What follows

- Jim Shank and I are tasked with developing the Computing Report for the Energy Frontier.
- Computing doesn’t drive the research program, but it does enable it.
- Looking at the machine plans. They are all high luminosity machines with potentially very high trigger rates and complicated events.
- Constrained budgets, and few miracle solutions.
- What follows are some observations to spawn discussion.
Looking Back

- We decided to look back 10 years before trying to look forward 10
  - Tevatron was in the 3rd year of Run2 in 2003

- Compare to 2012
  - The third year of LHC

- What it shows you is that new machines can lead to big jumps in some resources
Complexity and Collaborations

- Trigger rate, event size, and reconstruction time all rise by a factor of 10

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Trigger rate</td>
<td>50Hz</td>
<td>500Hz</td>
</tr>
<tr>
<td>Prompt Reconstruction rate/week</td>
<td>13M Events</td>
<td>120M events</td>
</tr>
<tr>
<td>Re-reconstruction rate</td>
<td>100M events per month</td>
<td>800M – 1B events per month</td>
</tr>
<tr>
<td>Reconstructed size</td>
<td>200kB</td>
<td>1-2MB</td>
</tr>
<tr>
<td>AOD size</td>
<td>20kB</td>
<td>200-300kB</td>
</tr>
<tr>
<td>Reconstruction time</td>
<td>1-2s on CPUs of the time</td>
<td>~10s on CPUs of the time</td>
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- Collaborations increase by a factor of 3

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<tbody>
<tr>
<td>Collaboration Size</td>
<td>800</td>
<td>2000-3000</td>
</tr>
<tr>
<td>Number of individual analysis submitters per day</td>
<td>100</td>
<td>300-400</td>
</tr>
<tr>
<td>Number of total analysis submitters</td>
<td>400</td>
<td>Greater than 1000</td>
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Resources

- Resources and challenges increase at different rates

<table>
<thead>
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<tr>
<td>Remote Computing Capacity</td>
<td>15kHS06 (DZero Estimated)</td>
<td>450kHS06 (CMS)</td>
</tr>
<tr>
<td>User Jobs launched per day</td>
<td>10k per day</td>
<td>200-300k jobs per day</td>
</tr>
<tr>
<td>Disk Capacity per experiment in PB</td>
<td>0.5PB</td>
<td>60PB</td>
</tr>
<tr>
<td>Data on Tape per experiment</td>
<td>400TB</td>
<td>70PB</td>
</tr>
<tr>
<td>MC Processing Capacity per month for Full Simulation</td>
<td>3M</td>
<td>300M</td>
</tr>
<tr>
<td>Data Served from dCache at FNAL per day</td>
<td>25TB per day</td>
<td>10PB per day</td>
</tr>
<tr>
<td>Wide Area networking from host lab</td>
<td>200Mb/s</td>
<td>20000Mb/s</td>
</tr>
<tr>
<td>Inter VO transfer volume per day</td>
<td>6TB (DZero SAM)</td>
<td>546TB (ATLAS)</td>
</tr>
</tbody>
</table>
Increases

- The processing has increased by a factor of 30 in capacity
- This is essentially what would be expected from a Moore’s law increase with a 2 year cycle
- Says we spent similar amounts
- Storage and networking have both increased by a factor of 100
- 10 times trigger and 10 times event size
For LHC Increases per year

- LHC Computing adds about 25k processor cores a year
- And 34PB of disk
- The $\chi^2$ of the linear fit is not very compelling, but it shows its currently increasing at a sustainable rate
  - A decade from now would be a factor of 4-5 in capacity
Looking Forward

- The programs suggested for energy frontier all have the potential for another factor of 10 in trigger and 10 in complexity.
- Simulation and reconstruction might continue to scale with Moore’s law as they did for LHC, but could just as easily increase much faster.
- How to make better use of resources as the technology changes?
Looking Forward

- Computing is at something of a cross roads
  - In one direction are clouds
    - Generic computing services that are bought, shared, or contributed
    - Computing as a service
  - In the other direction are very specialized systems
    - High performance, low power
      - Massively multi-core
    - GPUs
Clouds and Provisioning

- Commercial clouds are still very expensive for resources we use a lot
  - Small sites without a history of computing will probably be the first to simply buy capacity
- More opportunistic and academic resources will move to cloud provisioning methods
- Even sites we control will move to cloud provisioning tools because it simplifies the operations and places more expectations on the supported community to define and operate services
- We should expect our current service architecture will change to new provisioning tools
Service Architecture

- We should expect our current service architecture for accessing resources will become a lot more diverse.
- In LHC Run 1 we enjoyed a lot of consistency with the WLCG.
- Looking forward we will have Cloud interfaces, Grid, local, opportunistic, and whatever comes next.
- We will need to have systems that do resource provisioning on all of it, and make it look like a coherent system.
Current Hardware

- Currently energy frontier computing lives in a homogenous but non optimal environment
- Looking back we have typically supported many more platforms
- Most of the industry development is not in the chips that make up the bulk of our computing
- Cores are added, but individual cores tend to stay at similar speed, with the exception of power efficiency there is not the same incentive to replace gear
- We are not well optimized and we don’t tend to use the full capacity of the hardware
Specialized Hardware

- Specialized chips like GPUs and co-processors have the potential for big improvements in performance, but are challenging to program and introduce a lot of heterogeneity.
- Specialized machines like very high core count low power systems look like super computers.
- And have the programming challenges associated.
Specialized Hardware Steps

1.) We buy/get access to specialized gear like a super computer allocation
   - Big offline applications seems like the ideal use-case for buying or contributed capacity. Technology situation changes rapidly

2.) Places we completely control will get specialized gear for individual applications, but probably for niche applications
   - Trigger farms and other specialized use cases
Data Management

We will have a mix of local, cloud, opportunistic, and specialized resources and we will need a data management system that deals with all.

- On cloud the concept of data locality begins to lose a lot of meaning.
- We cannot really afford another factor of 100 increase in storage, so we need to find ways of being more efficient in the use of the space.
- We need to identify technology that allows a system to distribute and serve the data much more flexibly and dynamically.
Connectivity

- Given the connectivity of our clusters and the expectations of the users, I believe we will have to evolve to content delivery networks.
- Data Management resources that deliver data on demand.
- Will be cached and replicated and intelligent about the placement, but large independent local storage systems connected to clusters is probably not the most efficient.
- The data federations already being deployed are a first step, but work is needed.
Networking

- Data delivery systems give a lot of flexibility in terms of how to make use of diverse computing systems, but they put strong requirements on networking.
  - Currently a 10k core cluster (typical for 2020) would require 10Gb/s networking for organized processing like reconstruction.
  - Analysis would require 100Gb/s.
Becoming More Selective

- We have not really changed how we think about events we select
- Currently we make a trigger decision and then all events are equal
- Trigger rates continue to rise with intensity and most events are uninteresting background
- We may be able to afford to write things to tape, but may want to reduce the actively analyzed data
Not all events are equal

- A decision that is given 100ms of thought does not have to be the final word
- We should be prepared to reduce our active dataset through reprocessing and understanding the data
- Many things may be classified as known physics and put into distributions, but not kept in the active dataset
  - It’s the equivalent of what is done in analysis, but in a more organized way
- We can afford a lot of data on tape, but the active dataset is much more expensive
Energy Frontier

- As trigger rates proposed for Energy Frontier approach rates we would typically associate with Intensity Frontier we may need to adopt similar techniques
- ALICE is already planning for this post LS2. Much more immediate processing and identification
Outlook

- LHC moving forward may be sustainable with an evolution of how we work.
- A big increase in luminosity and complexity would lead to a big jump that would be potentially very expensive.
- To handle this we need to change how we work by being more selective.
- Move to be able to run on fast hardware.
- Solve the data management problem.