Activities in the ASC WG on Tools

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History: ASC exascale planning efforts

- NNSA formed five working groups in June 2010
  - Architectures, System SW, Programming Models & Tools, Viz/Data, I/O
  - Planning meeting in Washington DC
  - Exercised showed that tools and PM needed to be separate groups
- Subsequent planning meeting in September 2010 in Albuquerque
  - Added working groups for application side
  - Later refined to: applications & Solvers/Libraries, total of eight WGs
  - Outbriefs on challenges and gaps
- Working group leads represented NNSA in March 2011 ASCR meeting
- ASC exascale meeting in San Francisco, March 2011
  - Added members from ASCR labs and academia chosen by ASCR
  - Joint working group discussions on cross-cutting issues
  - Started with September outbriefs
  - Outbriefs for each working group with ASCR input
Recommendations for next steps/PathForward investments

Scope of the Tools WG

- Major Software Stack Elements the Group is Responsible for:
  - Tools for application development (debugging, correctness, performance)
    - Wide spectrum: memory, power, locality, resilience, …
    - Static analysis tools for code evaluation
  - Tools for SSW to evaluate the exascale stack itself
    - SSW, I/O, Network, File systems, Scheduler, …
    - Need to get away from ad-hoc tools, need whole system solution
  - Shared infrastructure for measurement, data gathering and presentation
    - Online analysis, data aggregation, shared across the system stack
    - Post-mortem, online, in site and batch tools
  - HW and SW APIs / information exchange with other WGs
    - APIs that we want to wrap and monitor
    - Introspection APIs (HW and SW)
    - Guidance for other system components (targeted, information isolation)
    - APIs exposing semantic information from the users to tools
  - Resources for testing/validation of the system (incl. tools)
- Not in scope: compilers (vendors!), resiliency techniques, runtimes

State of the Art (Sep. 2010)

- Some successful tools all the way to Petascale class machines
  - Many successes with brute force scaling
  - Still evolving and often brittle
  - Mostly focused on single paradigm codes
- BUT: traditional paradigms are starting to break down
  - Applications are turning towards hybrid models
  - Traditional debuggers don’t scale
  - Performance analysis has to deal with flood of data
  - Full tracing at Petascale is not feasible anymore
  - Fragmented runtime systems and environments
- New approaches most include the following principles
  - Data reduction and on-line analysis
  - Flexible infrastructures for prototype tools
  - Integration and sharing across topic areas and WGs
  - Integrated runtimes avoiding stove pipes

Exascale Challenges for/around Tools

- Challenges in providing new capabilities
  - Scalability of measurement, analysis, and presentation
    - Incl. new metrics: memory, power, …
  - Turning information into insight
    - Despite flood and complexity of data from billions of threads
  - Dealing with new programming methodologies
    - Heterogeneous systems/architectures (HW and SW)
    - Coupled systems and applications
  - “What if” tools for Co-Design
- Challenges for tool implementations
  - Quick design of prototype tools for new scenarios
    - Agile development to keep up with PMs
    - Need them early, enable specialized tools in this and other areas
  - Getting right interfaces with the right abstractions
    - To SSW, HWA, Apps, Libraries, Runtimes, Compilers, …
  - Resiliency for tools and tool infrastructures

Technical Goals to Provide Efficient Tools

Gaps that other groups look for the Tools WG to fill:

- Understand and evaluate node level resources
  - Memory and threading
  - Global understanding of node local data
  - Scalable analysis algorithm (on-line/in-situ)
- Support new high-level abstractions in new PM approaches
  - Understand the performance impact of their abstractions
  - Match performance <-> PM abstractions
  - Code refactoring/translation support
- Ability to correlate HW, SW, System, App Events/Data
  - Understand/distinguish impact of system events
  - Errors/faults incl. silent errors
  - Map it to common domains
- Root cause analysis for performance and correctness
  - Construct and understand dependency chains
  - Track data flowing through the system

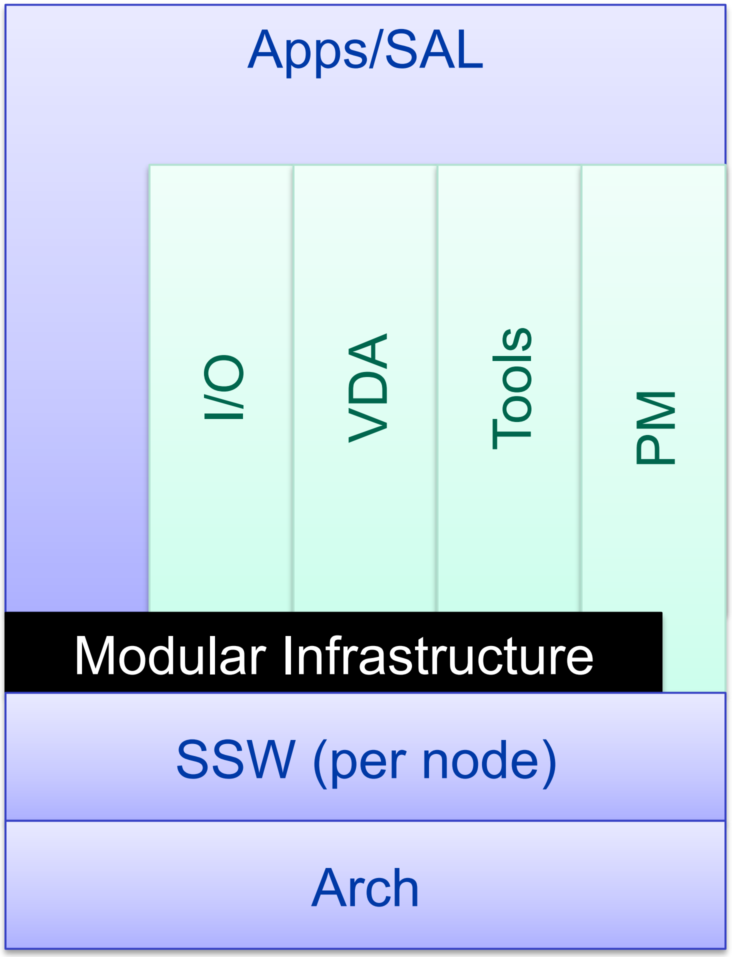
Technical Gaps for Building Tools

Gaps that need to be filled to provide the requested tools:

- Access to the necessary data from across the system
  - Standardized interfaces to HWA & SSW & PMs
  - New hardware features to get more data on memory
  - Low overhead is essential
- Scalable data collection and processing
  - Online and/or in-situ analysis
  - Requirements for scripting languages (?)
- Management and allocation of extra resources
  - Application launching
  - Launching and controlling tool/support daemons
  - Hide system differences
- Common service daemon architecture that is shared and reused
  - Tool component frameworks

Tool Needs: Modular Infrastructure

- Common infrastructure across WGs
  - Distributed/Cross-node architecture
  - Gather/Aggregate data
  - Online/In-situ analysis
  - Wiring up infrastructure
  - Easy to deploy and maintain
  - Easily reusable modules
- Use cases for tools (+related issues)
  - Performance information
  - Process/Debugging state
  - Status/Health monitoring
  - Dynamic resource management
  - Fault detection and mitigation
  - Online steering



Key Dependencies with Other 7 WGs (1)

Defense Programs

- HWA
  - Measures of resource consumption: power, network, memory bandwidth, issue slots, …
  - Raw measures of inefficiency (exposed latency, lack of memory parallelism)
  - Identification of resources (e.g., for heterogeneous nodes, GPU versions)
  - Hardware instrumentation to emulate 2018 machine costs with 2015 machine
- SSW
  - Right APIs incl. RAS and debugger interfaces (incl. testing)
  - Expose all hardware features, don't hide anything
    incl. counters, power, resiliency, faults, HW topology
  - Timely reporting and precise attribution of asynchronous events
  - Interfaces to scheduler, scheduling of tool resources
  - SSW runtime monitoring, runtime must expose right abstractions
- I/O & I/O Networks
  - For tools: interfaces to capture and measure performance (MPI_T like)
  - Capture network and storage topologies
  - Tool needs: load balancing and striping, detect link contention
  - modeling vs. measurement to find bottlenecks
  - Tracing data movements and separate between system and user traffic
  - Provide building blocks to enable specialized I/O tools (generic tracers/profilers)
  - More discussion needed: storage approaches and formats for tools (SQL DBs?)

Key Dependencies with Other 7 WGs (2)

- Visualization and Data Analysis (VDA)
  - Common needs, requirements on SSW (online analysis and data storage)
  - Exploit application knowledge available in Viz tools (data layout, …)
  - Provide building blocks to enable specialized VDA tools (e.g., in situ analysis)
  - Need VDA techniques for performance data analytics and visualization (outlier detection, equivalence groups, compression/data reduction, feature detection, …)
- Programming Models (PMs)
  - Compiler and runtime must provide information for tools to map costs back to PM abstractions
  - Translators/PMs/Compilers must expose abstractions to tools
  - PM runtime monitoring, runtimes must expose right abstractions
- Applications, Solvers, Algorithms, Libraries (Apps, SAL)
  - We are treating libraries as apps (exception: potential API interception)
  - List of expectations on tools – information that Apps/SAL people want to see
    - Data centric profiling – away from flop centric tools to memory centric tools
    - Memory locality and consumption
    - Data structures and access patterns
    - Opportunity analysis (concurrency, offload to accelerators, compiler feedback)
    - Delivering information on power and resiliency
  - Mini-Apps for testing of tools (for performance, complexity, SSW, …)
  - Application internal monitoring interfaces to capture semantic and performance data

Suggested PathForward Projects

- Memory Tools
  - New generation of tools to explore memory related metrics
- Tool Building Blocks / Infrastructure
  - Modular and Separable Tool Components
- Application-Tool Interfaces
  - Interfaces to exchange performance and semantic information
- Mini/Skeleton Applications
  - Aid in the definition of the collection of Mini-Apps
- Power Tools
  - Inclusion of power metrics into application oriented tools
- Correctness Tools
  - Verification of correct usage of PM abstractions
- Support for New Models
  - Investigation of support for new programming models

Big Picture Issues

- Coordination – must be a continuous, agile process
  - Among tool developers
    - Coordinate on common interfaces and components
    - Maintenance models
  - With Apps/SAL teams
    - Ensure their needs are met
    - Establish interfaces
  - With SSW, I/O, VDA
    - Share infrastructures
    - Avoid ad-hoc tools
  - With vendors
    - Need interfaces and documentation
    - Co-Design interactions on getting the right system hooks
- Test beds
  - Essential, need sufficient access for tools research
  - Work around security concerns (e.g., for power sensors)