# Resource Partitioning and Power Management in the Exascale Era

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Improving all layers of the open-source resource management ecosystem

***The goal of the Argo resource management effort is to provide user-facing advanced mechanisms to control and monitor resource usage across the system. This includes performance isolation, support for advanced workloads such as workflows and coupled-codes, and comprehensive power management.***

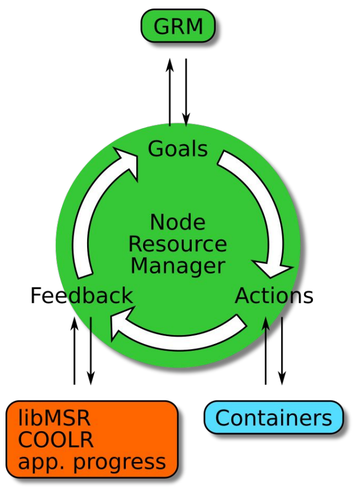
## Local (Node) Resource Management

### Overview

- Hierarchical resource partitioning
- Containers for intra-node resource partitioning
  - Using the cgroups mechanism of Linux
- More efficient "packing" of multi-component applications
- Arbitrate resources between applications and runtime services
- Reconfigurable, dynamically tracking resource changes
- Integration with batch schedulers, power management

### Node Resource Manager

- Single API endpoint for all node resource management services
- Map containers to topology, interact with container runtime
- Upstream API: interact with GRM, publish node events
- Downstream API: user access to container management, application reporting, power command
- Goals: integration across hierarchy levels, collaboration with job schedulers, MPI



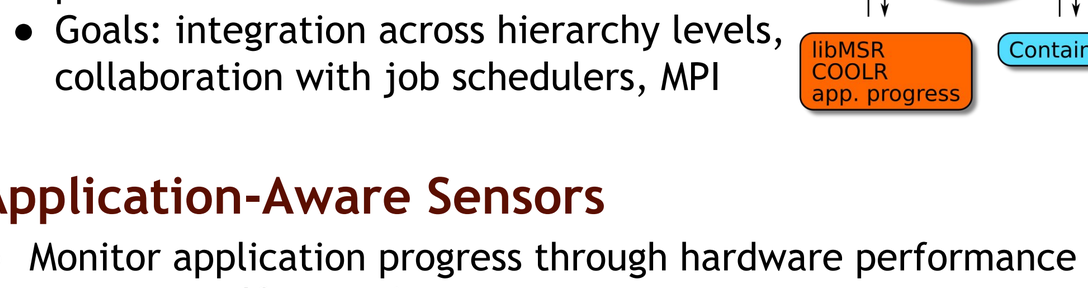

### Application-Aware Sensors

- Monitor application progress through hardware performance counters, self-reporting
- Monitor hardware sensors: power, temperature, fan speed, frequency
- GRM-provided power limit
- Closed-loop control mechanism, p-state/RAPL actuators
- ECP goals: improve control-loop, integrate more sensor data into policies

### Resource Abstraction and Control Synthesis

NRM performs abstracted resource accounting in the form of "sensors" and "actuators", enables their discoverability, and optimizes reconfigurable sensor optimization goals.

- Reconfigurable for any number of sensors and actuators
- Specified through a Control Problem Description format
- Synthetizes a Multi-Armed Bandit controller



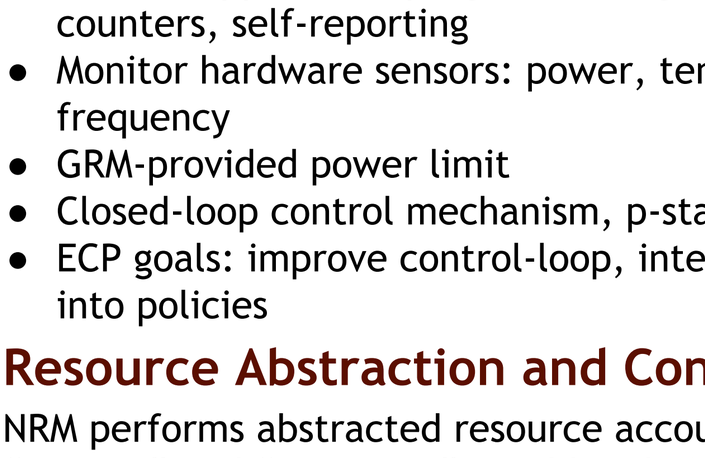
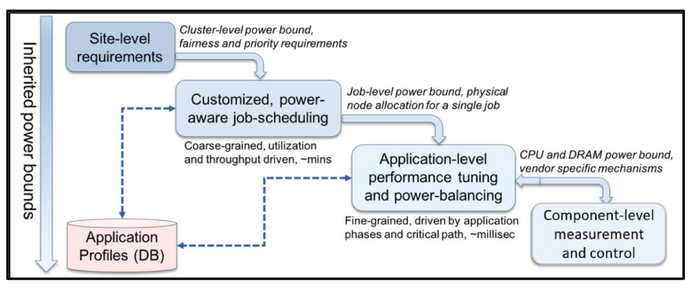



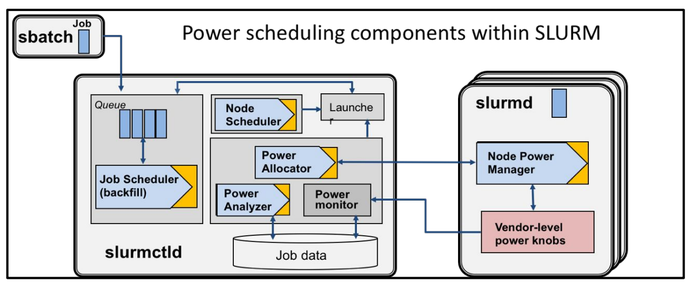

Figure: NRM's control synthesis and sensor integration mechanism.

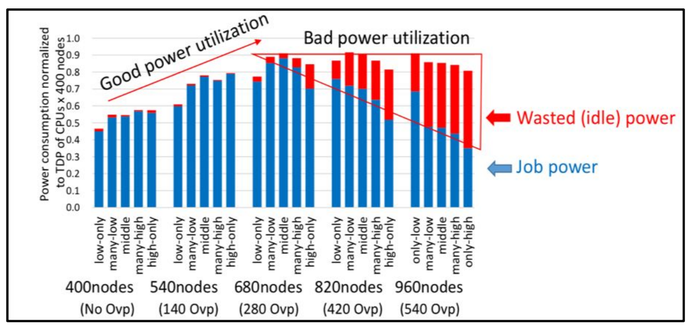
## Global Power Management

### Scheduler-Aware Hierarchical Control

- Integrate job scheduler, enclaves to control power across jobs
- Use NRM data to monitor power and application performance
- Steer power where it can most advance the application's progress
- ECP goals: production-ready GRM, integration across different hierarchy levels
- PowerStack: Develop first prototype and lead community effort toward capturing power management details from the microarchitecture-level up to the site-level.
- PowerStack will leverage and extend existing tools such as msr-safe, libmsr, variorum, Intel GEOPM (production codes) and Adagio, Conductor, RMAP, PowSched, P-SLURM (research codes)




As part of PowerStack, a Power-aware design of SLURM (GRM) has been developed and tested on 960-nodes on the HA8K supercomputer in Japan (collaborators). Results show the benefits of hardware overprovisioning at scale as well as sensitivity to the degree of overprovisioning.

### Variorum v1.0 Released:

- https://variorum.readthedocs.io
- Extensible, open-source library for exposing low-level hardware knobs
- Vendor-neutral API for power management, with current support across six Intel architectures, IBM Power9, and NVIDIA Volta.

### SLURM SPANK Plugin with GEOPM Released:

- https://github.com/geopm/geopm-slurm
- Allows for end-to-end control across jobs with and without GEOPM on Intel architectures
- Integration into TOSS deployment framework is underway
- Variorum + GEOPM integration is planned for FY20, allowing vendor-neutral implementation of PowerStack with SLURM.

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