NASA Big Data Challenges: Ames Perspective

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Agenda

• Ames Overview
• Big Data Challenges for Users
• NASA Supercomputing – HECC project
• Big Data related projects @ NAS
• Occupants: ~1130 civil servants; ~2,100 contractors; 1,650 tenants; ~1344 summer students in 2015
• FY2016 Budget: ~$915M (including reimbursable/EUL)
• ~1,900 acres (400 acres security perimeter); 5M building ft²
• Airfield: ~9,000 and 8,000 ft runways
Partnerships at Ames

- Partnering with external organizations to access capabilities under collaborative agreements
- Entering into reimbursable agreements for partner access to NASA capabilities
- Expanding overall landscape of space activity (maximizing public and private sector growth)
- Spurring innovation

![Partnerships Diagram](image)
Core Competencies at Ames Today

- Air Traffic Management
- Entry Systems
- Space and Earth Sciences
- Intelligent/Adaptive Systems
- Cost-Effective Space Missions
- Aerosciences
- Astrobiology and Life Science
- Advanced Computing & IT Systems
Executive Order -- Creating a National Strategic Computing Initiative, July 2015

Objectives:

1. Accelerate delivery of a capable exascale computing system delivering approximately 100 times the performance of current systems across a range of applications.

2. Increase coherence between the technology base used for modeling and simulation and that used for data analytic computing.

3. Establish a viable path forward for future HPC systems even after the limits of current semiconductor technology are reached (the "post-Moore's Law era").

4. Increase the capacity and capability of an enduring national HPC ecosystem.

5. Develop an enduring public-private collaboration to ensure that the benefits of the research and development advances are shared among government, industrial, and academic sectors.
High-End Computing Capability (HECC)

**NASA’s Premier Supercomputer Center**

*Resources have broad mission impact across all of NASA’s Mission Directorates*

*Over 500 science & engineering projects with more than 1,500 users*

*(hosted by the NASA Advanced Supercomputing (NAS) Division at Ames)*

- **Pleiades** – 7.25 PF peak
  - Distributed memory cluster SGI Altix ICE
  - 246K-core; 11472 nodes; 4 Xeon generations
  - #15 (#7 in US) on TOP500; #9 in HPCG list (06/2016)

- **Specialized Hardware**
  - *Endeavour:* shared memory nodes – 1024 core 4 TB & 512 core 2 TB
  - *GPGPU nodes:* 64 nodes  NVIDIA Tesla K40
  - *Xeon Phi:* 20 many-integrated core nodes
  - *NVIDIA DGX-1:* 8 Tesla Pascale GPUs for machine learning

- **Storage:** ~30 PB disk; ~500 PB tape capacity

- **Networking:** 10 Gb/s external peering
Integrated Spiral Support for MS&A

Develop and deliver the most productive integrated supercomputing environment in the world, enabling NASA to extend technology, expand knowledge, and explore the universe.

Outcome: Dramatically enhanced understanding and insight, accelerated science and engineering, and increased mission safety and performance.

Scientists and engineers plan computational analyses, selecting the best-suited codes to address NASA’s complex mission challenges.

NAS software experts utilize tools to parallelize and optimize codes, dramatically increasing simulation performance while decreasing turn-around time.

NAS visualization experts apply advanced data analysis and rendering techniques to help users explore and understand large, complex computational results.

NAS support staff help users to productively utilize NASA’s supercomputing environment (hardware, software, networks, and storage) to rapidly solve large computational problems.

NASA Mission Challenges

Performance Optimization

Data Analysis and Visualization

Computational Modeling, Simulation, & Analysis
Big Data Challenges for NASA Users

NASA supports enormous collections of big data sets:

**Observational Data**
- Estimate 100+ active satellites producing 50PBs per year

**Model Data**
- NAS has 30 PBs of online storage - MITGcm run produced > 3PBs

**Experimental Data**
- Wind tunnel tests projected to produce 100 TBs per test

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**Data Discovery**
- finding what data is available and where
  - Indexing, federated metadata service and semantic reasoning

**Data management**
- transferring very large data sets from archives to computational resources
  - Increased WAN bandwidth
  - Fault tolerant and resilient hardware/software infrastructure

**Tools/models/algorithms**
- developing analytics/analysis software at scale
  - Mechanisms for sharing software to reduce duplication

**Analysis workflow**
- increasing complexity of processing pipelines have multiple components requiring heterogeneous resources
  - Software for workflow description and management to tie all components together and facilitate re-use

**Analysis/Analytics infrastructure**
- inadequacy of available resources
  - I/O infrastructure
  - Large memory spaces for in-core analysis
  - Support for the heterogeneous resources in an integrated environment: distributed memory & shared memory systems, hadoop cluster, accelerators, FPGAs etc.

**Data Dissemination**
- difficult to share knowledge across a wider community
  - Support for dissemination and sharing of code, data products, results, etc.....

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Fun Fact: The term “Big Data” was first used by Michael Cox & David Ellsworth of the NAS Division at Ames in their paper: “Visualizing flow around an airframe” Visualization 97, Phoenix AZ.
- Biggest data set considered 7.5 GB; high-end analysis machines had less than 1GB memory

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Merging HPC and Data Analysis @ NAS: Data Intensive Supercomputing Environment

- **Analytics/Analysis Platforms**
  - Optimized for analytics/analysis
    - Visualization engines
    - Accelerators
    - FPGAs
  - Tools for data/workflow management; machine learning

- **Data Resources**
  - User & community Datasets
  - Shared across platforms

- **External Data Resources**
  - Cloud-based data servers, web servers

- **Large-scale Compute**
  - Pleiades
  - Endeavour
  - Optimized for large-scale simulation and analysis

- **Collaboration / User Portals**
  - Cloud-based data servers, web servers

- **High-speed WAN connection**

- **Data Repositories**
  - Experimental sources (labs, wind tunnels, etc.)
Big Data Related Projects @ NAS

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<th>Applications</th>
<th>Mining network flows for cyber-security risk assessment</th>
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<td>Tree cover classification for continental US</td>
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<th>Analytics</th>
<th>Machine learning algorithms using GPUs/Xeon Phis/FPGAs</th>
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<td>Large scale analytics on distributed and shared memory architectures</td>
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<th>Support Software</th>
<th>Collaboration platform for scientists (NASA Earth eXchange - NEX)</th>
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<td>Ontology-based data search environment for observational data</td>
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<td>Data tagging for security and data discovery</td>
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<th>Optimization of Lustre calls to improve QOS for applications</th>
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<td>Support for caching using SSDs</td>
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<td>- Lustre - target metadata and/or user access</td>
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<td>- Analysis of relationships for I/O�</td>
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<td>- RDMA - RDMA over IB</td>
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<th>Hardware Infrastructure</th>
<th>SSDs for I/O optimization – linux-based block device software</th>
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<td>Specialized clusters for data analytics</td>
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<td>- Xeon PHI, GPU, FPGA, Hadoop</td>
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Summary

- NASA has an abundance of big data: Observational, Simulation and Experimental
- NASA Big Data users face many challenges across the full workflow for analyzing such data:
  - Data discovery, data access & management, analytics/analysis algorithms and software, infrastructure, data dissemination
- Ames an the ideal location for merging HPC and Data Analytics since it hosts the Agency’s premier supercomputer
- Several of the Ames projects are aimed at filling the gaps in the integrated software/hardware environment for Big Data Analysis
Questions?
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Backup Slides
SSD Support for Data Analysis

**Goal:** Assess the benefits of utilizing Solid State Devices (SSDs) for handling Big Data in the HPC environment at NAS

**Hardware:**
- Hyperwall: 128 Intel NVMe P3500 2 TB medium-durability SSDs
- Lustre file system: 6 OSSs augmented with Intel NVMe P3600 1.6 TB high-durability SSDs

**Focus research areas** – utilize SSDs for:
- Caching for Lustre-based global file system (in collaboration with Intel)
  - Metadata on Lustre OSS
  - Data for specific job id or user
  - Sequential streams
- Caching for Applications on hyperwall - SSDs used
  - As local disk drives
  - As shared file system over 128 hyperwall nodes using RDMA access to remote SSD over Infiniband
NAS Situational Awareness System (NSAS)

Goal: to identify actionable security events that require human or automated mitigation based on an analysis of the mountain of network data that flows in and out of NAS.

• Data sources: Bi-directional network flow data, intrusion detection data, log data, Nessus vulnerability scanner data, Domain Name Server requests, etc.

• Analyst dashboard to keep track of and deep dive into information

• Utilizing data analytics and machine learning techniques on flow data along with user’s and system network behavior profiles to detect:
  • phishing attacks
  • Signs of possible exfiltration
  • Advanced persistent threats (APTs)
**Data Tagging for Security and Discovery (DTSD)**

**Goal:** to develop base requirements and prototype a data-centric approach to tag data so as to provide

- Information for protecting the data from a security perspective
- Information that describes the data from a semantic perspective.

- Security restrictions embodied in the data tags will allow NASA systems that handle the data to automatically
  - Enforce access to the data based on the tag
  - Enforce flow restrictions based on the tag, e.g., not releasing unencrypted ITAR data to Internet

- Semantic information associated with the data tags will describe the characteristics of the data
  - Support semantics-based data discovery tool
ODISEES & OlyMPUS

Goal: Ontology-based interactive framework for discovery of Earth science data
LaRC (Science Directorate), GSFC (NCCS), and ARC (NAS)

- **ODISEES**
  - enables parameter-level search with little knowledge about the data
  - extensible to address additional datasets by extending the ontology
  - implements a flexible architecture that can be adapted for other domains

- **OlyMPUS**: extends ODISEES with a metadata provisioning portal for data providers along with enhanced search capabilities for data consumers