Data Centric Systems (DCS)

Architecture and Solutions for High Performance Computing, Big Data and High Performance Analytics

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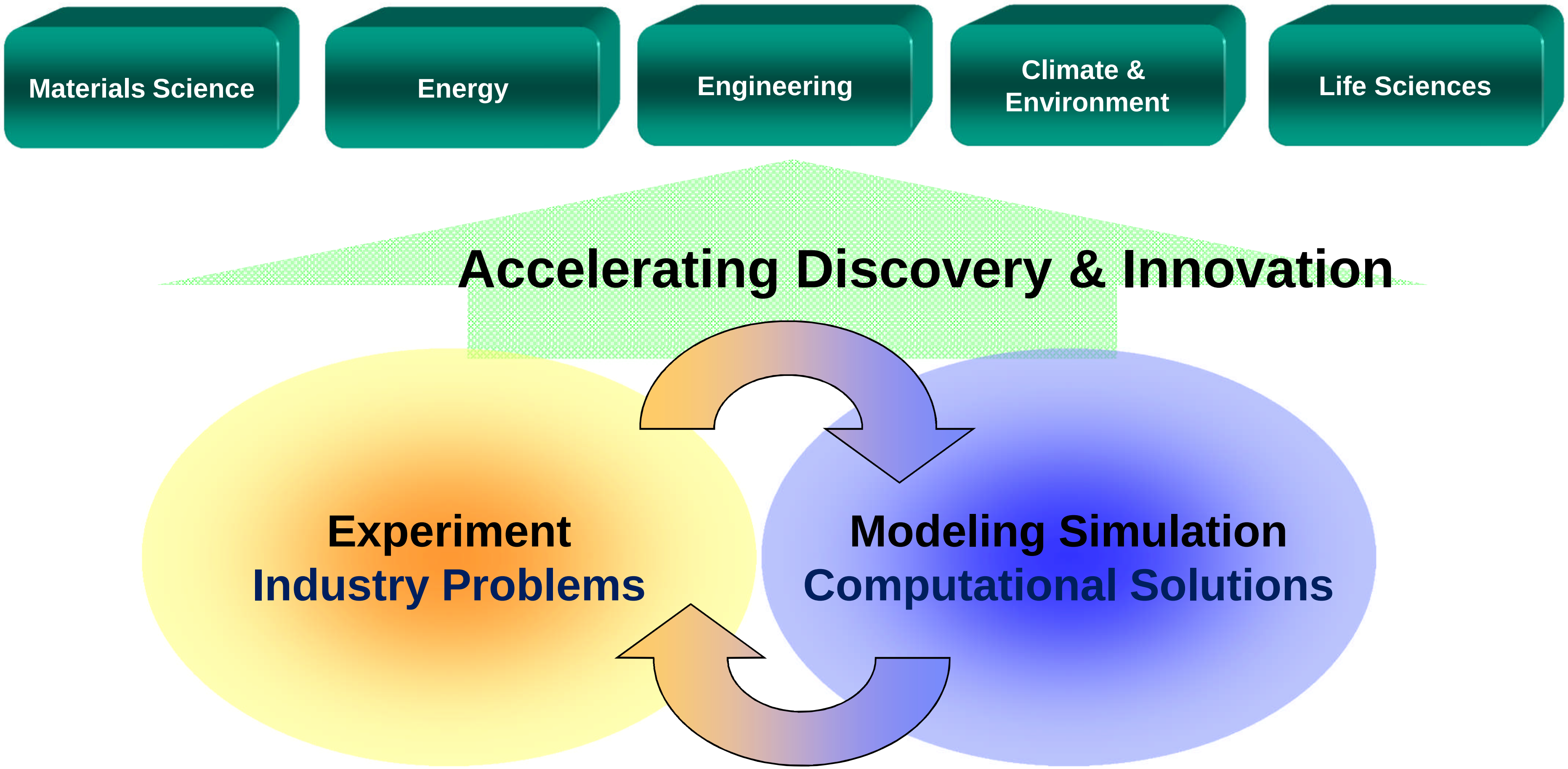
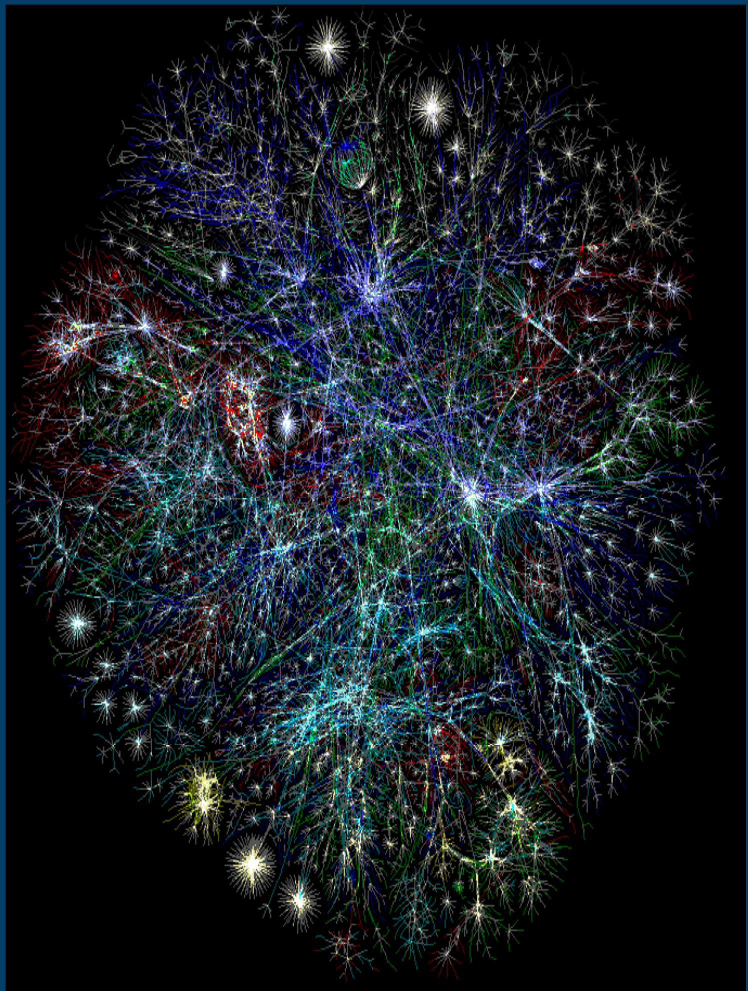
Motivation

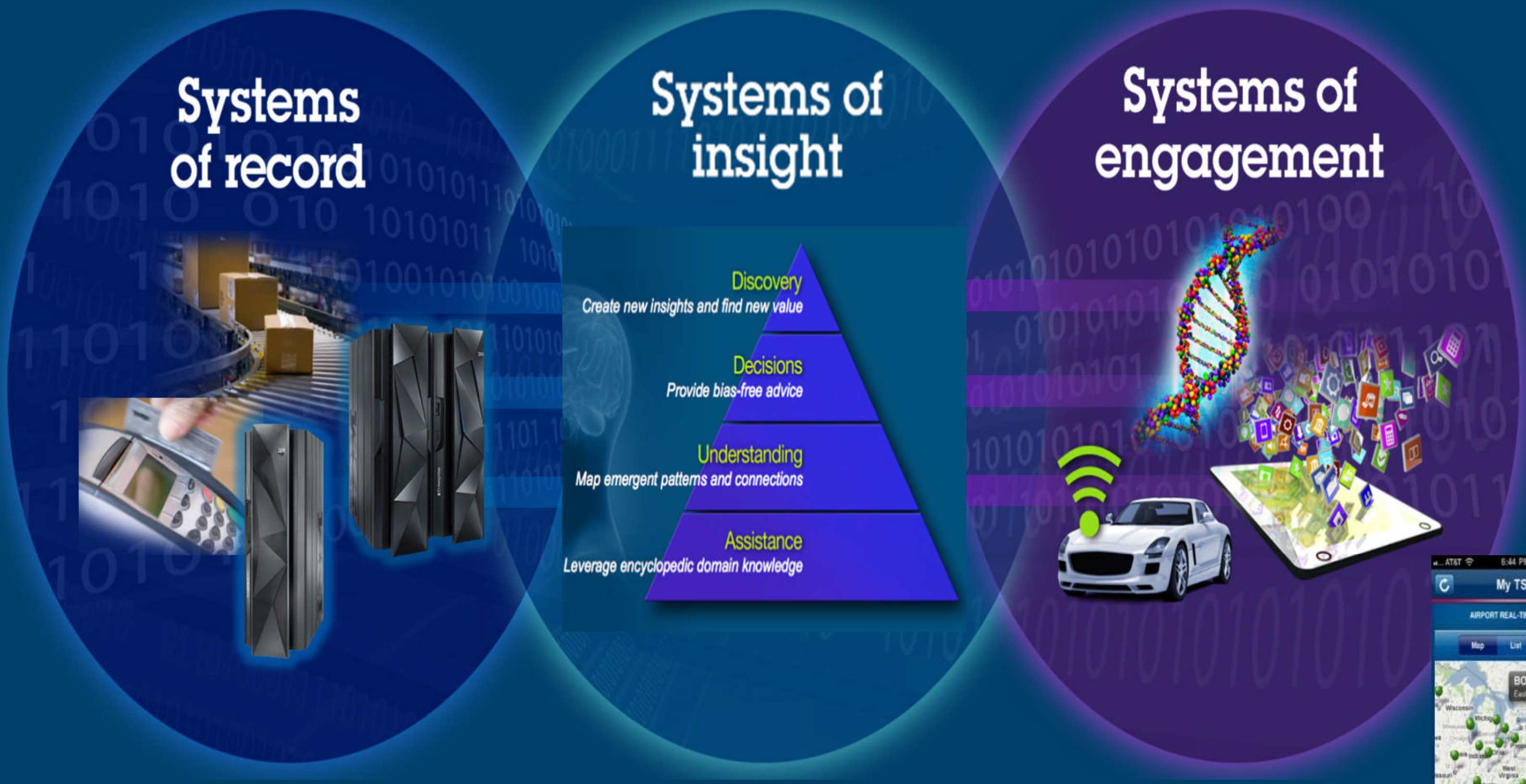
Exascale HPC – The Traditional View





- 1 trillion connected objects and devices on the planet generating data by 2015
- 2.5 billion gigabytes of data generated every day
- Data is the new basis of competitive advantage

The Next Era of IT Will be Defined by Systems of Insight



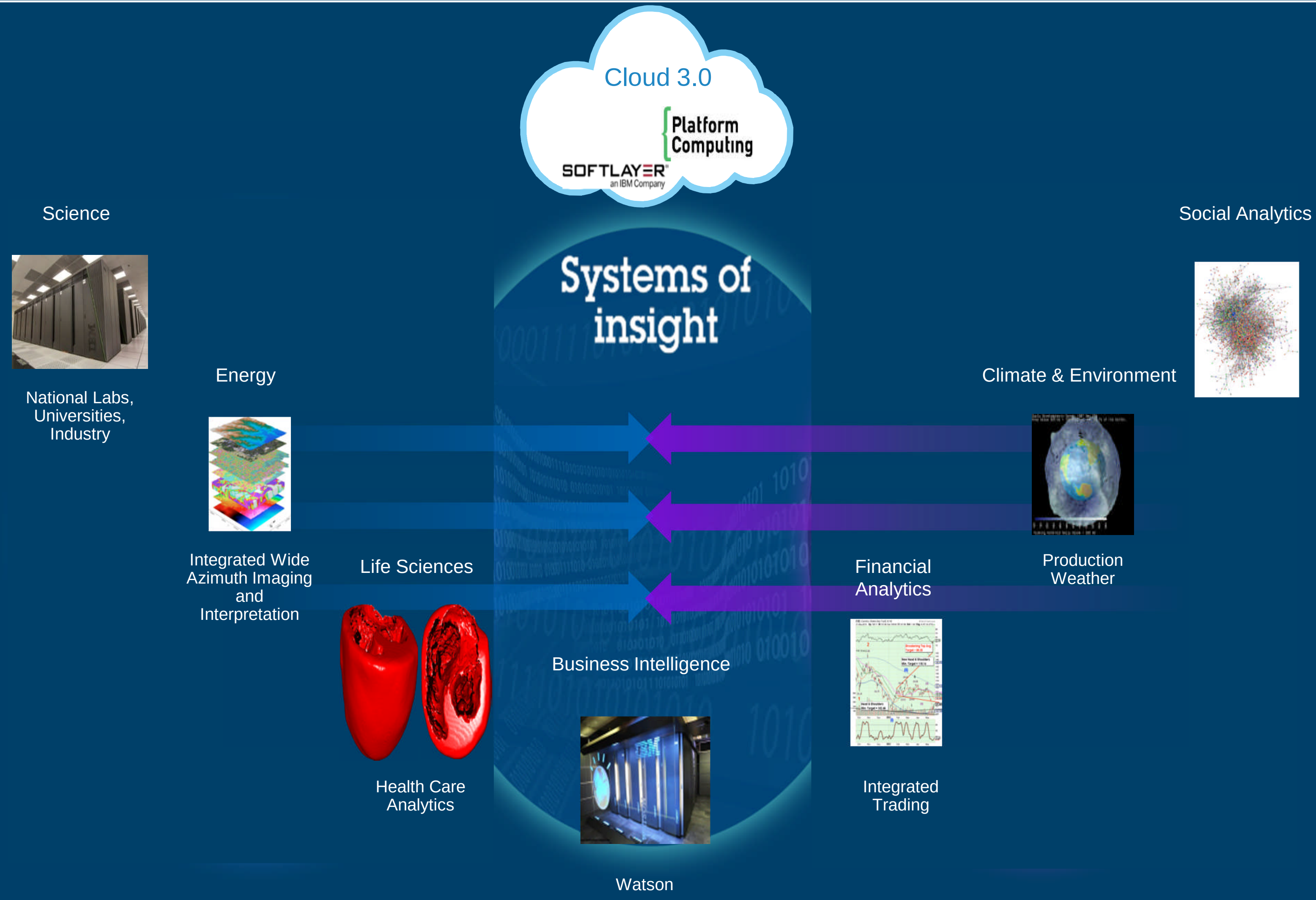
Back office
Legacy Systems

Cloud Meets Intelligence

Front Office
24/7 Mobile
Citizen Services

Data • Cloud • Engage • Watson

Systems of Insight are Important in Many Critical Economic Domains



Data • Cloud • Engage • Watson

Big Data Driving Common Requirements

High Performance Computing
- Structured data
- Exascale data sets
- Primarily scientific calculations

High Performance Analytics
- Unstructured data
- Giga- to petascale data
- Primarily data mining algorithms

Evolving requirements

Driver: **Doing more with models**
- Real-time decision making
- Uncertainty quantification
- Sensitivity analysis
- Metadata extraction

Driver: **Enhanced context Improves decision making**
- Incorporate modeling and simulation for better predictions
- Incorporate sensor data

Data Centric Systems

Architecture

Data Centric Design Principles

Massive data requirements drive a composable architecture for big data, complex analytics, modeling and simulation. The DCS architecture will appeal to segments experiencing an explosion of data and the associated computational demands

Principle 1: Minimize data motion

Principle 2: Compute Everywhere

Principle 3: Modularity

Principle 4: Application-driven design

Principle 5: Leverage OpenPower to Accelerate Innovation

MISSION: The OpenPOWER Consortium's mission is to **create an open ecosystem**, using the POWER Architecture to share expertise, investment and validated and compliant server-class IP **to serve the evolving needs of customers**

– Opening the architecture to give the industry the ability to innovate across the full Hardware and Software stack
  - Includes SOC design, Bus Specifications, Reference Designs, FW OS and Hypervisor Open Source

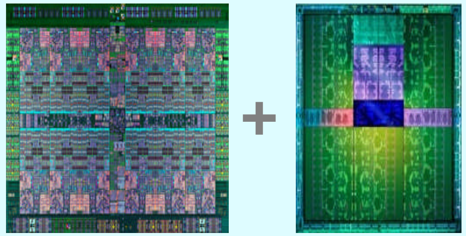
– Driving an expansion of enterprise class Hardware and Software stack for the data center

– Industry's first open system design for cloud data centers

– Building a vibrant and mutually beneficial ecosystem for POWER

Example:

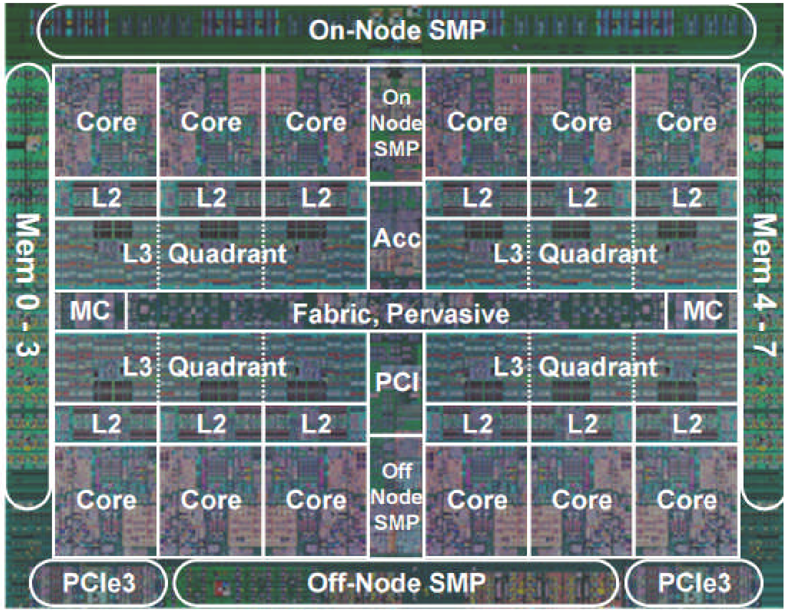
POWER CPU + NVIDIA GPU



Platinum Members

Altera, Google, Mellanox Technologies, NVIDIA, PowerCore, Ubuntu (Supported by Canonical), IBM, Micron, Samsung, Tyan

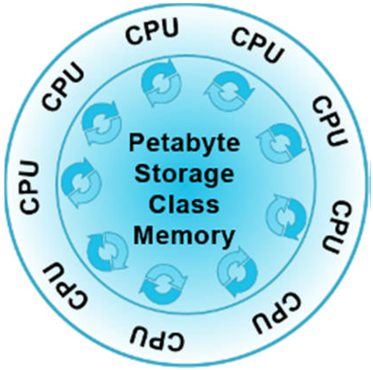
POWER8 Chip Overview



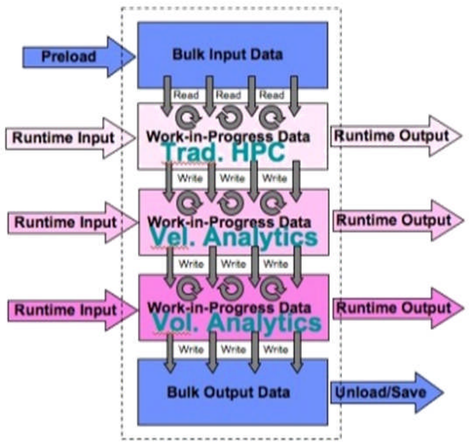
- Up to 2.5x socket perf vs. POWER7+
- 649mm² die size, 4.2B transistors
- 12 high-performance cores
- Large Caches
  - L2: 512KB private SRAM per core
  - L3: 96MB shared eDRAM w/ 8MB “fast access” partition per core
  - L4: Up to 128MB, located on memory buffer chips
- 4 High Throughput I/O interfaces
  - Memory, On-Node SMP, Off-Node SMP, PCIe Gen3
- CAPI: open infrastructure for off-chip, memory-coherent accelerators

From ISSCC 2014

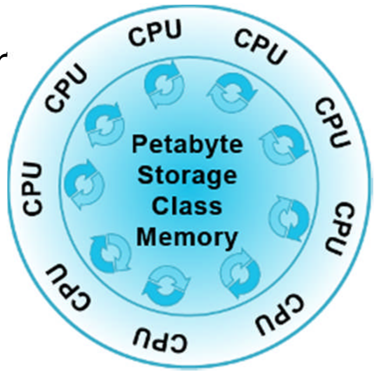
- **Commercially Viable System**
  - High Performance Analytics (HPA) and HPC markets
  - Scale from sub-rack to 100+ rack systems
  - Composed of cost effective components
  - Upgradeable and modular solutions
- **Holistic System Design**
  - Storage, network, memory, and processor architecture and design
  - Market demands, customer input, and workflow analysis influence design
- **Extensive Software Stack**
  - Compiler, tool chain, and ecosystem support
  - O/S, virtualization, system management
  - Evolutionary approach to retain prior investments
- **System Quality**
  - Reliability, availability, serviceability



New Data Centric Model



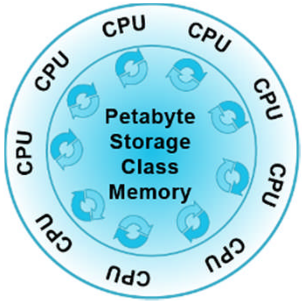
Software



Data Centric Model

- Exascale systems must address science and analytics mainstream
  - Broad range of users and skills
  - Range of computation requirements: dense compute, viz, etc
- Applications will be workflow driven
  - Workflows involve many different applications
  - Complex mix of algorithms,
  - Strong Capability Requirements
  - UQ, Sensitivity Analysis, Validation and Verification elements
  - Usability / Consumability
- Unique large scale attributes must be addressed
  - Reliability
  - Energy efficiency
- Underlying data scales pose significant challenge which complicates systems requirements
  - Convergence of analytics, modeling, simulation, visualization, and data management

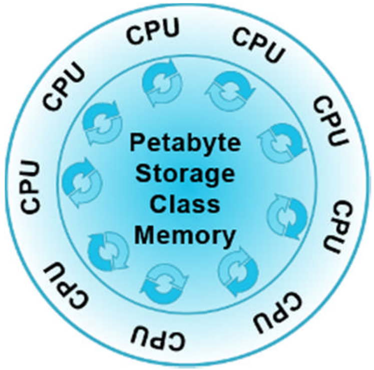
Role of the Programming Model in Future Systems



Data Centric Model

- Recent programming models focus is on node level complexity
- Computation and control are the primary drivers
  - Data and communication are secondary considerations
  - Little progress on system wide programming models
    - MPI, SHMEM, PGAS . . .
- Future, data centric systems will be workflow driven, with computation occurring at different levels of the memory and storage hierarchy
  - New and challenging problems for software and application developers
- Programming models must evolve to encompass all aspects of the data management and computation requiring a data-centric programming abstraction where:
  - Compute, data and communication are equal partners
  - High level abstraction will provide user means to reason about data and associated memory attributes
  - There will be co-existence with lower level programming models

Some Strategic Directions – With Pragmatic Choices

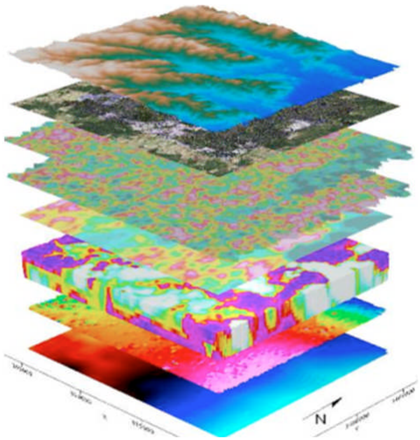


Data Centric Model

- Refine the node-level model and extend to support system wide elements
- Separate programming model concerns from language concerns
- Revisit holistic language approach – build on the 'endurance' of HPCS languages and evolve the concepts developed there:
  - Places, Asynchrony ..
- Investigate programming model concepts that are applicable across mainstream and HPC
- Focus on delivery through existing languages:
  - Libraries, runtimes, compilers and tools
- Strive for cross vendor support

Pursue open collaborative efforts – but in the context of integrated system development

Workflows




FXE (Currency Shares Euro Trust) NYSE
21-May-2012 Op 126.71 Hi 127.60 Lo 126.64 Cl 127.56 Vol 1.1M Chg +0.47 (+0.37%)
©StockCharts.com
Broadening Top Avg.
Target ~ 99.35
New Head & Shoulders
Min. Target = 118.14
Head & Shoulders
Min. Target = 102.46
FXE (Daily)
Oct
Nov
Dec
2012
Feb
Mar
Apr
May

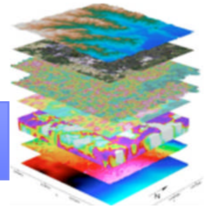
DCS Workflows: mixed compute capabilities required

IBM

Analytics Capability:

- Complex code
- Data Dependent Code Paths / Computation
- Lots of indirection / pointer chasing
- Often Memory System Latency Dependent
- C++ templated codes
- Limited opportunity for vectorization
- Limited scalability
- Limited threading opportunity

Oil and Gas



4-40 Racks

Reservoir

Seismic

Financial Analytics

2-20 Racks

Analytics

Value At Risk

All Source Analytics

1-5+ Racks

Graph Analytics

Image Analysis

Science

1-100’s Racks

Throughput

Capability

Massively Parallel Compute Capability:

- Simple kernels,
- Ops dominated (e.g. DGEMM, Linpack)
- Simple data access patterns.
- Can be preplanned for high performance.

Summary – Data Centric Systems

- The ability to generate, access, manage and operate on ever larger amounts and varieties of data is changing the nature of traditional technical computing. Technical Computing is evolving, the market is changing
- The extraction from Big Data of meaningful insights, enabling real time and predictive decision making across a range of industrial, commercial, scientific and government domains, requires similar computation techniques that have traditionally been characteristic of Technical Computing
  - The era of Cognitive Supercomputers:
    - Convergence in many future workflow requirements
      - Big Data driven analytics, modeling, visualization, and simulation
- A time of significant disruption - Data is emerging as the “critical” natural resource of this century
  - An optimized full system design and integration challenge
- Innovation in multiple areas, building off of an open ecosystem working with our OpenPOWER partners:
  - System architecture and design, modular building blocks
  - Hardware technology
  - Software enablement
  - Best in class resilience
- Development of DCS systems in close collaboration with technology providers and partners in multiple areas with focus on:
  - Workload-driven co-design
  - New hardware and software technologies
  - Programming models and tools
  - Open-source software