In 2010, the Large Hadron Collider (LHC) experiments ATLAS and CMS, collaborations of thousands of physicists across 200 institutions in 40 countries, produced their first physics results shortly after the data from the first event was recorded. Distributed Computing has proven to be the transformative enabling technology scientists were hoping for, providing an agile global single sign-on environment for scientific discovery. Over the next 5 years, the LHC is scheduled to reach its design energy and luminosity, generating a stream of experimental data that will provide the once-in-a-lifetime discovery opportunities the LHC was designed for.

The Worldwide LHC Computing Grid (WLCG) operates an unequalled global fabric of services that enables access to the tens of petabytes of raw detector, simulated, and processed data ATLAS and CMS have produced in one year, and are now mining for physics discoveries. The Open Science Grid (OSG) in collaboration with the US-LHC community provides a fabric of distributed high throughput computing (DHTC) services that comprise the US contribution to the WLCG. In Europe the European Grid Infrastructure (EGI), and National Grid Initiatives similarly underpin the WLCG.

The current set of data and workflow management services employed by ATLAS and CMS is based on a data ‘pre-staging’ computing model. Namely, data has to be staged by a fairly complex suite of data distribution services at University or Laboratory computing centers before it can be processed or analyzed. This limits data access to those centers with the effort to maintain these services, and makes interactive data access close to impossible. It is now time to revisit the computing model the LHC adopted in 2005 based on the set of common DHTC services provided by the WLCG at that time. These services were designed to meet the needs of the LHC scientific program during the early stages of data taking. The steady stream of early publications is a clear display to the effectiveness of this initial approach.

The success of the WLCG fabric also exposed the inherent limitations of the current computational model. In 2010 the experiments identified a critical need for adopting a new computing model that facilitates adding data analysis services to the common WLCG fabric. The requirements for these new services were discussed in a workshop in Amsterdam in July 2010. It was agreed that the WLCG will adopt a new model that also supports the re-direction of the input stream of an application to a remote site. Through ‘remote-access’ data services the new computing model will enable dynamic access to existing world-wide data caches and will provide the capabilities for applications on any laptop, server, or cluster to access data seamlessly from wherever it is stored. A fabric of DHTC services that brings together the pre-staging and remote-access data paradigms is a transformational change as it will give the distributed physics groups automated access to “Any Data” at “Anytime” from “Anywhere”, decreasing data access costs, reducing application failures due to missing data via remote fallback, and downloading on demand only data that is actually used.

Existing DHTC technologies are insufficient to support the new WLCG computing model in the capabilities of: dynamic management of petabytes of data; a performant global name space; mechanisms to regulate the aggregate access and prevent overload of the data sources and waste of processing capacity at the sinks; and performance and robustness in light of latency and bandwidth constraints for transatlantic data access.

The fabric realizing the vision of a computing model that delivers worldwide dynamic data access must clearly be international in scope and adoption. The collaboration between the groups developing this fabric of services - notably the US LHC collaborations in partnership with the OSG in the U.S, the global LHC collaborations, the EGI, data infrastructure, and middleware initiatives in Europe, and the centralized storage and data service groups at CERN - is critical to provide the global coverage necessary.

\[\text{1} \quad \text{http://indico.cern.ch/getFile.py/access?resId=0\&materialId=3\&confId=92416}\\\]
\[\text{2} \quad \text{http://indico.cern.ch/conferenceTimeTable.py?confId=92416\#20100616.detailed}\]
US Context, Plans and Goals


In the following we elaborate further on the specific context, plans, and goals in the US. While the context in Europe and the US is clearly different, the plans and technical goals are largely common.

As we build the next generation of DHTC services we are committed to the reuse of technologies across scientific domains. We have successfully lowered the barrier of entry for new communities via the common services and software of the OSG. For example, over the past few years the Condor project and the US LHC experiments have collaborated on developing scalable and robust job management overlay services across the entire WLCG infrastructure. This has been adopted as a core service by the OSG and is now supported for, and operated on behalf of more than six different communities across physics, applied mathematics, chemistry, and biology.

Once integrated into the OSG DHTC services, the “Any data, Anytime, Anywhere” capabilities will be available to the entire spectrum of scientific communities served by the OSG. This will be accomplished through the Virtual Data Toolkit (VDT) software infrastructure, and a comprehensive documentation, education and training program.

Delivering a suite of “Any Data, Anytime, Anywhere” services will be a concrete contribution to the NSF CF21 vision in terms of enabling transformative data intensive science with novel distributed high throughput computing services for data intensive research across the DOE and NSF scientific communities. The proposed services will enable:

- Interactive access from any location with internet access worldwide to any data hosted by the tens of petabytes globally distributed disk storage systems by any of the scientists collaborating on the LHC experiments, subject to the access policies of groups and individuals within the experiments.
- Expanded access to the data by small and medium university groups through reducing the overhead of operating the WLCG data services.
- Balancing of data analysis across the entire WLCG CPU resources rather than partitioning these resources into clusters that can access only locally stored data.
- Harnessing commercial or scientific "cloud" and "opportunistic grid" computing resources for data analysis as co-location of data is no longer an impediment.

Since the Amsterdam meeting the US LHC collaborations and CERN have demonstrated prototypes of data services\(^3\) that can meet the immediate needs of the collaborations. This is based on software and protocols collaboratively developed by University groups and National Labs on both sides of the Atlantic. We believe that through incremental focused efforts we can bring these services to fruition to benefit the LHC community over the next 3 years, and establish a foundation from which to extend the capabilities and deploy the services for all OSG stakeholders during the second 1/2 of that period. The technical work will include:

- A network of redirectors to route data access requests from anywhere to the ‘best’ location with the requested data.
- Extensions to the Condor system to support co-scheduling of processing and data access resources.
- Improvements in the IO client libraries on the application side.
- Integration of the new technologies into the WLCG and OSG software stacks.
- Deployment and operation of the new capabilities jointly by OSG and WLCG, becoming part of the global fabric of DHTC services that the two organizations jointly operate.
- Support the use and adoption of the “Any Data, Anytime, Anywhere” technologies and services by the entire range of scientific communities served by the OSG.

\(^3\) [http://indico.cern.ch/getFile.py/access?contribId=5&sessionId=0&resId=0&materialId=slides&confId=118230](http://indico.cern.ch/getFile.py/access?contribId=5&sessionId=0&resId=0&materialId=slides&confId=118230) 
[http://indico.cern.ch/getFile.py/access?contribId=6&sessionId=0&resId=1&materialId=slides&confId=118230](http://indico.cern.ch/getFile.py/access?contribId=6&sessionId=0&resId=1&materialId=slides&confId=118230)