# EXASCALE … AND BEYOND

DEHPC 2015

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THE NEW CENTER OF POSSIBILITY

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# KEY CHALLENGES TO EXASCALE

Power
- Many aspects drive and are driven by power

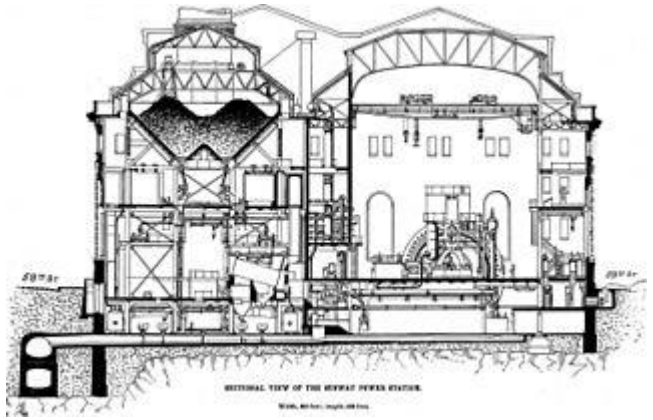
Scalability
- Forcing hybrid programming models and hierarchy system software

Reliability
- Application and system software not designed to handle faults

Communication bandwidth and latency
- Induces challenges in existing BSP model

Memory bandwidth, latency, and capacity
- Pushes on threading and increased need for parallelism

# POWER



## An increasing concern

- TN8: power band and ramp
  - Lower-bound a whole site issue
- HPC Power API Spec
  http://powerapi.sandia.gov/

## Energy efficiency

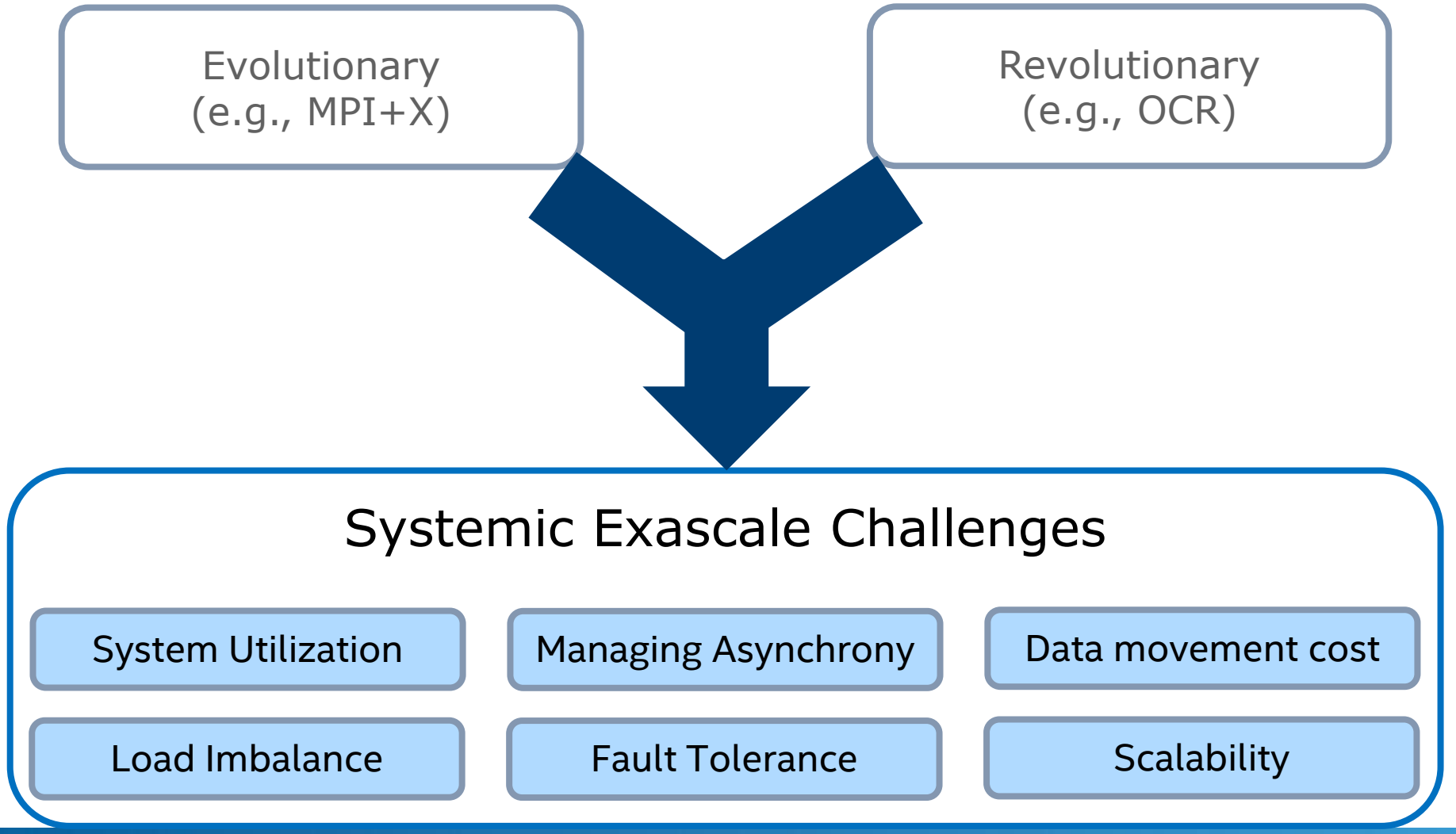
- A prime focus at LRZ
- Will become more common?

## Tools

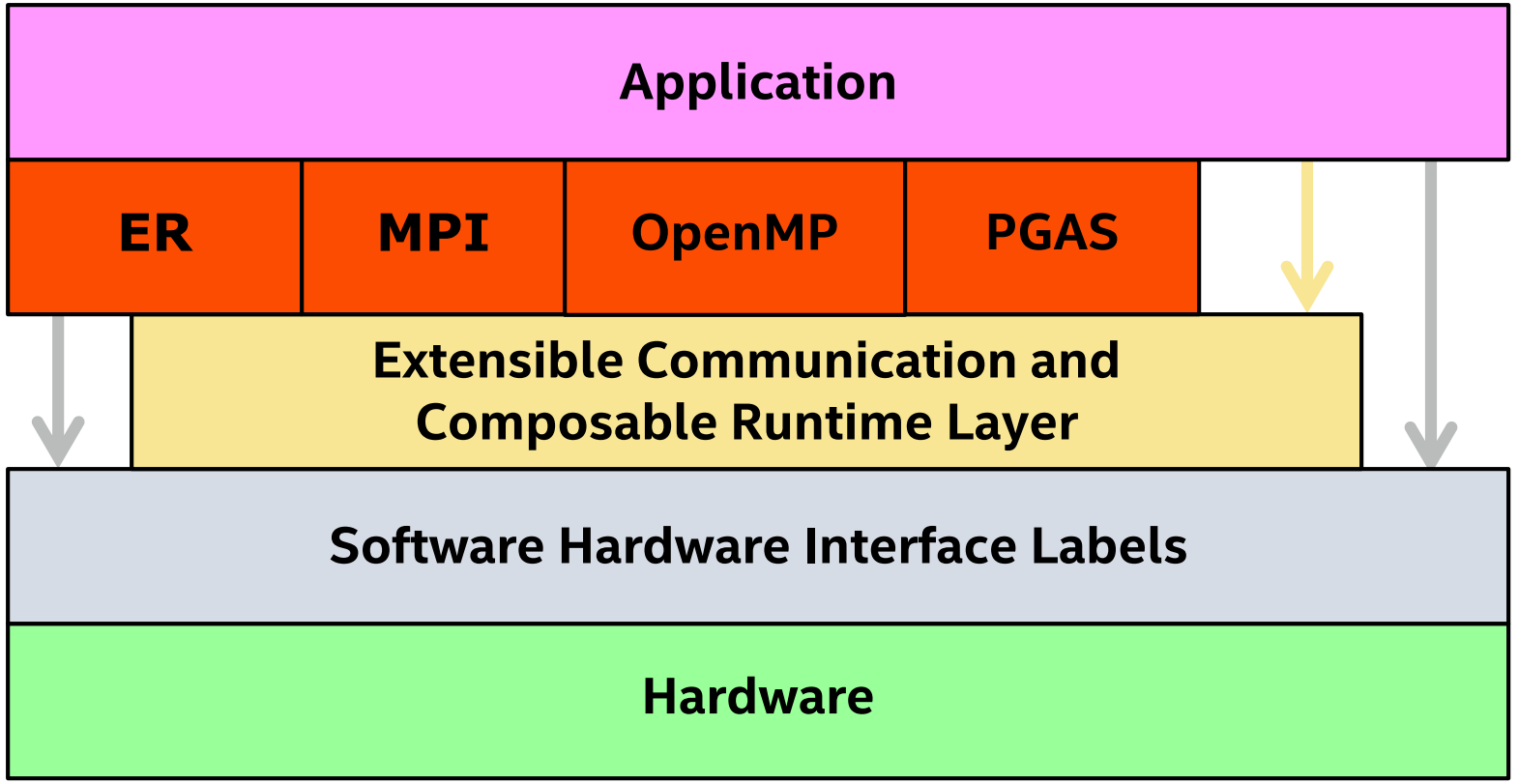
- Energy efficiency for clients/servers
  - Sleep as much as possible
    → PowerTop
    https://01.org/powertop
- Energy efficiency for HPC
  - Understanding the code
    - Global observation v. tuning
  - Manage performance to achieve goals
    → Global Energy Optimization
    https://geopm.github.io/geopm/

    Just posted; feedback on interfaces, docs

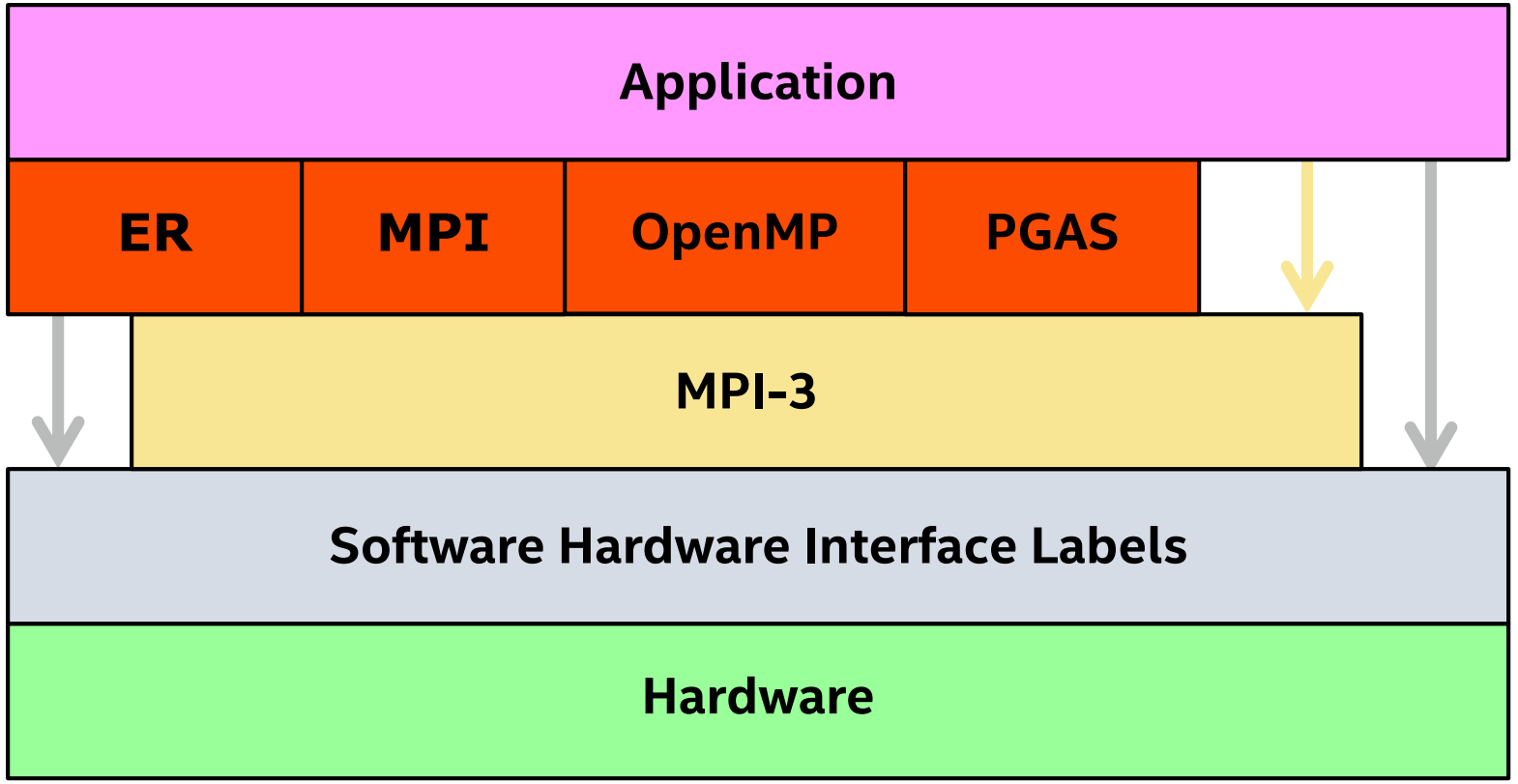
# PATHWAYS TO EXASCALE



# PROGRAMMING MODEL COMPOSABILITY



# PROGRAMMING MODEL COMPOSABILITY




Non-blocking collectives, topology, one-sided comms, POSIX/Sys5 SHMEM, …

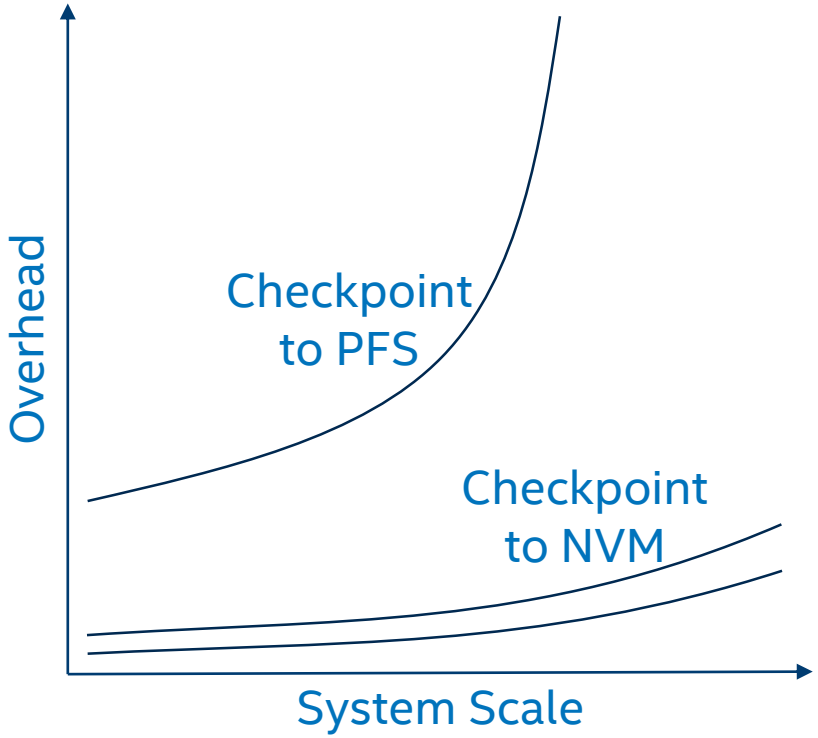
Focus on implementations and tools

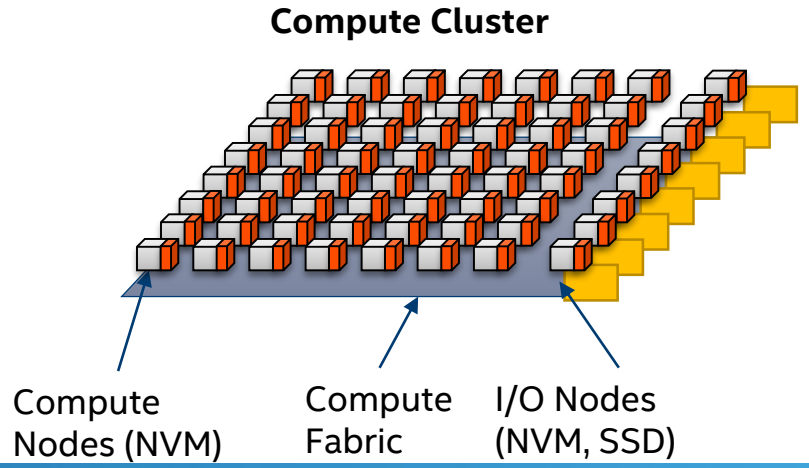
# CHECKPOINT/RESTART

NVM greatly reduces checkpoint/restart overhead

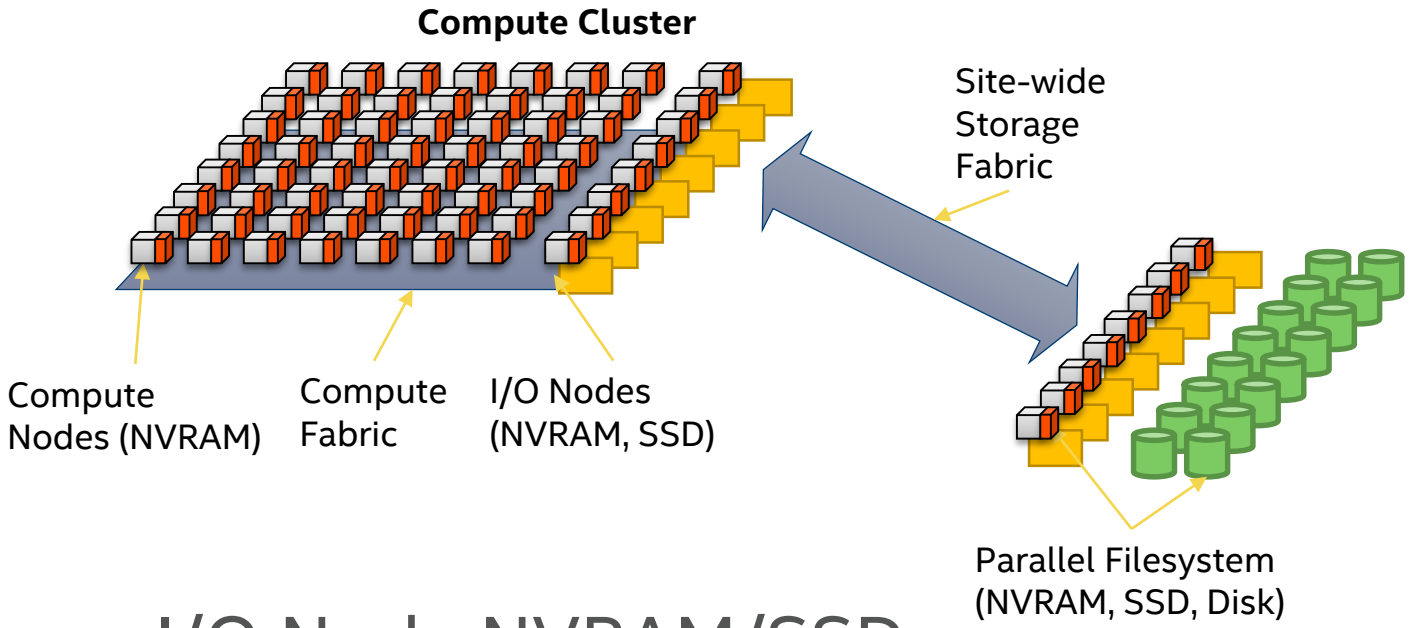
Where is the NVM located?

- Global (e.g., I/O Nodes)
  - Fabric BW
  - Globally accessible
  - Lower scale, resilience, …
- Local (i.e., Compute Nodes)
  - Full aggregate BW
  - Locality & durability concerns
- Opportunity for Local v. Global checkpoint
  - Local: HER + SER + OER
  - Global: HER



# STORAGE ARCHITECTURE




## Compute Node NVRAM

- Hot data
  - High valence & velocity
  - Brute-force, ad-hoc analysis
  - Extreme scale-out
- Full fabric bandwidth
  - O(1PB/s)→O(10PB/s)
- Extremely low fabric & NVRAM latency
  - Extreme fine grain
  - New programming models

## I/O Node NVRAM/SSD

- Semi-hot data / staging buffer
- Fractional fabric bandwidth
  - O(10TB/s)→O(100TB/s)

## Parallel Filesystem NVRAM/SSD/Disk

- Site-wide shared warm storage
  - SAN limited – O(1TB/s)→O(10TB/s)
- Indexed data

# PERSISTENT MEMORY AND RESOURCE MANAGEMENT

Persistent memory complicates resource management

- Data locality introduces hysteresis

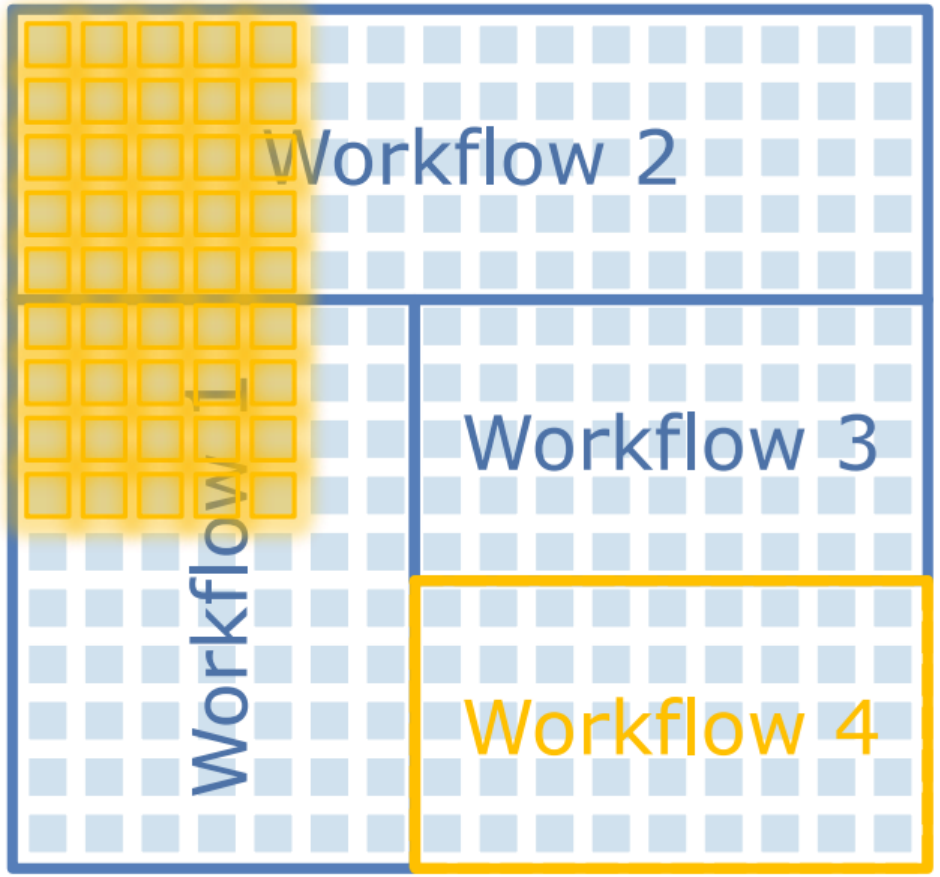
Data migration issues

- Space at destination
- Fabric interference

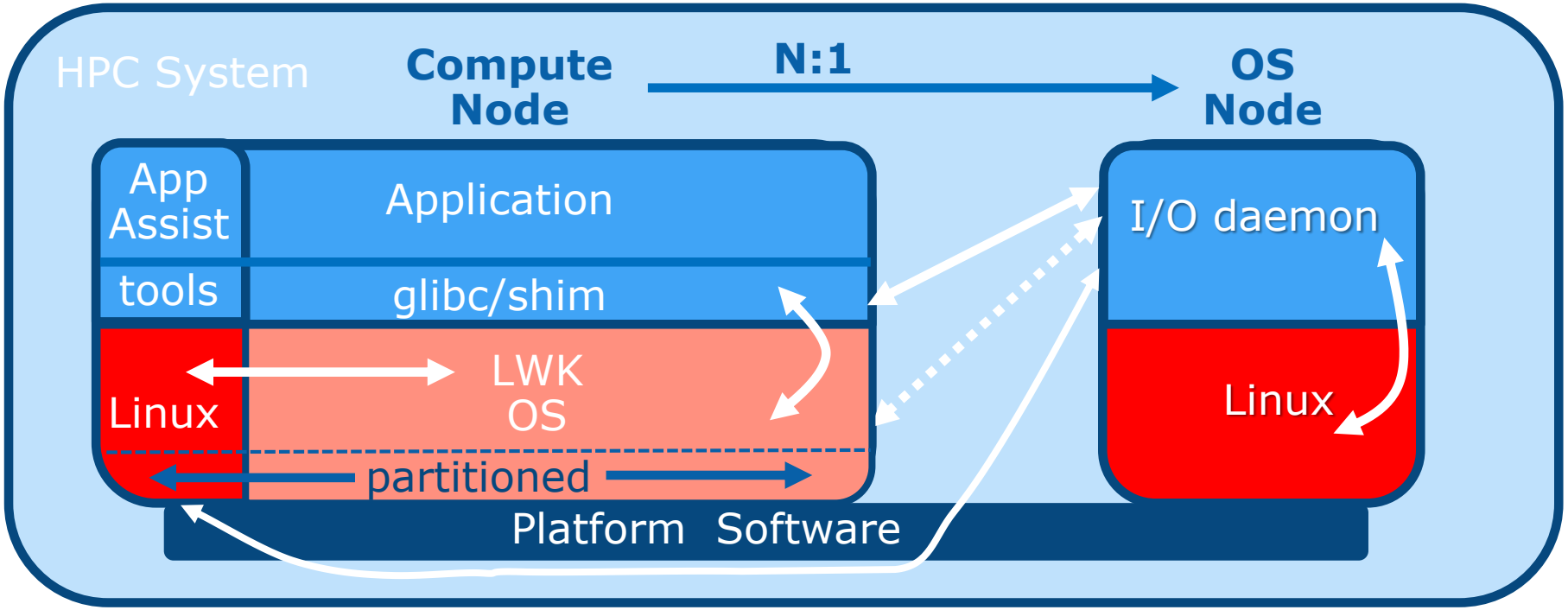
Data movement v. data reconstruction

Security considerations

- Encryption may be useful for some



# SCALABLE OS




- CNOS that fully supports Linux API and ABI
- Nimble to support new technology effectively
- Move to hierarchy of OS offload for scalability
- Support fine-grained threading and asynchronous requests
- Provide support for and be amenable to running on differentiated cores

# BACKUP

# APPLICATION SCALABILITY

Substantial pressure on application scalability

- System scale
- Cores/threads

MPI + X

- OpenMP
- C++ (lambda), RAJA, Kokkos, …
- OCR, AutoOCR, CnC, …

http://openmp.llvm.org/
https://www.openmprtl.org/

https://01.org/open-community-runtime