Dynamic Cloud-based clusters with HTCondor

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Outline

Context & Goals

Dependencies/Limitations

System Components

- Workflow coordination: Job Factory
- Virtual Machines: Creation and Deployment
- HTCondor pool: Scaling for the WAN
- Cloud platform(s): EC2/OpenStack

Results

Glitches, Issues, and Problems

Next Steps

Context

ATLAS

- LHC Experiment at CERN
- In the US: BNL Tier 1, ~dozen Tier 2s, Tier 3s (local research groups)

Heavy users of OSG and HTCondor, but...

- No opportunistic use on OSG due to software constraints.
- Declining budget environment.
- Highly variable needs from Tier 3s/researchers
- Inefficient use of Tier 1 resources for simulation (low I/O)

Large-scale clusters have been done before. This work:

- Attempts to provide a complete workload solution. Wide-area pool + VM invocation.
- Allows repeatability via published docs/recipes.

How?

- $50K Amazon research grant. Thanks Michael!

Goal(s)

Run large Condor pool on multiple cloud platforms and/or providers.

- Spread across large area, possibly multi-continental.
- Include facility OpenStack instance(s).
- Utilize spot pricing on EC2.
- Allow the size of the distributed pool to be adjusted dynamically.
- Run typical ATLAS production (simulation) workloads on it.

Why?

- Free up high-performance Tier 1 resources for user analysis by moving low I/O work to EC2 and/or academic clouds.
- Pre-position ATLAS to utilize additional cloud-based resources that might become available.

Dependencies/Limitations

Inconsistent behavior, bugs, immature software:

- shutdown -h means destroy instance on EC2, but means shut off on OpenStack (leaving the instance to count against quota).
- EC2 offers public IPs, Openstack nodes behind NAT

VO infrastructures often not designed to be fully dynamic:

- E.g., ATLAS workload system assumes static sites.
- Data management assumes persistent endpoints
- Others? Any element that isn't made to be created, managed, and cleanly deleted programmatically.

EC2 imposes data export costs.

- Not appropriate for large-output work. (yet)

BNL imposes security and networking constraints.

Elastic Cluster Components

AutoPyFactory (APF): Coordinates submissions

- One APF queue observes a Panda queue, submits pilots to local Condor pool.
- Second APF queue
  - Observes a local Condor pool, when jobs are Idle, submits WN VMs to IaaS (up to a limit).
  - Notices spot terminations, submits additional VMs.

Worker Node VMs

- Condor startds join back to local Condor cluster.
- VMs are identical, don't need public IPs, and don't need to know about each other.

HTCondor pool

- Static Central Manager.
- Dynamic Execute hosts.

AutoPyFactory (APF)

APF (v2) is the ATLAS pilot factory utility

- Multi-threaded OO Python daemon. 1 thread per “APF queue”
- Uses HTCondor-G for grid submission
- Has done all ATLAS pilot submission in the US for 1 year+
- Migration to APFv2 nearly complete in Europe.
- Developed at BNL

Used by ATLAS, but modular and generic:

- Plug-in architecture for WMS, Batch, and scheduling functionality.
- No required ATLAS/Panda coupling or dependencies.
- Used within CloudScheduler at UVic.

Virtual Machines

Worker Node VM creation and deployment using Boxgrinder:

- http://boxgrinder.org/
- http://svn.usatlas.bnl.gov/svn/griddev/boxgrinder/

Notable features:

- Modular appliance inheritance. The wn-atlas definition inherits from the wn-osg and wn-batch profile, which in turn inherit from base.
- “Baked in” HTCondor startd connects back to static Central Manager.
- BG uploads built images directly to Openstack (v3+), EC2, **libvirt**, or local directory via 'delivery plugins'.

Bad News! Boxgrinder being deprecated.

- Superceded by Aeolus/Oz/Imagefactory.
- Similar, but different model: XML, embedded resources, no inheritance.
- I prefer BG model, but don't have much choice.

WN Image Deployment

Build and upload VM:

svn co http://svn.usatlas.bnl.gov/svn/griddev/boxgrinder

<Add condor_password file to source tree.>

<Edit COLLECTOR_HOST to point to your collector>

boxgrinder-build -f boxgrinder/sl6-x86_64-wn-atlas.appl -p ec2 -d ami

boxgrinder-build -f boxgrinder/sl6-x86_64-wn-atlas.appl -p ec2 -d ami
--delivery-config region:us-west-2,bucket:racf-cloud-2

```
#~.boxgrinder/config
plugins:
  openstack:
    username: jhover
    password: XXXXXXXXX
    tenant: bnlcloud
    host: cldext03.usatlas.bnl.gov
    port: 9292
```

```
s3:
    access_key: AKIAJRDFC4GBBZY72XHA
    secret_access_key: XXXXXXXXXXX
    bucket: racf-cloud-1
    account_number: 4159-7441-3739
    region: us-east-1
    snapshot: false
    overwrite: true
```

Condor Scaling: Naive attempt

Known requirements:

- Condor Connecton Broker (some startds are behind NAT)
- Password authentication (simplest secure setup on WAN)
- HTCondor 7.9.x

Naive Approach:

- Single Condor host (schedd, collector, etc.)
- Single process for each daemon

Result: **Maxed out at ~3-4 thousand nodes.**

- Collector load causing timeouts of schedd daemon.
  - WAN latencies + strong auth?
- Network connections exceeding open file limits/open ports
- Collector duty cycle regularly >= .99.

Collector & Schedd Tuning 1

OS-level Adjustments:

- Host-based firewall open on relevant ports
- Institutional firewall open on relevant ports
- Sufficient open files/ user process limits/ max connections:

```
#/etc/security/limits.conf
*   -    nofile      1000000
*   -    nproc       unlimited
*   -    memlock     unlimited
*   -    locks       unlimited
*   -    core        unlimited

#/etc/sysctl.conf
fs.file-max = 1000000
```

Collector & Schedd Tuning 2

Split (Collector, Negotiator, CCB) host from Schedd host

- Protects schedd from Collector and network-related load

Multiple condor_collector *processes*

- 20 collector processes reporting to single top-level collector.
- (glideinWMS uses as many as ~200+.)
- Execute hosts randomly choose one at boot-time.

Enable the shared port daemon everywhere possible

- Reduces number of separate TCP connections between execute, schedd, and collector hosts.

Enable session auth.

- Minimize security re-negotiation, which is very costly in high-latency scenarios.

```
# /etc/condor/config.d/50cloudcollector.config
# Available at http://svn.usatlas.bnl.gov/svn/griddev/boxgrinder/
# /condor/50cloudcollector.config

# Multiple collector processes
COLLECTOR_HOST=$(CONDOR_HOST):29650
USE_SHARED_PORT = TRUE
COLLECTOR.USE_SHARED_PORT = FALSE
DAEMON_LIST = COLLECTOR, MASTER, NEGOTIATOR, SCHEDD, SHARED_PORT
COLLECTOR1 = $(COLLECTOR)
COLLECTOR2 = $(COLLECTOR)
COLLECTOR1_ARGS = -f -p 29660
COLLECTOR2_ARGS = -f -p 29661
DAEMON_LIST = $(DAEMON_LIST) COLLECTOR1 COLLECTOR2

# Enable session auth.
SEC_ENABLE_MATCH_PASSWORD_AUTHENTICATION  = True

# Don't preempt *ever*
PREEMPT = FALSE
KILL = FALSE
PREEMPTION_REQUIREMENTS = False
RANK = 0
NEGOTIATOR_CONSIDER_PREEMPTION = False
CLAIM_WORKLIFE = 3600
```

Execute Host Tweaks

Choose random Collector port to connect to.

- Implemented via /etc/init.d/condorconfig script.

Similar tweaks to Central Manager:

- Enable SHARED_PORT
- Enable CCB
- Enable session auth.

Collect and export cloud info from metadata server:

- instance-id, public-hostname,public-ipv4

Allow the central management of startd state:

- This will be used for retirement, shutdown.
- E.g. via ***condor_off -peaceful***

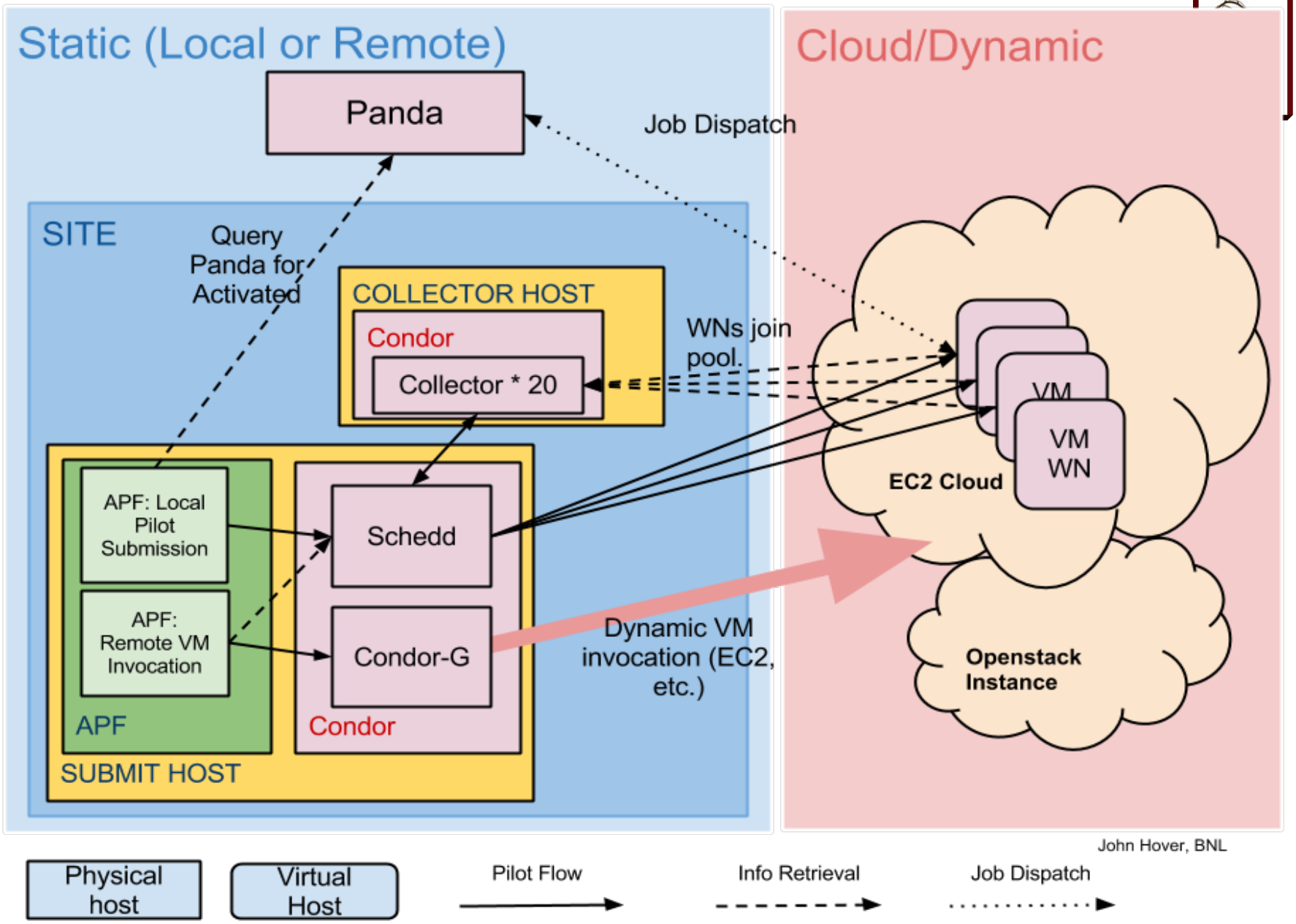
```
# /etc/condor/config.d/50cloudcondor.config
# Available at http://svn.usatlas.bnl.gov/svn/griddev/boxgrinder/

DAEMON_LIST = MASTER, STARTD, SHARED_PORT
CCB_ADDRESS = $(COLLECTOR_HOST)
UID_DOMAIN = localhost.localdomain

# Security
ALLOW_WRITE = condor_pool@*
SEC_DEFAULT_AUTHENTICATION = REQUIRED
SEC_DEFAULT_AUTHENTICATION_METHODS = PASSWORD, FS
SEC_PASSWORD_FILE = /etc/condor/password_file
SEC_DEFAULT_ENCRYPTION = REQUIRED
SEC_DEFAULT_INTEGRITY = REQUIRED
SEC_ENABLE_MATCH_PASSWORD_AUTHENTICATION  = True

# Allow remote admin
ALLOW_WRITE = $(ALLOW_WRITE), submit-side@matchsession/*
ALLOW_ADMINISTRATOR = condor_pool@*/*

USER_JOB_WRAPPER = /usr/libexec/jobwrapper.sh
DEDICATED_EXECUTE_ACCOUNT_REGEXP = slot[1-8]+
```


Static (Local or Remote)
Cloud/Dynamic
Panda
Job Dispatch
SITE
Query Panda for Activated
COLLECTOR HOST
Condor
Collector * 20
WNs join pool.
VM
VM WN
EC2 Cloud
APF: Local Pilot Submission
APF: Remote VM Invocation
APF
Schedd
Condor-G
Condor
SUBMIT HOST
Dynamic VM invocation (EC2, etc.)
Openstack Instance
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Physical host
Virtual Host
Pilot Flow
Info Retrieval
Job Dispatch

EC2 and HTCondor

On-demand vs. Spot

- On-Demand: You pay standard price. Never terminates.
- Spot: You declare *maximum* price. You pay current,variable spot price. When spot price exceeds your maximum, instance is terminated without warning.
- But partial hours are *not charged*.
- HTCondor handles spot by making one-time spot request, then cancelling it when fulfilled.

Problems:

- Memory provided in units of 1.7GB (less than ATLAS req).
- More (or less) memory than needed per “virtual core”
- On our private Openstack, we created a 1-core, 2GB RAM instance type.

EC2 Spot Considerations

Users utilizing spot pricing need to consider:

- Shorter jobs. Simplest approach. ATLAS originally worked to ensure jobs were *at least* a couple hours, to avoid pilot flow congestion. Now we have the opposite need.
- Checkpointing. Some work in Condor world providing the ability to checkpoint without linking to special libraries.
- Per-work-unit stageout (e.g. event server in HEP).

With sub 1-hour units of work, users could get significant free time!

EC2 Types

Type	Memory	VCores	"CUs"	CU/Core	$Spot/hr Baseline	$On-Demand/hr	Slots?
m1.small	1.7G	1	1	1	.007	.06	-
m1.medium	3.75G	1	2	2	.013	.12	1
m1.large	7.5G	2	4	2	.026	.24	3
m1.xlarge	15G	4	8	2	.052	.48	7

Questions:

- We currently bid 3 * <baseline>. Is this optimal?
  - Seems to result in ~1/3 churn per day.
- Spot is ~1/10th the cost of on-demand. Nodes are ~1/2 as powerful as our dedicated hardware. **Based on estimates of Tier 1 costs, this is competitive.** But need exact numbers.
- Do 7 slots on m1.xlarge perform economically?

Results

HTCondor Scaling Results

- Smooth operation, even with bursts of new execute hosts.
- DaemonCoreDutyCycle ~.35. Lots more headroom.

Overall Project Results

- Ran ~5000 EC2 (1-slot) nodes for ~3 weeks.
- 3 EC2 zones (Virginia, California, Oregon)
- Added in ~250 Openstack slots to virtual pool as well.
- Spent approximately $13K. Only $750 was for data transfer.
- Poor EC2 efficiency poor due to long jobs. Otherwise reliable operation.
- Actual spot price paid very close to baseline, e.g. still less than . $.01/hr for m1.small.

Results 2

"Replicate-able"

- Entire setup was duplicated on 2 other hosts in ~3 hours.
- Now running ~4000 slots on Google Compute Engine
- GCE does not permit image upload (yet), so execute adjustments added manually and snapshotted.

Public

- All recipes are in our Boxgrinder SVN repo. No "secret sauce".
- APF is generic and modular enough to be used as a general-purpose conditional job factory.

Glitches, Issues, Problems

Don't want to preempt, ever!

- Rather tricky to express. Took several iterations.

Allowing admin access to pool from particular user account.

- Required somewhat hack-ish:

```
#~/.bash_profile

export _condor_SEC_PASSWORD_FILE=/var/home/apf/etc/password_file
```

Documentation

- In general, lack of high-level design documentation combined with detailed recipes (like this use case).
- Now being addressed as a result of this activity.

Glitches, Issues, Problems 2

Multi-collector setup is awkward

- Requires verbose, complex CM config
- Requires execute host coupling (i.e. port range to choose from).
- Team is considering simpler config, e.g.
  NUM_COLLECTORS=20
  and auto-discovery of real collector port from CM by startd.

Shared port daemon should be the default?

- No harm. Great benefit.

Next Steps

Last piece of the Puzzle: Contraction

- Currently we ramp up and/or maintain (KeepNRunning) automatically with APF.
- APF needs to ramp down by retiring unneeded WNs.
  - Done by correlating condor_q and condor_status information, joining on instance ID.

Noticing terminations as they occur

- Will allow HTCondor to accurately track startd state. (Todd Miller)
- Currently testing Todd M's detection daemon on our WNs.

Drive ATLAS to create short-job workloads approriate for Spot.

Run another large-scale test. Precisely test CU/slot efficiency.

Conclusions

HTCondor: Configurable, flexbile, complete, scale-able.

- HTCondor is configurable enough to be scalable to very high levels, even over WAN.
- HTCondor is flexible enough to be programmatically integrated/controlled by an outside system (e.g. APF in this case).
- HTCondor is complete enough to serve as both local pool infrastructure and as cloud client framework (Condor-G).

Our work was done with a pilot system. But could work the same with real jobs submitted to local pool.

Acknowledgements

Jose Caballero: APF development

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Todd Miller, Todd Tennenbaum, Jaime Frey, Miron Livny: Condor scaling assistance

David Pellerin, Stephen Elliott, Thomson Nguy, Jaime Kinney, Dhanvi Kapila: Amazon EC2 Spot Team

Questions?

Extra Slides

Boxgrinder Base Appliance

```
name: sl5-x86_64-base
os:
  name: sl
  version: 5
hardware:
  partitions:
    "/":
      size: 5
packages:
  - bind-utils
  - curl
  - ntp
  - openssh-clients
  - openssh-server
  - subversion
  - telnet
  - vim-enhanced
  - wget
  - yum
```

```
repos:
  - name: "sl58-x86_64-os"
    baseurl: “http://host/path/repo”

files:
  "/root/.ssh":
    - "authorized_keys"
  "/etc":
    - "ntp/step-tickers"
    - "ssh/sshd_config"

post:
  base:
    - "chown -R root:root /root/.ssh"
    - "chmod -R go-rwx /root/.ssh"
    - "chmod +x /etc/rc.local"
    - "/sbin/chkconfig sshd on"
    - "/sbin/chkconfig ntpd on"
```

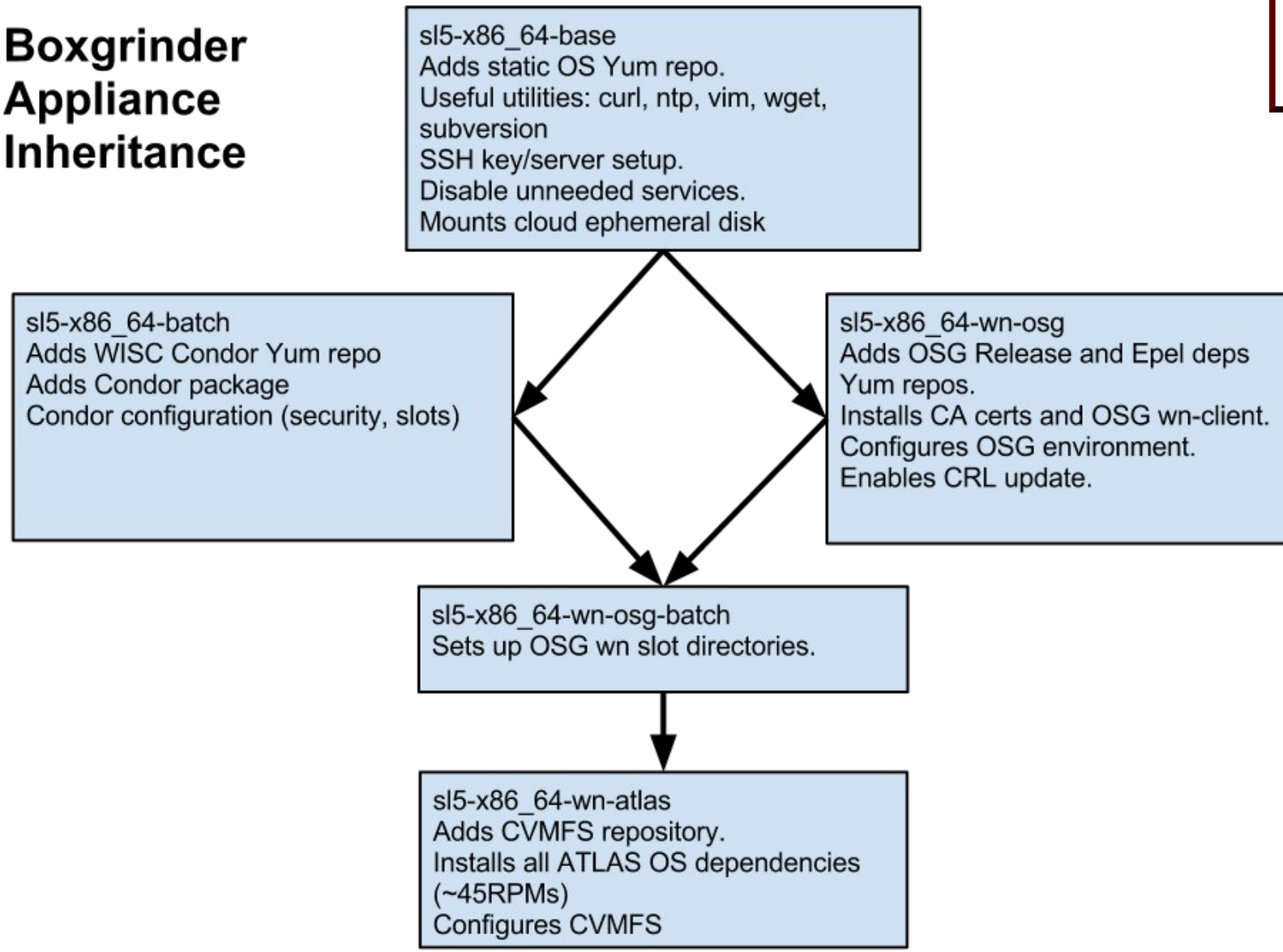
Boxgrinder Child Appliance

```
name: sl5-x86_64-batch
appliances:
  - sl5-x86_64-base
packages:
  - condor
repos:
  - name: "htcondor-stable"
    baseurl:
"http://research.cs.wisc.edu/htcondor/yum/stable/rhel5"

files:
  "/etc":
    - "condor/config.d/50cloud_condor.config"
    - “condor/password_file”
    - "init.d/condorconfig"

post:
  base:
    - "/usr/sbin/useradd slot1"
    - "/sbin/chkconfig condor on"
    - "/sbin/chkconfig condorconfig on"
```

Boxgrinder Child Appliance 2

```
name: sl5-x86_64-wn-osg
summary: OSG worker node client.
appliances:
  - sl5-x86_64-base
packages:
  - osg-ca-certs
  - osg-wn-client
  - yum-priorities
repos:
  - name: "osg-release-x86_64"
    baseurl: "http://dev.racf.bnl.gov/yum/snapshots/rhel5/osg-release-
2012-07-10/x86_64"
  - name: "osg-epel-deps"
    baseurl: "http://dev.racf.bnl.gov/yum/grid/osg-epel-
deps/rhel/5Client/x86_64"

files:
  "/etc":
    - "profile.d/osg.sh"
post:
  base:
    - "/sbin/chkconfig fetch-crl-boot on"
    - "/sbin/chkconfig fetch-crl-cron on"
```

Boxgrinder Appliance Inheritance



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```
#/etc/apf/queues.conf
[BNL_CLOUD]
wmsstatusplugin = Panda
wmsqueue = BNL_CLOUD
batchstatusplugin = Condor
batchsubmitplugin = CondorLocal
schedplugin = Activated

sched.activated.max_pilots_per_cycle = 80
sched.activated.max_pilots_pending = 100
batchsubmit.condorlocal.proxy = atlas-production
batchsubmit.condorlocal.executable = /usr/libexec/wrapper.sh

[BNL_CLOUD-ec2-spot]
wmsstatusplugin = CondorLocal
wmsqueue = BNL_CLOUD
batchstatusplugin = CondorEC2
batchsubmitplugin = CondorEC2
schedplugin = Ready,MaxPerCycle,MaxToRun
sched.maxpercycle.maximum = 100
sched.maxtorun.maximum = 5000

batchsubmit.condorec2.gridresource = https://ec2.amazonaws.com/
batchsubmit.condorec2.ami_id = ami-7a21bd13
batchsubmit.condorec2.instance_type = m1.xlarge
batchsubmit.condorec2.spot_price = 0.156
batchsubmit.condorec2.access_key_id = /home/apf/ec2-racf-cloud/access.key
batchsubmit.condorec2.secret_access_key = /home/apf/ec2-racf-
cloud/secret.key
```