The Fermilab HEPCloud Facility: Adding **60,000** Cores for Science!

Burt Holzman, for the Fermilab HEPCloud Team

HTCondor Week 2016

May 19, 2016
My last Condor Week talk …

Condor in the CMS Experiment

Burt Holzman
Condor Week 2009
April 21, 2009
The Fermilab Facility: Today

Traditional Facility

- Non-preemptible
  - Opportunistic Local
  - Dedicated Local

- Preemptible
  - Opportunistic Local

User Submitter

Gateway

Scheduler

physical resources
Drivers for Evolving the Facility

- HEP computing needs will be 10-100x current capacity
  - Two new programs coming online (DUNE, High-Luminosity LHC), while new physics search programs (Mu2e) will be operating

- Scale of industry at or above R&D
  - Commercial clouds offering increased value for decreased cost compared to the past
Drivers for Evolving the Facility: Elasticity

- Usage is not steady-state
- Computing schedules driven by real-world considerations (detector, accelerator, …) but also ingenuity – this is research and development of cutting-edge science

<table>
<thead>
<tr>
<th>Year</th>
<th>Actual</th>
<th>Request</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>90M</td>
<td></td>
</tr>
<tr>
<td>FY16</td>
<td>120M</td>
<td>147M</td>
</tr>
<tr>
<td>FY17</td>
<td>148M</td>
<td>187M</td>
</tr>
<tr>
<td>FY18</td>
<td>171M</td>
<td>223M</td>
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NOvA jobs in the queue at FNAL

Facility size
Classes of Resource Providers

**Grid**
- Virtual Organizations (VOs) of users trusted by Grid sites
- VO allocations ➔ Pledges
  - Unused allocations: opportunistic resources

“Things you borrow”

**Cloud**
- Community Clouds - Similar trust federation to Grids
- Commercial Clouds - Pay-As-You-Go model
  - Strongly accounted
  - Near-infinite capacity ➔ Elasticity
  - Spot price market

“Things you rent”

**HPC**
- Researchers granted access to HPC installations
- Peer review committees award Allocations
  - Awards model designed for individual PIs rather than large collaborations

“Things you are given”
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Fermilab HEPCloud Facility

- Provision commercial cloud resources in addition to physically owned resources
- Transparent to the user
- Pilot project / R&D phase
HEPCloud Collaborations

- Engage in collaboration to leverage tools and experience whenever possible

- **HTCondor** – common provisioning interface
  - Foundation underneath **glideinWMS**
  - Grid technologies – Open Science Grid, Worldwide LHC Computing Grid
  - Preparing communities for distributed computing

- CMS – collaborative knowledge and tools, cloud-capable workflows

- BNL and ATLAS – engaged in next HEPCloud phase
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- HTCondor – common provisioning interface, Foundation underneath glideinWMS, Panda
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Fermilab HEPCloud: expanding to the Cloud

• Where to start?
  – Market leader: Amazon Web Services (AWS)
AWS topology – three US data centers ("regions")

Each Data Center has 3+ different “zones”
Each zone has different “instance types”
(analogous to different types of physical machines)
Pricing: using the AWS “Spot Market”

- AWS has a fixed price per hour (rates vary by machine type)
- Excess capacity is released to the free (“spot”) market at a fraction of the on-demand price
  - End user chooses a bid price
  - If (market price < bid), you pay only market price for the provisioned resource
    - If (market price > bid), you don’t get the resource
  - If the price fluctuates while you are running and the market price exceeds your original bid price, you may get kicked off the node (with a 2 minute warning!)
Some HEPCloud Use Cases

**NoVA Processing**
Processing the 2014/2015 dataset
16 4-day “campaigns” over one year
Demonstrates stability, availability, cost-effectiveness
Received AWS academic grant

**Dark Energy Survey - Gravitational Waves**
Search for optical counterpart of events detected by LIGO/VIRGO gravitational wave detectors (FNAL LDRD)
Modest CPU needs, but want 5-10 hour turnaround
Burst activity driven entirely by physical phenomena (gravitational wave events are transient)
Rapid provisioning to peak

**CMS Monte Carlo Simulation**
Generation (and detector simulation, digitization, reconstruction) of simulated events in time for Moriond conference
56000 compute cores, steady-state
Demonstrates scalability
Received AWS academic grant
Neutrinos rarely interact with matter. When a neutrino smashes into an atom in the NOvA detector in Minnesota, it creates distinctive particle tracks. Scientists explore these particle interactions to better understand the transition of muon neutrinos into electron neutrinos. The experiment also helps answer important scientific questions about neutrino masses, neutrino oscillations, and the role neutrinos played in the early universe.
NOvA Use Case

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![Graph showing data processing and support](image-url)

Supported by FNAL and KISTI

First proof-of-concept from Oct 2014 – small run of NOvA jobs on AWS
NOvA Use Case – running at 4k cores

- Added support for general-purpose data-handling tools (SAM, IFDH, F-FTS) for AWS Storage and used them to stage both input datasets and job outputs
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CMS: Large Hadron Collider Experiment

See Farrukh’s Talk
Results from the CMS Use Case

• All CMS simulation requests fulfilled for Moriond
  – 2.9 million jobs, 15.1 million wall hours
    • 9.5% badput – includes preemption from spot pricing
    • 87% CPU efficiency
  – 518 million events generated
Reaching ~60k slots on AWS with FNAL HEPCloud

Slots Summary (single-core equivalent)

60000 slots

10% Test

25%
HEPCloud AWS slots by Region/Zone

Each color corresponds to a different region+zone
HEPCloud AWS slots by Region/Zone/Type

Each color corresponds to a different region+zone+machine type
HEPCloud/AIDS: 25% of CMS global capacity

Running Job Cores
168 Hours from 2016-02-01 to 2016-02-08 UTC

Production
Analysis
Reprocessing
Production on AWS via FNAL HEPCloud

Burt Holzman | Fermilab HEPCloud Facility
Fermilab HEPCloud compared to global CMS Tier-1

Running jobs
30 Days from 2016-01-11 to 2016-02-11

Via Fermilab HEPCloud:
CMS Amazon Web Services (AWS) Usage

Fermilab Tier-1

Tier-1 (Italy)
Tier-1 (Germany)
Tier-1 (France)
Tier-1 (Russia)
Tier-1 (UK)
Tier-1 (Spain)
HEPCloud: Orchestration

- Monitoring and Accounting
  - Synergies with FIFE monitoring projects
  - But also monitoring real-time expense
  - Feedback loop into Decision Engine

Cloud Instances by type

Cost in Last Six Hours: $135.73
Cost Rate in Last Six Hours: $22.62 / hour
Cost in Last Day: $172.94
Cost Rate in Last Day: $7.21 / hour

Balance

Fermilab
On-premises vs. cloud cost comparison

• Average cost per core-hour
  – On-premises resource: \(0.9\) cents per core-hour
    • Includes power, cooling, staff
  – Off-premises at AWS: \(1.4\) cents per core-hour
    • Ranged up to 3 cents per core-hour at smaller scale

• Benchmarks
  – Specialized (“ttbar”) benchmark focused on HEP workflows
    • On-premises: \(0.0163\) (higher = better)
    • Off-premises: \(0.0158\)

• Raw compute performance roughly equivalent
• Cloud costs larger – but approaching equivalence
HTCondor: Critical to Success

- **All resources** provisioned with HTCondor
- **First test** of EC2 GAHP at scale
  - Worked* with HTCondor team to improve EC2 GAHP
    - Improved stability of GAHP (less mallocs)
    - Improved Gridmanager response to crashed GAHP
    - Reduce number of EC2 API calls and exponential backoff (BNL request)
- We need a agent to speak to **bulk provisioning APIs**
- **condor_annex** (see next talk)
  - We want HTCondor to provision the “big three”
    - Amazon EC2
    - Google Cloud Engine
    - Microsoft Azure
  - `condor_annex` should be part of the HTCondor ecosystem (ClassAds, integration with condor tools, run as non-privileged user)

* Todd M codes, we test
Thanks

- HTCondor team
- CMS and NOvA experiments
- The glideinWMS project
- FNAL HEPCloud Leadership Team: Stu Fuess, Gabriele Garzoglio, Rob Kennedy, Steve Timm, Anthony Tiradani
- Open Science Grid
- Energy Sciences Network
- Amazon Web Services
- ATLAS/BNL for initiating work with AWS team (and for providing some introduction in John Hover’s talk yesterday!)