The Future of Distributed Computing Systems in ATLAS: Boldly Venturing Beyond Grids

Fernando Barreiro[1], Doug Benjamin[2], Taylor Childers[2], Kaushik De[1],
Johannes Elmsheuser[4], Andrej Filipcic[3], Alexei Klimentov[4], Mario Lassnig[5], Tadashi Maeno[4], Danila Oleynik[1], Sergey Panitkin[4], Torre Wenaus[4]
on behalf of the ATLAS collaboration

[1]University of Texas at Arlington, USA
[2]Argonne National Laboratory, USA
[3]Jozef Stefan Institute, Slovenia
[4]Brookhaven National Laboratory, USA
[5]European Center for Nuclear Research, Switzerland

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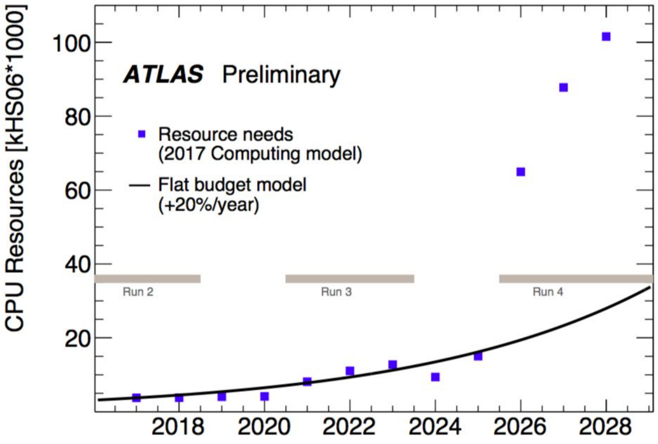
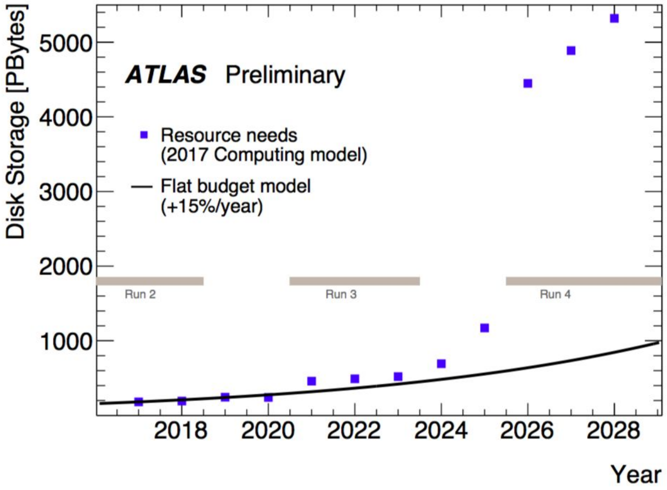
Motivation

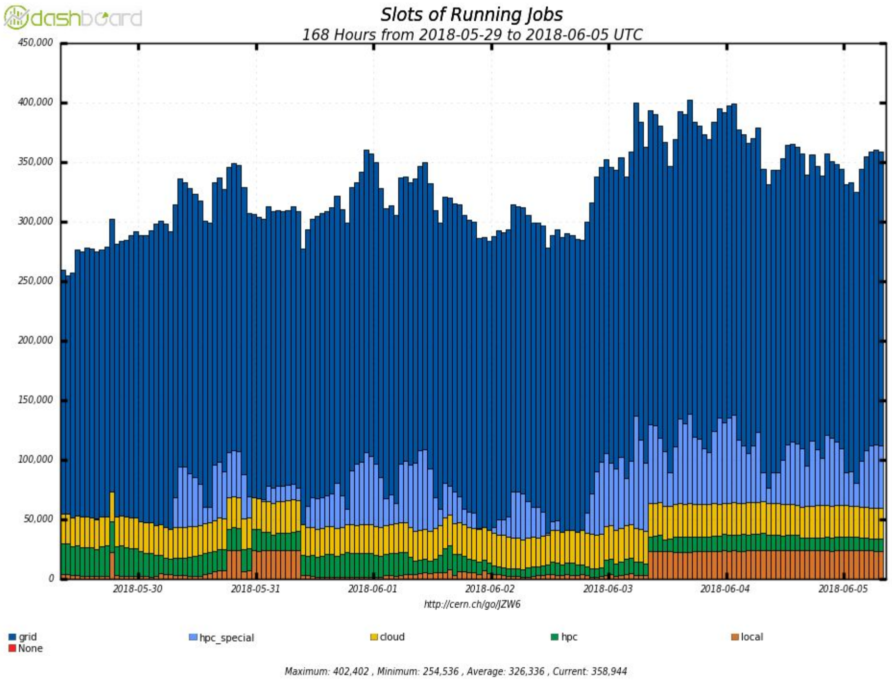




- LHC computing needs keep increasing, while budget is flat at best
- IT landscapes, computing infrastructures and funding models change
- Heterogeneous workloads, architectures, resource types, storages
- We need to be able to use every resource available and use it efficiently
- ...and there is a general manpower limitation

ATLAS usage on opportunistic resources

- Cloud, HPC & volunteer resources used successfully for >5 years
- Resources not always tailored for ATLAS: adaptation needed and inherent limitations in suitable workflows
- This presentation will focus on the effort to harmonize the adaptations and overcome some of the most challenging limitations using Harvester[1]



[1] *See T Maeno's Harvester talk in this conference*

Revised architecture: Server - Harvester - Pilot

Harvester as edge service, capable of integrating heterogeneous resources through plugin interface

HPC

- Run on edge node of each HPC, or potentially centrally if HPC provides a CE
- Data pre-placement and output transfer through download/upload or 3rd party transfer
- Job management
    - Combine jobs into multi node submission
    - Jumbo jobs management with Yoda
- Exploited in US DOE HPC facilities and available for other HPCs

Cloud

- Can run anywhere, usually centrally in shared instance
- VM lifecycle management: create, monitor and delete VMs
- Plugins existing for Google Compute Engine and Openstack

Grid

- Can run anywhere, usually centrally in shared instance
- Standard Pilot submission in different modes
    - Push/pull
    - Closer integration with PanDA server and can receive commands for e.g. Unified PanDa queues

HPC: architectures and software

- Each HPC has own set of architectures and restrictions
  - Different operating systems
  - SW installation: local installations, CVMFS, trend on containers
  - Possibility to provide a Computing Element in the future
  - Different CPU architectures and increasing presence of co-processors
    - Effort on ATLAS SW compilation methodology
    - Currently unable to use GPU co-processors
    - Nodes without disk, using shared filesystem
      - Concurrent file access can create a bottleneck and needs to be optimized

Specifications and Features

Processor: IBM POWER9™

GPUs: NVIDIA Volta™

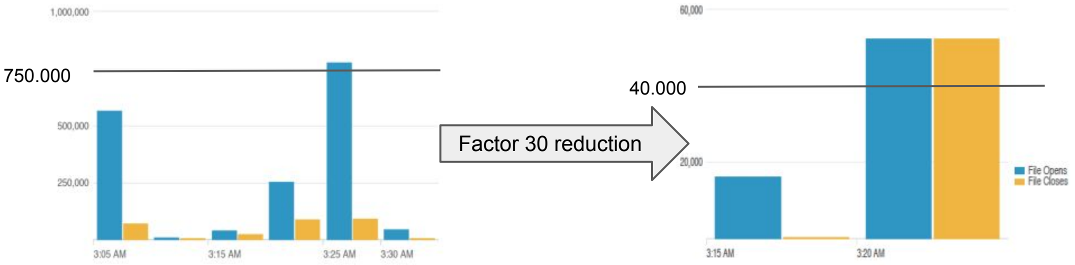
Nodes: ~4600

Node Performance: >40TF

Memory/node: 512GB DDR4 + HBM

NV Memory/node: 1600GB

ORNL Summit specs



16 Aug 2017

4 Sept 2017

I/O operations reduction on Lustre filesystem at ORNL Titan

HPC: data management

- Not always storage element present at HPC
- HPCs with external I/O can use a remote grid storage element
- Restrictive HPCs require data pre-placement to local storage or shared filesystem
    - Download
    - 3rd party transfers managed by Rucio
        - FTS
        - Globus Online
    - Difficult to converge on one solution

HPC: internal scheduling

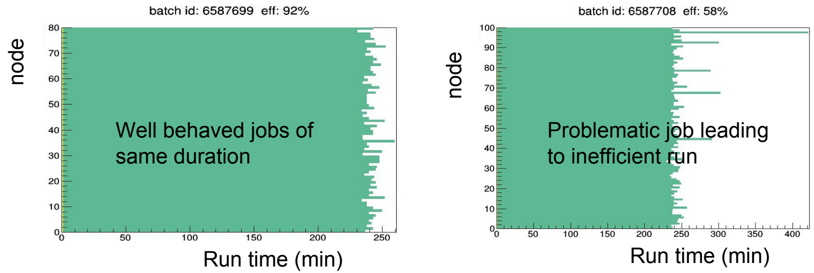
- HPC allocations usually awarded by n million node-hours over a period
- HPC internal scheduling policies optimize the usage of their infrastructures while honouring users' fair shares
  - Usually only multi-node slots
  - Large requests often prioritized
  - Max walltime can depend on the size of the request
  - Backfill opportunities outside your allocation
    - Fill out leftovers with limitation on running time
- However ATLAS workloads are loosely coupled (pleasantly parallel)
  - Typically each job needs 1-16 cores, 2-4 GB RAM/core
  - Runs over a file with few hundred events over several hours

Bin	Min Nodes	Max Nodes	Max Walltime (Hours)	Aging Boost (Days)
1	11,250	–	24.0	15
2	3,750	11,249	24.0	5
3	313	3,749	12.0	0
4	126	312	6.0	0
5	1	125	2.0	0

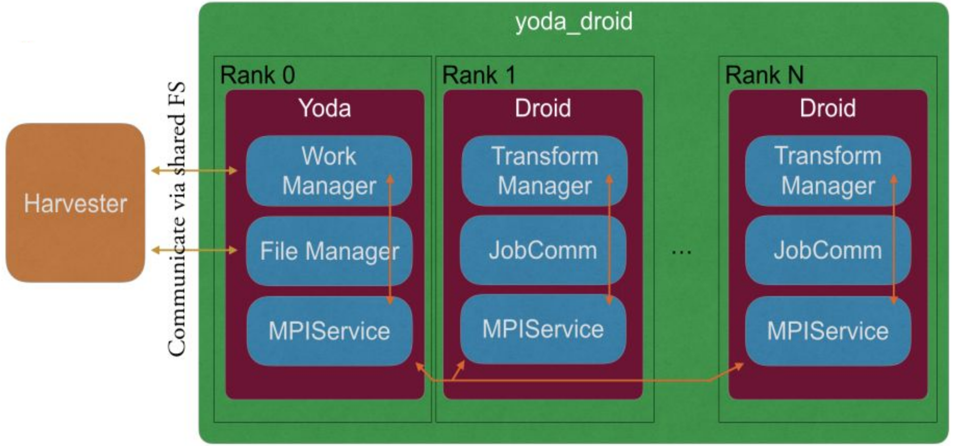
ORNL Titan scheduling policies

HPC: improving the efficiency

- Combining ATLAS jobs into HPC multi-node jobs
  - Manual task assignment to ensure same duration of jobs
  - Failure of one node leads to failure of all concurrent ATLAS jobs
  - Turnaround time not guaranteed, limiting to non-urgent jobs
- Jumbo jobs and Yoda: manage finer granularity jobs through MPI
  - Jumbo jobs package together multiple related jobs and manage these at event level
  - Yoda runs on the HPC and feeds event ranges to subsequent ranks through MPI
  - Further down the line envisage event level streaming

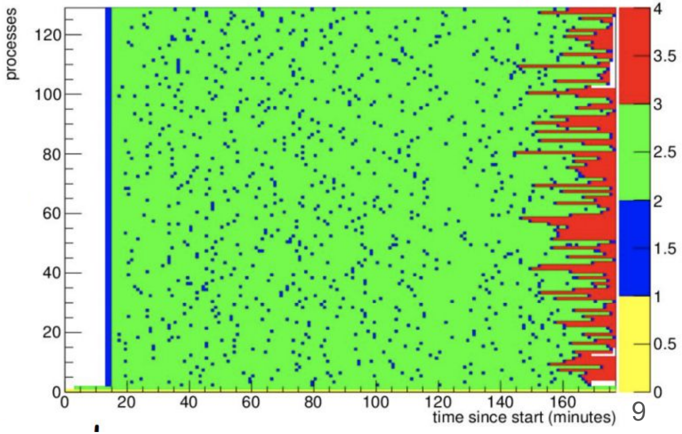


NERSC utilization per node



A Yoda job at Theta/ALCF with 16k cores

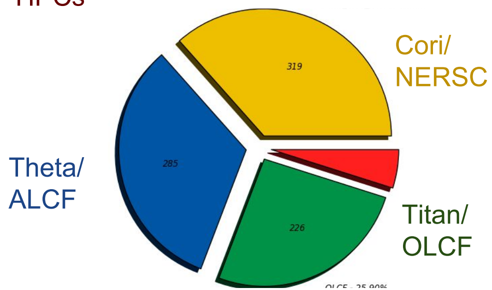
Idle, Processing events which completed, Processing events which didn't complete

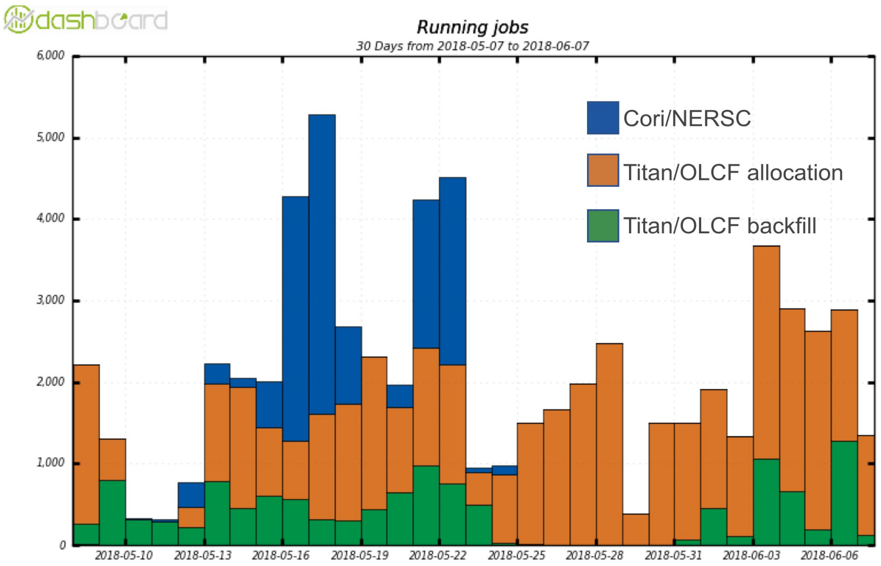


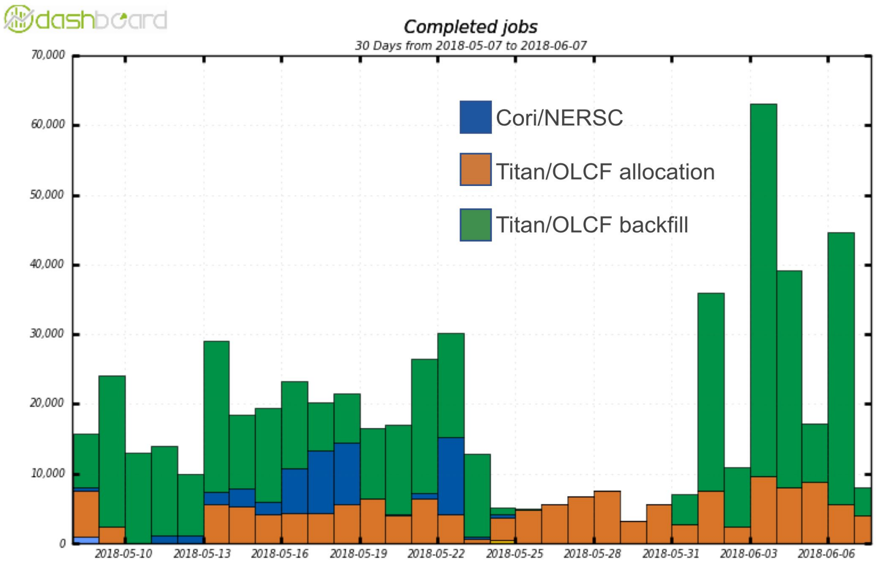
HPC: status

- Flexible plugin architecture in Harvester to integrate very different HPCs
- In use at US DOE HPC facilities
  - Inclusion of other HPCs in EU or US NSF under discussion

Total number of events (in M) processed in 6 months at US DOE HPCs







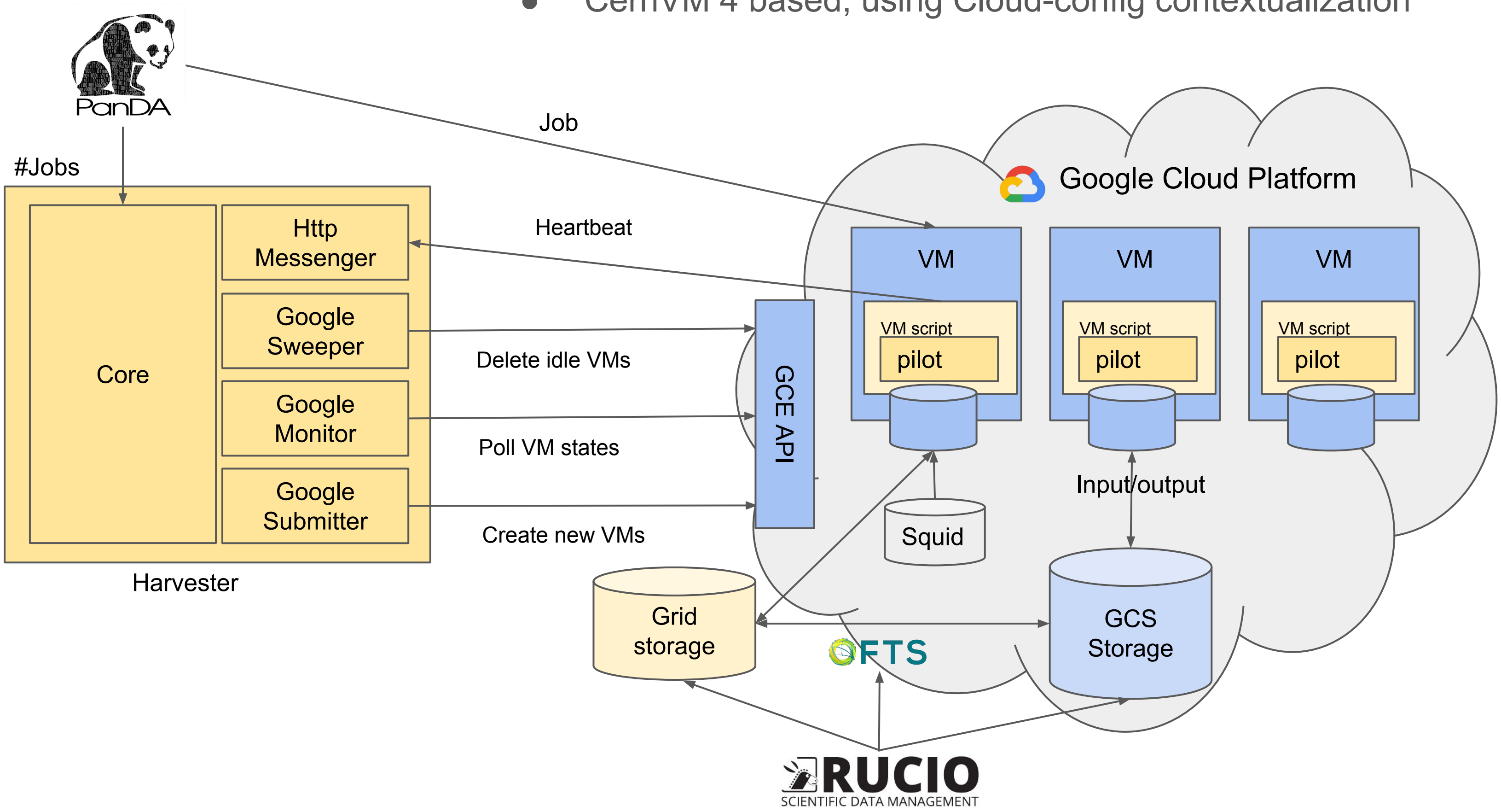
ATLAS Google Data Ocean Project[1]

- Storage becoming a driving cost factor for High Luminosity LHC
  - ATLAS-Google common project to evaluate more dynamic use of storage
  - Store ATLAS data on Google Cloud Storage and access anywhere in the world
- First ATLAS attempt to run both storage and compute on a commercial cloud
- **Data** management: Google Cloud **Storage** like any other storage element for data transfer and accounting
  - Based on signed URLs
  - Third party transfer through FTS
    - Possible from all recent DPM and dCache WebDav endpoints
  - Download and upload of files through Rucio clients
- **Workload** management: manage Google **Compute** Engine resources through Harvester
  - Running a queue for simulation and a queue for analysis

[1] *See also M Lassnig's talk in this conference*

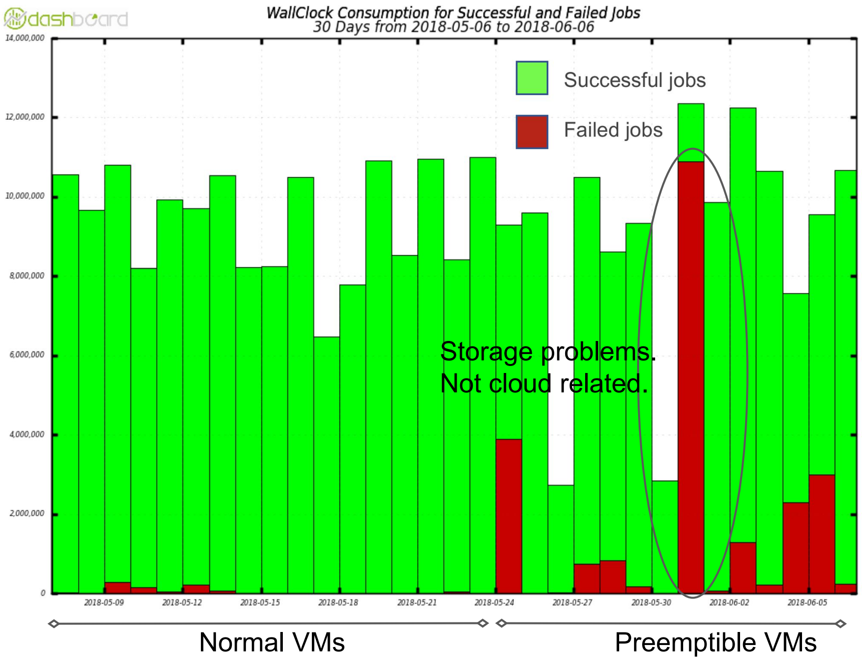
Block diagram

- Top-down, pure PanDA-GCE implementation
- CernVM 4 based, using Cloud-config contextualization



Results

- Google Cloud Platform completely integrated in Rucio for data and PanDA for workload management
- Analysis use case in progress using cloud storage
- Expand on performance, scalability and cost studies



Efficiency of preemptible VMs can be optimized through usage of Event Service

Conclusions

- Increasing HL-LHC computing needs
- Grid funding stagnates, but other public and private resources appear
- Harvester edge service with its plugin infrastructure allows interfacing them all
- Examples with key players of today’s IT landscape have been shown
- Current focus on improving efficiency, demonstrating scale and thriving towards standardization to reduce operational costs