The Principles of HTC

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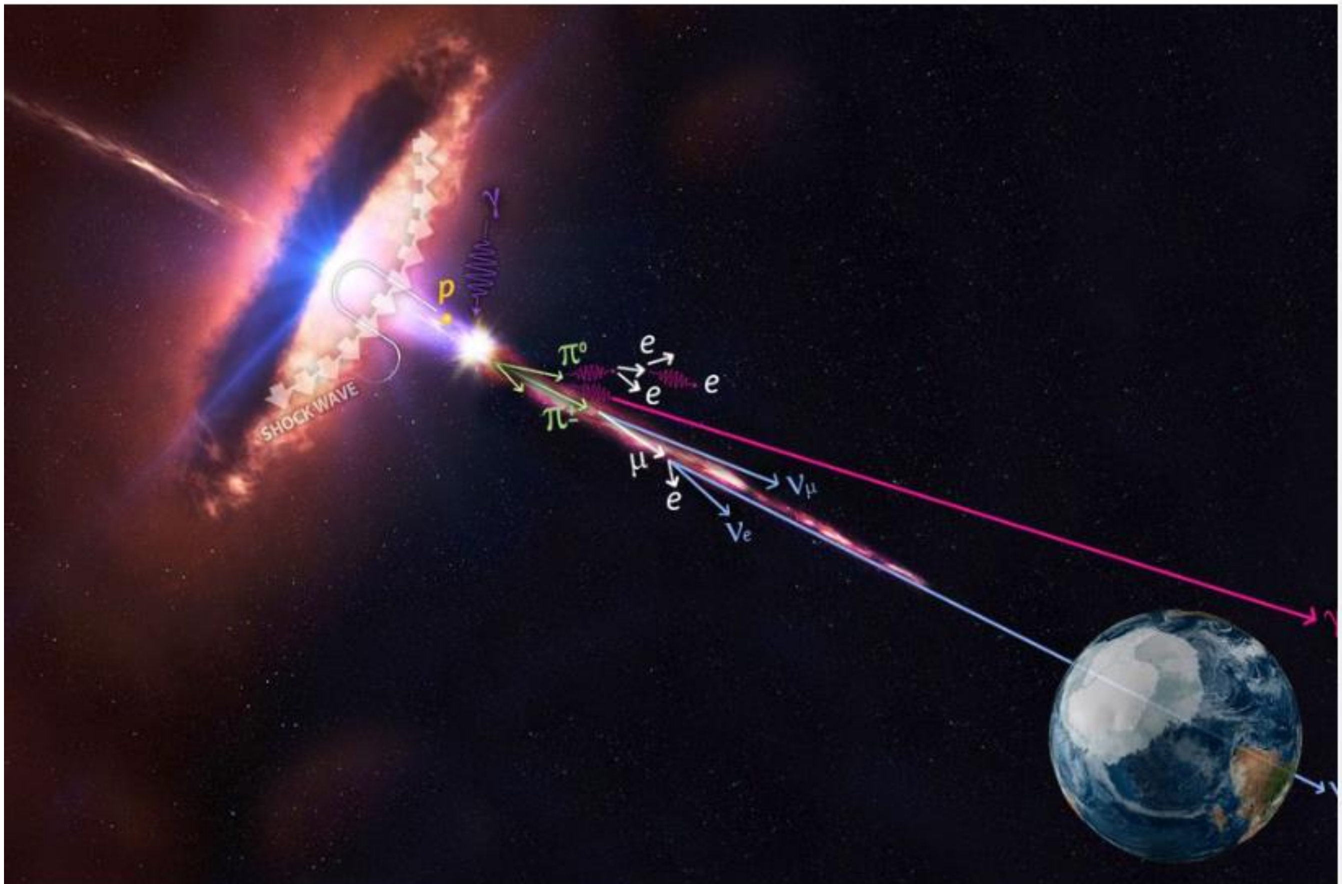
CENTER FOR HIGH THROUGHPUT COMPUTING
WISCONSIN INSTITUTE FOR DISCOVERY

How a single neutrino just helped crack a 100-year-old cosmic ray mystery

An enormous ice cube at the South Pole is revealing mysteries about the universe.

By Brian Resnick | @B_resnick | brian@vox.com | Jul 12, 2018, 11:00am EDT

f SHARE



In an artist's depiction that is very, very not-to-scale, a blazar is shown shooting a beam of cosmic rays at the Earth. | IceCube/NASA

What Did We Learn From Serving a Quarter of a Million Batch Jobs on a Cluster of Privately Owned Workstations

1992

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User Prospective

- Maximize the capacity of resources accessible via a single interface
- Minimize overhead of accessing remote capacity
- Preserve local computation environment

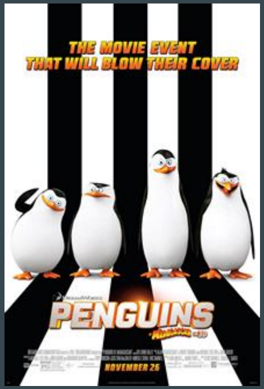
Focus on the needs and expectations of researchers

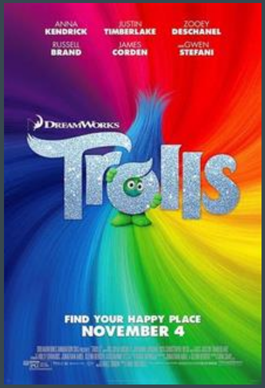
HTCondor at DreamWorks

...

Collin Mehring

Using HTCondor Since 2011





How do we have HTCondor configured?

- All DAG jobs
  - Many steps involved in rendering a frame
- GroupId.NodeId.JobId instead of ClusterId
  - Easier communication between departments
- No preemption (yet)
  - Deadlines are important - No lost work
  - Checkpointing coming soon in new renderer
- Heavy use of group accounting
  - Render Units (RU), the scaled core-hour
  - Productions pay for their share of the farm
- Execution host configuration profiles
  - e.g. Desktops only run jobs at night
  - Easy deployment and profile switching
- Load data from JobLog/Spool files into Postgres, Influx, and analytics databases

Quick Facts

- Central Manager and backup (HA)
  - On separate physical servers
- One Schedd per show, scaling up to ten
  - Split across two physical servers
- About 1400 execution hosts
  - ~45k server cores, ~15k desktop cores
  - Almost all partitionable slots
- Complete an average of 160k jobs daily
- An average frame takes 1200 core hours over its lifecycle
- Trolls took ~60 million core-hours

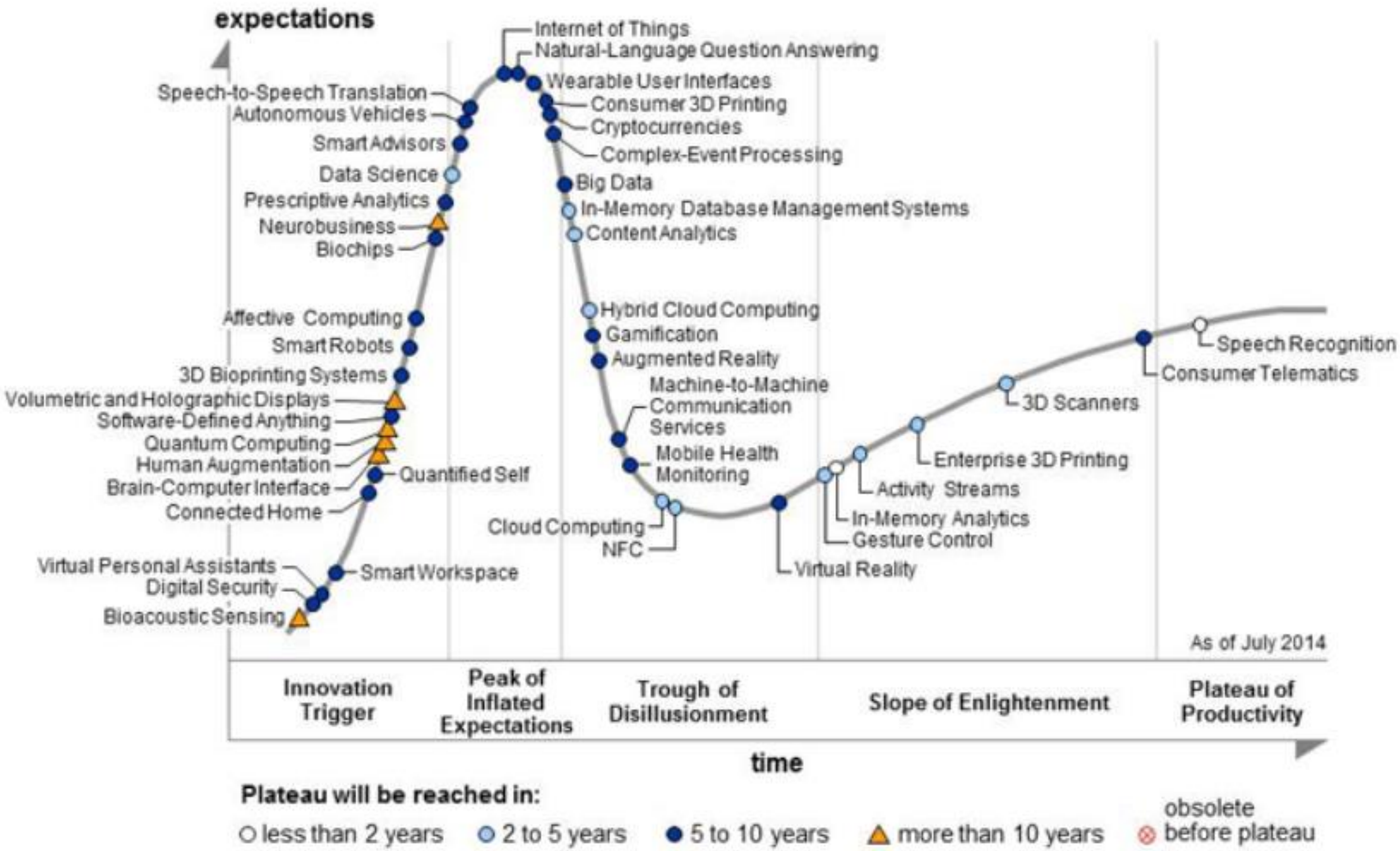
The words of Koheleth son of David, king in Jerusalem ~ 200 A.D.

***Only that shall happen
Which has happened,
Only that occur
Which has occurred;
There is nothing new
Beneath the sun!***

Ecclesiastes, (קֹהֶלֶת, *Kohelet*, "son of David, and king in Jerusalem" alias Solomon, Wood engraving Gustave Doré (1832–1883)

Ecclesiastes Chapter 1 verse 9

We are driven by Principals (– Hype)



Source: Gartner (August 2014)

Perspectives on Grid Computing
(2010)

Uwe Schwiegelshohn Rosa M. Badia Marian Bubak Marco Danelutto Schahram Dustdar Fabrizio Gagliardi Alfred Geiger Ladislav Hluchy Dieter Kranzlmüller Erwin Laure Thierry Priol Alexander Reinefeld Michael Resch Andreas Reuter Otto Rienhoff Thomas Rüter Peter Sloot Domenico Talia Klaus Ullmann Ramin Yahyapour Gabriele von Voigt

We should not waste our time in redefining terms or key technologies: clusters, Grids, Clouds... What is in a name? Ian Foster recently quoted Miron Livny saying: "I was doing Cloud computing way before people called it Grid computing", referring to the ground breaking Condor technology.

The paradigm shift of 70's – computing hardware packaged and sold in small units

The paradigm shift of 00's – computing capacity leased by the minute when needed

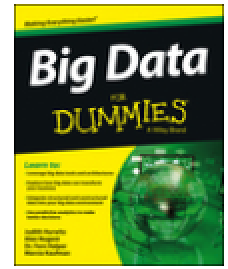
Claims for "benefits" provided by Distributed Processing Systems

P.H. Enslow, *"What is a Distributed Data Processing System?"* Computer, January 1978

- High Availability and Reliability
- High System Performance
- Ease of Modular and Incremental Growth
- Automatic Load and Resource Sharing
- Good Response to Temporary Overloads
- Easy Expansion in Capacity and/or Function

PROGRAMMING > BIG DATA > ENGINEERING > DISTRIBUTED COMPUTING BASICS FOR BIG DATA

DISTRIBUTED COMPUTING BASICS FOR BIG DATA



RELATED BOOK

Big Data For Dummies

By Judith Hurwitz, Alan Nugent, Fern Halper, Marcia Kaufman

If your company is considering a big data project, it's important that you understand some distributed computing basics first. There isn't a single distributed computing model because computing resources can be distributed in many ways.

Definitional Criteria for a Distributed Processing System

P.H. Enslow and T. G. Saponas ""*Distributed and Decentralized Control in Fully Distributed Processing Systems*" Technical Report, 1981

- Multiplicity of resources
- Component interconnection
- **Unity of control**
- System transparency
- **Component autonomy**

Unity of Control

All the component of the system should be **unified** in their desire to achieve a **common goal**. This goal will determine the rules according to which each of these elements will be controlled.

Component autonomy

The components of the system, both the logical and physical, should be **autonomous** and are thus afforded the ability to refuse a request of service made by another element. However, in order to achieve the system's goals they have to interact in a **cooperative** manner and thus adhere to a common set of policies. These policies should be carried out by the control schemes of each element.

It is always a tradeoff

In 1983 I wrote a Ph.D. thesis –

"Study of Load Balancing Algorithms for Decentralized Distributed Processing Systems"

http://www.cs.wisc.edu/condor/doc/livny-dissertation.pdf

Minimize wait (job/task queued) while Idle (a resource that is capable and willing to serve the job/task is running a lower priority job/task)

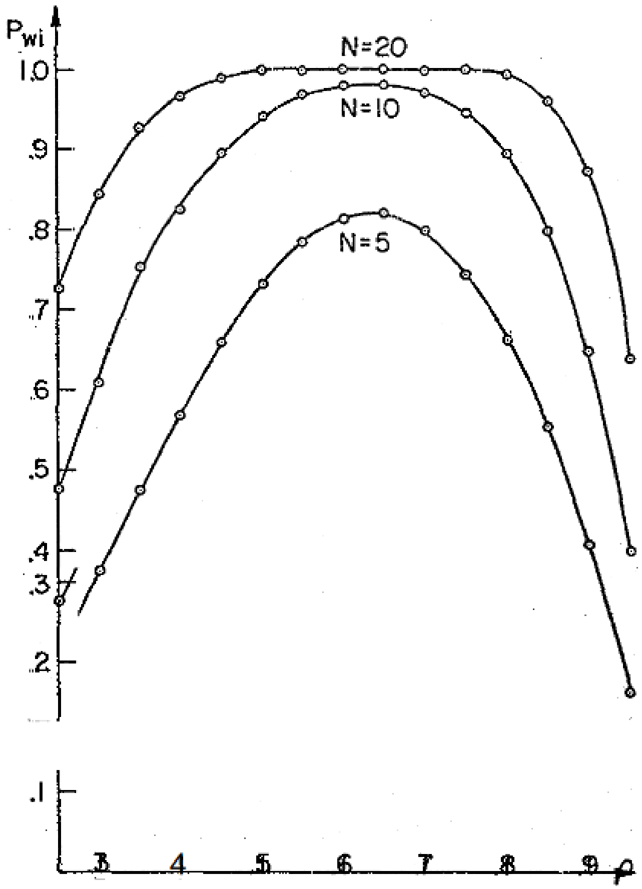


figure: 1 P_{wi} as a function of ρ

When each resource has a it's own queue, when should I stay at the current queue and wait and when should I move to another queue?

“ … Since the early days of mankind the primary motivation for the establishment of *communities* has been the idea that by being part of an organized group the capabilities of an individual are improved. The great progress in the area of inter-computer communication led to the development of means by which stand-alone processing sub-systems can be integrated into multi-computer *‘communities’*. … “

Miron Livny, “ *Study of Load Balancing Algorithms for Decentralized Distributed Processing Systems*.”,
Ph.D thesis, July 1983.

In 1985 we extended the scope of the distributed load balancing problem to include "ownership" of resources

Should I share my resource and if I do with whom and when?


MINE
YOURS
OURS

Now you have a community of customers who are motivated to share and act as consumers, providers or both

In 1996 I introduced the distinction between High **Performance** Computing (**HPC**) and High **Throughput** Computing (**HTC**) in a seminar at the NASA Goddard Flight Center in and a month later at the European Laboratory for Particle Physics (CERN). In June of 1997 HPCWire published an interview on High Throughput Computing.

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HIGH THROUGHPUT COMPUTING: AN INTERVIEW WITH MIRON LIVNY          06.27.97
by Alan Beck, editor in chief                                     HPCwire
==========================================================================

  This month, NCSA's (National Center for Supercomputing Applications)
Advanced Computing Group (ACG) will begin testing Condor, a software system
developed at the University of Wisconsin that promises to expand computing
capabilities through efficient capture of cycles on idle machines. The
software, operating within an HTC (High Throughput Computing) rather than a
traditional HPC (High Performance Computing) paradigm, organizes machines
```

Future Directions for NSF Advanced Computing Infrastructure to Support U.S. Science and Engineering in 2017-2020

AUTHORS

Committee on Future Directions for NSF Advanced Computing Infrastructure to Support U.S. Science in 2017-2020; Computer Science and Telecommunications Board; Division on Engineering and Physical Sciences; National Academies of Sciences, Engineering, and Medicine

"... many fields today rely on **high-throughput computing** for **discovery**."

"Many fields **increasingly** rely **on high-throughput computing**"

High Throughput Computing requires **automation** as it is a **24-7-365** activity that involves large numbers of jobs

FLOPY ≠ *(60*60*24*7*52)*FLOPS*

100K Hours*1 Job ≠ 1 H*100K J

Obstacles to HTC

- **Ownership Distribution** **(Sociology)**
- **Size and Uncertainties** **(Robustness)**
- **Technology Evolution** **(Portability)**
- **Physical Distribution** **(Technology)**

1997

The Open Science Grid (OSG) national fabric of distribute HTC services

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"The members of OSG are united by a commitment to promote the adoption and to advance the state of the art of *distributed high throughput computing (DHTC) – shared utilization of autonomous resources* where all the elements are optimized for maximizing computational throughput."

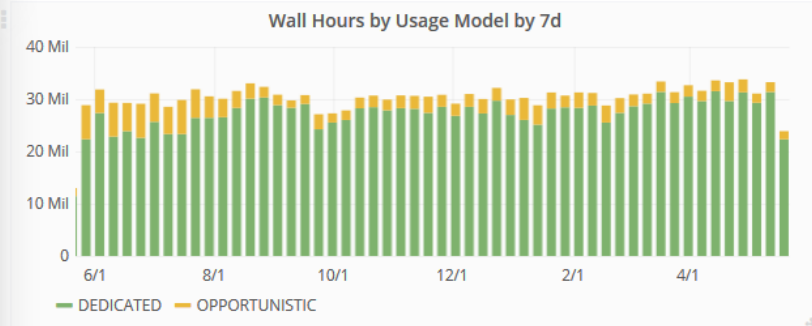
1.60B core hours in 12 months!

Almost all jobs executed by the **OSG** leverage HTCondor technologies:

- **Condor-G**
- **HTCondor-CE**
- **Basco**
- **Condor Collectors**
- HTCondor **overlays**
- HTCondor **pools**

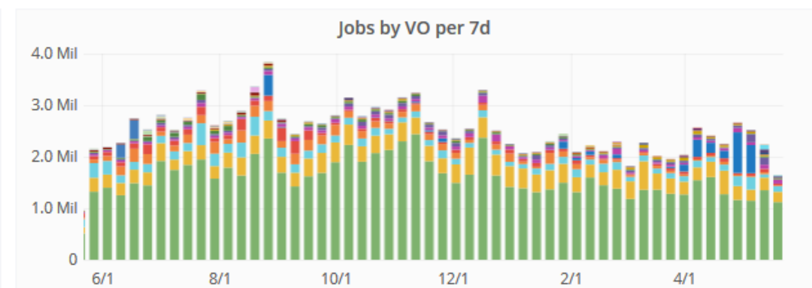
Total Wall Hours

1.602 Bil



Total Jobs

133.3 Mil



Submit locally (queue and manage your jobs/tasks locally; leverage your local resources) **and run globally** (acquire any resource that is capable and willing to run your job/task)

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- **Job owner identity is local**
  - Owner identity should never “travel” with the job to execution site
  - Owner attributes are local
- **Name spaces are local**
  - File names are locally defined
- **Resource acquisition is local**
  - Submission site (local) is responsible for the acquisition of all resources

- "external" forces moved us away from this "pure" local centric view of the distributed computing environment.
- With the help of capabilities (short lived tokens) and reassignment of responsibilities we are committed to regain full local control.
- Handing users with money (real or funny) to acquire commuting resources helps us move (push) in this positive direction.

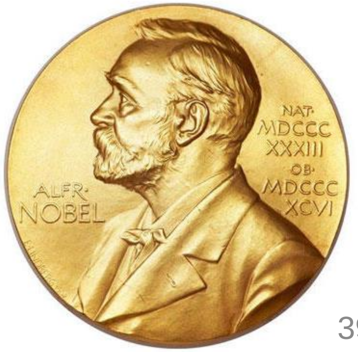
Using Directed Acyclic Graphs (DAGs) to support declarative automation of interdependent tasks

2017 Nobel Prize in Physics

High Throughput Computing helps LIGO confirm Einstein's last unproven theory

March 8, 2016 | By Brian Mattmiller | For news media

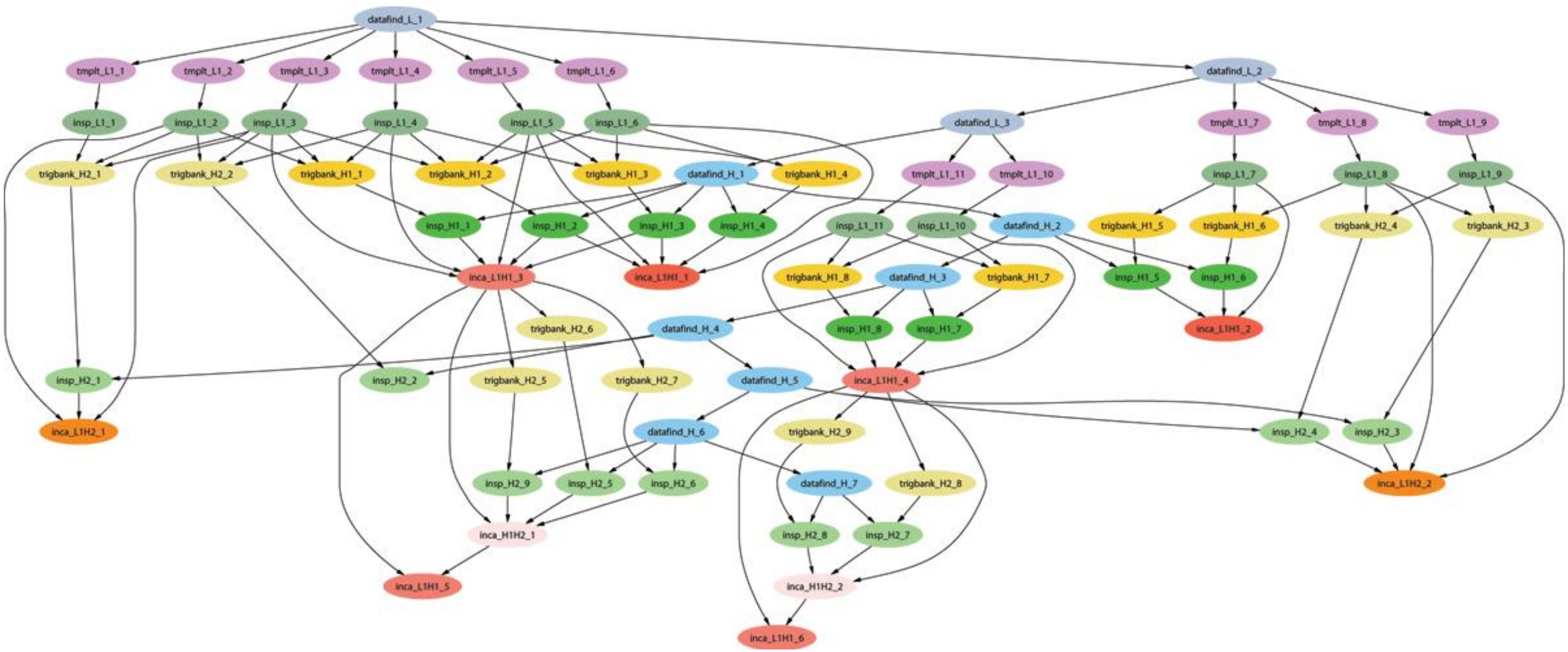
A computer simulation shows the collision of two black holes, a tremendously powerful event detected for the first time ever by the Laser Interferometer Gravitational-Wave Observatory, or LIGO. Source: Simulating eXtreme Spacetimes (SXS)



- “When a workflow might consist of 600,000 jobs, we don’t want to rerun them if we make a mistake. So we use DAGMan (Directed Acyclic Graph Manager, a meta-scheduler for HTCondor) and Pegasus workflow manager to optimize changes,” added Couvares. “The combination of Pegasus, Condor, and OSG work great together.” Keeping track of what has run and how the workflow progresses, Pegasus translates the abstract layer of what needs to be done into actual jobs for Condor, which then puts them out on OSG.

LSC

Example of a LIGO Inspiral DAG (Workflow)



HTC is about sharing across many **jobs**, many **users**, many **servers**, many **sites** and (potentially) long running **workflows**

A job submitted to a batch service consists of an Acquisition Request (**AquR**) and a Job Description (**JobD**).

The Provision Manager (**Pman**) of the service provisions the resources and then runs the job on theses resources via the Job Launcher (**JaL**)

Most batch services manage a static collection of resources

HTCondor uses a matchmaking process to dynamically **acquire** resources.

HTCondor uses a matchmaking process to **provision** them to queued jobs.

HTCondor launches jobs via a task delegation protocol.

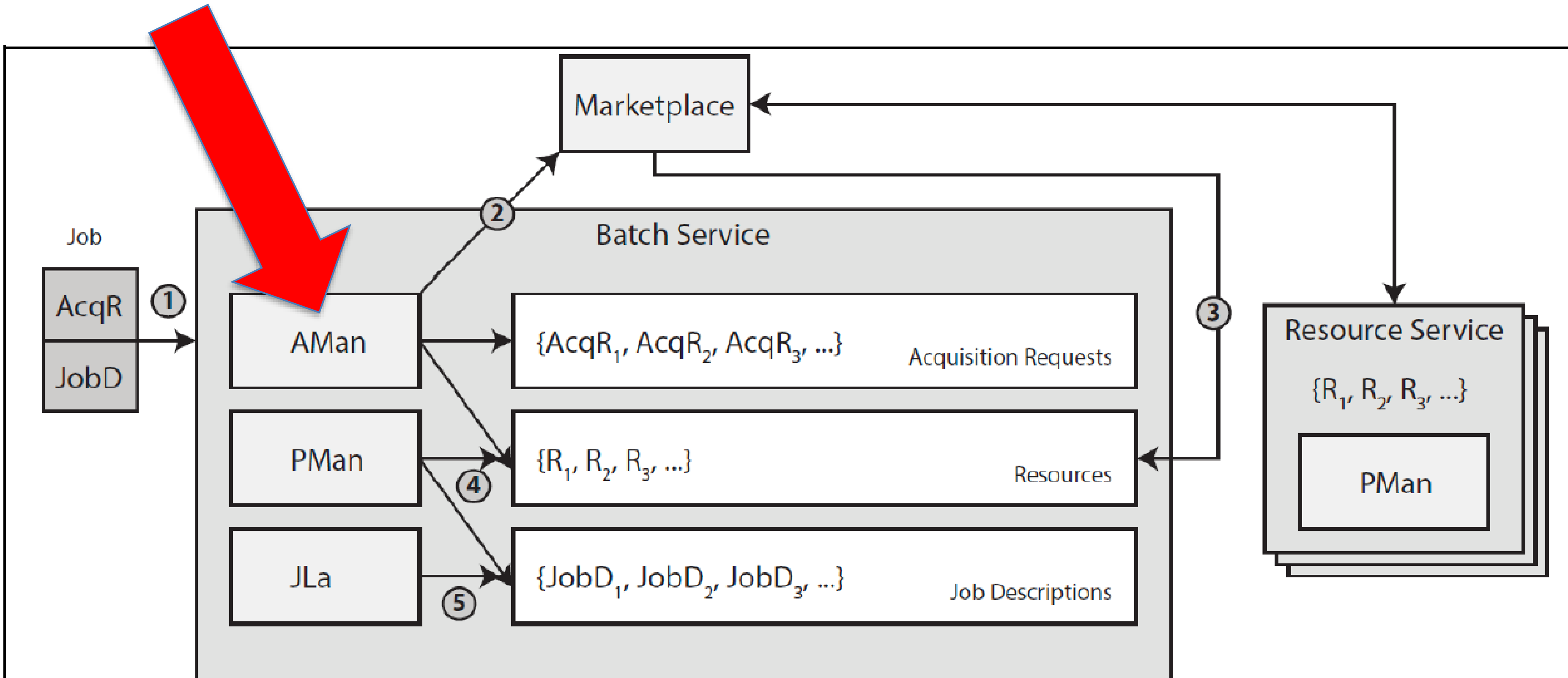
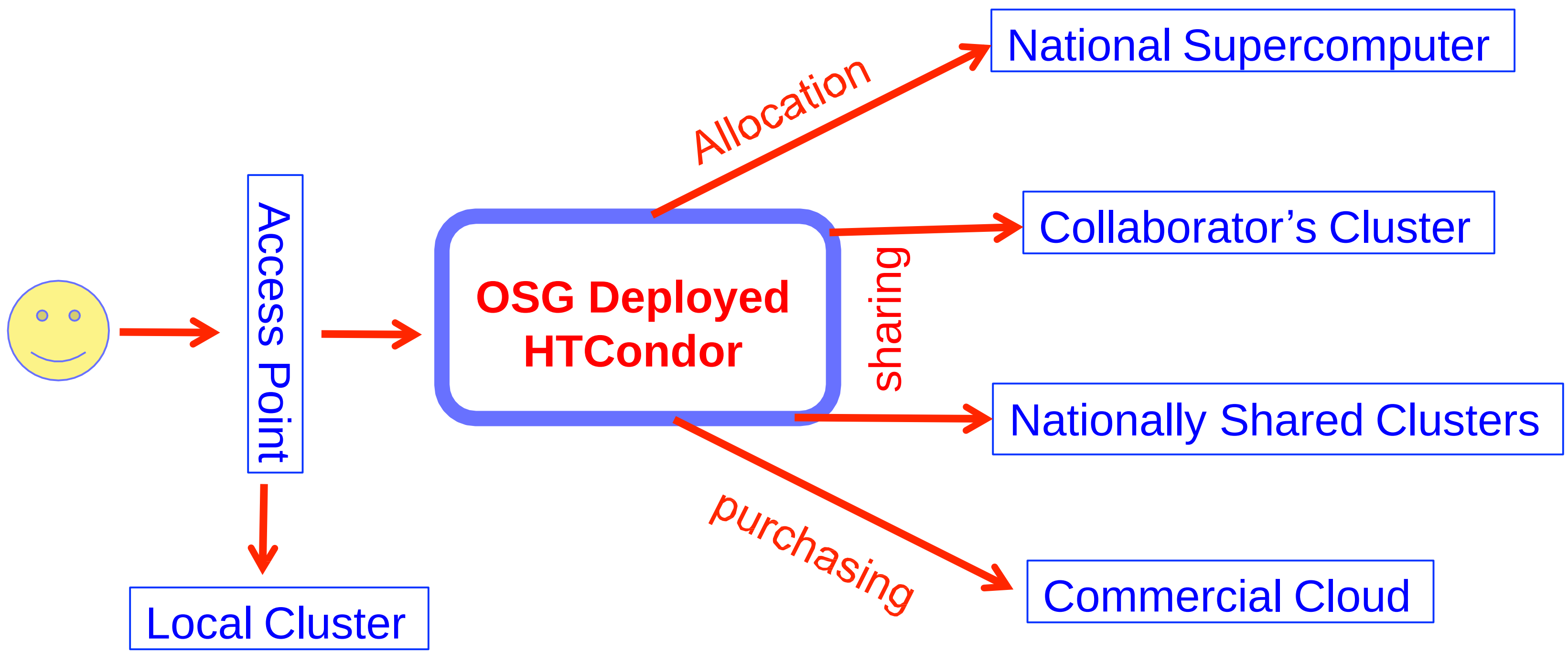


Figure 1: The HTC Framework: (1) A user submits job, composed of an AcqR and a JobD. (2) The AMan requests a resource compatible with an AcqR. (3) The MarketPlace offers a compatible Resource to the batch service. (4) The Pman selects a job description and Resource to send to (5) the JLa, which runs the job.

Submit Locally Run Globally



OSG integrates computing across different resource types and business models.

Traditional (low frequency) Capacity Planning

Turning $s into computing power

- Collect workload characteristics and customer (performance) metrics
- Understand the cost-performance profile of the hardware and software options
- **Acquire** (select, purchase, install) the resources and place them under the control of a **batch service**
- Live with your decision for (5-8) years

Next generation (High frequency) Capacity Planning when resources can be rented by the minute or by the hour

Researcher or VOs may have …

- **Resources** they own and therefore fully control
- An **allocation** of resources on shared campus/national computing facility
- **“Fair Share” privileges** on shared campus/national computing facilities
- **Opportunistic Resources** provided by collaborators
- **Funding** to purchase resources from a commercial cloud provider

Commercial clouds offer to individuals with money …

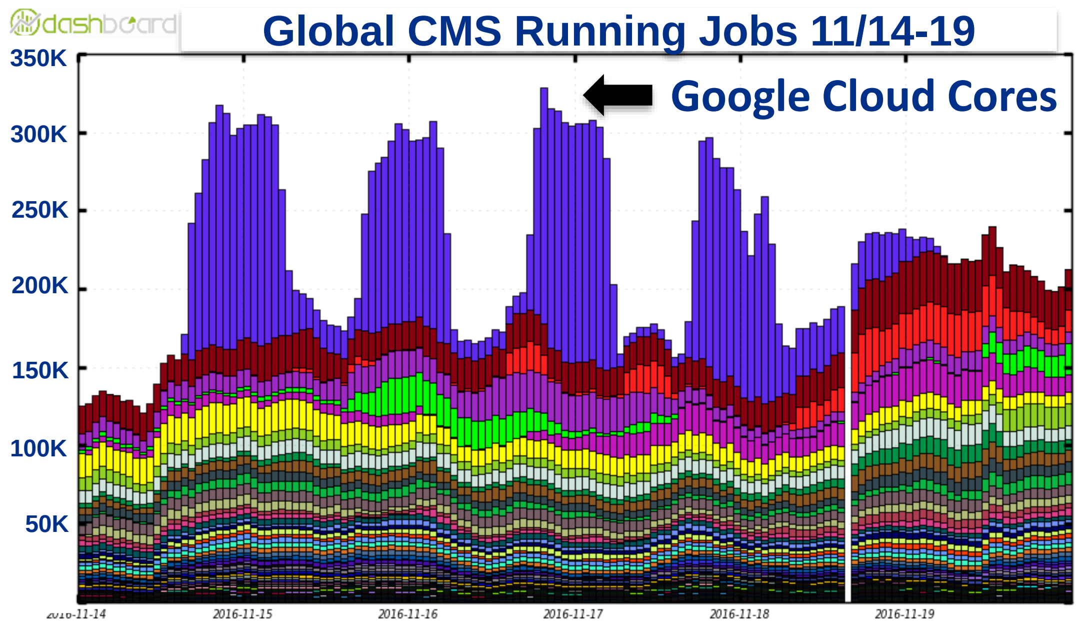
- **Unbounded** on demand capacity for (almost) as long as needed
- A **variety** of cost/performance option for processing and storage resources
- **Dynamic cost** structures that track demand and supply
- **Diverse** (and competing) suppliers of computing resources and associated services

SC16 Demo: On Demand Doubling of CMS Computing Capacity

Joint project

HEPCloud (Fermilab), **HTCondor** (UW-Madison),

- **HEPCloud** provisions **Google Cloud** with **HTCondor** in two ways
  - **HTCondor** talks to Google API
  - Resources are joined into **HEP HTCondor** pool
- Demonstrated sustained large scale elasticity (>150K cores) in response to demand and external constraints
  - Ramp-up/down with opening/closing of exhibition floor
  - Tear-down when no jobs are waiting



730,172 jobs consumed 6.35M core hours to produce 205M simulated events (81.8 TB)

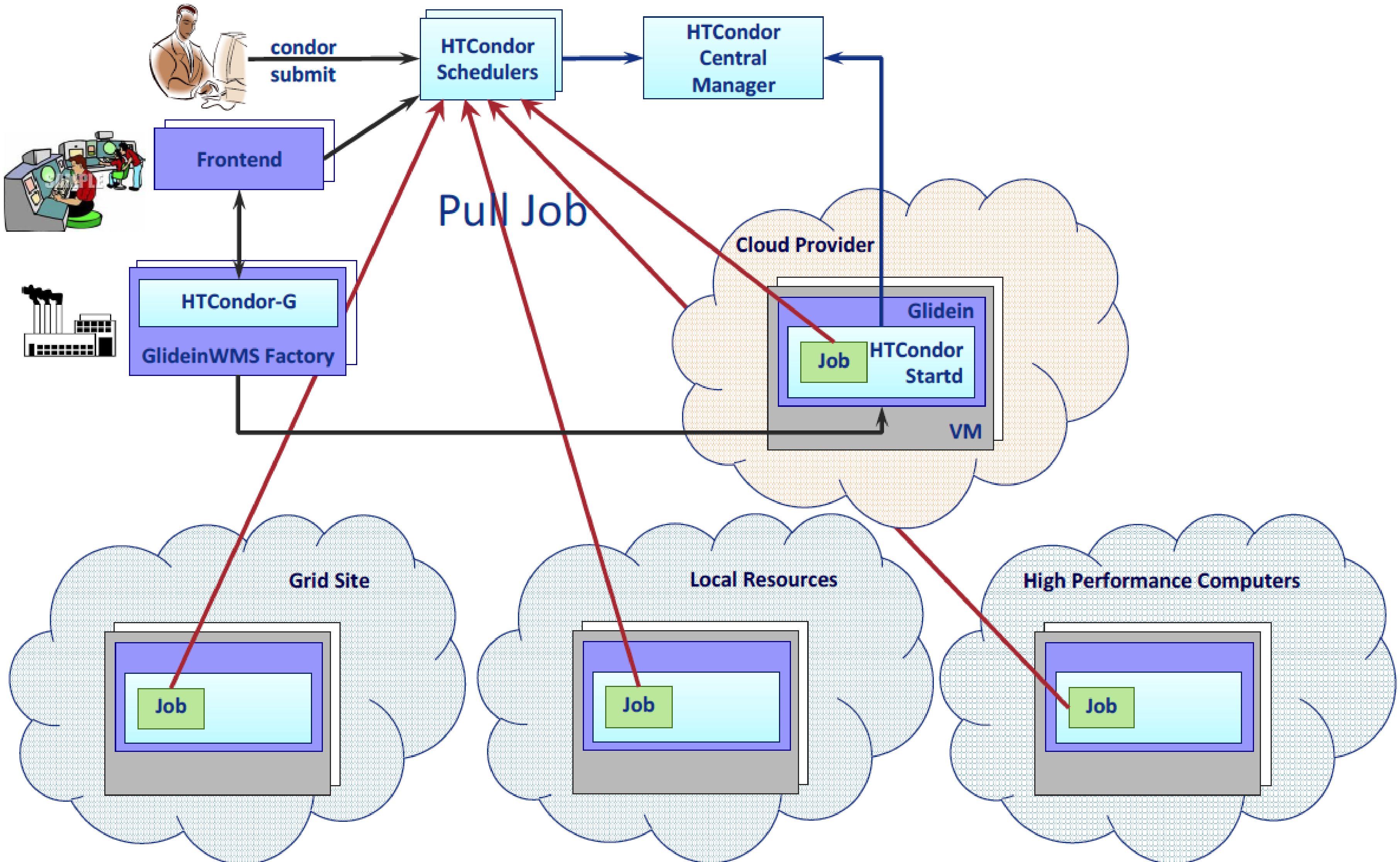
Total cost ~$100K

500 TB were placed in Google Cloud in advance. 80TB where moved back to Fermi.

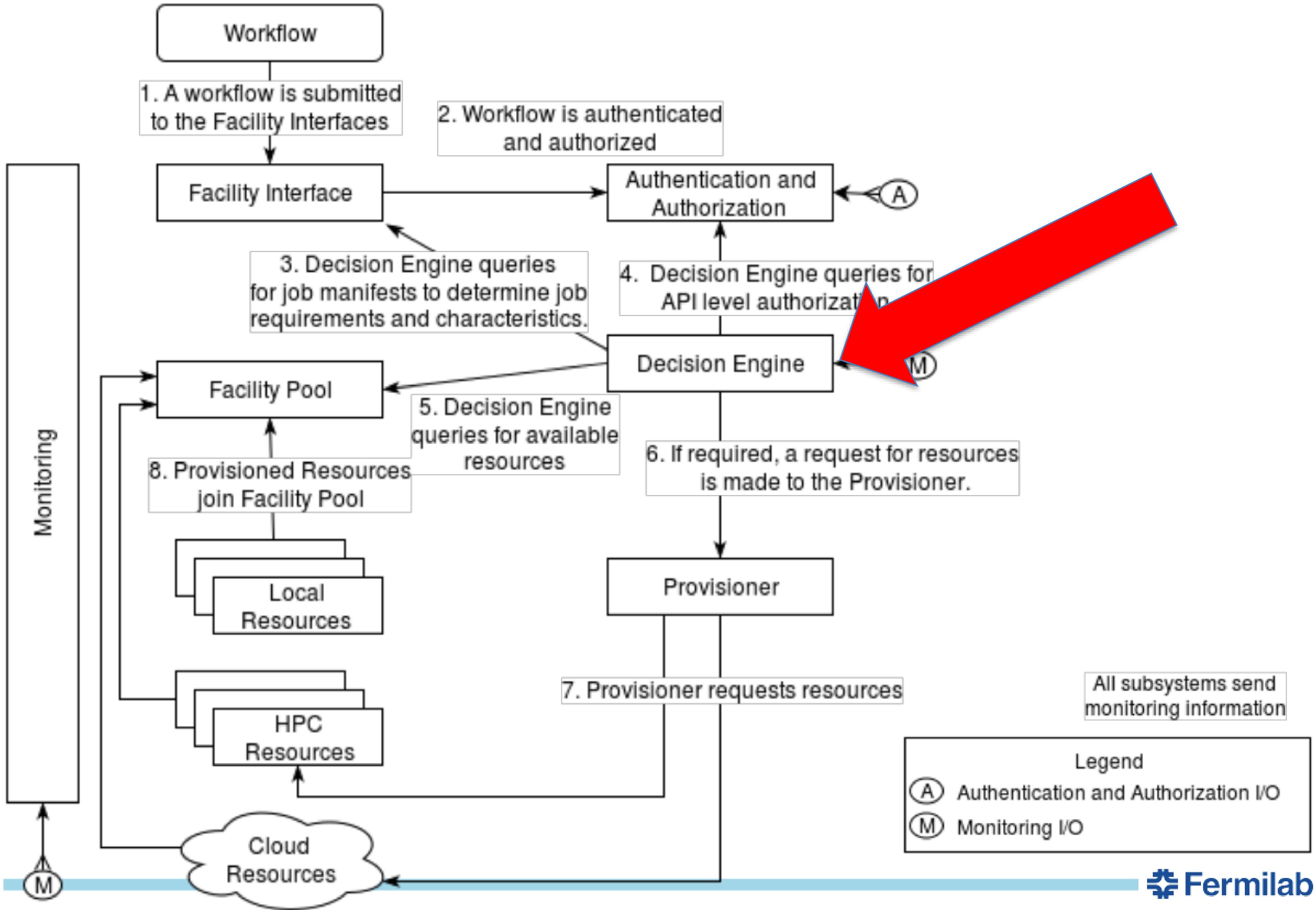
- $8.6k network egress
- $8.5k disk attached to VMs
- $3.5k cloud storage for input data

HEPCloud is an R&D project led by the Fermi computing division

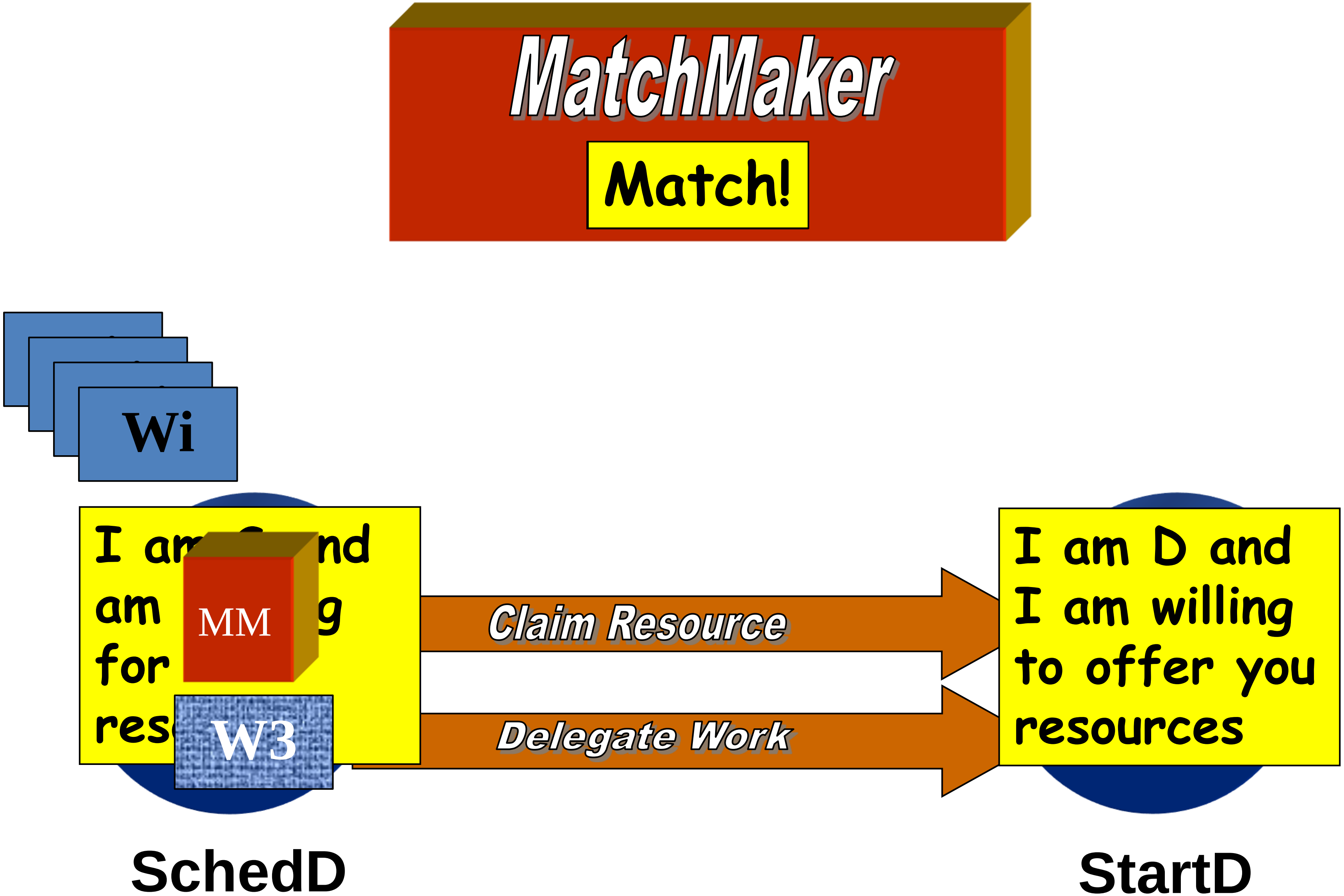
HEPCloud – glideinWMS and HTCondor



HEPCloud Architecture



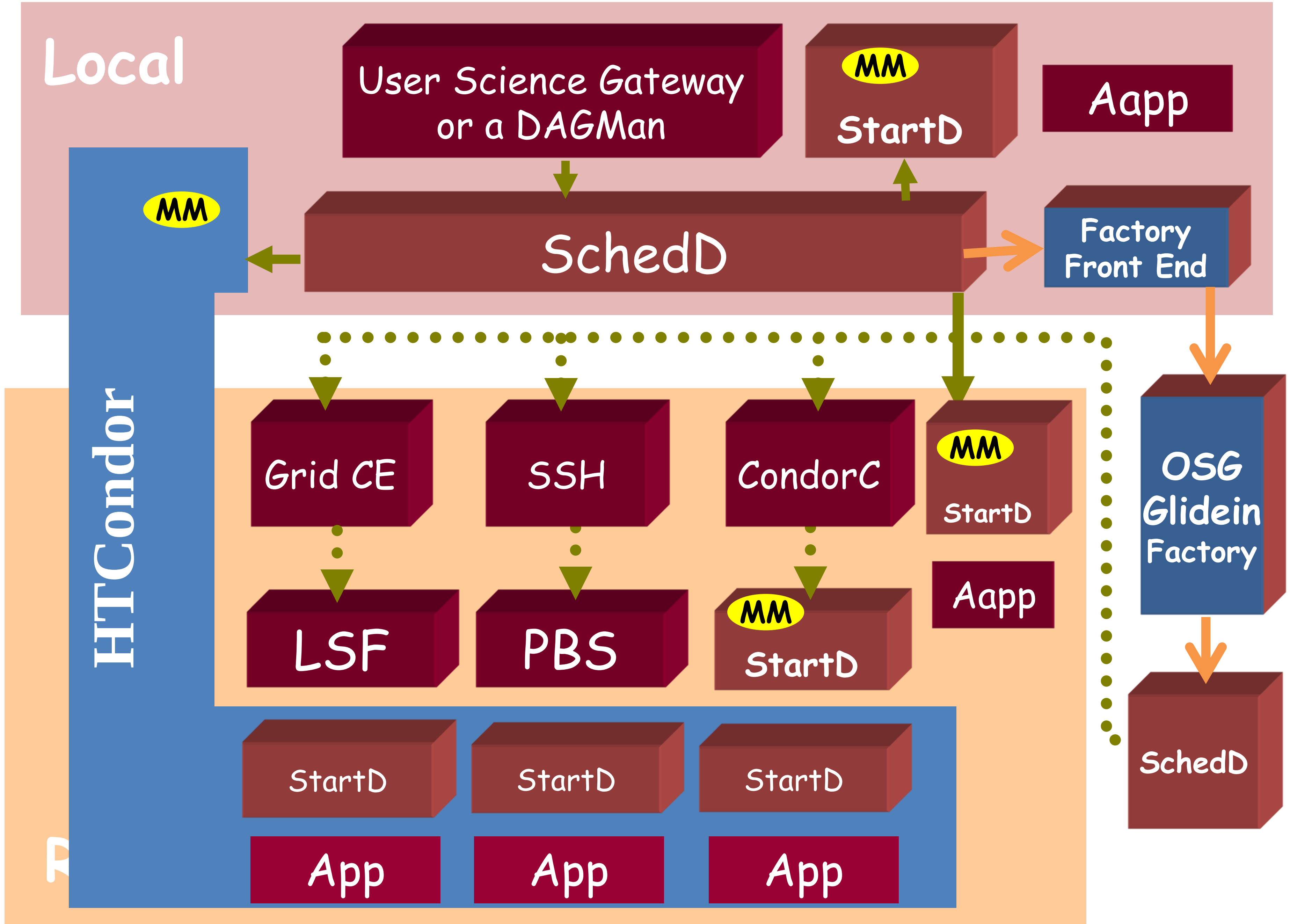
Here is what the OSG offers today with the support of HTCondor technologies



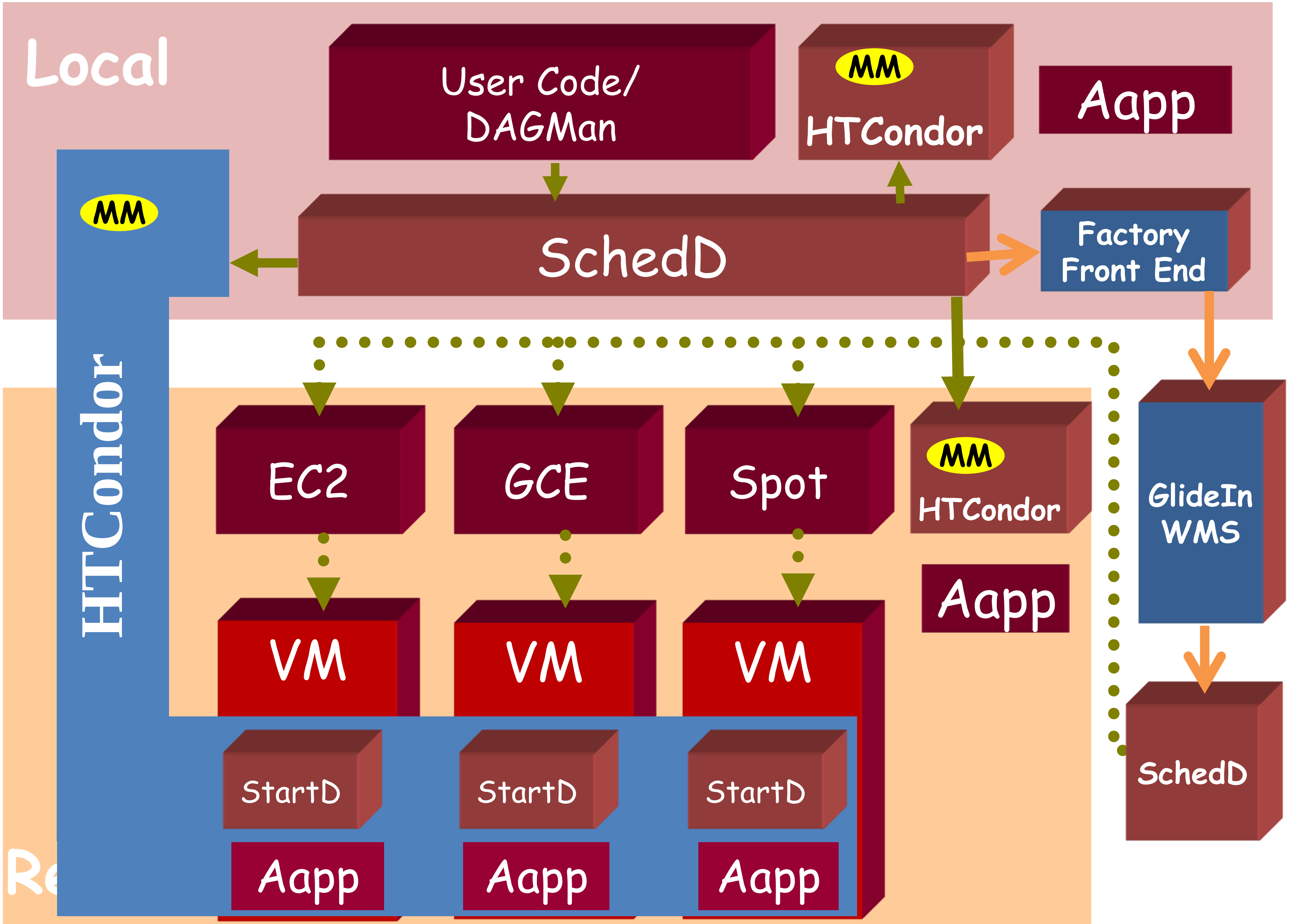
MatchMaker
Match!
Wi
I am nd
am g
for
res
MM
W3
Claim Resource
Delegate Work
I am D and
I am willing
to offer you
resources
SchedD
StartD

HTCondor 101

- Jobs are submitted to the HTCondor **SchedD**
- A job can be a **Container** or a **VM**
- The **SchedD** can **Flock** to additional **Matchmakers**
- The **SchedD** can delegate a job for execution to a **HTCondor StartD**
- The **SchedD** can delegate a job for execution to a another **Batch system**.
- The **SchedD** can delegate a job for execution to a **Grid Compute Element (CE)**
- The **SchedD** can delegate a job for execution to a **Commercial Cloud**



Local
User Science Gateway or a DAGMan
MM
StartD
Aapp
MM
SchedD
Factory Front End
HTCondor
Grid CE
SSH
CondorC
MM
StartD
OSG Glidein Factory
LSF
PBS
MM
StartD
Aapp
SchedD
StartD
StartD
StartD
App
App
App



Local
User Code/
DAGMan
MM
HTCondor
Aapp
MM
SchedD
Factory
Front End
HTCondor
EC2
GCE
Spot
MM
HTCondor
GlideIn
WMS
Aapp
VM
VM
VM
SchedD
StartD
StartD
StartD
Re
Aapp
Aapp
Aapp

Welcome to the HTC Community

Timeline of projects