HammerCloud: A Stress Testing System for Distributed Analysis

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Abstract. Distributed analysis of LHC data is an I/O-intensive activity which places large demands on the internal network, storage, and local disks at remote computing facilities. Commissioning and maintaining a site to provide an efficient distributed analysis service is therefore a challenge which can be aided by tools to help evaluate a variety of infrastructure designs and configurations. HammerCloud is one such tool; it is a stress testing service which is used by central operations teams, regional coordinators, and local site admins to (a) submit arbitrary number of analysis jobs to a number of sites, (b) maintain at a steady-state a predefined number of jobs running at the sites under test, (c) produce web-based reports summarizing the efficiency and performance of the sites under test, and (d) present a web-interface for historical test results to both evaluate progress and compare sites. HammerCloud was built around the distributed analysis framework Ganga, exploiting its API for grid job management. HammerCloud has been employed by the ATLAS experiment for continuous testing of many sites worldwide, and also during large scale computing challenges such as STEP'09 and UAT'09, where the scale of the tests exceeded 10,000 concurrently running and 1,000,000 total jobs over multi-day periods. In addition, HammerCloud is being adopted by the CMS experiment; the plugin structure of HammerCloud allows the execution of CMS jobs using their official tool (CRAB).

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1. Introduction

Present day high energy physics research relies on the availability of powerful computing resources which allow physicists to process vast quantities of collision data in a timely manner. The resources of the World-wide LHC Computing Grid (WLCG) have been deployed to meet this demand. Nevertheless, the optimization of existing WLCG computing sites and configuration of newly commissioned resources motivates tools which aid in the design and configuration of a grid site to ensure that its capabilities meet or exceed the requirements of the foreseen user applications.

HammerCloud is an automated site testing service with two main goals. First, it is a stress-testing tool which can deliver large numbers of real jobs to objectively aid in the commissioning of new sites and to evaluate changes to site configurations. Second, it is an end-to-end functional testing tool which periodically sends short jobs to continually validate the site and related grid services. In addition to delivering the test jobs to grid sites, HammerCloud provides a user-friendly web interface to test results. The service presents plots of job efficiency and many

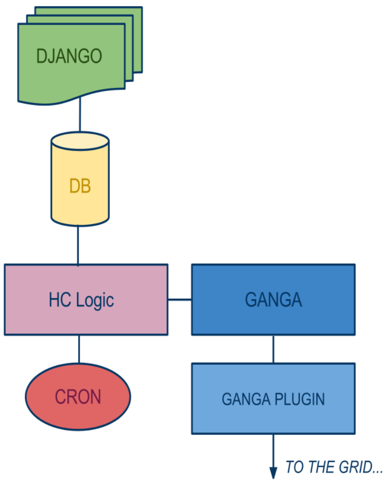


Figure 1. The architecture of HammerCloud including a Django-based web frontend and Ganga-based job submission system.

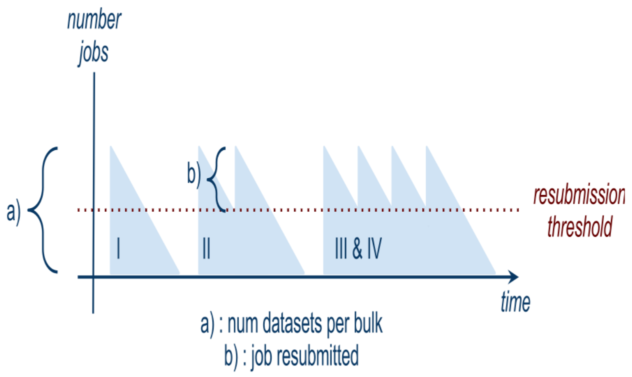


Figure 2. Job submission thresholds.

performance metrics to enable quick comparisons to past configurations and between other sites.

This paper presents the current status of HammerCloud as it has been designed and deployed for three LHC experiments, namely ATLAS, CMS, and LHCb.

2. HammerCloud Design

The HammerCloud service (general architecture in Figure 1) is implemented as a python application using Ganga [1, 2] to submit jobs to relevant grid execution backends and features a Django-based web interface for both public testing results browsing and adminstrative operations such as creating and maintaining tests.

The basic concepts and terminology of HammerCloud are enumerated here:

Test: A *test* is the basic object describing the actions to be carried out by the HammerCloud backend. Each test is described by options including the analysis code to run, the input datasets to process, a list of sites to test, parameters describing how many jobs to send to each site, and a start time and end time.

Template: A test *template* is composed of a set of test options which can be reused from test to test. Templates do not have an associated start time or end time.

User: A HammerCloud *user* has the ability to configure and request a test at a particular start time. The test request can be approved or rejected by an HammerCloud operator or automatic approval logic.

Stress Templates and Tests: A template or test of category *stress* is used for on-demand testing of a set of grid sites with the same analysis code and list of input dataset. Generally, a user selects a stress template, adds start/end times and the sites to test, and then submits the request for approval.

Functional Test: A template of category *functional*, when marked *active* by an operator, is automatically-scheduled as functional tests in order to periodically validate a large set (or all) grid sites with a short analysis job. Tests of this sort are useful for not only site validation but also testing new grid middleware (e.g. client or pilot software).

2.1. HammerCloud Backend Logic

The HammerCloud Backend Logic was designed to serve a few purposes:

- Execute *tests* at the scheduled times: this includes generating test jobs, submitting the jobs to the sites under test, monitoring the jobs when they run and complete, resubmitting further jobs to keep each site at the target workload during the test, and to kill leftover running jobs at the end of a test.
- Automatically schedule *activated* functional templates as needed.
- Compute summary statistics for tests: this includes plotting metric summaries and overall HammerCloud activity.

When a test is running at a given site, HammerCloud monitors the jobs in active states (submitted, running) to determine if more jobs should be submitted to the site. Each site i in a test has associated resubmission parameters `resubmit_enabled` (here, E_i), `num_datasets_per_bulk` (D_i), `min_queue_depth` (S_i), and `max_running_jobs` (R_i). When a test first starts, HammerCloud generates a job for each site with a configuration to process D_i input datasets; since each job can process partial datasets, D_i datasets may map to J_i jobs where $J_i > D_i$. After the first set of jobs has been submitted to all sites, HammerCloud begins monitoring the states of the jobs with the following resubmission algorithm (written in python-based pseudocode). Note that experiment HammerCloud plugins may make minor changes to this resubmission algorithm.

```
for site in sites:
    (s,r) = getNumSubmittedAndRunningJobs(site)
    if E[i] and s < S[i] and r < R[i]:
        submitNewBulkJob(site)
```

The effects of this algorithm on the number of running jobs at a site is depicted in Figure 2.

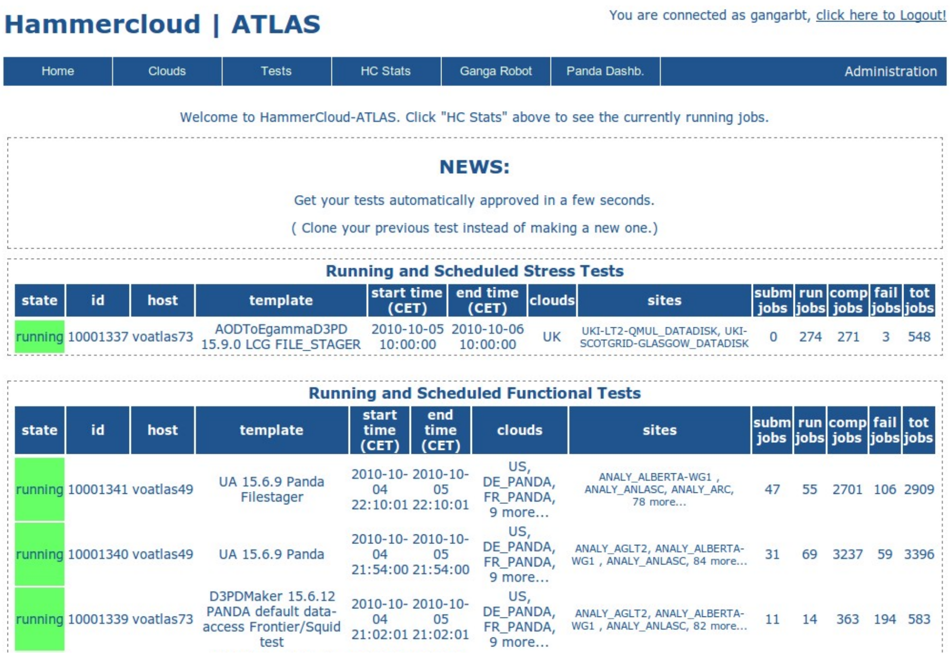
2.2. Django-based Frontend

A web interface has been implemented in using Django; this framework separates data models from business logic and interface views, thereby enabling a clean and efficient design of the web application. The HammerCloud web interface serves two use cases:

- An adminstrative interface for HammerCloud operators and users. HammerCloud operators use this to maintain test templates and other data types including sites, analysis files, and dataset lists. HammerCloud users make test requests via the administrative interface.
- A public results browser lists all scheduled, running, and completed tests; allows users to get summary statistics for each test, including metric plots and tables; and presents summary statistics for all HammerCloud tests, such as a historical plot of number of running jobs across all HammerCloud tests.

The home page for HammerCloud is presented in Figure 3. Here, the ATLAS instance of HammerCloud is shown. The home page presents the list of currently scheduled or running tests, separated into the *stress* and *functional* test categories.

When a user clicks a test, they are shown a test summary (example of a CMS summary shown in Figure 4). The test summary shows the overall job successes and some performance metric histograms, such as the event processing rate. Below, the sites involved in a test are listed along with their respective job statuses; users can easily click to view the individual test jobs directly in order to debug problems.



Welcome to HammerCloud-ATLAS. Click "HC Stats" above to see the currently running jobs.

NEWS:

Get your tests automatically approved in a few seconds.

(Clone your previous test instead of making a new one.)

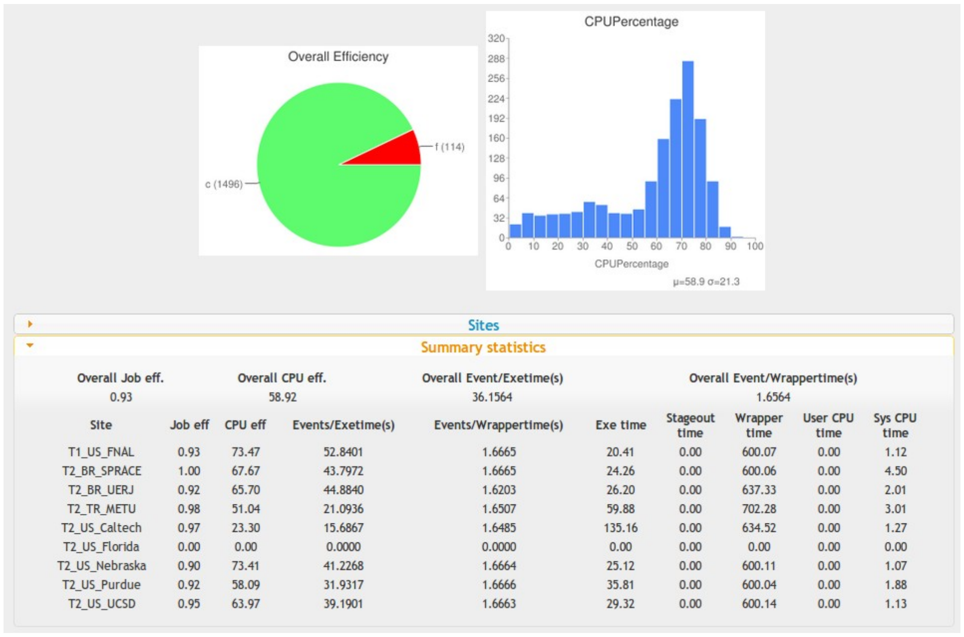
Running and Scheduled Stress Tests

state	id	host	template	start time (CET)	end time (CET)	clouds	sites	subm jobs	run jobs	comp jobs	fail jobs	tot jobs
running	10001337	voatlas73	AODToEgammaD3PD 15.9.0 LCG FILE_STAGER	2010-10-05 10:00:00	2010-10-06 10:00:00	UK	UKI-LT2-QMUL_DATADISK, UKI-SCOTGRID-GLASGOW_DATADISK	0	274	271	3	548

Running and Scheduled Functional Tests

state	id	host	template	start time (CET)	end time (CET)	clouds	sites	subm jobs	run jobs	comp jobs	fail jobs	tot jobs
running	10001341	voatlas49	UA 15.6.9 Panda Filestager	2010-10-04 22:10:01	2010-10-05 22:10:01	US, DE_PANDA, FR_PANDA, 9 more...	ANALY_ALBERTA-WG1 , ANALY_ANLASC, ANALY_ARC, 78 more...	47	55	2701	106	2909
running	10001340	voatlas49	UA 15.6.9 Panda	2010-10-04 21:54:00	2010-10-05 21:54:00	US, DE_PANDA, FR_PANDA, 9 more...	ANALY_AGLT2, ANALY_ALBERTA-WG1 , ANALY_ANLASC, 84 more...	31	69	3237	59	3396
running	10001339	voatlas73	D3PDMaker 15.6.12 PANDA default data-access Frontier/Squid test	2010-10-04 21:02:01	2010-10-05 21:02:01	US, DE_PANDA, FR_PANDA, 9 more...	ANALY_AGLT2, ANALY_ALBERTA-WG1 , ANALY_ANLASC, 82 more...	11	14	363	194	583

Figure 3. HammerCloud home page for the ATLAS instance.



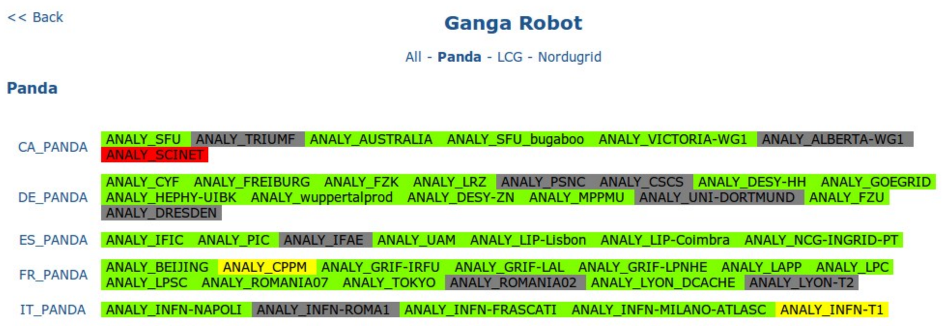
Overall Job eff.	Overall CPU eff.	Overall Event/Exetime(s)	Overall Event/Wrappertime(s)
0.93	58.92	36.1564	1.6564

Site	Job eff	CPU eff	Events/Exetime(s)	Events/Wrappertime(s)	Exe time	Stageout time	Wrapper time	User CPU time	Sys CPU time
T1_US_FNAL	0.93	73.47	52.8401	1.6665	20.41	0.00	600.07	0.00	1.12
T2_BR_SPRACE	1.00	67.67	43.7972	1.6665	24.26	0.00	600.06	0.00	4.50
T2_BR_UERJ	0.92	65.70	44.8840	1.6203	26.20	0.00	637.33	0.00	2.01
T2_TR_METU	0.98	51.04	21.0936	1.6507	59.88	0.00	702.28	0.00	3.01
T2_US_Caltech	0.97	23.30	15.6867	1.6485	135.16	0.00	634.52	0.00	1.27
T2_US_Florida	0.00	0.00	0.0000	0.0000	0.00	0.00	0.00	0.00	0.00
T2_US_Nebraska	0.90	73.41	41.2268	1.6664	25.12	0.00	600.11	0.00	1.07
T2_US_Purdue	0.92	58.09	31.9317	1.6666	35.81	0.00	600.04	0.00	1.88
T2_US_UCSD	0.95	63.97	39.1901	1.6663	29.32	0.00	600.14	0.00	1.13

Figure 4. An example test summary for CMS.

Some functional tests might be deemed critical by the experiment grid operators. The HammerCloud *GangaRobot* view (example in Figure 5) shows a summary chart displaying the success of each site when running these critical tests. More information about the GangaRobot view in HammerCloud can be found in [3].

Users can also view the results of the HammerCloud test jobs directly in the experiment monitoring system. For ATLAS, functional test jobs are labelled with



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Ganga Robot

All - **Panda** - LCG - Nordugrid

Panda

CA_PANDA: ANALY_SFU ANALY_TRIUMF ANALY_AUSTRALIA ANALY_SFU_bugaboo ANALY_VICTORIA-WG1 ANALY_ALBERTA-WG1 ANALY_SCINET

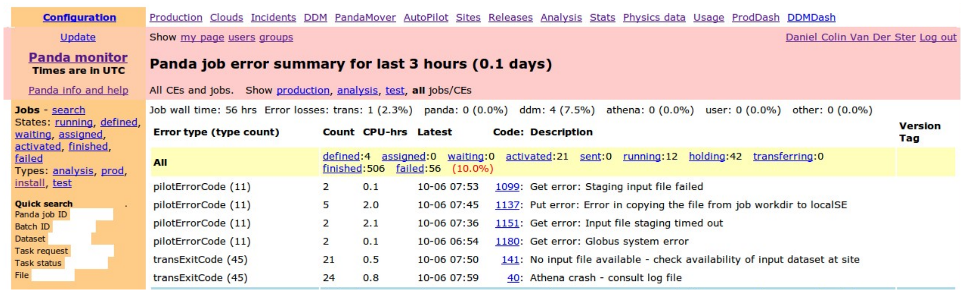
DE_PANDA: ANALY_CYF ANALY_FREIBURG ANALY_FZK ANALY_LRZ ANALY_PSNC ANALY_CSCS ANALY_DESY-HH ANALY_GOEGRID ANALY_HEPHY-UIBK ANALY_wuppertalprod ANALY_DESY-ZN ANALY_MPPMU ANALY_UNI-DORTMUND ANALY_FZU ANALY_DRESDEN

ES_PANDA: ANALY_IFIC ANALY_PIC ANALY_IFAE ANALY_UAM ANALY_LIP-Lisbon ANALY_LIP-Coimbra ANALY_NCG-INGRID-PT

FR_PANDA: ANALY_BEIJING ANALY_CPPM ANALY_GRIF-IRFU ANALY_GRIF-LAL ANALY_GRIF-LPNHE ANALY_LAPP ANALY_LPC ANALY_LPSC ANALY_ROMANIA07 ANALY_TOKYO ANALY_ROMANIA02 ANALY_LYON_DCACHE ANALY_LYON-T2

IT_PANDA: ANALY_INFN-NAPOLI ANALY_INFN-ROMA1 ANALY_INFN-FRASCATI ANALY_INFN-MILANO-ATLASC ANALY_INFN-T1

Figure 5. The GangaRobot view of test results [3].



Configuration

Production Clouds Incidents DDM PandaMover AutoPilot Sites Releases Analysis Stats Physics data Usage ProdDash DDMDash

Update

Show my page users groups — Daniel Colin Van Der Ster Log out

Panda monitor
Times are in UTC

Panda job error summary for last 3 hours (0.1 days)

Panda info and help

All CEs and jobs. Show production, analysis, test, **all** jobs/CEs

Jobs - search
States: running, defined, waiting, assigned, activated, finished, failed
Types: analysis, prod, install, test

Quick search
Panda job ID
Batch ID
Dataset
Task request
Task status
File

Job wall time: 56 hrs Error losses: trans: 1 (2.3%) panda: 0 (0.0%) ddm: 4 (7.5%) athena: 0 (0.0%) user: 0 (0.0%) other: 0 (0.0%)

Error type (type count)	Count	CPU-hrs	Latest	Code: Description	Version Tag
All	defined:4 assigned:0 waiting:0 activated:21 sent:0 running:12 holding:42 transferring:0 finished:506 failed:56 (10.0%)				
pilotErrorCode (11)	2	0.1	10-06 07:53	1099: Get error: Staging input file failed	
pilotErrorCode (11)	5	2.0	10-06 07:45	1137: Put error: Error in copying the file from job workdir to localSE	
pilotErrorCode (11)	2	2.1	10-06 07:36	1151: Get error: Input file staging timed out	
pilotErrorCode (11)	2	0.1	10-06 06:54	1180: Get error: Globus system error	
transExitCode (45)	21	0.5	10-06 07:50	141: No input file available - check availability of input dataset at site	
transExitCode (45)	24	0.8	10-06 07:59	40: Athena crash - consult log file	

Figure 6. View in the Panda Monitor of HammerCloud FUNCTIONAL test jobs for ATLAS.

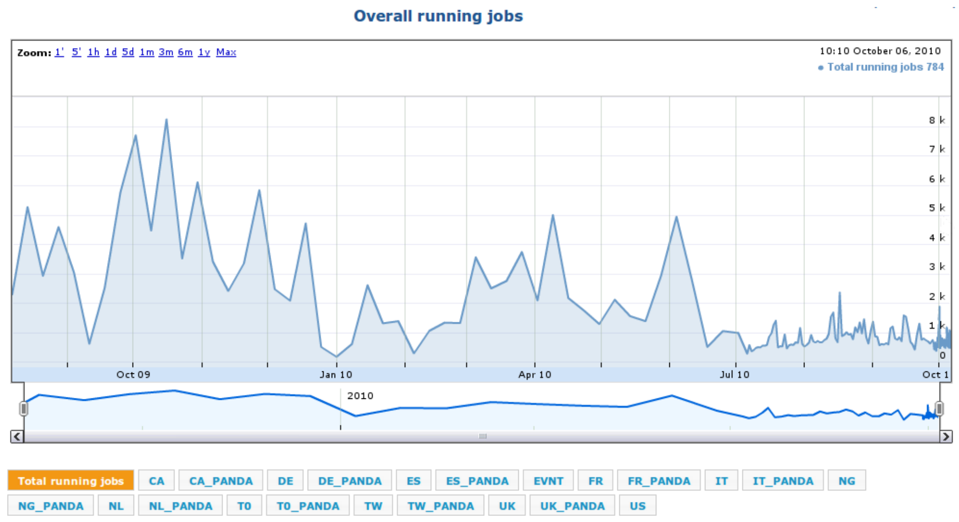


Figure 7. Number of running test jobs over the past year.

`processingType=gangarobot`; this way, the Panda [4] monitor displays the results of these specific jobs. An example of this view is in Figure 6.

3. Usage in LHC Computing

HammerCloud was initially designed and implemented in cooperation with the ATLAS experiment. The work began as manually submitted stress tests by multiple ATLAS users, and the results of the early tests motivated the development of an automated stress testing system that became HammerCloud. Automated job robots such as HammerCloud have been demonstrated previously, such as the CMS Job Robot and the ATLAS GangaRobot predecessors.

Since fall 2008, HammerCloud has been used by ATLAS for around 300,000 CPU-days of site testing. In almost 4000 tests, 10,000,000 jobs have been executed with an 87% overall success rate at more than 100 ATLAS sites or queues. The service was heavily used during the year before data taking in order to prepare sites for the high loads expected from real users. This preparation was successful to help enable the high reliability of the ATLAS grid sites that we observe today. Presently, ATLAS sites continue to use HammerCloud to evaluate new configurations, and the functional tests are used to automatically exclude malfunctioning sites from the Panda [4] job brokerage system. Many recent examples of HammerCloud usage can be found in these proceedings [5, 6, 7, 8, 9, 10, 11, 12, 13].

Following the ATLAS success with HammerCloud, the CMS and LHCb experiments have worked to develop HammerCloud plugins to test their grid sites. CMS and LHCb prototypes have been delivered in mid-2010. The CMS HammerCloud service has been working in production since fall 2010 [14, 15], and the service is currently being further integrated into the daily CMS grid operations procedures. The LHCb plugin has been used in production, for example to help commission a new storage service at Rutherford Appleton Laboratory; finalizing the rollout of this service for LHCb in planned for early 2011.

4. Conclusions and Future Work

HammerCloud has been developed to enable grid site administrators and operators to easily and repeatedly test their facilities. Via on-demand stress tests and frequent short functional tests, HammerCloud provides end-to-end testing of an experiment's distributed analysis facilities. Being involved since the conception of HammerCloud, ATLAS has made significant use of the service. CMS and LHCb plugins for HammerCloud have been developed in 2010 and the service is presently being incorporated into the daily grid operations of these experiments.

Acknowledgements

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