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EXASCALE DESIGN SPACE EXPLORATION

# ASCR Modeling and Simulation of Exascale Systems and Applications

September 18-19, 2013

University of Washington

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Albuquerque, NM



U.S. DEPARTMENT OF  
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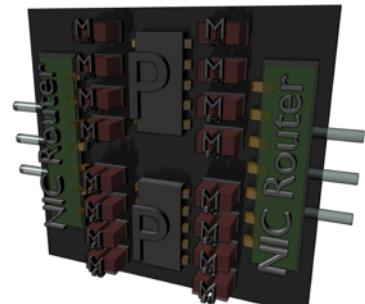
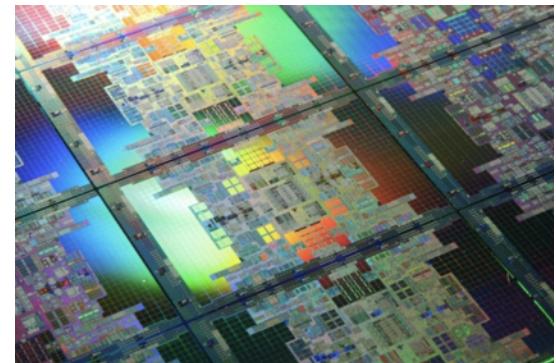
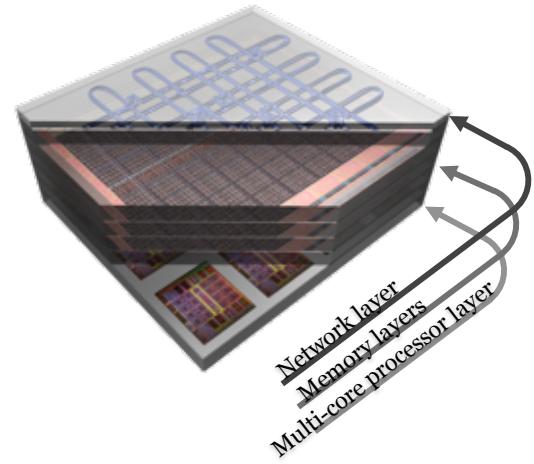
# Exascale Challenges

We need to Motivate and *Influence* Architectural Changes

- COTS Processor Architectures
- System Architectures

Our Investments are not only in Architectures

- We cannot just develop new Exascale Architectures and *Throw it over the wall* to our application developers
- Hardware/Software Co-Design is not only Application SW – includes System SW
  - X-Stack
  - OS/R
  - Application Code Teams



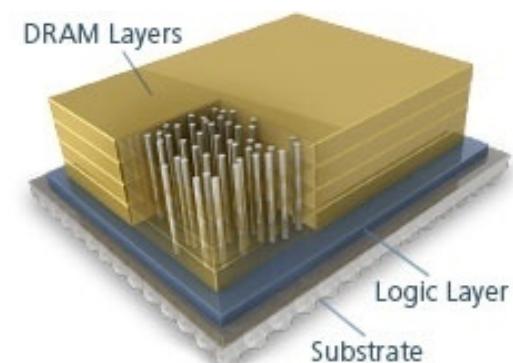
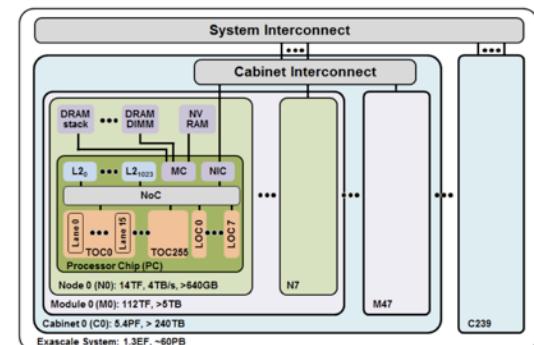
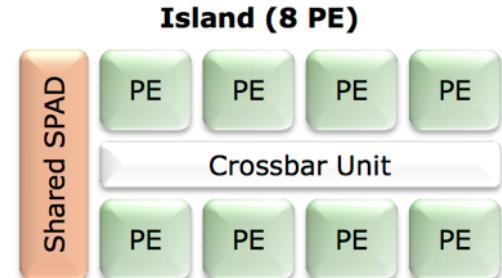
# Paths to *Influence* COTS Development

## Fund R&D Projects with Industry

- Fast Forward and Design Forward R&D Projects with Industry
  - Improvement on Original ASCI Path Forward Program
  - National Laboratory Staff collaborate with Industry Partners via Co-Design activities, Proxy Applications, **Proxy/Proto Architectures, BSM, X-Stack, OS/R**, et al
- DOE establishing R&D Projects with Micron

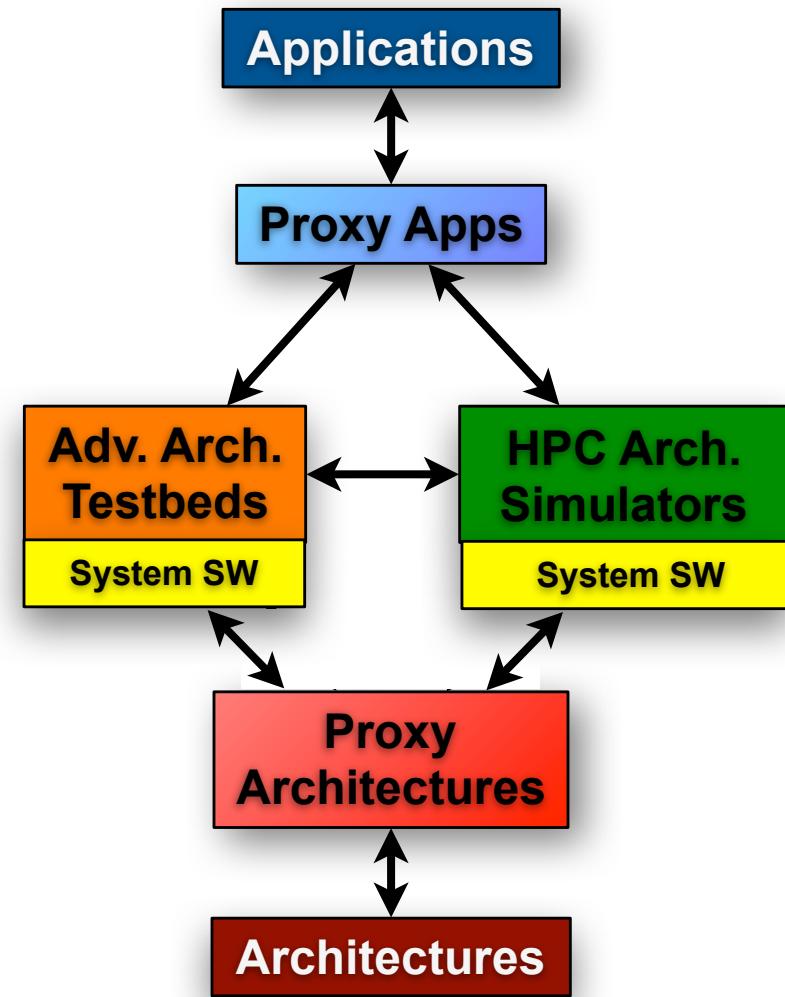
## Explore SoC options for development of HPC COTS processors

- Discussions with ARM Holdings and several SoC companies, including some “traditional” companies such as Nvidia and AMD



# Define the HPC Co-design Methodology

- Key Co-design Capabilities
  - Proxy/Proto mini Applications
  - Development and evolution to represent mission needs
- HPC Architectural Simulators
  - Flexible to accommodate fidelity/speed tradeoffs
- Proxy/Proto Architectures to explore advanced concepts
  - Abstract machine models
- Advanced architecture testbeds
  - Evolving representation of vendor “state of the art”
  - Support agile system software R&D
    - X-stack, OS/R, BSM, Execution Model Projects



# Computer Architecture Lab: Scope

- Modeling and Simulation Infrastructure:  
Assemble a common set of tools to establish a unified capability *for quantitative analysis of the design space* for hardware and algorithmic/software design
- Computer Architecture Research and Exploration:  
Lead the definition, development and evolution of *proxy architectures* to facilitate non-proprietary exploration of advanced architecture concepts
- Proving Ground for Industry Technology Options:  
Provide computer architecture staff to function as technical liaisons between the *Architecture Fast Forward and Design Forward* awardees and ESCE RD&EI projects
- Nexus for Co-design/Arch interaction:  
Act as a liaison among the *co-design centers/projects* and commercial *computing technology providers* to help establish interactions

# Fast Forward Program

- **Objective:** *Accelerate transition of innovative ideas from processor and memory architecture research into products*
- Evaluate advanced research concepts and develop quantitative evidence of their benefit for DOE applications (using Co-design Proxy apps)
  - Engage DOE application teams to understand technology trends constraints (how it impacts their code development)
  - Understand how to *program* these new features
  - Quantitative evidence to lower risk to adoption of innovative ideas by product teams
- Processor and Memory Fast Forward Projects
  - AMD – Mike Schulte and Mike Ignatowski, Lab TR – Arun Rodrigues and Jim Ang
  - IBM – Ravi Nair, Jaime Moreno, and Doug Joseph, Lab TR – Bronis de Supinski
  - Intel – Alan Gara and Shekhar Borkar, Lab TR – Sudip Dosanjh and Scott Hemmert
  - NVIDIA - Bill Dally and Steve Keckler, Lab TR John Shalf and Nick Wright

# Design Forward Program

## Design Forward Technology Focus Areas:

- System design and integration:
  - Overall System Architecture
  - Resilience and Reliability
  - Packaging Density
  - Programming Environment
  - Energy Utilization
  - Data Movement through the System
  - System Software
- Interconnect Networks:
  - Overall Interconnect Architecture
  - Interconnect Integration with Processor and Memory
  - Multiple Communication Library Progression and Interaction
  - Interconnect Fabrics and Management
  - Protocol Support
  - Scalability

# CAL Collaborates with FastForward (& DF) Partners and ESCE\* RD&EI<sup>†</sup> projects

- The CAL Project has responsibility to develop Proxy Architecture models that represent FF/DF designs
- The DOE ESCE Co-design Projects have responsibility to develop Proxy Apps that are represent their real apps
- Collaborate with Fast Forward & future Design Forward Projects to understand ability to tune Proxy Architecture models to represent their proprietary advanced architecture concepts in our simulators
- Share (perhaps detuned) Proxy Architectures with ESCE RD&EI projects

\* Extreme Scale Computing Effort

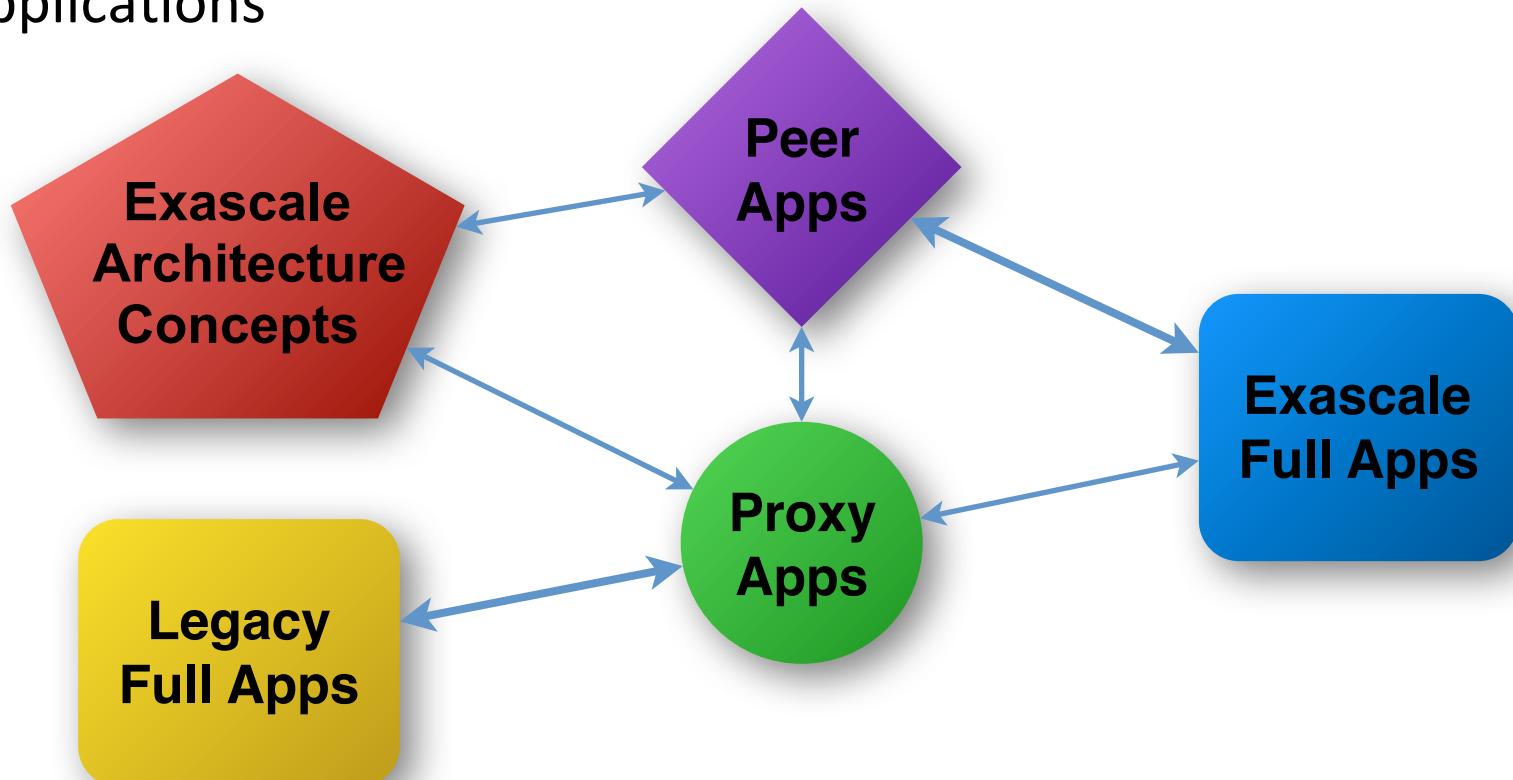
† Research, Development, Integration and Engineering

# CAL is also Collaborating with the DOE Co-design Projects

- The three ASCR Co-design Centers and the ASC Co-design Project have responsibility to define and develop Proxy Apps that are representative of their real applications
  - CAL bridges Fast Forward & Design Forward Architecture-centric Projects and App-centric Co-Design Projects
- CESAR – Center for Exascale Simulation of Advanced Reactors
- ExMatEx – Exascale Co-Design Center for Materials in Extreme Environments
- ExaCT: Center for Exascale Simulation of Combustion in Turbulence
- ASC Co-design Project – Working on Tri-Lab coordination within the ASC/IC and ASC CSSE program elements

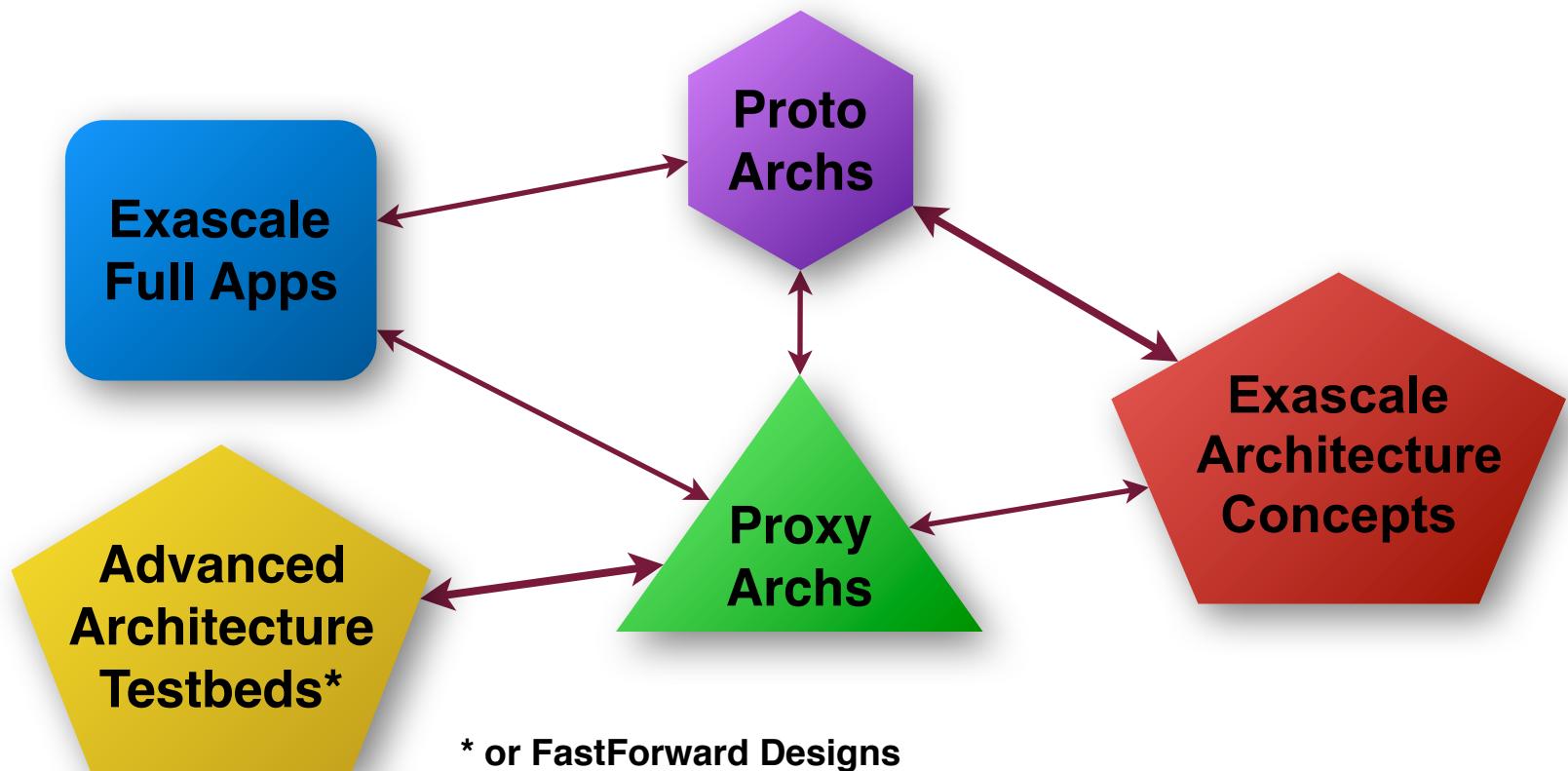
# Application Abstractions: MiniApps: Proxy and Peers

- Relationship among Full Applications, Proxy and Peer mini Applications

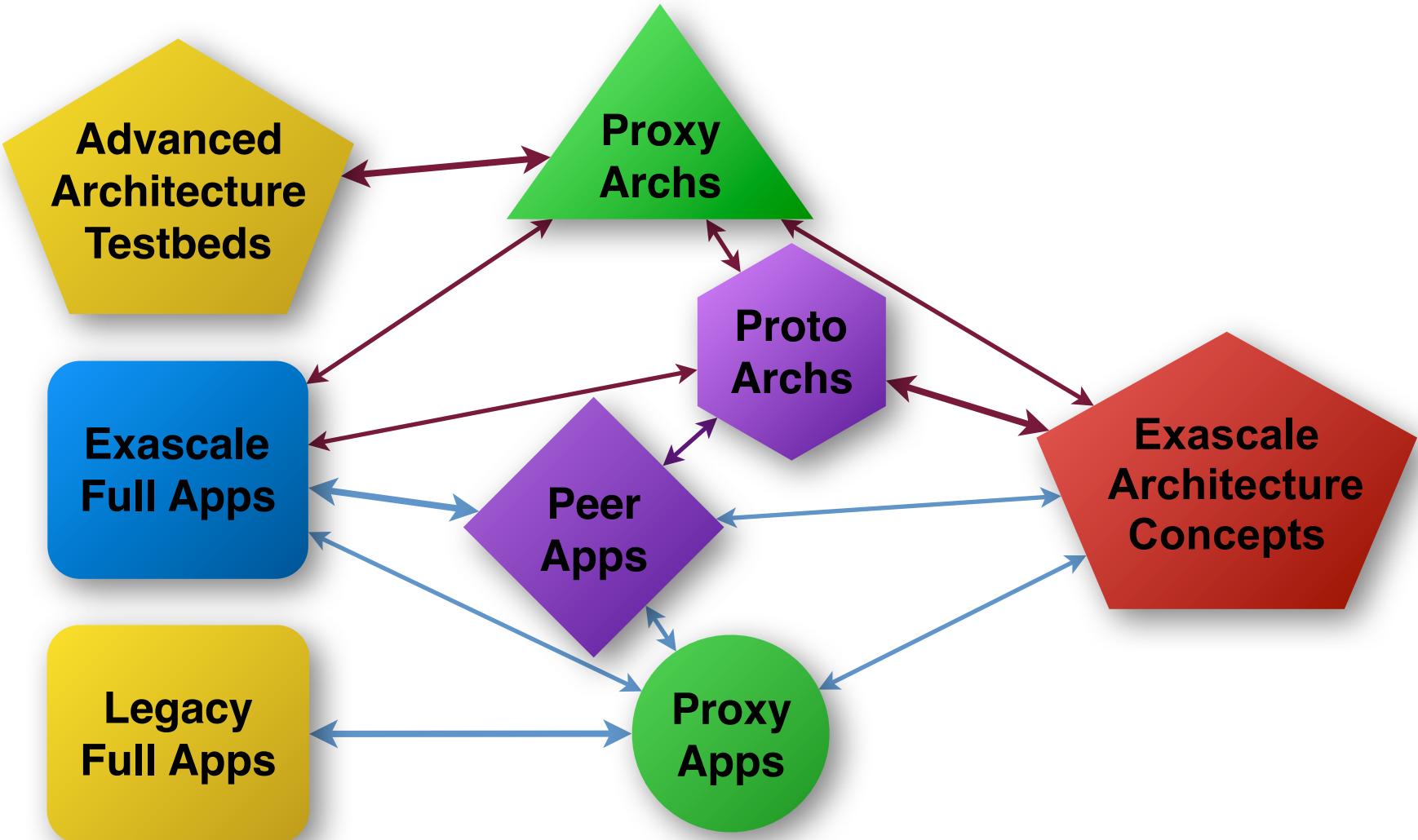


# Architecture Abstractions: Proxy and Proto Architectures

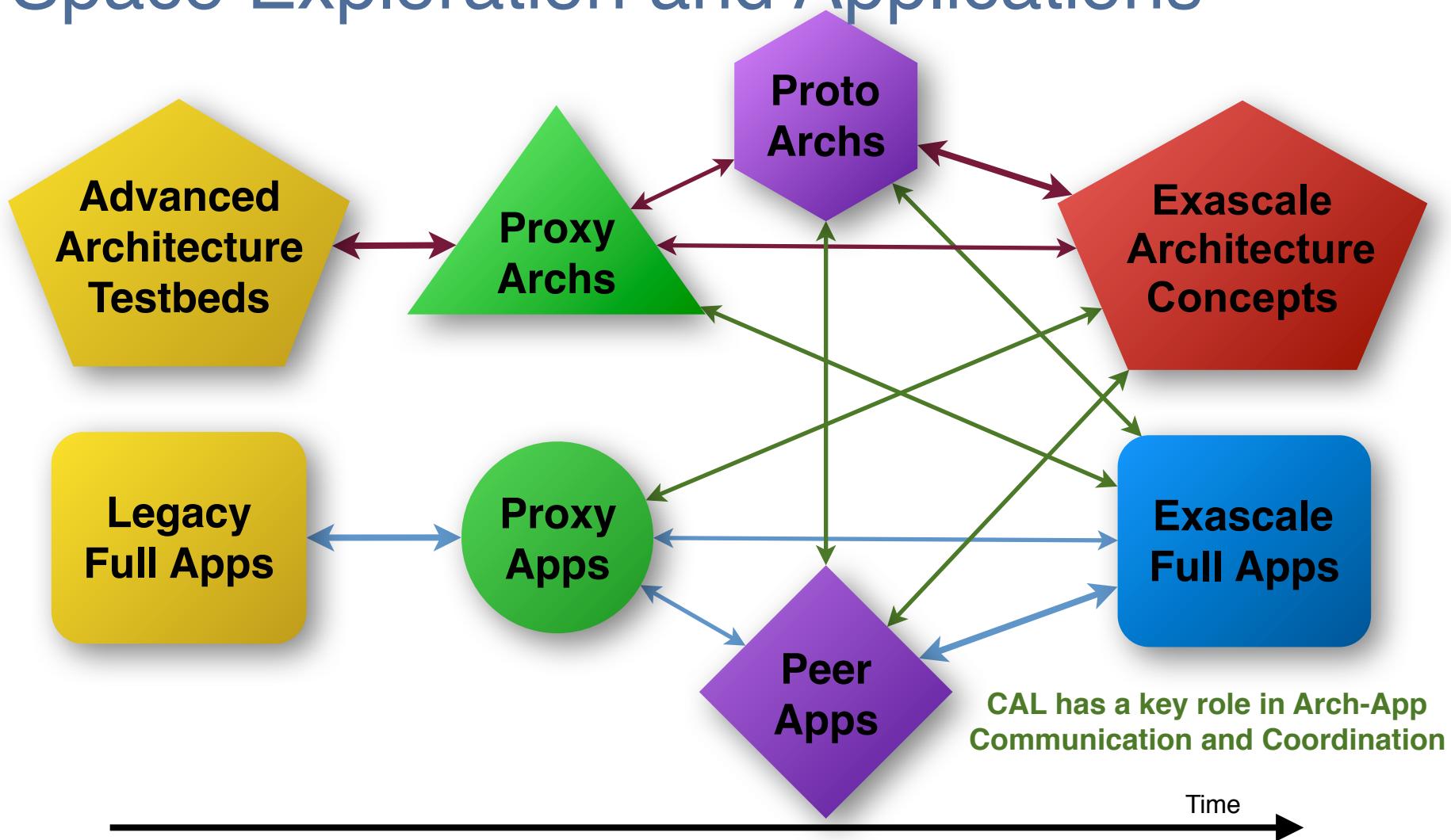
- Relationship among Current, Future, Proxy and Proto Architectures for Design Space Exploration



# Overview: Architecture Design Space Exploration and Applications



# Another View Architecture Design Space Exploration and Applications



# Concluding Thoughts

- Hardware elements of Co-Design Apply to both:
  - Processor / node architecture
  - System architecture
- We need to rethink COTS and system balance
  - Component performance
  - Investment
    - Platform costs
    - R & D investments