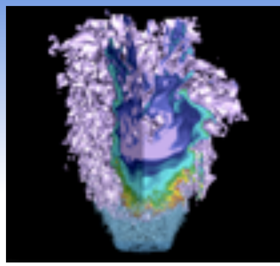
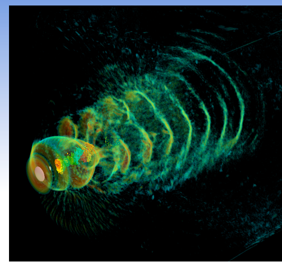
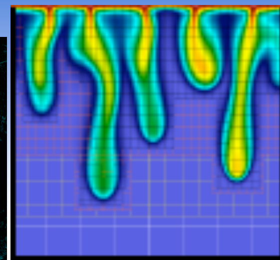
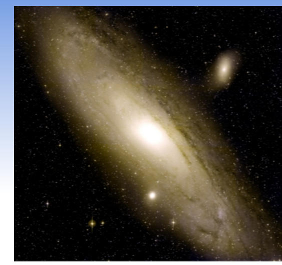
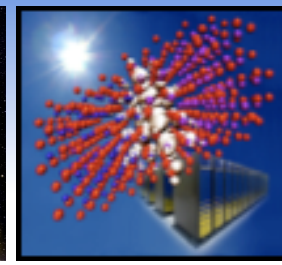
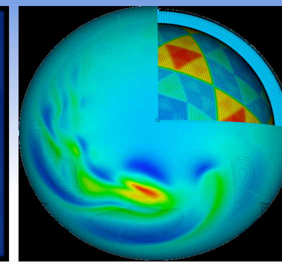

Magellan Status Report

A Test Bed to Explore Cloud Computing for Science

Shane Canon (Berkeley Lab)
Susan Coghlan (Argonne)

ASCAC
March 22, 2011

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Outline

- Overview of the Magellan Project
- Overview of Cloud Computing
- Overview of the distributed Testbed
- Lines of Inquiry (early findings)
- Conclusions

Magellan

Exploring Cloud Computing

Co-located at two DOE-SC Facilities

- **Argonne Leadership Computing Facility (ALCF)**
- **National Energy Research Scientific Computing Center (NERSC)**
- **Funded by DOE under the American Recovery and Reinvestment Act (ARRA)**

RECOVERY.GOV

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Magellan Scope

- **Mission**
  - Determine the appropriate role for private cloud computing for DOE/SC midrange workloads
- **Approach**
  - Deploy a test bed to investigate the use of cloud computing for mid-range scientific computing
  - Evaluate the effectiveness of cloud computing models for a wide spectrum of DOE/SC applications

Magellan Timeline

Activity	Argonne	NERSC
Project Start	Sep 2009	
Core System Deployed	Jan 2010 – Feb 2010	Dec 2009 – Jan 2010
User Access	Mar 2010 (Cloud)	April 2010 (Cluster) Oct 2010 (Cloud)
Acceptance	Feb 2010	May 2010
Hadoop User Access	Dec 2010	May 2010
Joint Demo (MG-RAST)	June 2010	
Nimbus Deployed	Jun 2010	N/A
OpenStack Deployed	Dec 2010	N/A
Eucalyptus 2.0 Deployed	Jan 2011	Feb 2011
ANI research projects on	Apr 2011 – Dec 2011	
Magellan cloud ends	Sep 2011	
ANI 100G active	Oct 2011	
Magellan ANI ends	Dec 2011	

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What is a Cloud? Definition

According to the National Institute of Standards & Technology (NIST)…

- *Resource pooling.* Computing resources are pooled to serve multiple consumers.
- *Broad network access.* Capabilities are available over the network.
- *Measured Service.* Resource usage is monitored and reported for transparency.
- *Rapid elasticity.* Capabilities can be rapidly scaled out and in (pay-as-you-go)
- *On-demand self-service.* Consumers can provision capabilities automatically.

What is a cloud?
Cloud Models

<u>Hardware focus</u>

<u>Software focus</u>

Infrastructure as a Service (IaaS)

Provisions processing, storage, networks, and other fundamental computing resources. Consumer can deploy and run arbitrary software, including OS.

- Amazon EC2
- RackSpace

Platform as a Service (PaaS)

Provides programming languages and tools. Consumer applications created with provider's tools.

- Microsoft Azure
- Google AppEngine

Software as a Service (SaaS)

Provides applications on a cloud infrastructure. Consumer provides data.

- Salesforce.com
- Google Docs
- Application Portals

- **Opaque infrastructure**
- **Capacity >> Demand**
- **Available for rent**
- **Self-service**

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Magellan Distributed Testbed

Distributed Testbed Summary

- **Compute**
  - IBM iDataPlex: 504 nodes at Argonne and 720 nodes at NERSC
- **Storage**
  - Mix of disk storage, archival storage, and two classes of flash storage
- **Architected for flexibility and to support research**
  - Similar to high-end hardware in HPC clusters
  - Suitable for scientific applications
  - Included some specialized hardware such as GPUs

Argonne Magellan Hardware

Compute Servers

504 Compute Servers
Nehalem Dual quad-core 2.66GHz
24GB RAM, 500GB Disk
Totals
4032 Cores, 40TF Peak
12TB Memory, 250TB Disk

Active Storage Servers

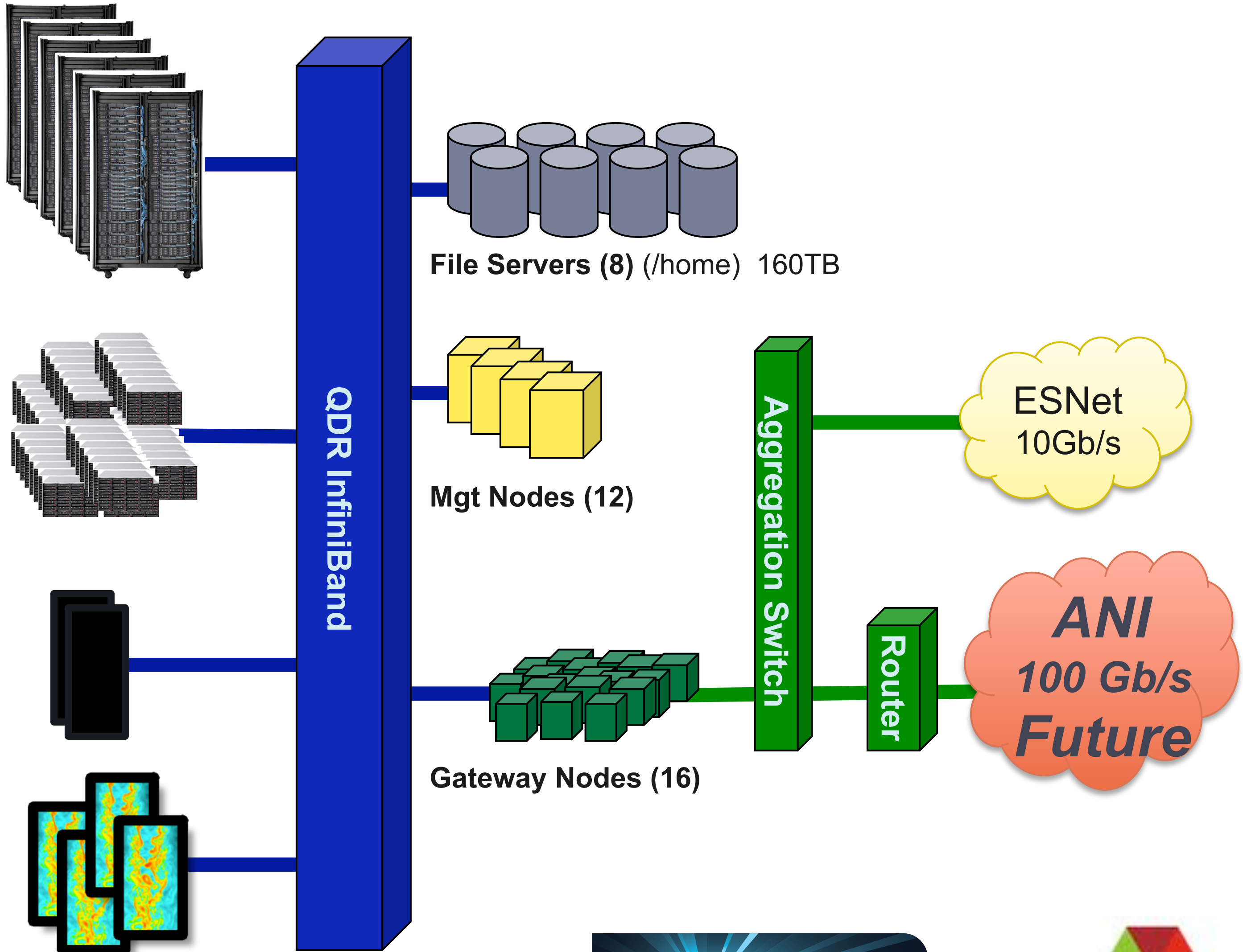
200 Compute/Storage Nodes
40TB SSD Storage
9.6TB Memory
1.6PB SATA Storage

Big Memory Servers

15 Servers
15TB Memory, 15TB Disk

GPU Servers

133 GPU Servers
8.5TB Memory, 133TB Disk
266 Nvidia 2070 GPU cards



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NERSC Magellan Hardware

Compute Servers

720Compute Servers
Nehalem Dual quad-core 2.66GHz
24GB RAM, 500GB Disk
Totals
5760 Cores, 40TF Peak
21TB Memory, 400 TB Disk

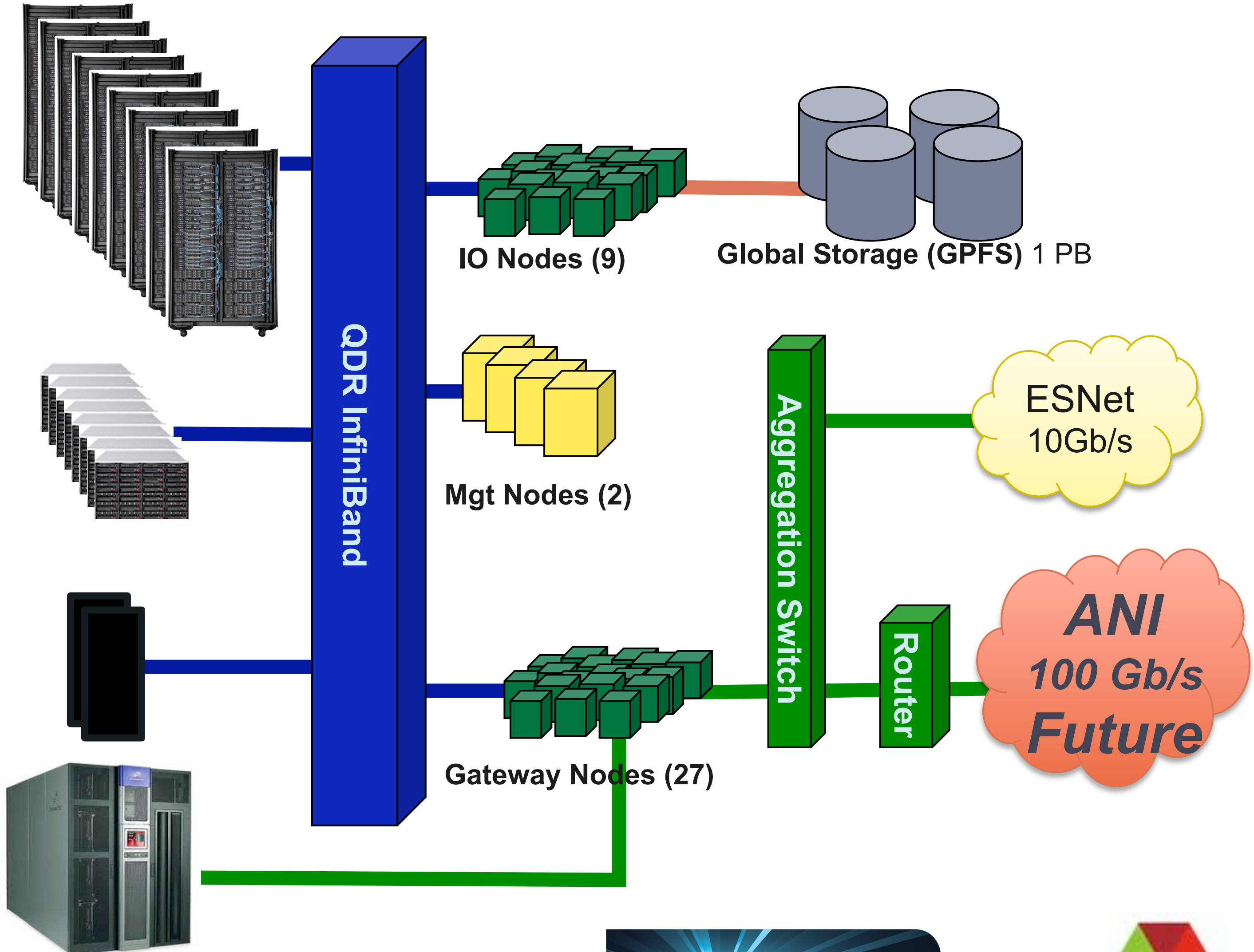
Flash Storage Servers

10 Compute/Storage Nodes
8TB High-Performance FLASH
20 GB/s Bandwidth

Big Memory Servers

2 Servers
2TB Memory

Archival Storage



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Early Findings
Based on progress to date

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Magellan Research Agenda and Lines of Inquiry

- Are the *open source* cloud software stacks ready for DOE HPC science?
- Can DOE cyber security requirements be met within a cloud?
- Are the new cloud programming models useful for scientific computing?
- Can DOE HPC applications run efficiently in the cloud? What applications are suitable for clouds?
- How usable are cloud environments for scientific applications?
- When is it cost effective to run DOE HPC science in a cloud?
- What are the ramifications for data intensive computing?

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Cloud Software Stacks

Are the *open source* cloud software stacks ready for DOE HPC science?

- **DOE HPC cluster software stacks**
  - **Mature**
  - **Stable**
  - **Scalable**
  - **Depth and breath in tool availability**
  - **Integrated I/O**
  - **High performance**
- **What about the IaaS cloud software stacks?**

Cloud Software Stacks Evaluation Process

- **Evaluated the top *open source* cloud software stacks**
  - **All but one were deployed on Magellan**
    - **OpenNebula evaluation was based on staff code analysis and documentation review as well as evaluations run at CERN and Fermi**
  - **Evaluation done by staff + special users**
    - **Test suite with stress tests, scaling tests, etc.**
    - **Code analysis, documentation review**
    - **Scientific users running regular workloads and stress test workloads**

Cloud Software Stacks Evaluation Criteria

- Evaluation criteria included
  - Feature Set
  - Stability
  - Infrastructure Scalability
  - Usability
  - Manageability
  - Sustainability
- Evaluation did not include performance
  - Except to note I/O performance challenges

Cloud Software Stacks Evaluation Results

Evaluation Area	Eucalyptus 1.6.2	Eucalyptus 2.0	OpenStack	Nimbus	OpenNebula
Feature Set					
Stability				External	External
Infrastructure Scalability					
Usability				External	
Manageability				External	
Sustainability					

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Cloud Software Stacks
Early Findings and Next Steps

Early Findings:

- Significant improvements in stability and scaling in past year
  - Not production ready yet
- Accounting, monitoring, logging, debugging not at necessary levels
- Networking is complicated and challenging to get right
  - Current architecture bottlenecks performance and scalability

Next Steps:

- Scalability – implement highly distributed infrastructure, integrate new data storage and retrieval module
- Performance – utilize Infiniband for I/O and distributed infrastructure
- Features – provide Infiniband access to users

DOE Cyber Security in the Cloud

Can DOE cyber security requirements be met within a cloud?

- **Current cyber security frameworks, architectures and mitigating controls were developed for onsite traditional HPC cluster installations**
- **Some parallels between clusters and clouds**
- **But cloud systems provide unique challenges beyond the traditional HPC clusters**
  - **These require new approaches**
- **Biggest cyber security risks are with the IaaS cloud model**
  - **Much of this work was required to deploy the testbeds**

IaaS Cyber Security Overview DOE Private Cloud

Defined Risk Areas	Defined Threats	Defined Mitigations
Machine Definition and Management	• User owned, managed, shared Virtual Machine Images (VMI). • Malicious images shared with users. • Encrypted VMIs are opaque to sites	• DOE provides secured and approved machine images as a base for user customization. • DOE audits user supplied images
System Instance Configuration Management	• Users with no system administration experience with full root privileges. • Relying on users to comply with cyber security best practices and DOE cyber security requirements • System level audit data disappears with exit of instance	• User education for cyber sec and system administration best practices • Limit root access for users • Limited system and network based auditing for intrusion and anomaly detection • Develop forensic analysis tools • Develop auditing tools for VMs
Network Authorization and Management	• Users manage the firewall conduits for their machines. • Potential malicious network activity generated by/from virtual machine instances.	• File and system integrity tools and network access controls implemented to prevent virtual machine cross-talk • Constant scanning for bad accounts, bad passwords, open ports

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Cyber Security
Early Findings and Next Steps

Early Findings:

- Trust issues
  - User provided VMIs uploaded and shared
  - Root privileges by untrained users opens the door for mistakes
- Network separation is complicated
  - Due to the ephemeral nature of virtual machine instances, an effective Intrusion Detection System (IDS) strategy challenging
- Fundamental threats are the same, security controls are different

Next Steps:

- Can hypervisors play new roles in security monitoring and auditing?
- What sort of forensic analysis could be done on virtual machine instances?

Programming Models

Are the new cloud programming models useful for scientific computing?

- Platform as a Service models have appeared that provide their own Model
  - Parallel processing of large data sets
  - Examples include Hadoop and Azure
- Common constructs
  - MapReduce: map and reduce functions
  - Queues, Tabular Storage, Blob storage

Windows Azure
Microsoft's Cloud Services Platform

Programming Models
Hadoop for Bioinformatics

- **Bioinformatics using MapReduce**
  - Researchers at the Joint Genome Institute have developed over 12 applications written in Hadoop and Pig
  - Constructing end-to-end pipeline to perform gene-centric data analysis of large metagenome data sets
  - Complex operations that generate parallel execution can be described in a few dozen lines of Pig

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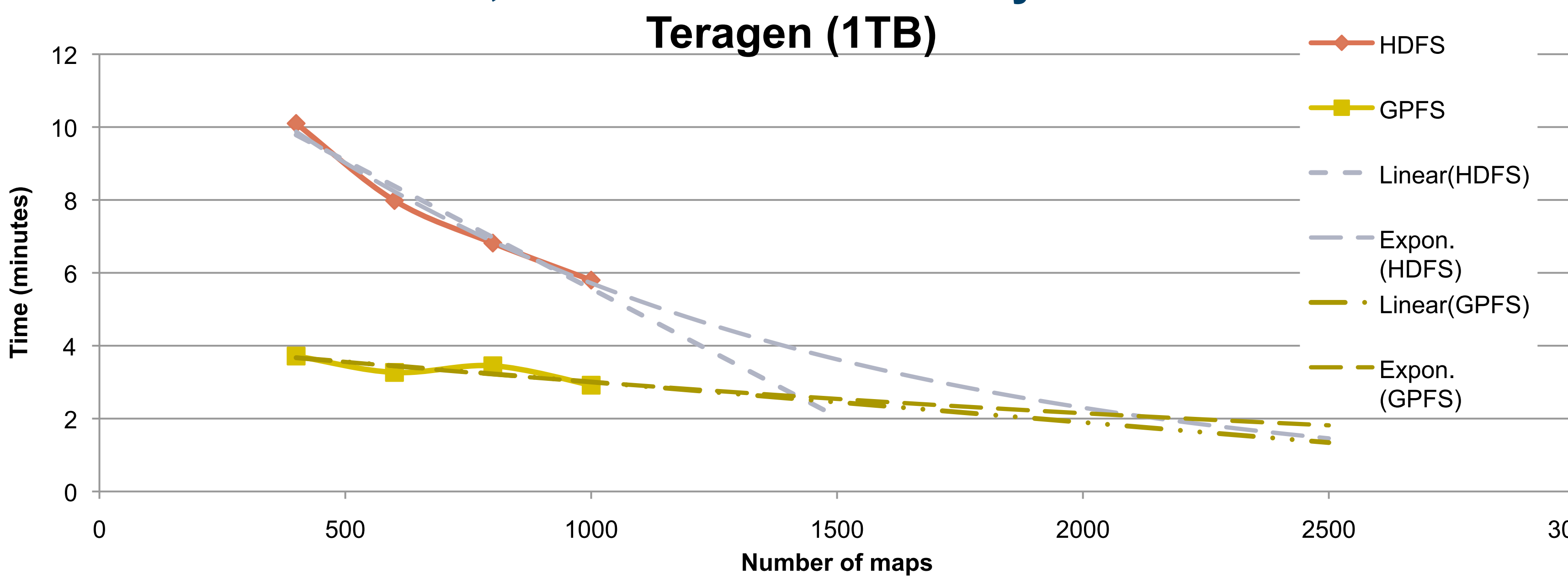
Programming Models
Evaluating Hadoop for Science

- **Benchmarks such as Teragen and Terasort**
  - evaluation of different file systems and storage options
- **Ported applications to use Hadoop Streaming**
  - Bioinformatics, Climate100 data analysis



Programming Models
Early Findings and Next Steps

Early Findings:

- New models are useful for addressing data intensive computing
- Hides complexity of fault tolerance
- High-level languages can improve productivity
- Challenge in casting algorithms and data formats into the new model

Next Steps:

- Evaluate scaling of Hadoop and HDFS
- Evaluate Hadoop with alternate file systems
- Identify other applications that can benefit from these programming models

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Application Performance

Can DOE HPC applications run efficiently in the cloud? What applications are suitable for clouds?

- Can parallel applications run effectively in virtualized environments?
- How critical are high-performance interconnects that are available in current HPC systems?
- Are some applications better suited than others?

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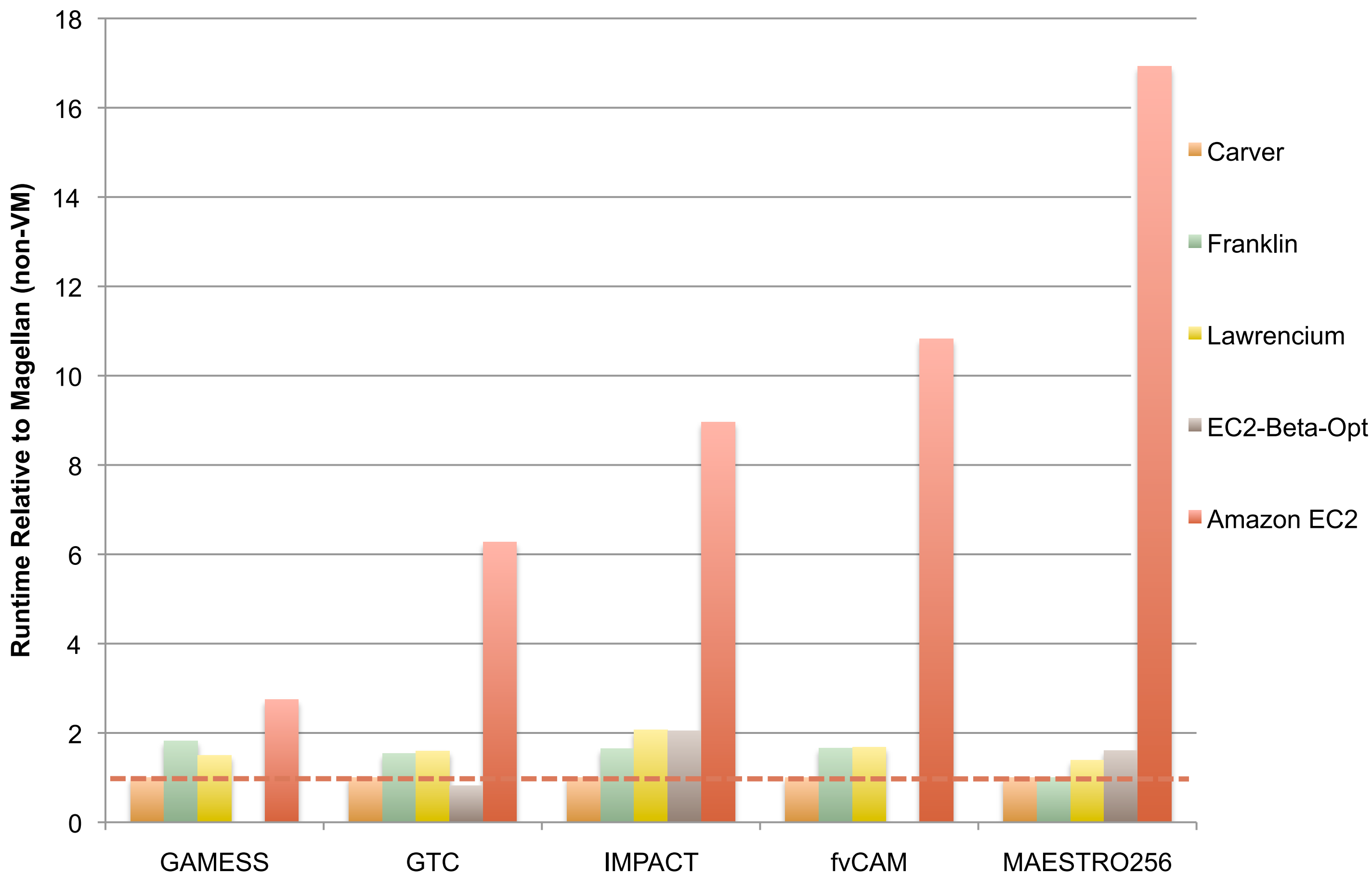
Application Performance Application Benchmarks



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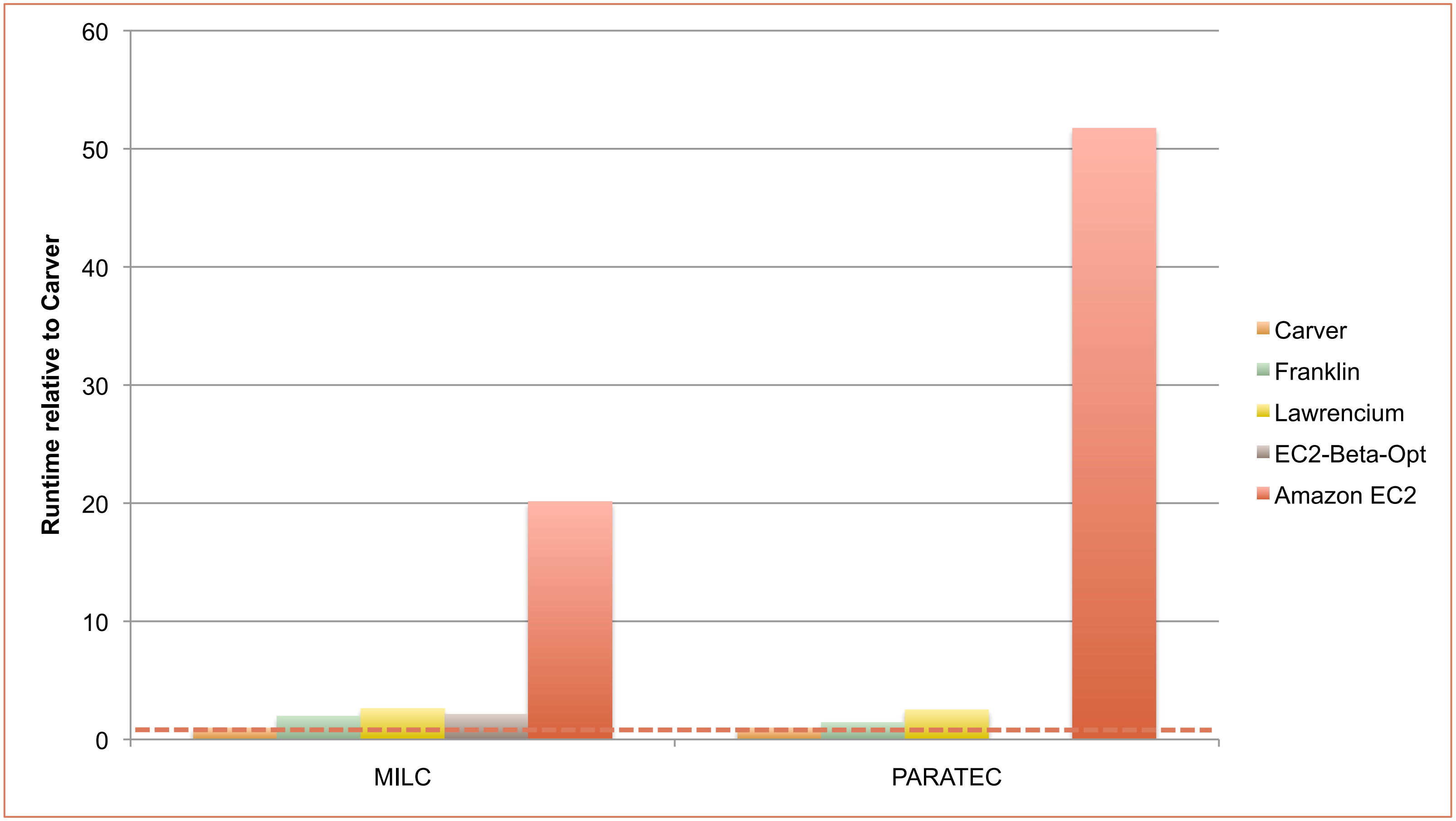
Application Performance
Application Benchmarks



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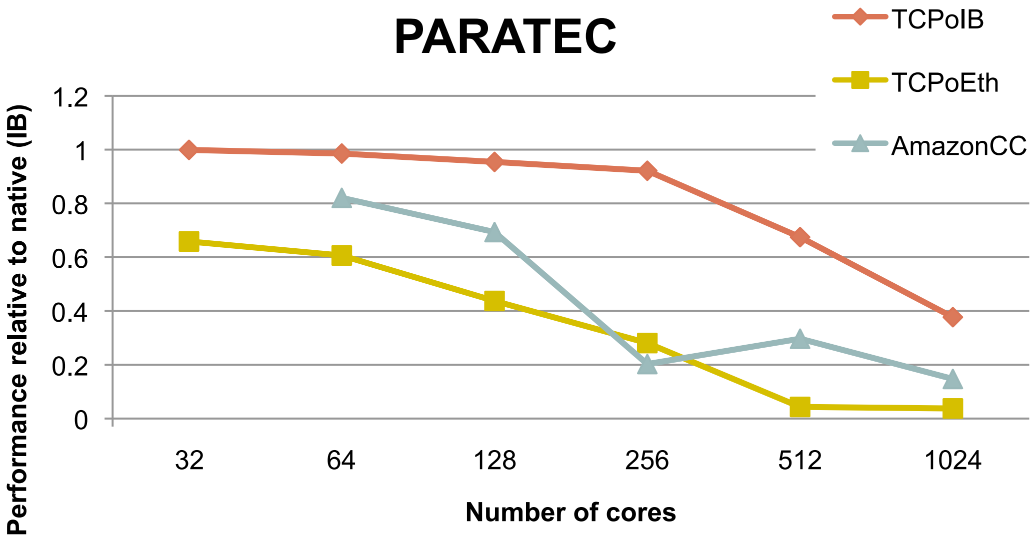
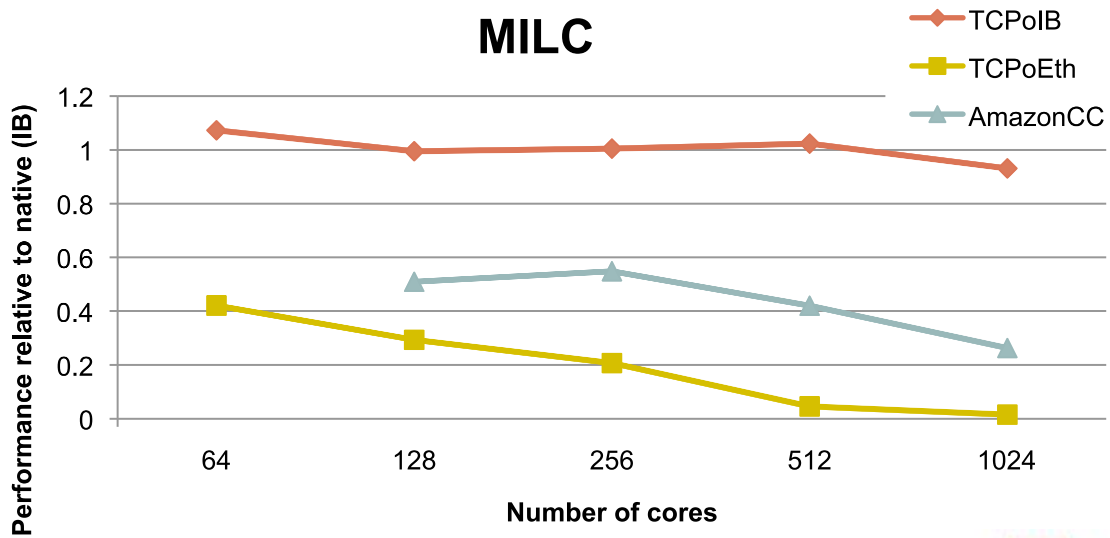
Application Performance
Application Scaling





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Application Performance
Early Findings and Next Steps

Early Findings:

- Benchmarking efforts demonstrate the importance of high-performance networks to tightly coupled applications
- Commercial offerings optimized for web applications are poorly suited for even small (64 core) MPI applications

Next Steps:

- Analyze price-performance in the cloud compared with traditional HPC centers
- Analyze workload characteristics for applications running on various mid-range systems
- Examine how performance compares at larger scales
- Gathering additional data running in commercial clouds

User Experience

How usable are cloud environments for scientific applications?

- How difficult is it to port applications to Cloud environments?
- How should users manage their data and workflow?

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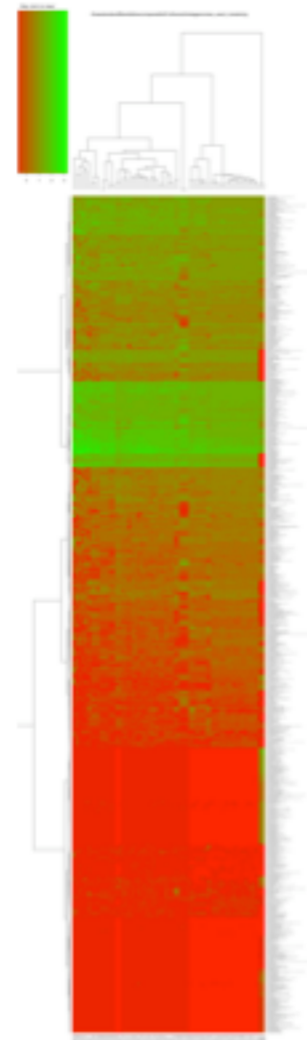
User Experience
User Community

- **Magellan has a broad set of users**
  - **Various domains and projects (MG-RAST, JGI, STAR, LIGO, ATLAS, Energy+)**
  - **Various workflow styles (serial, parallel) and requirements**
  - **Recruiting new projects to run on cloud environments**
- **Three use cases discussed today**
  - **MG-RAST - Deep Soil sequencing**
  - **STAR – Streamed real-time data analysis**
  - **Joint Genome Institute**

User Experience
MG-RAST: Deep Soil Analysis



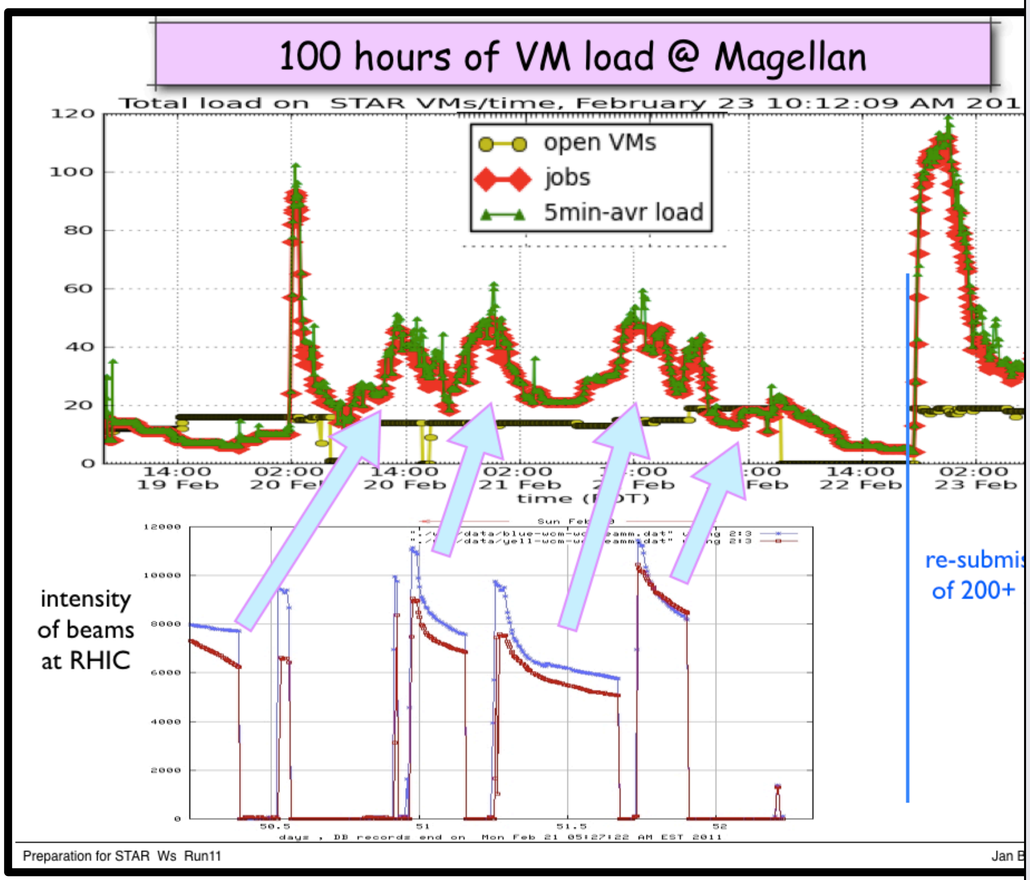
Background: Genome sequencing of two soil samples pulled from two plots at the Rothamsted Research Center in the UK.

Goal: Understand impact of long-term plant influence (rhizosphere) on microbial community composition and function.

Used: 150 nodes for one week to perform one run (1/30 of work planned)

Observations: MG-RAST application is well suited to clouds. User was already familiar with the Cloud

Early Science - STAR



Details

- STAR performed Real-time analysis of data coming from RHIC at BNL
- First time data was analyzed in real-time to a high degree
- Leveraged existing OS image from NERSC system
- Used 20 8-core instances to keep pace with data from the detector
- STAR is pleased with the results

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User Experience
JGI on Magellan

- **Magellan resources made available to JGI to facilitate disaster recovery efforts**
  - Used up to 120 nodes
  - Linked sites over layer-2 bridge across ESnet SDN link
  - Manual provisioning took ~1 week including learning curve
  - Operation was transparent to JGI users
- **Practical demonstration of HaaS**
  - Reserve capacity can be quickly provisioned (but automation is highly desirable)
  - Magellan + ESnet were able to support remote departmental mission computing

User Experience
Early Findings and Next Steps

Early Findings:

- IaaS clouds can require significant system administration expertise and can be difficult to debug due to lack of tools.
- Image creation and management are a challenge
- I/O performance is poor
- Workflow and data management are problematic and time consuming
- Projects were eventually successful, simplifying further use of cloud computing

Next Steps:

- Gather additional use cases
- Deploy fully configured virtual clusters
- Explore other models to deliver customized environments
- Improve tools to simplify deploying private virtual clusters

Conclusions
Cloud Potential

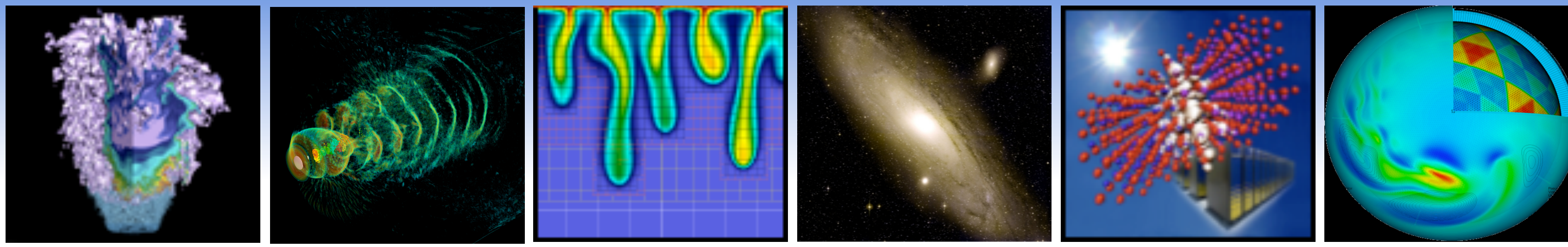
- Enables rapid prototyping at a larger scale than the desktop without the time consuming requirement for an allocation and account
  - DOE cyber security requirements may block this benefit
- Supports tailored software stacks
- Supports different levels of service
- Supports surge computing
- Facilitates resource pooling
  - But DOE HPC clusters are frequently saturated

Conclusions
Cloud Challenges

- Open source cloud software stacks are still immature, but evolving rapidly
- Current MPI-based application performance can be poor even at small scales due to interconnect
- Cloud programming models can be difficult to apply to legacy applications
- New security mechanisms and potentially policies are required for ensuring security in the cloud

Conclusions
Next Steps

- Characterize mid-range applications for suitability to cloud model
- Cost analysis of cloud computing for different workloads
- Finish performance analysis including IO performance in cloud environments
- Support the Advanced Networking Initiative (ANI) research projects
- Final Magellan Project report



Thank you!

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