HTCondor with Google Cloud Platform

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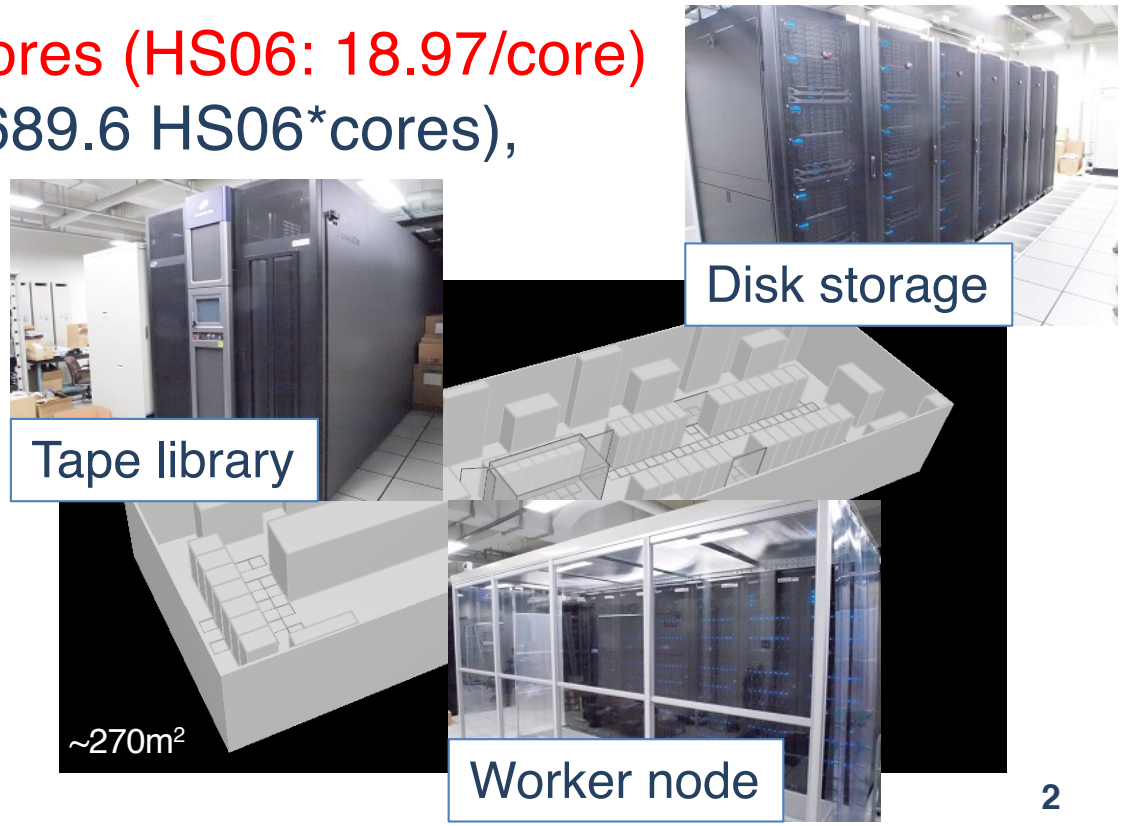
22/May/2019, HTCondor Week, Madison, US

The Tokyo regional analysis center

- The computing center at ICEPP, the University of Tokyo
- Supports ATLAS VO as one of the WLCG Tier2 sites
  →Provides local resources to the ATLAS Japan group, too
- All hardware devices are supplied by the three years rental
- Current system (Starting from Jan/2019):
  →Worker node: 10,752cores (HS06: 18.97/core)
  (7,680 for WLCG, 145689.6 HS06*cores),
  3.0GB/core
  →File server: 15,840TB,
  (10,560TB for WLCG)



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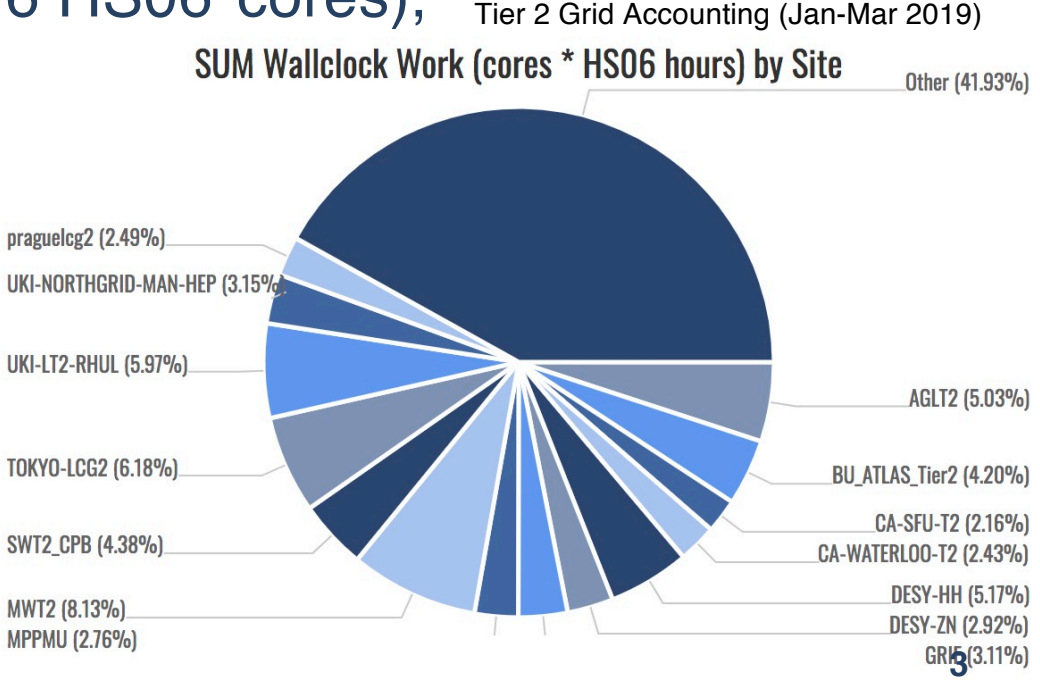
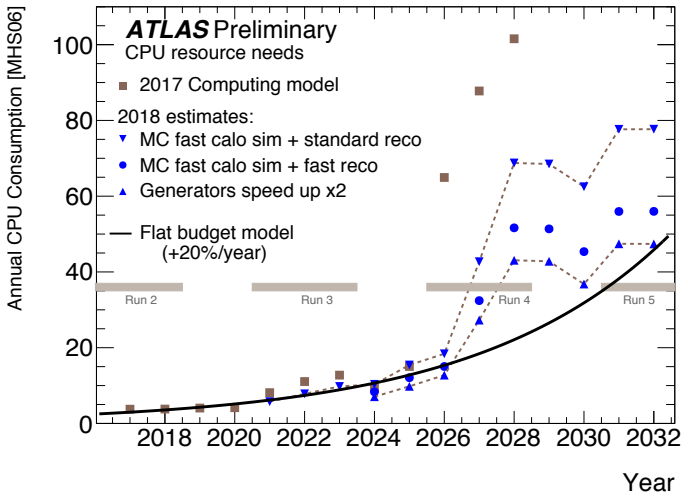
TOKYO-LCG2 provides
6% of Tier 2



Increasing Computing Resources Requirement

- Data amount of HEP experiments becomes larger and larger
  →Computing resource is one of the important piece for experiments
- CERN plans High-Luminosity LHC
  →The peak luminosity: x 5
  →Current system does not have enough scaling power
  →Some new ideas are necessary to use data effectively
    →Software update
    →New devices: GPGPU, FPGA, (QC)
    →New grid structure: Data Cloud
    →External resources: HPC, Commercial cloud



Commercial Cloud

- Google Cloud Platform (GCP)
  - →Number of vCPU, Memory are customizable
  - →CPU is almost uniform:
    - → At TOKYO region, only Intel Broadwell (2.20GHz) or Skylake (2.00GHZ) can be selected (they show almost same performances)
  - →Hyper threading on
- Amazon Web Service (AWS)
  - →Different types (CPU/Memory) of machines are available
  - →Hyper threading on
  - →HTCondor supports AWS resource management from 8.8
- Microsoft Azure
  - →Different types (CPU/Memory) of machines are available
  - →Hyper threading off machines are available

Google Computing Element

- **HT On**
  - → All Google Computing Element (GCE) at GCP are HT On
  - → TOKYO system is HT off

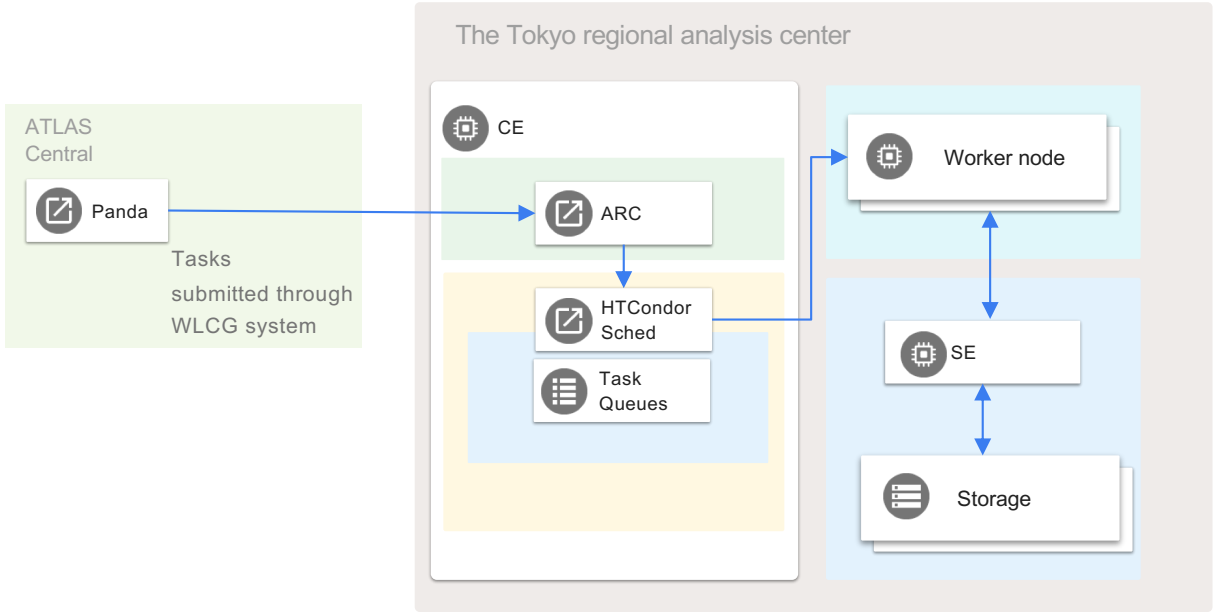
System	Core(vCPU)	CPU	SPECInt/core	HEPSPEC	ATLAS simulation 1000events (hours)
TOKYO system: HT off	32	Intel(R) Xeon(R) Gold 6130 CPU @ 2.10GHz	46.25	18.97	5.19
TOKYO system: HT on	64	Intel(R) Xeon(R) Gold 6130 CPU @ 2.10GHz	N/A	11.58	8.64
GCE (Broadwell)	8	Intel(R) Xeon(R) CPU E5-2630 v4 @ 2.20GHz	(39.75)	12.31	9.32
GCE (Broadwell)	1	Intel(R) Xeon(R) CPU E5-2630 v4 @ 2.20GHz	(39.75)	22.73	N/A
GCE (Skylake)	8	Intel(R) Xeon(R) Gold 6138 CPU @ 2.00GHz	(43.25)	12.62	9.27

- SPECInt (SPECint_rate2006):
  - Local system: Dell Inc. PowerEdge M640
  - GCE(Google Compute Engine)'s value were taken from Dell system with same corresponding CPU
    - GCE (Broadwell): Dell Inc PowerEdge R630
    - GCE (Skylake): Dell Inc. PowerEdge M640
- ATLAS simulation: Multi process job 8 processes
  - For 32 and 64 core machine, 4 and 8 parallel jobs were run to fill cores, respectively

  - → Broadwell and Skylake show similar specs
    - → Costs are same. But if instances are restricted to Skylake, instances will be preempted more
    - → Better not to restrict CPU generation for preemptible instances
  - → GCE spec is ~half of TOKYO system

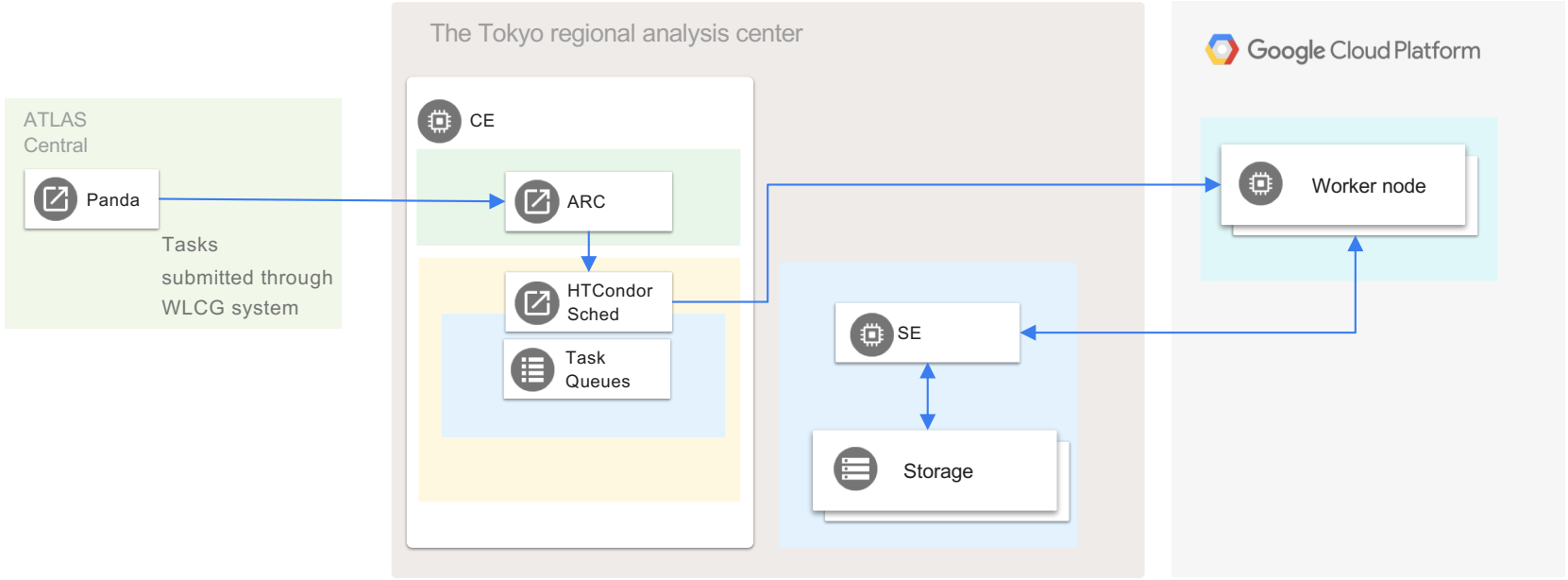
- **Preemptible Instance**
  - → Shut down every 24 hours
  - → Could be shut down before 24 hours depending on the system condition
  - → The cost is ~1/3

Current Our System



- Panda: ATLAS job management system, using WLCG framework
- ARC-CE: Grid front-end
- HTCondor: Job scheduler

Hybrid System



- Some servers need certifications for WLCG

  →There is a political issue to deploy such servers on cloud

  →No clear discussions have been done for the policy of such a case

- Cost of storage is high

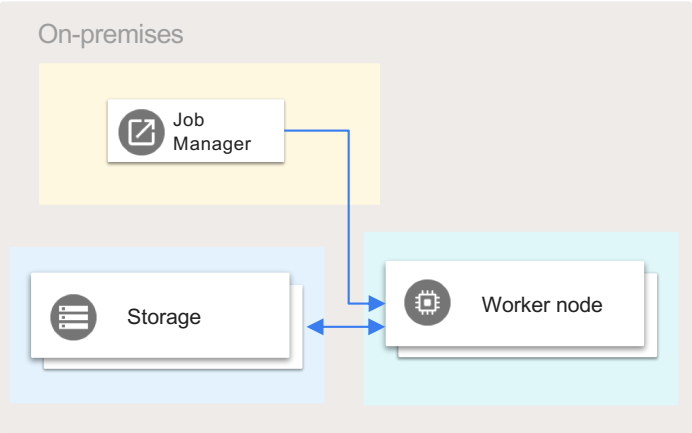
  →Additional cost to extract data

- Only worker nodes (and some supporting servers) were deployed on cloud, and other services are in on-premises

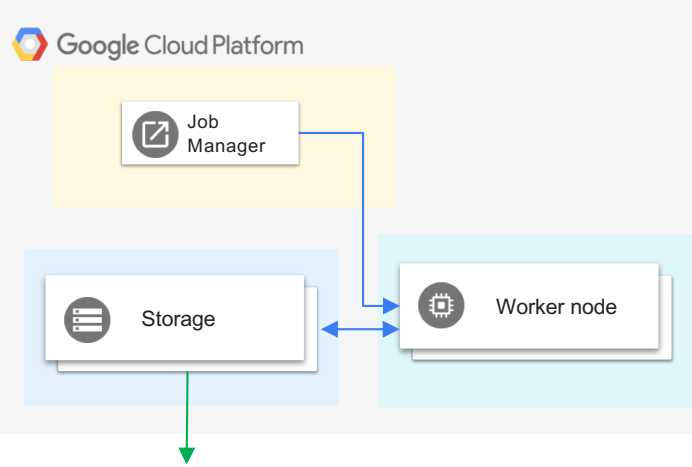
  →Hybrid system

Cost Estimation

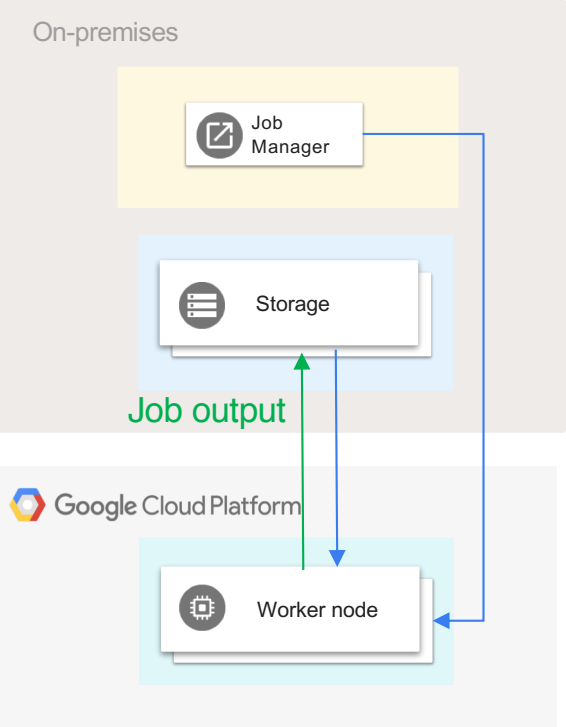
Full on-premises system



Full cloud system



Hybrid System



- Estimated with Dell machines
- 10k cores, 3GB/core memory, 35GB/core disk: $5M
- 16PB storage: $1M
- Power cost: $20k/month
  → For 3 years usage: ~$200k/month (+Facility/Infrastructure cost, Hardware Maintenance cost, etc…)

- For GCP, use 20k to have comparable spec
  → Use Preemptible Instance
- 8PB storage which is used at ICEPP for now
- Cost to export data from GCP

https://cloud.google.com/compute/pricing
https://cloud.google.com/storage/pricing

Cost Estimation

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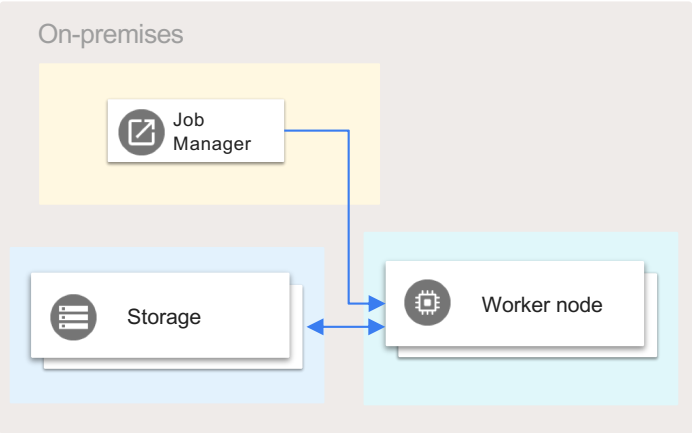

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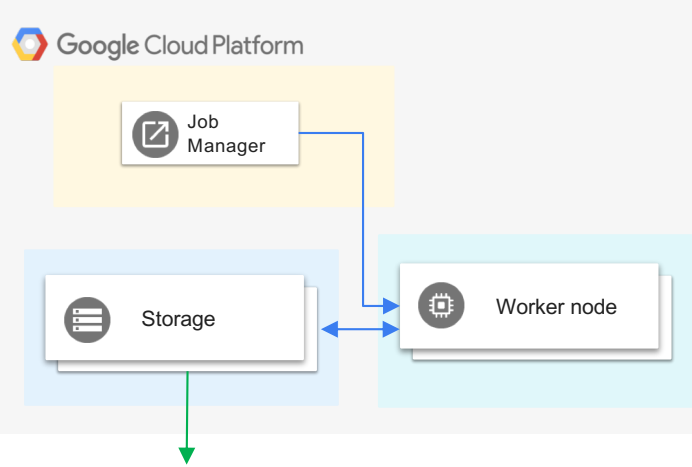

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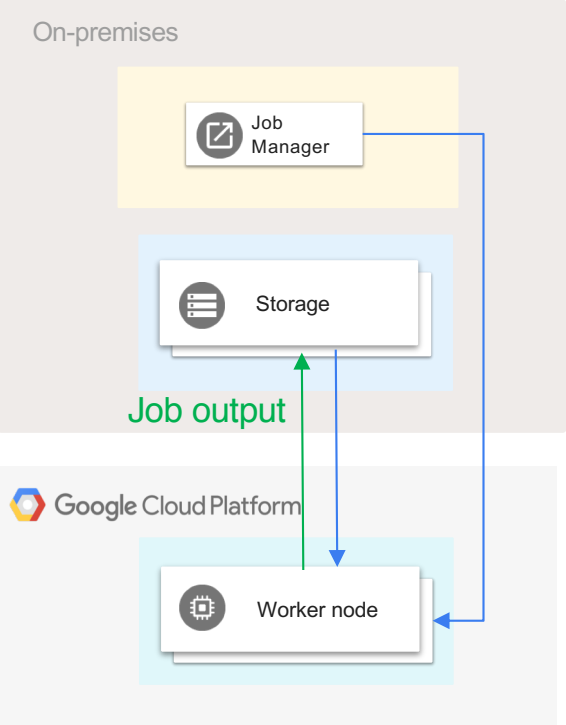

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Resource	Cost/month
vCPU x20k	$130k
3GB x20k	$52k
Local Disk 35GBx20k	$36k
Storage 8PB	$184k
Network Storage to Outside 600 TB	$86k

Total cost: $480k/month

Resource	Cost/month
vCPU x20k	$130k
3GB x20k	$52k
Local Disk 35GBx20k	$36k
Network GCP WN to ICEPP Storage 280 TB	$43k

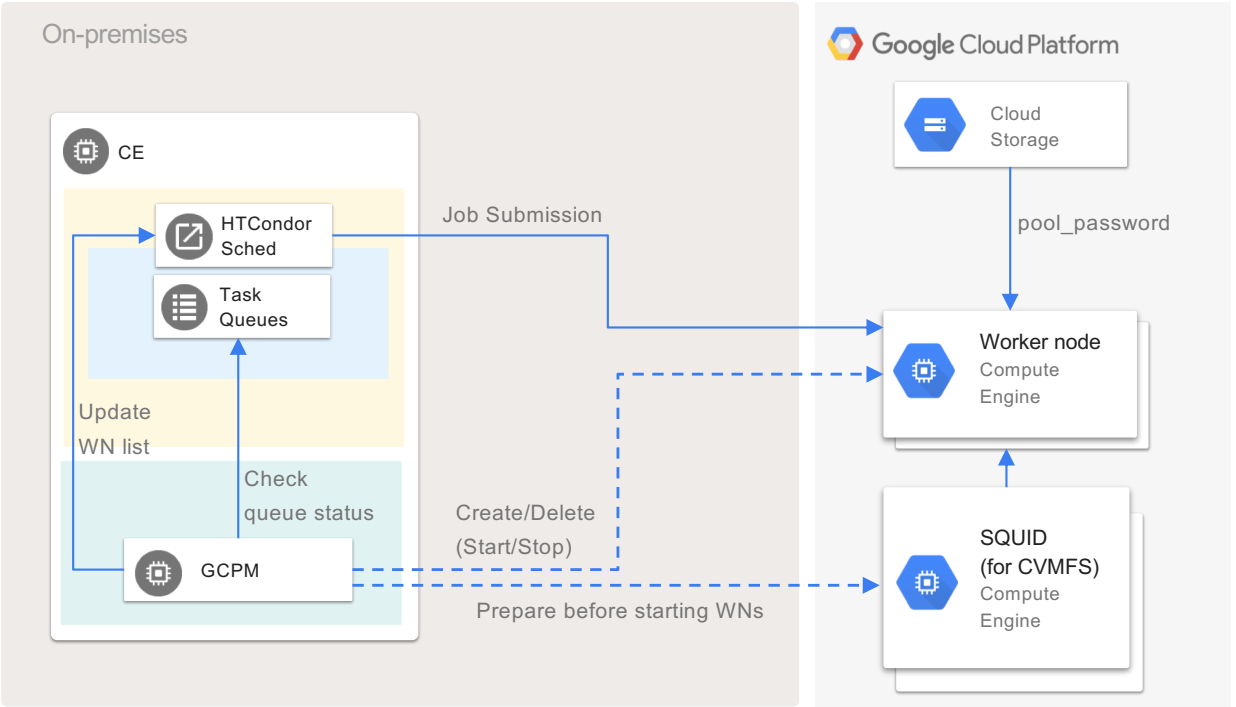
Total cost: $252k/month
+ on-premises costs
(storage + others)

Technical Points on HTCndor with GCP

- No swap is prepared as default:
  → No API option is available, need to make swap by a startup script
- Memory must be 256MB x N
- yum-cron is installed and enabled by default
  → Better to disable to manage packages (and for performance)
- Preemptible machine
  → The cost is ~1/3 of the normal instance
  → It is stopped after 24 h running
    → It can be stopped even before 24 h by GCP (depends on total system usage)
    → **Better to run only 1 job for 1 instance**
- Instances are under VPN
  → They don't know own external IP address
  → Use HTCndor Connection Brokering (CCB)
    → ***CCB_ADDRESS = $(COLLECTOR_HOST)***
- Instance's external address is changed every time it is started
  → Static IP address is available, but it needs additional cost
  → To manage worker node instance on GCP, a management tool has been developed:
    → **Google Cloud Platform Condor Pool Manager (GCPM)**

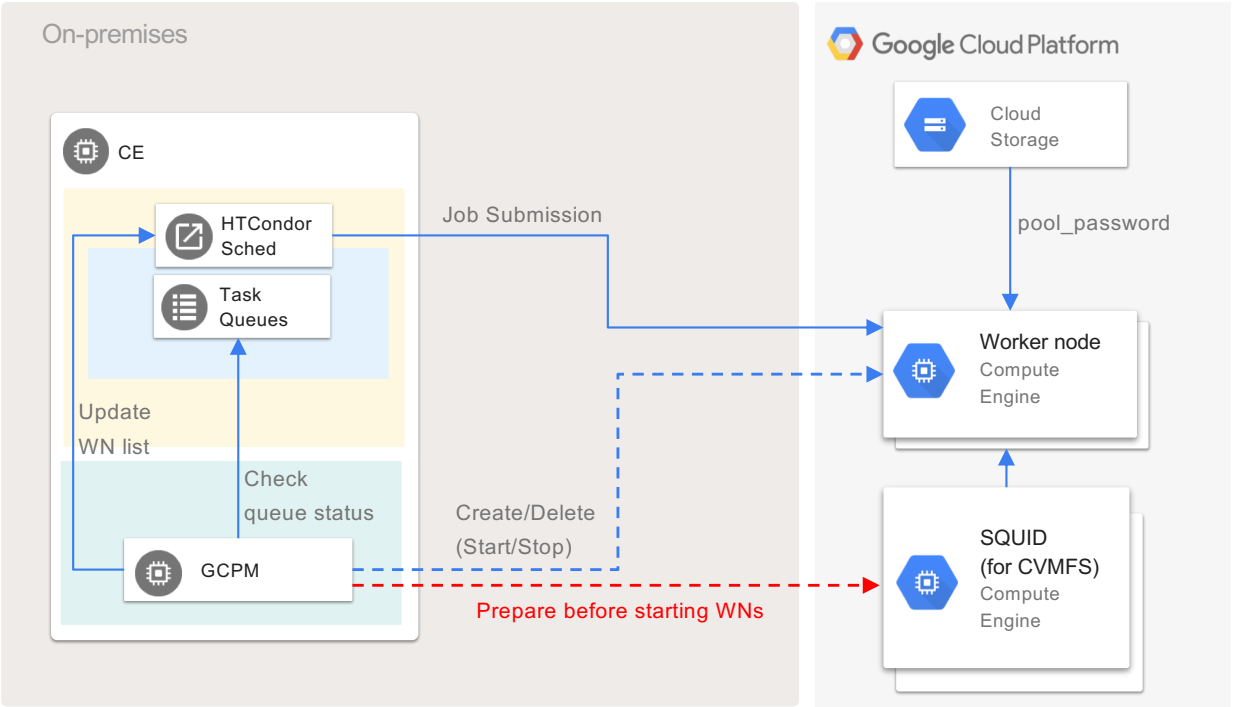
Google Cloud Platform Condor Pool Manager

- https://github.com/mickaneda/gcpm
  → Can be installed by pip:
    → ***$ pip install gcpm***
- Manage GCP resources and HTCondor's worker node list



Google Cloud Platform Condor Pool Manager

- Run on HTCondor head machine
  - → Prepare necessary machines before starting worker nodes
  - → Create (start) new instance if idle jobs exist
  - → Update WN list of HTCondor
  - → Job submitted by HTCondor
  - → Instance's HTCondor startd will be stopped at 10min after starting
    - → ~ only 1 job runs on instance, and it is deleted by GCPM
      - → Effective usage of preemptible machine



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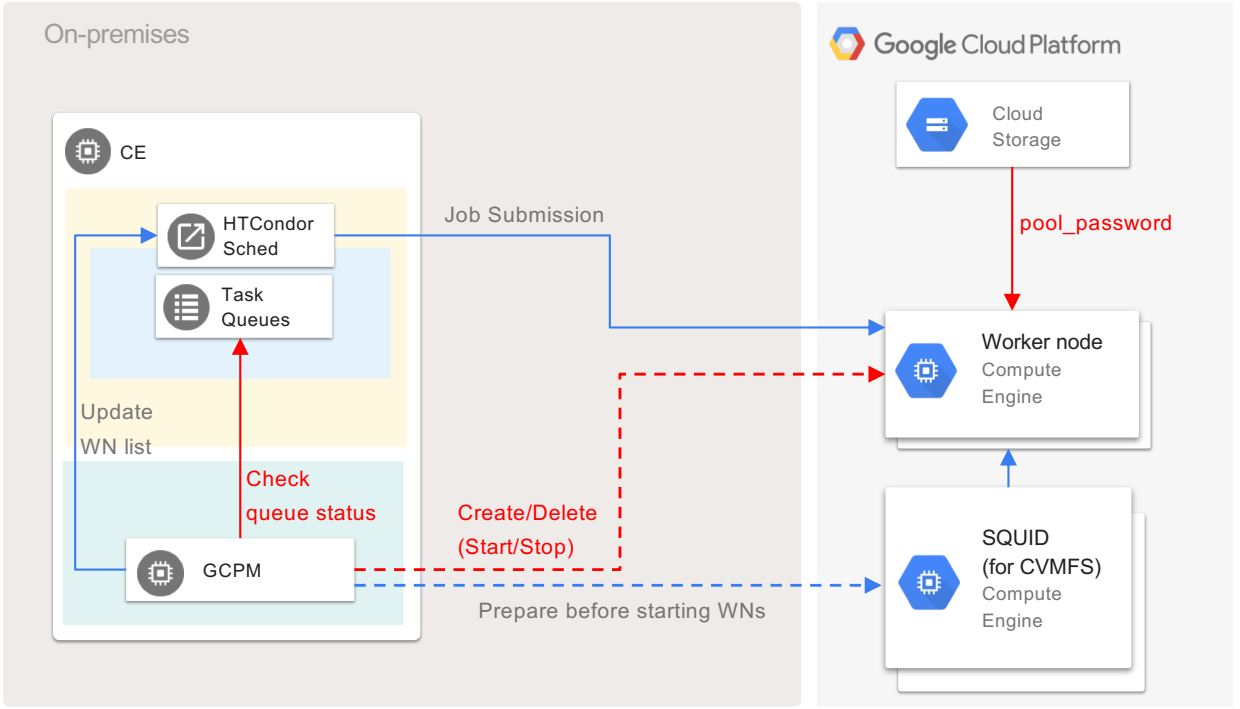
- Check requirement for number of CPUs and prepare for each N CPUs instances
- Each machine types (N CPUs) can have own parameters (disk size, memory, additional GPU, etc…)



pool_password file for the authentication is taken from storage by startup script

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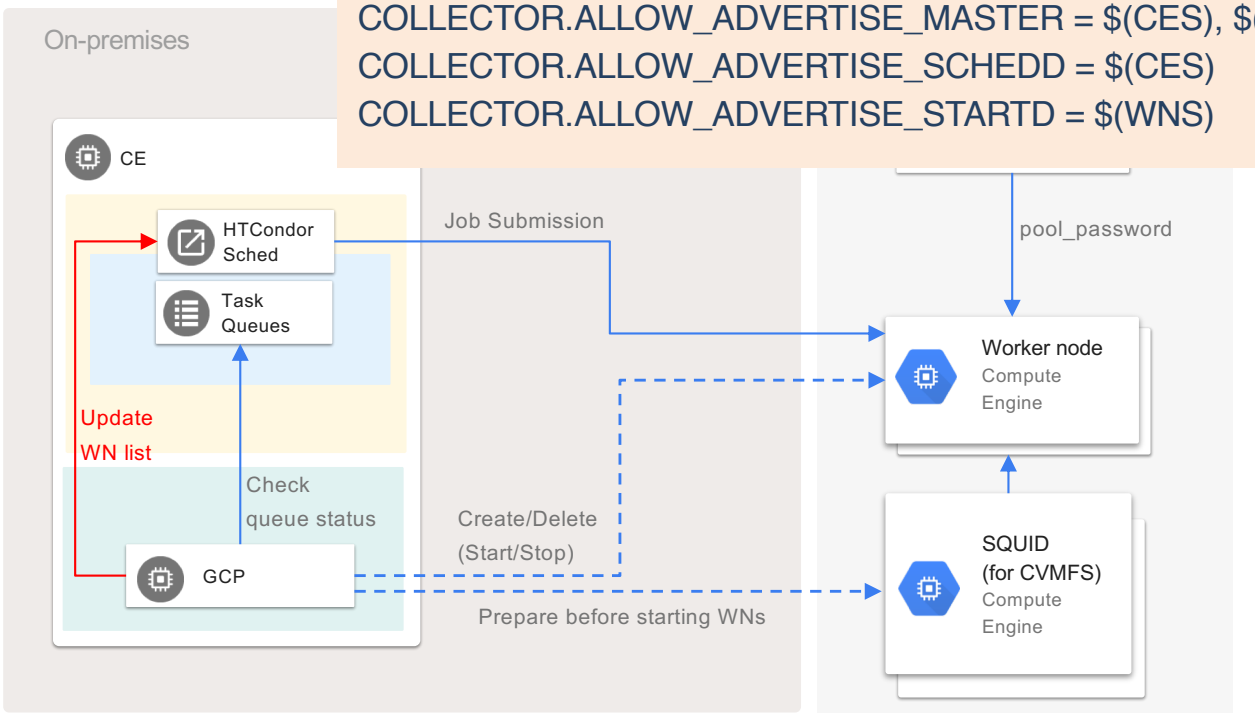
```
SETTABLE_ATTRS_ADMINISTRATOR = ¥
$(SETTABLE_ATTRS_ADMINISTRATOR) WNS

WNS =

COLLECTOR.ALLOW_ADVERTISE_MASTER = $(CES), $(CMS), $(WNS)
COLLECTOR.ALLOW_ADVERTISE_SCHEDD = $(CES)
COLLECTOR.ALLOW_ADVERTISE_STARTD = $(WNS)
```



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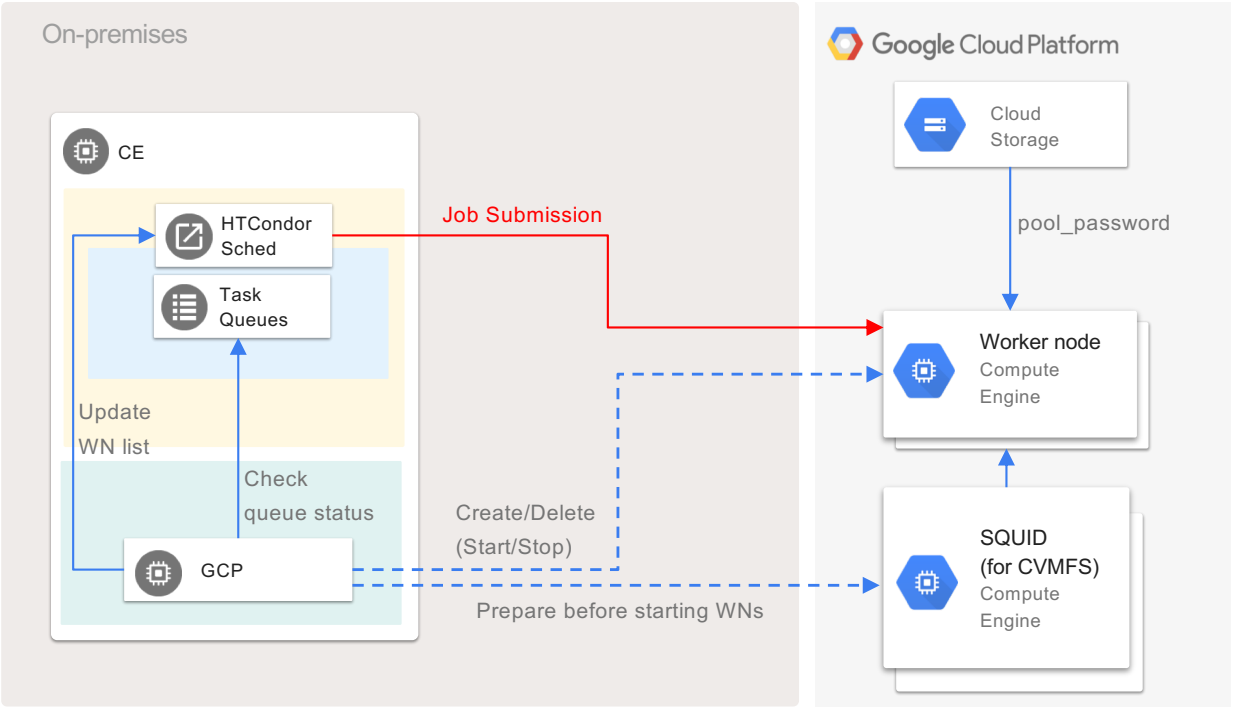


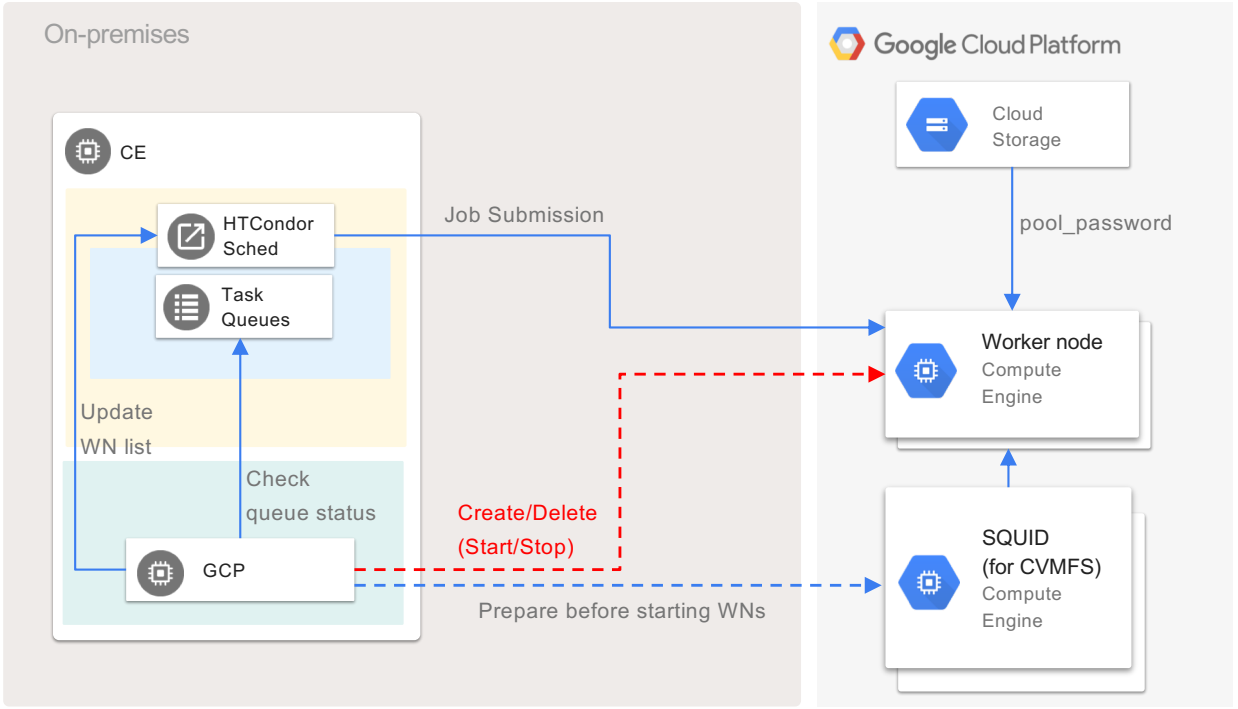
Google Cloud Platform Condor Pool Manager

- Set to execute `*condor_off -peaceful –startd*` after 10min (customizable) by the startup script for GCE instance
- When a job finished, the instance is removed from `*condor_status*` list
- Then GCPM deletes (sotps) the instance
- Another method to run only one job:
  → https://htcondor-wiki.cs.wisc.edu/index.cgi/wiki?p=HowToConfigRunOneJobAndExit

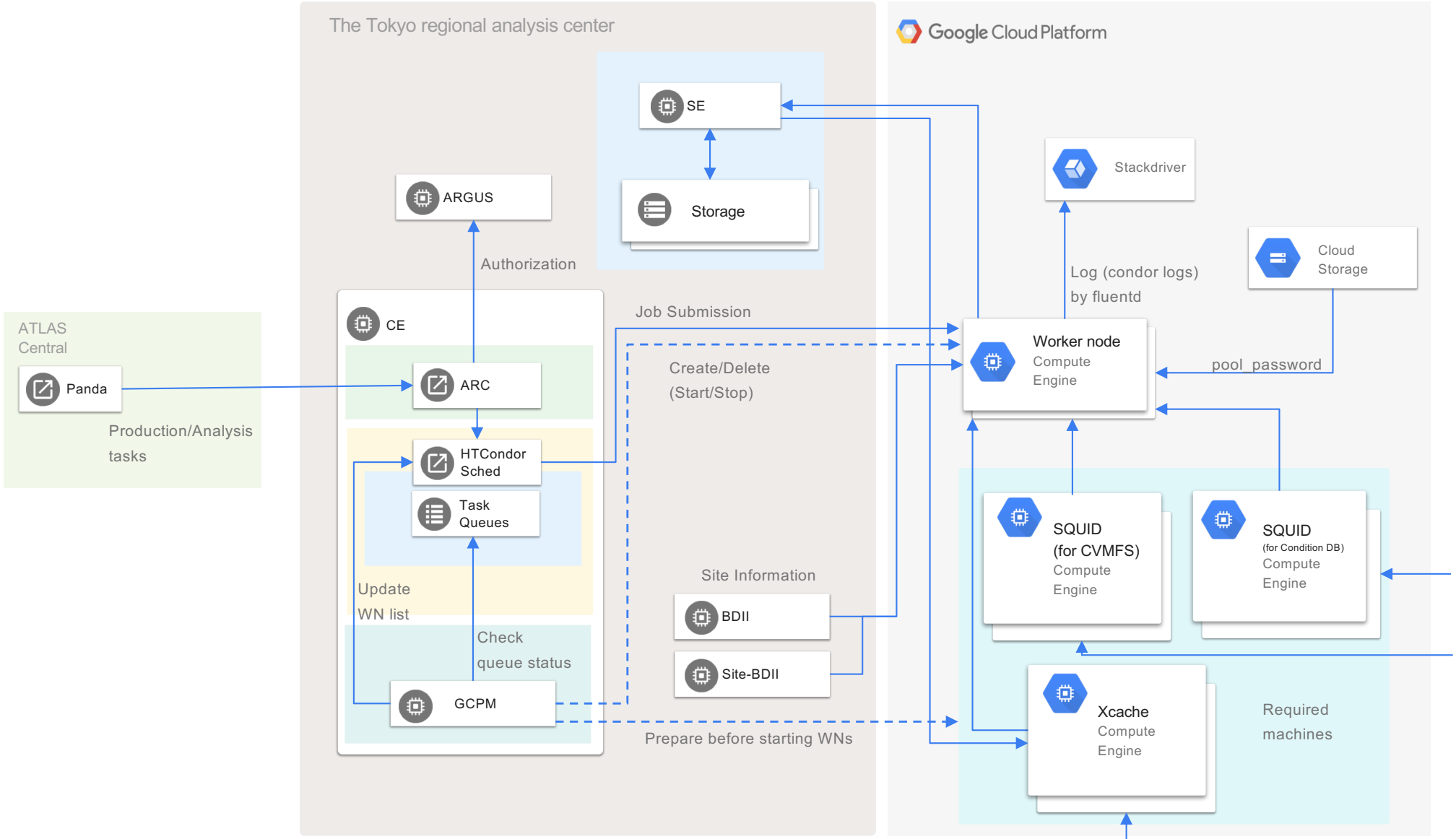
→ Instance's HTCondor startd will be stopped at 10min after starting

→ ~ only 1 job runs on instance, and it is deleted by GCPM

→ Effective usage of preemptible machine



System for R&D

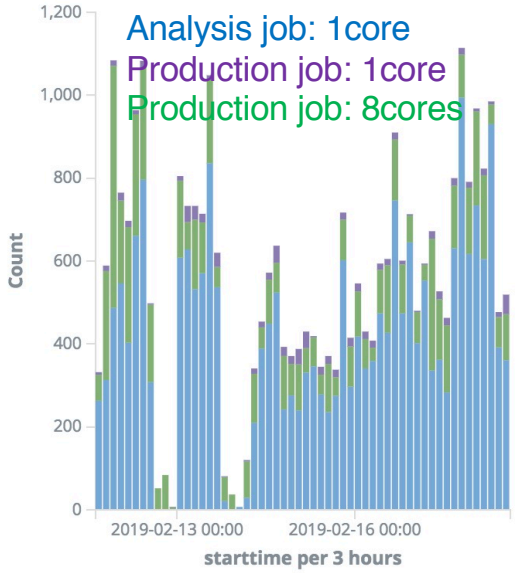


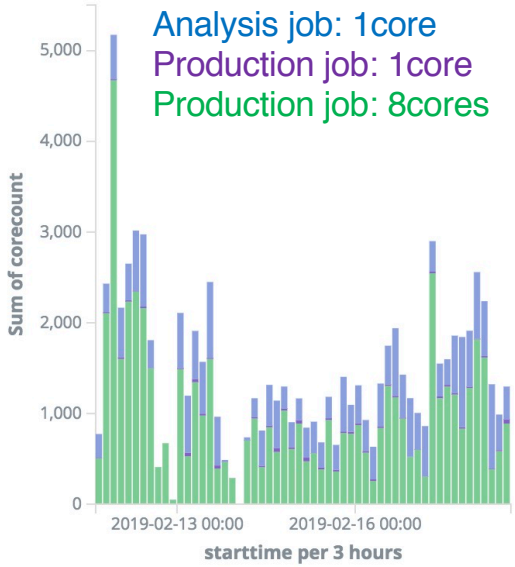
GCE Instance limit for R&D

- 1 vCPU instances: Memoery 2.6GB, Disk 50GB, max 200 instances
- 8 vCPU instances: Memory 19.2GB, Disk 150GB, max 100 instances
  → Total vCPU max: 1000

Jobs Running on GCP

Monitors of job starting time

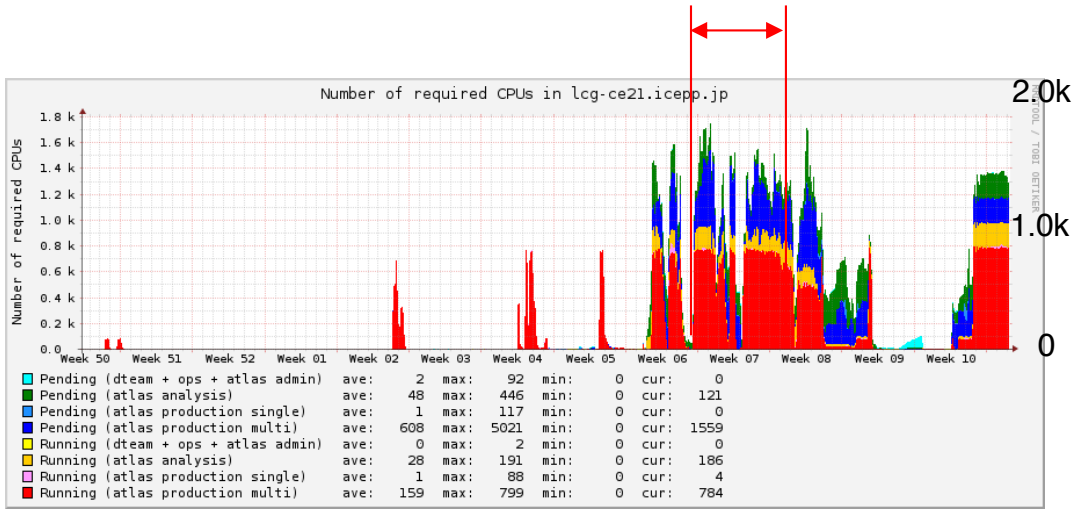




Number of jobs

Number of vCPUs

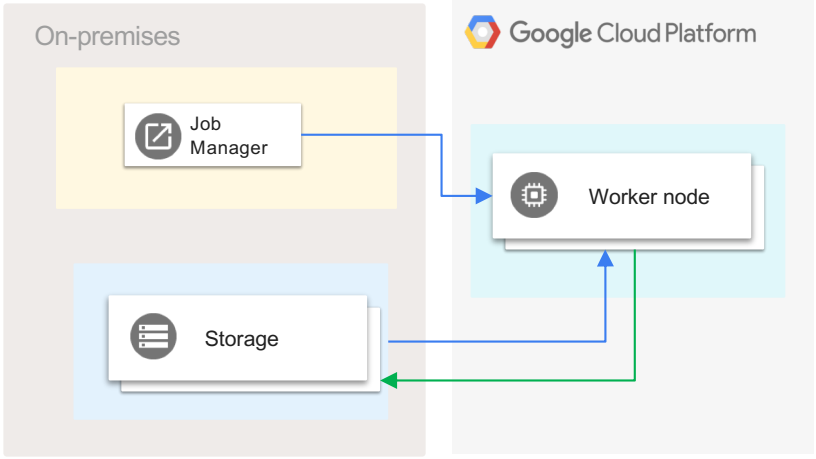
vCPUs



HTCondor status monitor

Analysis job: 1core idle
Production job: 8cores idle
Analysis job: 1core running
Production job: 8cores running

1 Day Real Cost



Hybrid system: 1k cores, 2.4GB/core memory

→ Cost for month (x30), with 20k cores (x20): ~$240k + on-premises costs

1 Day Real Cost (13/Feb)

	Usage	Cost/day	x30x20
vCPU (vCPU*hours)	20046	$177	$106k
Memory (GB*hours)	47581	$56	$34k
Disk (GB*hours)	644898	$50	$30k
Network (GB)	559	$78	$47k
Other services		$30	$18k
Total		$391	$236k

vCPU: 1vCPU instances max 200, 8 vCPUs instances max 100
Memory: 2.4 GB/vCPU
Disk: 50GB for 1vCPU instance, 150 GB for 8 vCPUs instance

Cost Estimation

Resource	Cost/month
vCPU x20k	$130k
3GB x20k	$42k
Local Disk 35GBx20k	$28k
Network GCP WN to ICEPP Storage 300 TB	$43k
Total	$243k

Preemption

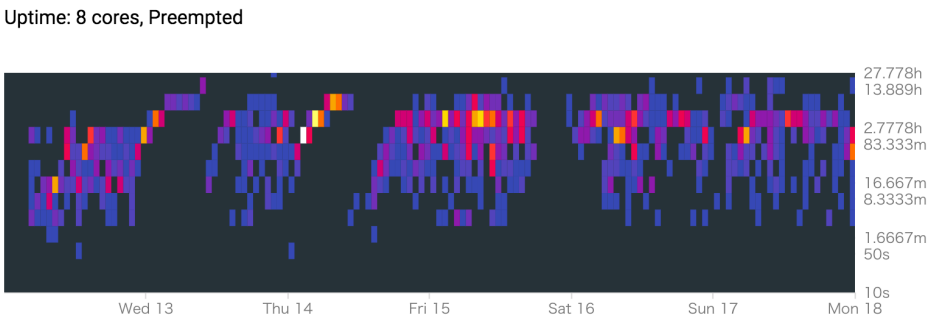
- HTCondor can manage jobs even if instance preemption happened

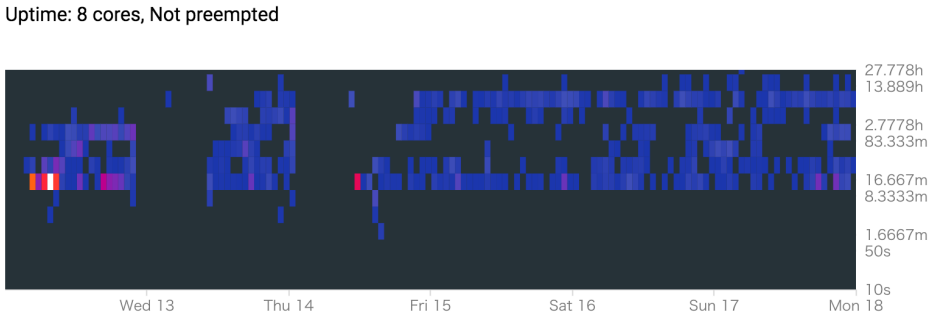
  →The job is evicted and submitted to another node

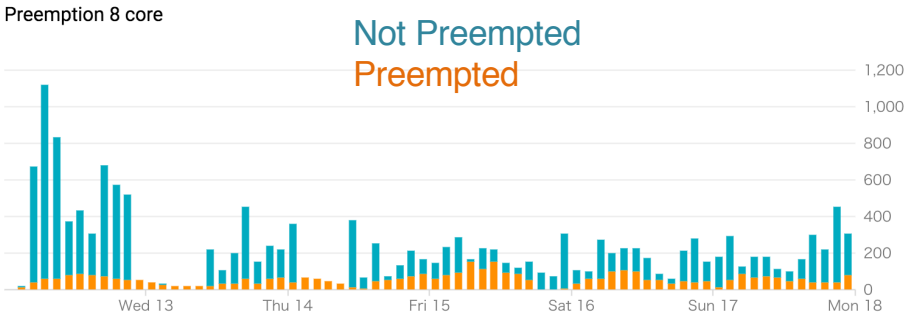
- 30% jobs were affected for 10 hours jobs

- Some upstream managers may not able to manage in such a case, though…

8 core instances







Summary

- The cost of GCP is reasonable
  → Same order compared with on-premises,
  especially if preemptible instances are used

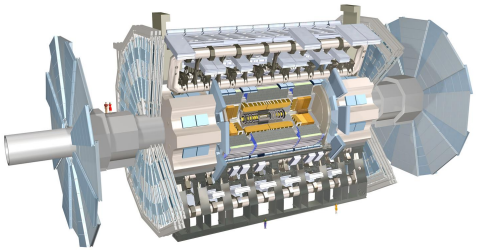
- Hybrid system with GCPM works on the ATLAS Production System in WLCG
  → HTCondor+GCPM can work for small clusters, too,
  in which CPUs are always not fully used
    → You need to pay only for what you used
    → GCPM can work for GPU worker nodes, too

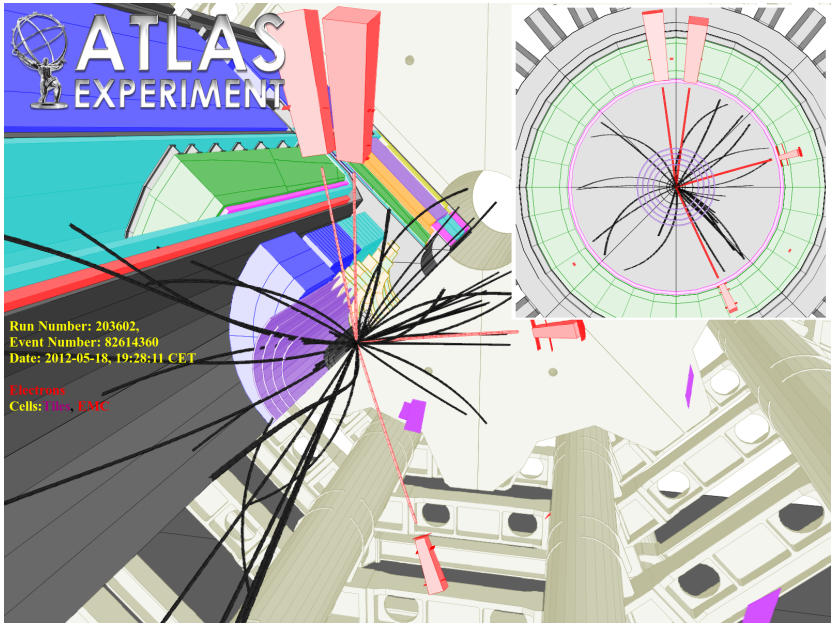
- GCPM is available:
  → https://github.com/mickaneda/gcpm
    → You can install by pip: $ pip install gcpm
  → Puppet example for head and worker nodes:
    → https://github.com/mickaneda/gcpm-puppet

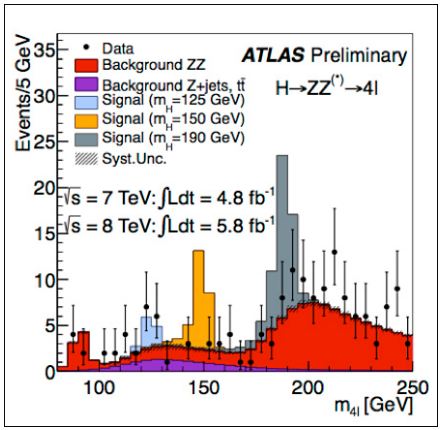
- HTCondor natively supports AWS worker nodes since 8.8
  → Integration of GCPM functions in HTCondor…?

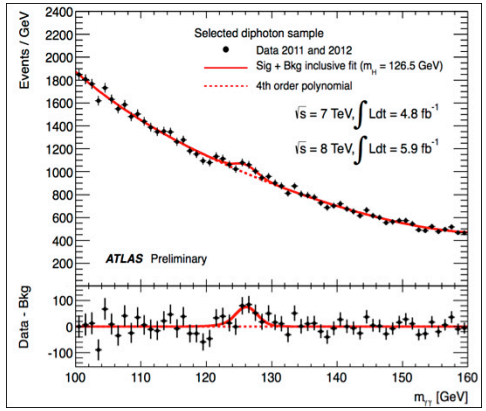
Backup

The ATLAS Experiment



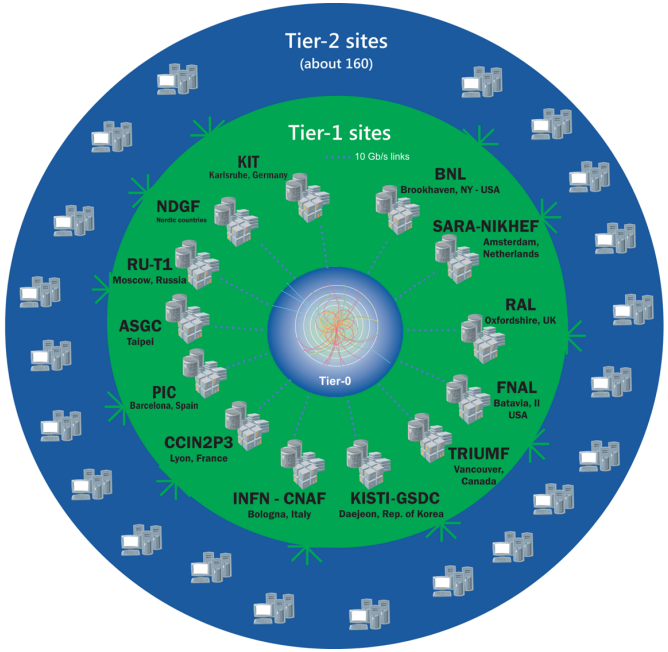






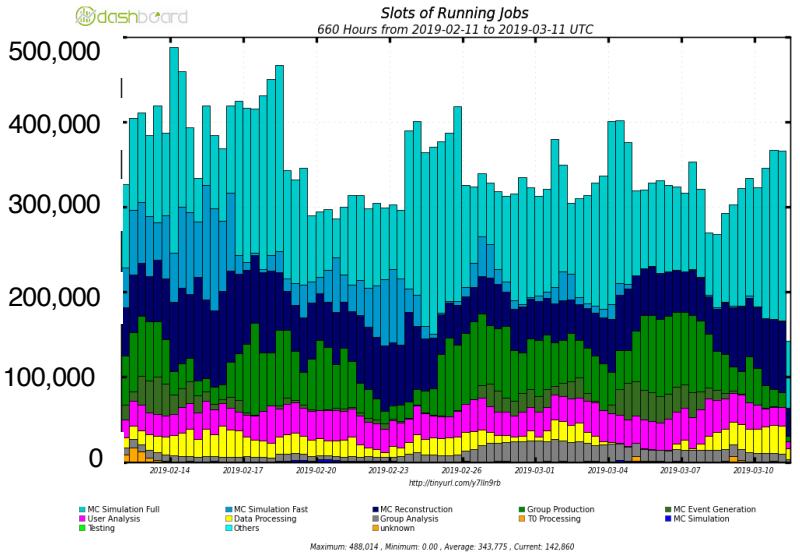
The Higgs Boson Discovery in 2012

Worldwide LHC Computing Grid (WLCG)



- A global computing collaboration for LHC
  → Tier0 is CERN

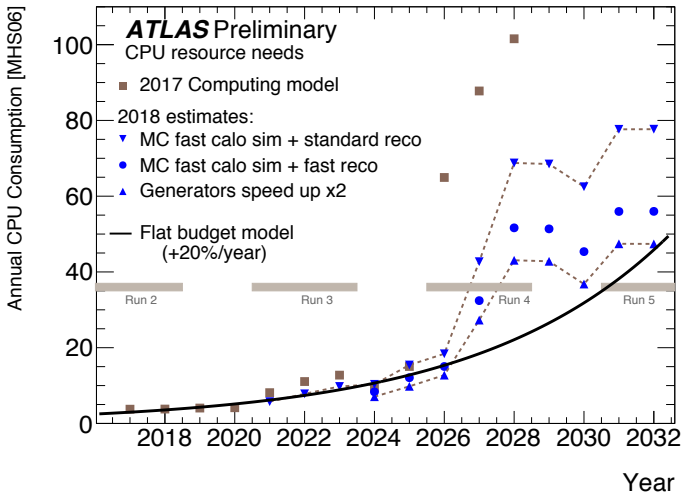
- The Tokyo regional analysis center is one of Tier2 for ATLAS



Number of cores used by ATLAS

Computing Resources for HEP

- Data amount of HEP experiments becomes larger and larger
  - →Computing resource is one of the important piece for experiments
- CERN plans High-Luminosity LHC
  - →The peak luminosity: x 5
  - →Current system does not have enough scaling power
  - →Some new ideas are necessary to use data effectively
    - →Software update
    - →New devices: GPGPU, FPGA, (QC)
    - →New grid structure: Data Cloud
    - →External resources: HPC, Commercial cloud



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- Amazon Web Service (AWS)
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  - →Hyper threading on
  - →HTCondor supports AWS resource management from 8.8
- Microsoft Azure
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  - →Hyper threading off machines are available

ARC CE Hacking

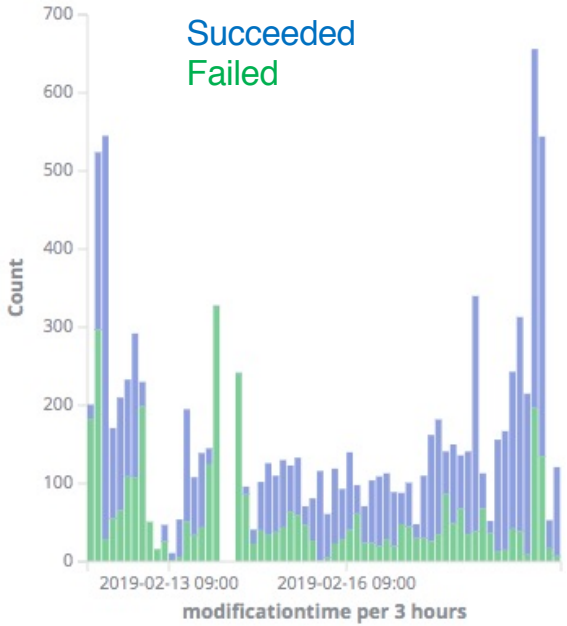
- ARC checks a number of available slots before submitting jobs
  - → If a job specifies a number of CPUs and there are not enough slots, job submission fails
  - → GCP pool has no slot at the start, jobs cannot be submitted
  - → Hack /usr/share/arc/Condor.pm to return non-zero cpus if it is zero

```
#
# returns the total number of nodes in the cluster
#
sub condor_cluster_totalcpus() {
    # List all machines in the pool. Create a hash specifying the
TotalCpus
    # for each machine.
    my %machines;
    $machines{$$_{machine}} = $$_{totalcpus} for @allnodedata;

    my $totalcpus = 0;
    for (keys %machines) {
        $totalcpus += $machines{$_};
    }

    # Give non-zero cpus for dynamic pool
    $totalcpus ||= 100;
    return $totalcpus;
}
```

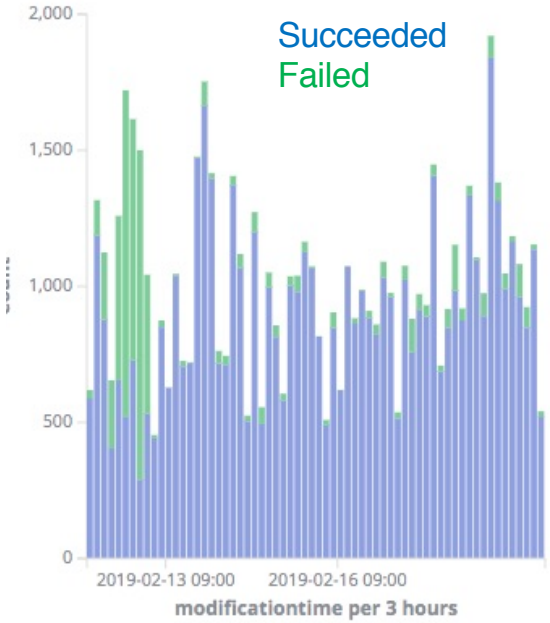
Other Features of GCPM

- Configuration files:
  → YAML format
- Machine options are fully customizable
- Can handle instances with different number of cores
- Max core in total, max instances for each number of cores
- Management of other than GCE worker nodes
  → Static worker nodes
  → Required machines
  → Working as an orchestration tool
- Test account
- Preemptible or not
- Reuse instances or not
- Pool_password file management
- Puppet files are available for
  → GCPM set
  → Example worker node/head node for GCPM
  → Example frontier squid proxy server at GCP

Failure Rate (Production Jobs)



GCP Worker Nodes
(Production Job)

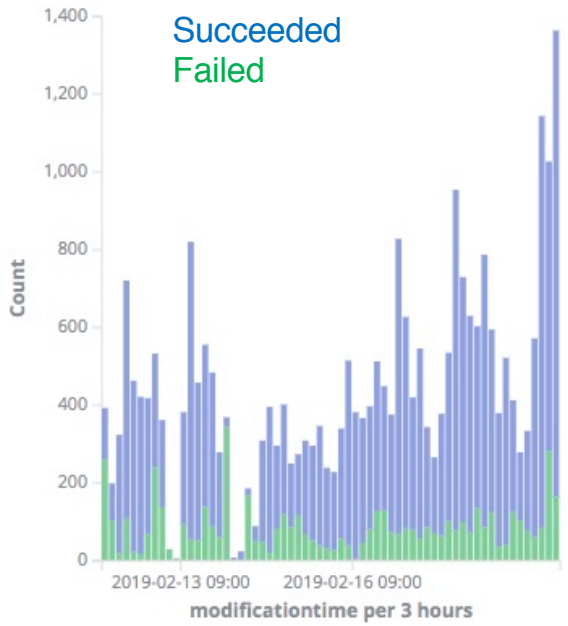


ICEPP Worker Nodes
(Production Job)

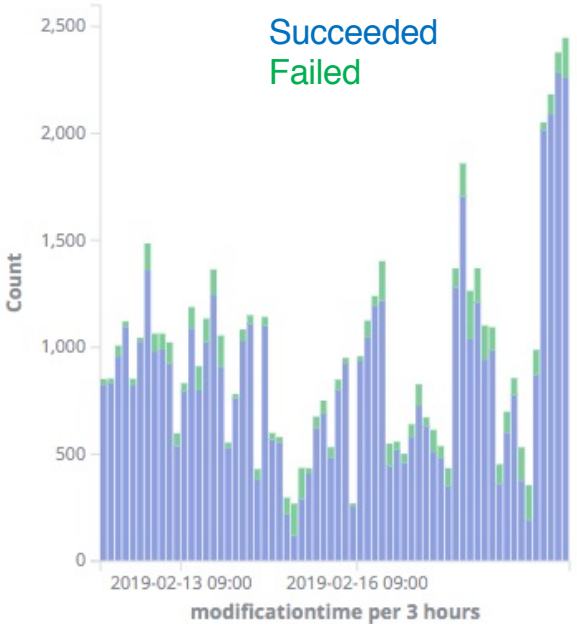
Job Type	Error rate
GCP Production (Preemptible)	35%
GCP Production (Non-Preemptible)	6%
Local Production	11%

Mainly 8 core jobs, long jobs (~10 hours/job)

Failure Rate (Analysis Jobs)



GCP Worker Nodes
(Analysis Job)



ICEPP Worker Nodes
(Analysis Job)

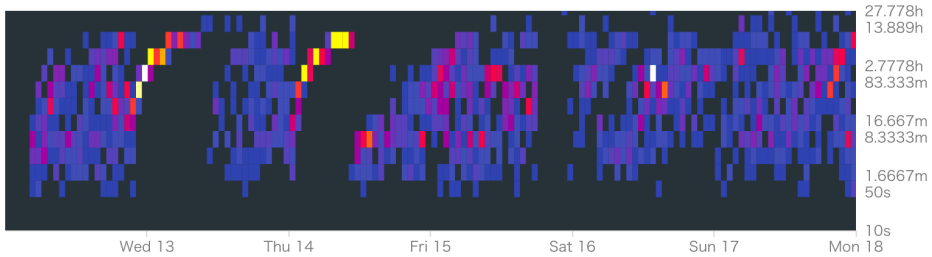
Job Type	Error rate
GCP Analysis (Preemptible)	19%
GCP Analysis (Non-Preemptible)	14%
Local Analysis	8%

Only 1 core job, shorter jobs

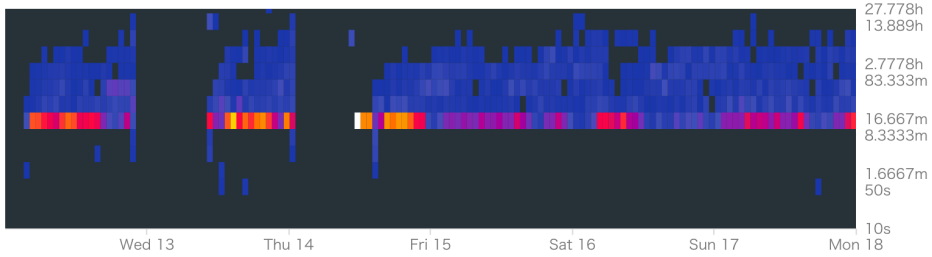
Preemption

1 core instances

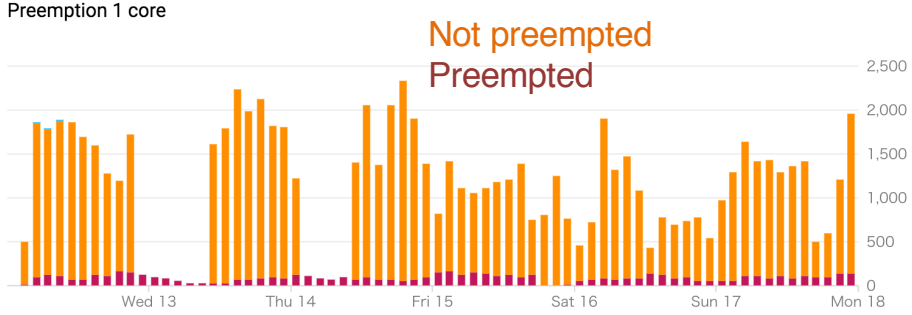
Uptime: 1 core, Preempted



Uptime: 1 core, Not preempted

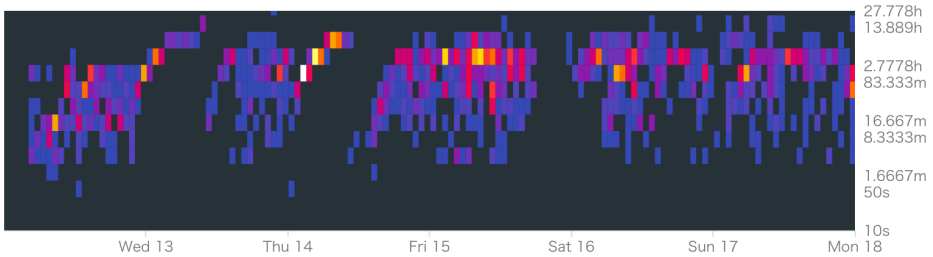


Preemption 1 core

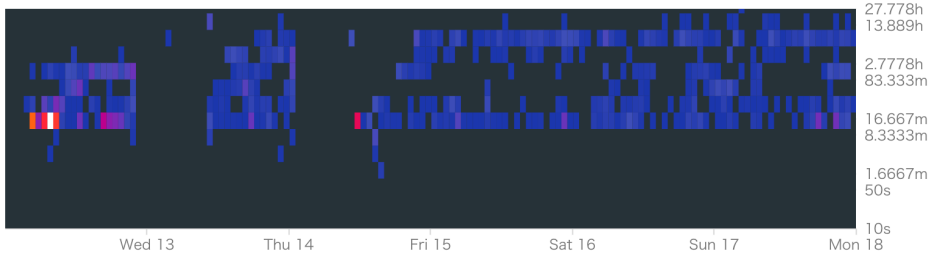


8 core instances

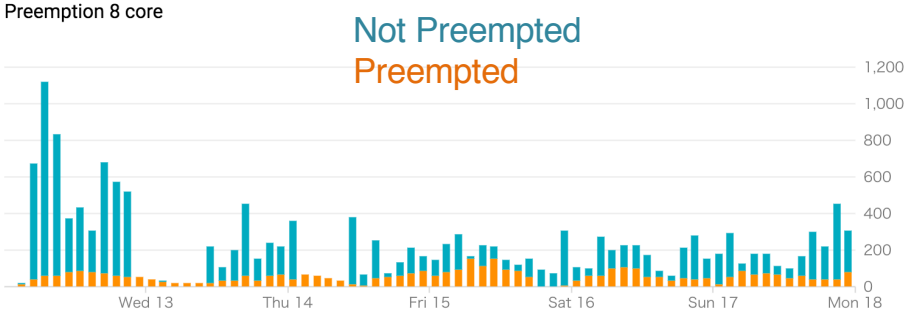
Uptime: 8 cores, Preempted



Uptime: 8 cores, Not preempted

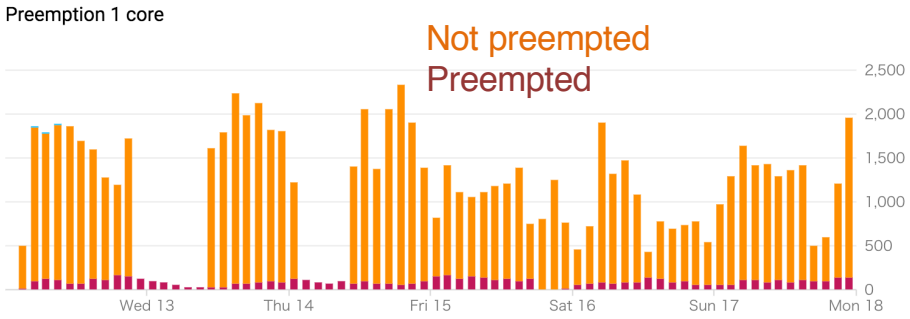


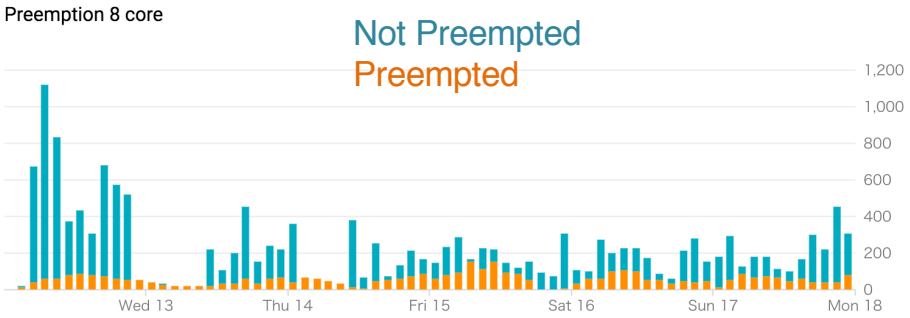
Preemption 8 core



Preemption v.s. Failure jobs

- 5~30 % instances were shut down by Preemption
  →Made failure jobs
- Typically shut down around 3~10 hours
  →Some instances were shutdown before 1 hours running
- More preemptions in 8 core jobs (production: reco/sim) because job running times are longer





Develop Environment for Python-GCPM

Package manager: Poetry
CLI: made with python-fire
License: Apache 2.0

Local Machine

Secret files are encrypted by git-crypt
travis encrypt-file is also used for travis job
(service account file for gcp, etc…)

GitHub

Tests by pytest
On Ubuntu Xenial
For python 2.7, 3.5, 3.6, 3.7

pytest-cov result
(in gh-pages branch)

Travis CI

The Python Package Index (PyPI)
($ pip install gcpm)

Develop Environment for Python-GCPM

Package manager: Poetry
CLI: made with python-fire
License: Apache 2.0

Package manager: Poetry

Directory Structure

```
gcpm
 |--|-- pyproject.toml
    |-- src
    |    |-- gcpm
    |    |    |-- __init__.py
    |    |    |-- __main__.py
    |    |    |-- __version__.py
    |    |    |-- cli.py
    |    |    |-- core.py
    |-- tests
    |    |-- __init__.py
    |    |-- conftest.py
    |    |-- data
    |    |    |-- gcpm.yml
    |    |    |-- service_account.json
    |    |-- test_cli.py
```

- Package initialization
- Management of package dependencies
- Build & Publish to PyPi
- Automatic virtualenv management
- Easy to make CLI tool

```
$ poetry init                    # Initialize package
$ poetry add fire                # Add fire to dependencies
$ poetry run gcpm version        # Run gcpm in virtualenv
$ poetry run pytest              # Run pytest in virtualenv
$ poetry publish –build          # Build and publsh to PyPi
```

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Develop Environment for Python-GCPM

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CLI: made with python-fire

```
from .core import Gcpm
import fire


class CliObject(object):

    def __init__(self, config=""):
        self.config = config

    def version(self):
        Gcpm.version()

    def run(self):
        Gcpm(config=self.config).run()


def cli():
    fire.Fire(CliObject)

if __name__ == "__main__":
    cli()
```

- Library for automatically generating CLI from absolutely any Python object

```
$ gcpm version
gcpm: 0.2.0
$ gcpm –-config /path/to/config run
Starting gcpm
…
```

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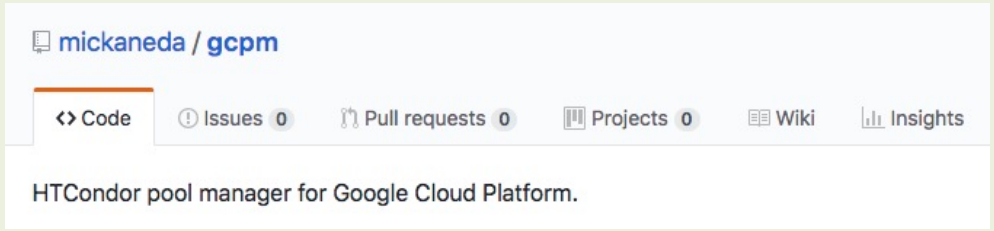
GitHub

Source code at: GitHub



- Open source
  - License: Apache 2.0
- Automatic test/build on Travis CI at push

t
nial
, 3.5, 3.6, 3.7

pytest-cov result
(in gh-pages branch)

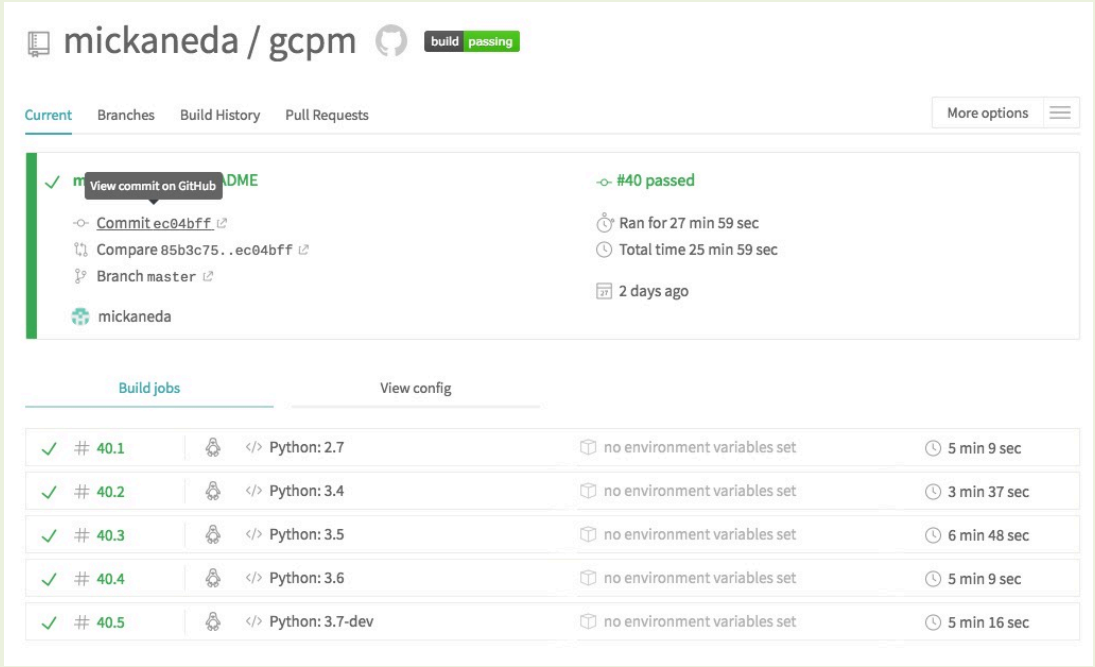
Travis CI

Develop Environment for Python-GCPM

Package manager: Poetry

ire

Test/Build on Travis CI



- Run pytest for every push
- Tested with python2.7, 3.4, 3.5, 3.6 and 3.7-dev
- Build & publish to PyPi after test on Tag may be useful (not implemented)

```
289 tests/test_service.py::test_service[kw0] PASSED                    [ 83%]
290 tests/test_service.py::test_service[kw1] PASSED                    [ 87%]
291 tests/test_utils.py::test_expand PASSED                            [ 90%]
292 tests/test_utils.py::test_proc PASSED                              [ 93%]
293 tests/test_utils.py::test_make_startup_script PASSED               [ 96%]
294 tests/test_utils.py::test_make_shutdown_script PASSED              [100%]
295
296 ---------- coverage: platform linux2, python 2.7.15-final-0 ----------
297 Coverage HTML written to dir htmlcov
```

vis job

GitHub

nial

, 3.5, 3.6, 3.7

pytest-cov result
(in gh-pages branch)

Travis CI

Develop Environment for Python-GCPM

Package manager: Poetry

pytest-cov result in gh-pages branch

- Test coverage is measured by pytest-cov
- There result is published in gh-pages of gcpm repository at GitHub

Google Cloud Platform Condor Pool Manager (GCPM)

build passing (Coverage report)

HTCondor pool manager for Google Cloud Platform.

Coverage report: 69%

Module ↓	statements	missing	excluded	coverage
src/gcpm/__init__.py	3	0	0	100%
src/gcpm/__main__.py	6	3	0	50%
src/gcpm/__version__.py	1	0	0	100%
src/gcpm/cli.py	26	3	0	88%
src/gcpm/condor.py	90	65	0	28%
src/gcpm/core.py	457	163	0	64%
src/gcpm/files.py	30	8	0	73%
src/gcpm/gce.py	139	17	0	88%
src/gcpm/gcs.py	41	1	0	98%
src/gcpm/service.py	43	3	0	93%
src/gcpm/utils.py	27	1	0	96%
Total	**863**	**264**	**0**	**69%**

coverage.py v4.5.2, created at 2019-01-20 17:16

vis job

nial

, 3.5, 3.6, 3.7

GitHub

pytest-cov result
(in gh-pages branch)

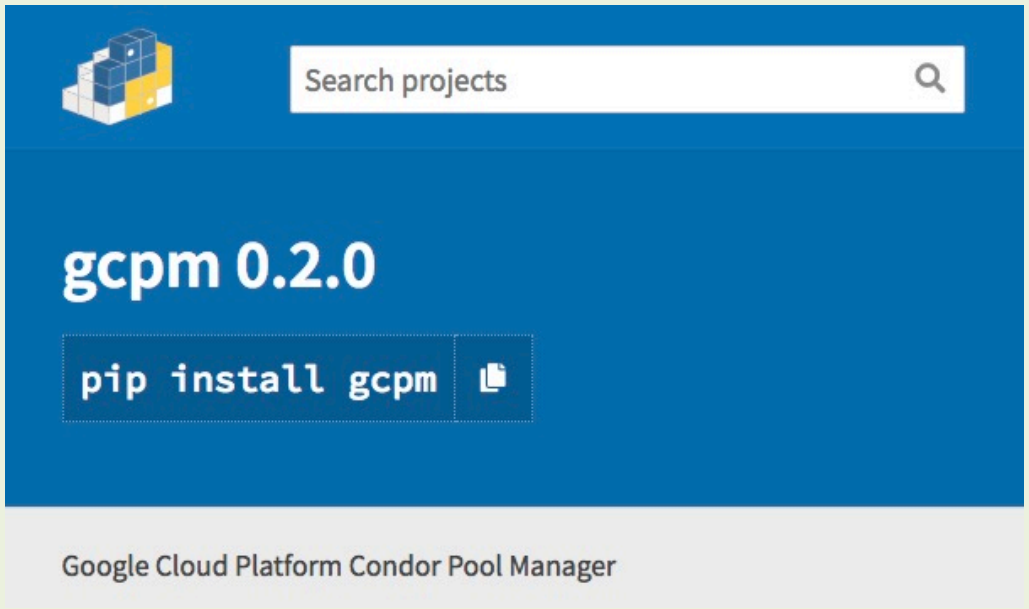
Travis CI

Develop Environment for Python-GCPM

python powered

Local Machine

Published on the Python Package Index (PyPI)



$ pip install gcpm

Travis CI

The Python Package Index (PyPI)
($ pip install gcpm)