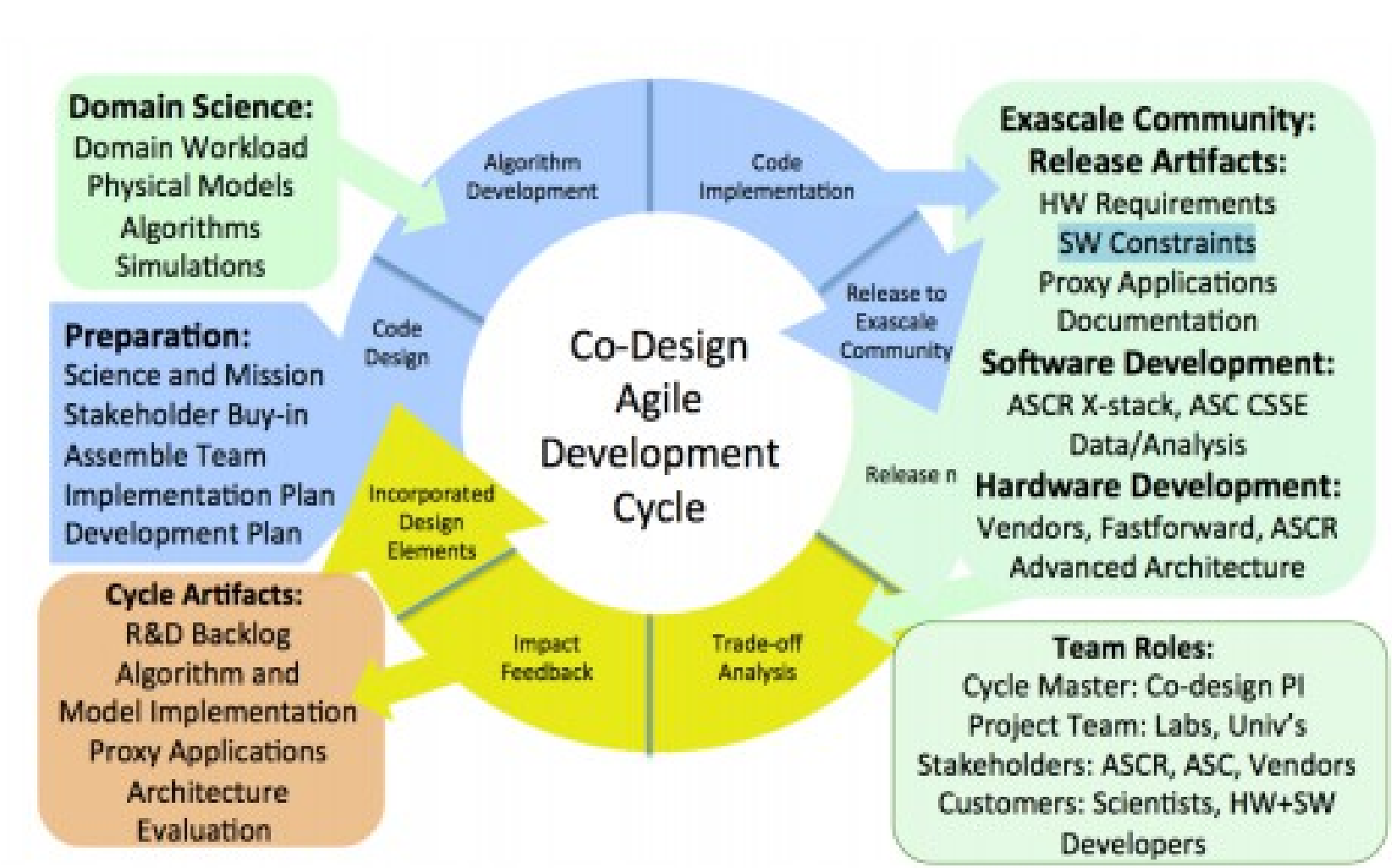
Co-Design and Integration Framework

- Execution Model
- Architecture
- Performance Metrics

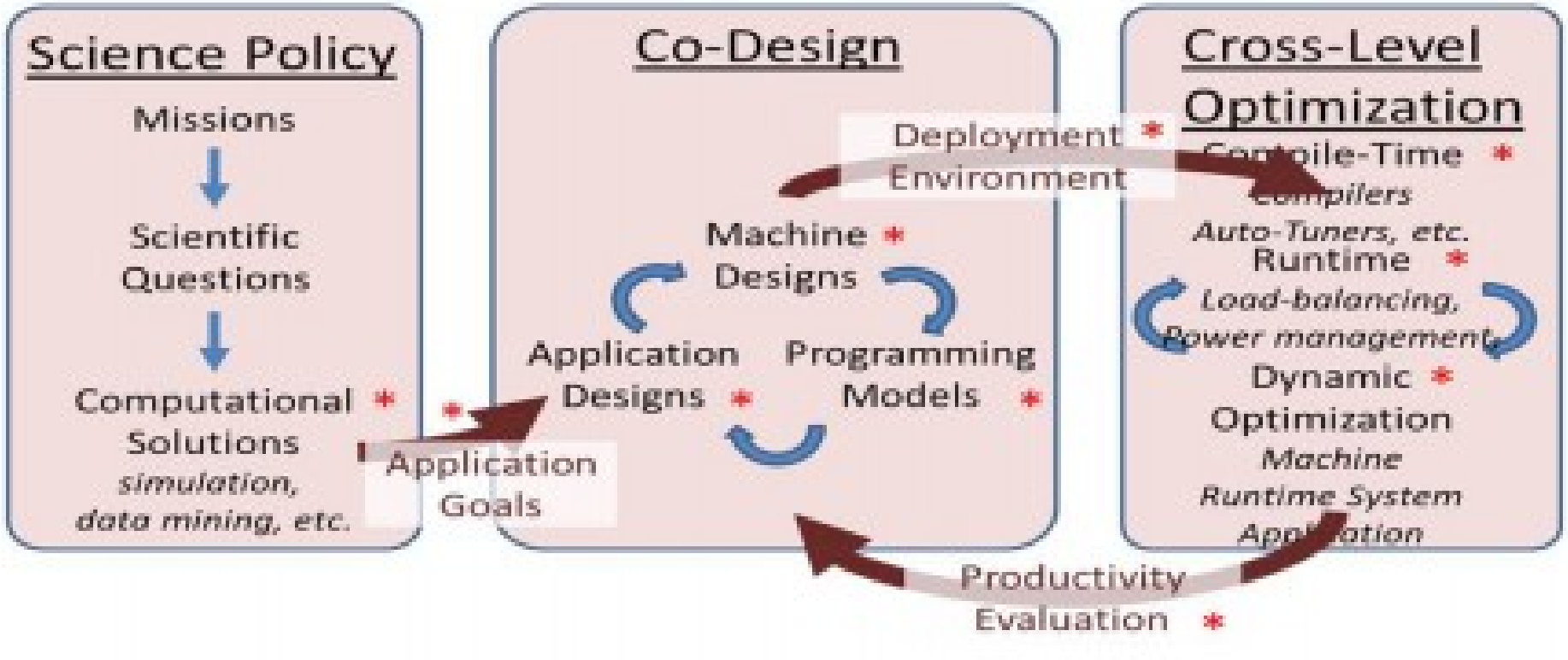
Integration Framework



Design Process



Modeling and Simulation



Recommendations

Current State

- Four countries currently have plans for exascale systems
  - Economic considerations?
  - Political considerations?

- Reed, Dongarra, "Exascale Computing and Big Data: The Next Frontier" 2015

Exascale Computing Project

- National Strategic Computing Initiative (2015)
  - Unite HPC and Big Data
  - Preserve US Dominance in HPC
  - Improve interoperability between supercomputers
  - Provide widespread access and training to researchers
  - Develop post-silicon technologies

- Messina, Lee, "The Exascale Computing Project" 2017

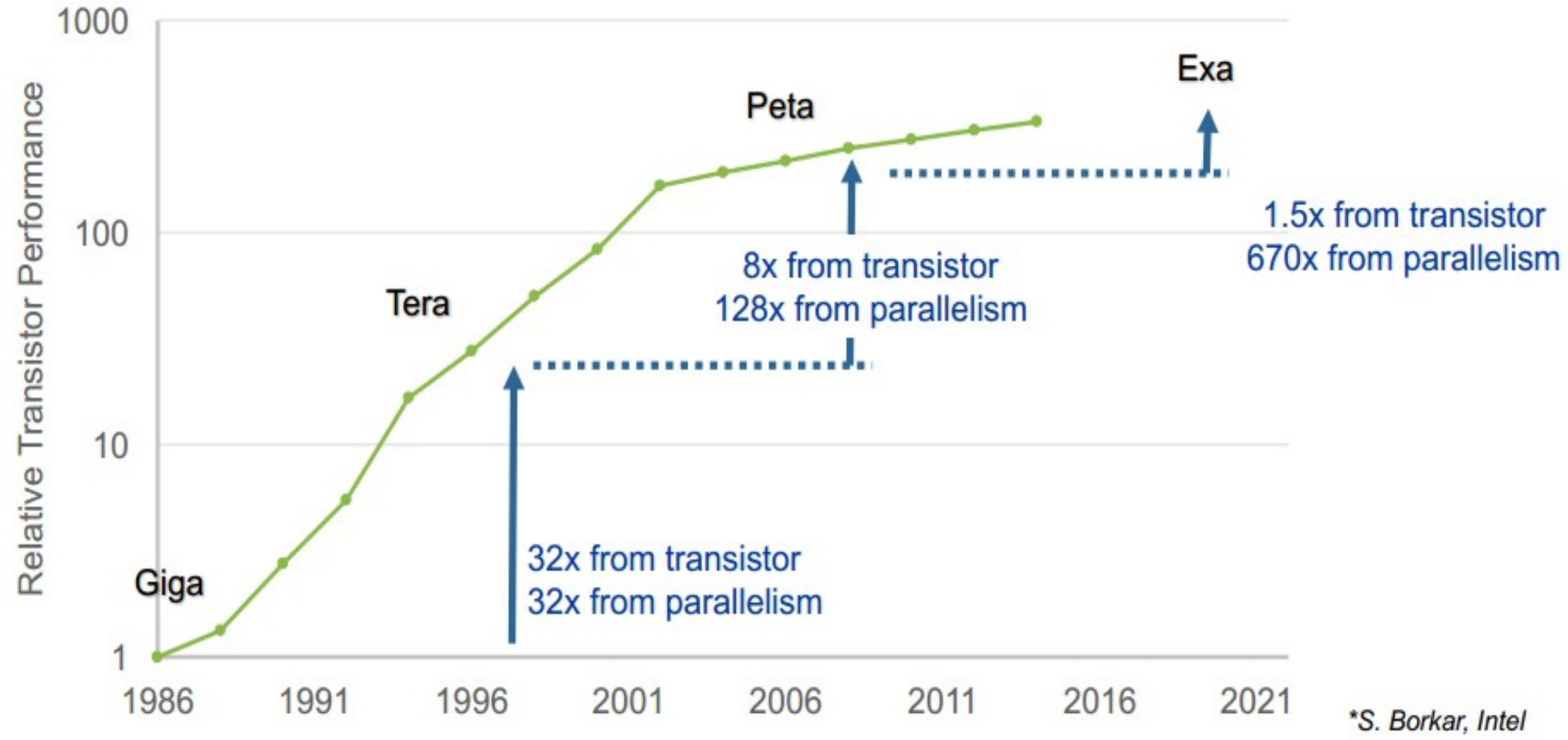
Exascale Computing Project

- Lead Agencies
  - DoE, NSF, DoD
- 7 year project
  - $3.5-5.7 billion

Four Key Challenges

- Parallelism
- Memory and Storage efficiencies
- Reliability
- Energy Consumption

Performance from Parallelism



Goals

- Deliver two exascale systems by 2023
  - First in 2021 based on "advanced architecture"
  - 20-30 MW
  - Sufficiently resilient
  - Support a broad range of workloads

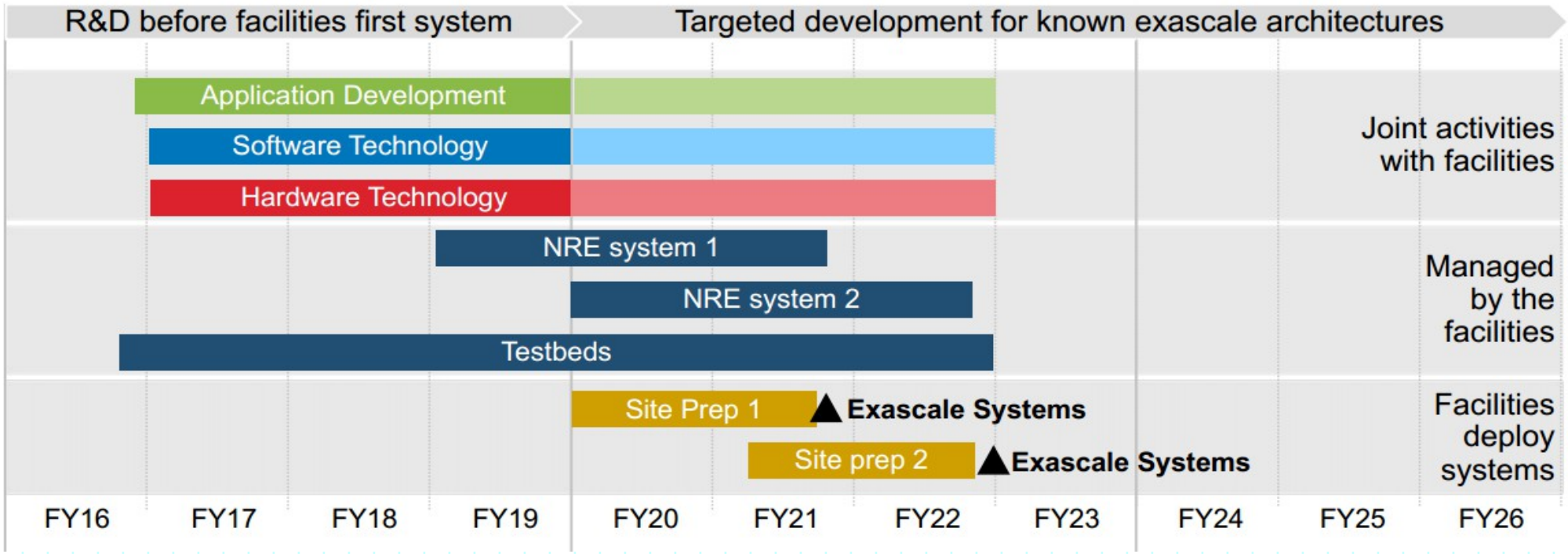
Strategic Pillars

- National Security
- Energy Security
- Economic Security
- Scientific Discovery
- Earth System
- Health Care

Software and Hardware Goals

- Software
- Hardware

Schedule


R&D before facilities first system
Targeted development for known exascale architectures
Application Development
Software Technology
Hardware Technology
NRE system 1
NRE system 2
Testbeds
Site Prep 1
Exascale Systems
Site prep 2
Exascale Systems
Joint activities with facilities
Managed by the facilities
Facilities deploy systems
FY16
FY17
FY18
FY19
FY20
FY21
FY22
FY23
FY24
FY25
FY26

Current Status

- Recent Actions
- Risks

Alternative Architectures

- What does this mean?
- Options?

Course Recap / Discussion