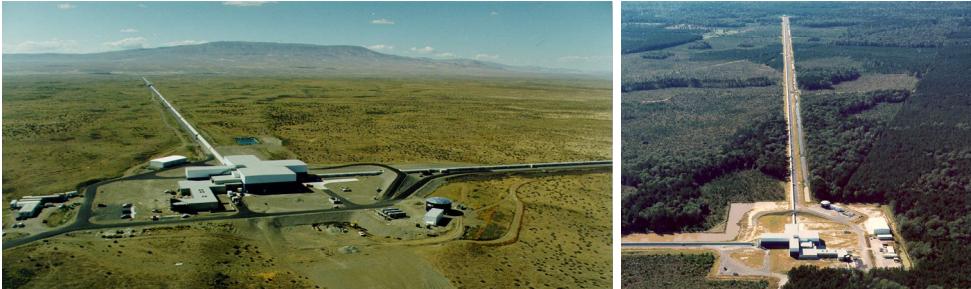# Grid Enabled LIGO Data Monitoring

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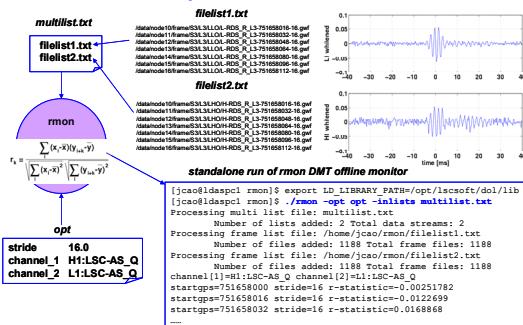For the LIGO Scientific Collaboration (LSC)

LIGO: Laser Interferometer Gravitational-wave Observatory

- The LIGO project aims to make the first direct detection of gravitational waves as predicted by Einstein's General Theory of Relativity.
- LIGO manages and operates two national observatories for gravitational waves, located at Hanford, WA and Livingston, LA.
- The LIGO Scientific Collaboration (LSC) consists of nearly 400 scientists from about 40 institutions worldwide.

For More Information …

http://www.ligo.caltech.edu
http://www.ligo.mit.edu/lsc-itr2003
http://www.ligo.org
http://www.lsc-group.phys.uwm.edu/lscdatagrid
http://www.ligo.mit.edu/ldg
http://www.griphyn.org
http://www.ivdgl.org
http://www.opensciencegrid.org

The LSC Data Grid (LDG)

- In the LSC, a grid computing infrastructure is utilized for LIGO data analysis and monitoring with thousands of CPUs and terabytes of data storage capabilities distributed over 10 sites in the USA and Europe.
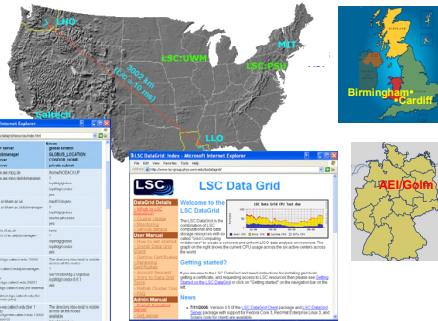
- The LSC Data Grid (LDG) client/server environment is built on top of the Virtual Data Toolkit (VDT).

The Data Monitoring Toolkit (DMT)

- DMT defines tools and environments necessary to support continuous data monitoring of LIGO interferometers.
- While DMT is essentially a production-level software package being used in LIGO control rooms, researchers find the enrichment of DMT libraries make it an ideal environment for offline LIGO data analysis.
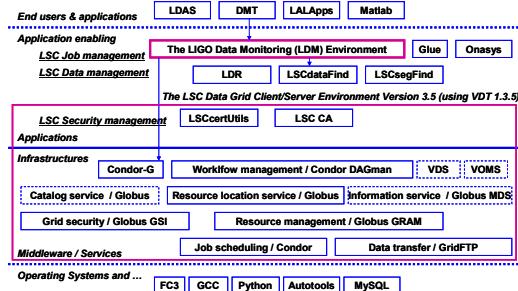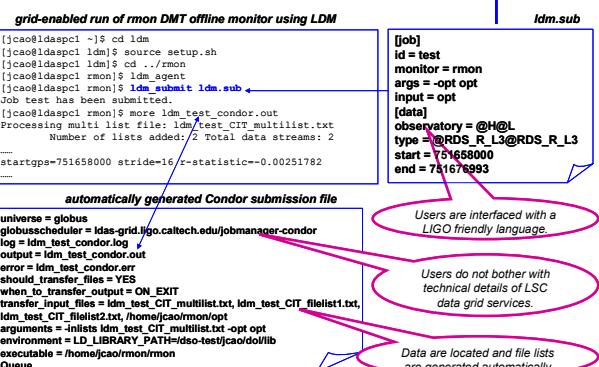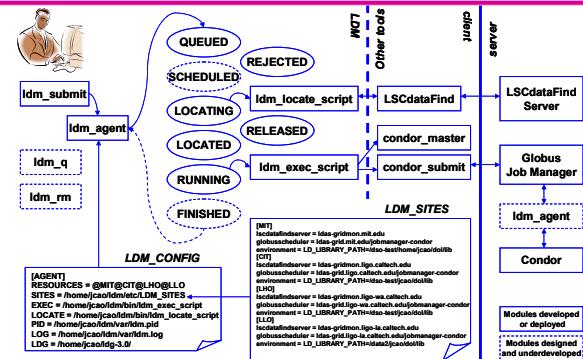

$$r_k = \frac{\sum (x_i - \bar{x})(y_{i+k} - \bar{y})}{\sqrt{\sum (x_i - \bar{x})^2} \sqrt{\sum (y_{i+k} - \bar{y})^2}}$$

standalone run of rmon DMT offline monitor

```
[jcao@ldaspc1 rmon]$ export LD_LIBRARY_PATH=/opt/lscsoft/dol/lib
[jcao@ldaspc1 rmon]$ ./rmon -opt opt -inlists multilist.txt
Processing multi list file: multilist.txt
        Number of lists added: 2 Total data streams: 2
Processing frame list file: /home/jcao/rmon/filelist1.txt
        Number of files added: 1188 Total frame files: 1188
Processing frame list file: /home/jcao/rmon/filelist2.txt
        Number of files added: 1188 Total frame files: 1188
channel[1]=H1:LSC-AS_Q channel[2]=L1:LSC-AS_Q
startgps=751658000 stride=16 r-statistic=-0.00251782
startgps=751658016 stride=16 r-statistic=-0.0122699
startgps=751658032 stride=16 r-statistic=0.0168868
......
```

The LIGO Data Monitoring (LDM) Environment

- LDM interfaces users with a LIGO friendly language instead of the more CS flavor Condor language.
- Technical details of grid computing are hidden from end users (mostly gravitational wave physicists in the LSC).
- The experience gained in this work will be applied for future deployment of the Open Science Grid (OSG) infrastructure for LIGO applications.

grid-enabled run of rmon DMT offline monitor using LDM

```
[jcao@ldaspc1 ~]$ cd ldm
[jcao@ldaspc1 ldm]$ source setup.sh
[jcao@ldaspc1 ldm]$ cd ../rmon
[jcao@ldaspc1 rmon]$ ldm_agent
[jcao@ldaspc1 rmon]$ ldm_submit ldm.sub
Job test has been submitted.
[jcao@ldaspc1 rmon]$ more ldm_test_condor.out
Processing multi list file: ldm_test_CIT_multilist.txt
        Number of lists added: 2 Total data streams: 2
......
startgps=751658000 stride=16 r-statistic=-0.00251782
......
```

automatically generated Condor submission file

```
universe = globus
globusscheduler = ldas-grid.ligo.caltech.edu/jobmanager-condor
log = ldm_test_condor.log
output = ldm_test_condor.out
error = ldm_test_condor.err
should_transfer_files = YES
when_to_transfer_output = ON_EXIT
transfer_input_files = ldm_test_CIT_multilist.txt, ldm_test_CIT_filelist1.txt,
ldm_test_CIT_filelist2.txt, /home/jcao/rmon/opt
arguments = -inlists ldm_test_CIT_multilist.txt -opt opt
environment = LD_LIBRARY_PATH=/dso-test/jcao/dol/lib
executable = /home/jcao/rmon/rmon
Queue
```

ldm.sub

```
[job]
id = test
monitor = rmon
args = -opt opt
input = opt
[data]
observatory = @H@L
type = @RDS_R_L3@RDS_R_L3
start = 751658000
end = 751676993
```

- Users are interfaced with a LIGO friendly language.
- Users do not bother with technical details of LSC data grid services.
- Data are located and file lists are generated automatically