US ATLAS Computing Facilities

Draft 3

1. Introduction

US ATLAS computing facilities are those facilities procured, installed and operated to support US physicists in their participation in the ATLAS project at CERN's LHC. US ATLAS computing facilities are intended to provide the following functions:

- Meet any ***MOU*** defined obligations of US ATLAS to supply direct Information Technology (IT) (computational/network/storage) services to ATLAS.
- Supply IT support for the design, development, construction, calibration and any other activity associated with detector subsystems for which US ATLAS is responsible.
- Supply IT support for US ATLAS obligations to design, develop, test and maintain software, both applications and infrastructure, for ATLAS.
- Supply all IT support beyond the desktop, needed by US ATLAS physicists in analyzing ATLAS data and participating fully in the production of ATLAS physics results.
- Supply such IT resources as required to investigate, prototype, and validate plans for developing optimized facilities, software and infrastructure serving the above functions

The model for US ATLAS facilities is that of a transparent hierarchical distributed grid of computing resources. The components of this Grid are:

- The primary ATLAS Tier 0 computing center at CERN
- A single US ATLAS Tier 1 computing center
- Multiple US ATLAS Tier 2 region computing centers
- Multiple US ATLAS Tier 3 institutional computing facilities
- A dedicated high performance network link between the US ATLAS Tier 1 center and CERN
- Multiple high performance network links connecting together various US ATLAS computing centers and collaborating institutions
- The desktop systems of individual ATLAS collaborator who are members of US institutions

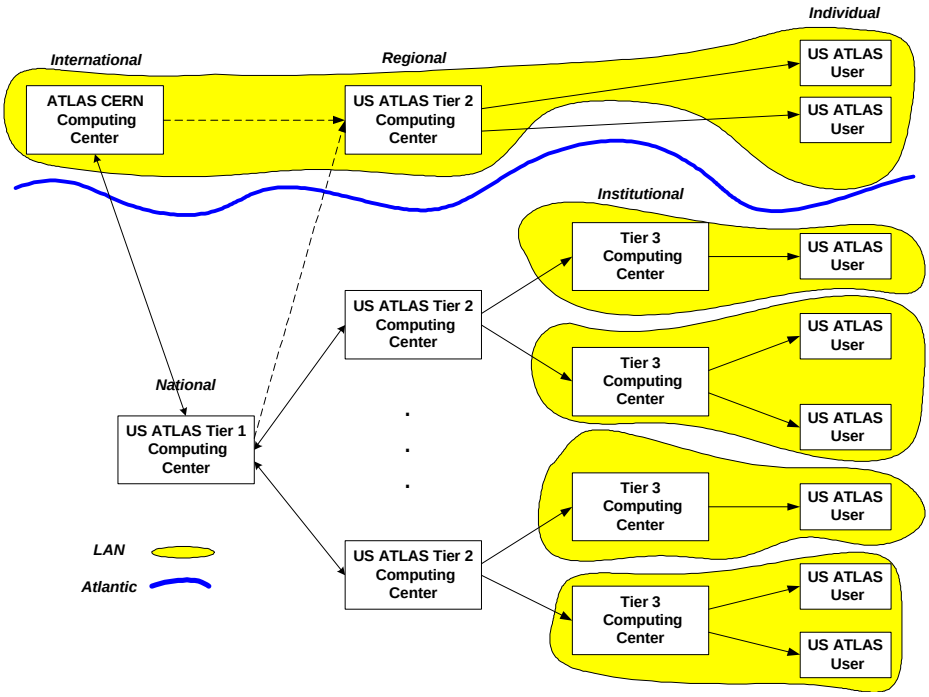


Fig. I Schematic of US ATLAS Computing Facilities Model

In the current model, US ATLAS computing resource will be distributed primarily between Tier 1 and Tier 2 computing centers. There will be a single Tier 1 facility located at Brookhaven National Laboratory, which will be national in scope. This facility will, at least initially, be operated in synergistic conjunction with the RHIC Computing Facility (RCF) currently in operation there. There will be approximately six Tier 2 facilities whose scope will be regional. One of these would likely be located at CERN to support US ATLAS physicists while working there. The sites of other Tier 2 centers remain to be determined but will be selected so as to maximize the number of US ATLAS collaborators who have good access and to maximally leverage local institutional resources and expertise. Tier 3, institutional computing, is expected to be supported primarily from non-ATLAS project sources, with case by case decisions made regarding low levels of project support to facilitate an institutions effective utilization of Tier 1 or 2 resources.

2. Computing Facilities Requirements

The requirements that must be met by US ATLAS computing facilities are highly time dependent. For planning purposes considerable attention has been focused on requirements for the first year of operation, 2005. Clearly as the collider luminosity rises in later years the ATLAS computing requirements will continue to rise but the largest fractional jump in capacity is expected to be for this first year of operation. The computing requirements for 2000 and 2001 can be estimated with reasonable accuracy based on the current people involved and the activities they anticipate for the next couple of years. Year 2002 – 2004 requirements will be associated with the construction, integration and testing of systems and subsystems. This will include optimization of analysis strategies and validation of the computing architecture itself. The ramping up of computing facilities will scale with the number of full time people involved and the number and scale of activities they undertake. The requirements profile for these years is probably least well understood and a relatively simple interpolation between the better defined near term and first physics requirements has been assumed.

The requirements estimate for US ATLAS computing facilities presented here is in derived in part from the requirements established for ATLAS as a whole. The ATLAS assumption is that the main production reconstruction passes on all raw data will be performed at CERN. All other computing functions will be performed in a distributed manner making extensive use of facilities located among the ATLAS collaborating institutions. The general rule of thumb established by ATLAS is that each regional center should supply about 20% of the general ATLAS need. In some cases this distributed computing will be centrally coordinated and done in support of ATLAS in general, for example the production of Monte Carlo data sets. In other cases the computing will be done under local control and will function in support of local physicists, for example the analyses of particular physics channels.

The estimate below was made as follows. The US ATLAS requirement for any particular computing function starts from the ATLAS estimate of that requirement and the estimate made centrally by ATLAS of the fraction of that requirement which is appropriate to a “typical” Tier 1 facility. This initial value is then review from a US ATLAS perspective and on the basis of experience, cost and criticality to US ATLAS participation in the ATLAS physics program this estimate is commonly increased. This revised estimate is then evaluated in the context of the Tier 1 / Tier 2 US ATLAS model. The transition from a monolithic Tier 1 model to a model including Tier 2 centers has to result in some enhancement in overall installed capacity as well as increased collaborator autonomy to justify the increase in technical effort and risk. An increase in the requirement estimate is in some instances made for those functions that are distributed because of the potential for decreased efficiency for distributed resources. The estimating process is discussed below by function for the principle contributors to the scale of US ATLAS computing facilities.

- Modeling & Simulation: The running of programs modeling various physics processes and the simulated propagation of the resultant particles through the detector will play an important role in understanding the response of the ATLAS detector. In its most complete form the results of such simulations are data sets which are identical in format to actual detector produced raw data. The same analysis chain as is used on actual raw data can then process this simulated data. By so doing one obtains detailed information about acceptances for signals and backgrounds and is able to most directly

confront physics models with measurements. Simulation is a very CPU intensive and ATLAS has estimated the need for about 50x10^3 SPECint95 of installed computing capacity to meet this requirement in 2005. It is assume that US ATLAS will supply 20% of this general ATLAS requirement. In addition, US ATLAS feels it prudent to have the capability to perform a similar amount of simulation in direct support of the analyses of US ATLAS physicists. Thus the simulation requirement for US ATLAS facilities is estimated to be of order 2 x 20% of 50x10^3 SPECint95 or ~20x10^3 SPECint95 of installed capacity. This capacity is something reasonably well suited to relatively lean, in terms of personnel, Tier 2 centers. Therefore in the US ATLAS facilities model a significant fraction of the simulation computing is assigned to Tier 2 centers with a reduction in the simulation capacity which might otherwise have been located at the Tier 1.

- Calibration: While during the construction and testing phase of detectors, for which US ATLAS has responsibility, calibration may be performed by computing resources in the US, it is expected that such calibrations will be done by computing system which are part of the CERN facility once operations begin. In any case this is not expected to be a large load when compared to the simulation, reconstruction or analysis loads. The faction of this load, which actually makes use of U. S. ATLAS resources, is contained within the U.S. ATLAS reconstruction and analysis requirement estimate.

- Reconstruction: The conversion of the digitized values recorded by the detector (raw data) into event summary data (ESD), a description of events in terms of physics variables, is an activity that is expected to occur at least twice for all ATLAS data. It is expected to occur many times more for events of special interest. These reconstruction passes will also produce analysis object data (AOD) which is data optimized for access during final analysis and will contributed to the event tag data (TAG) which enables fast classification of events. Reconstruction is highly CPU intensive and ATLAS has estimated that 70x10^3 SPECint95's of installed computing capacity will be required to satisfy this need in 2005. While the compute resources for the production reconstruction of the Raw data are to be located at CERN, US ATLAS facilities must include the capacity to perform re-reconstruction passes on samples of events of special interest to US ATLAS physicists in doing their analyses. These re-reconstruction passes would usually start from existing ESD but would on occasion go back to the raw data. It is estimate that perhaps 10% of the raw data would be so reprocessed and that the processing load for re-reconstruction from ESD would be about twice this raw data level. Thus the reconstruction requirement for US ATLAS facilities is estimate to be of order 3 x 10% x (70x10^3SPECint95)/2 or ~10x10^3 SPECint95 of installed capacity. A requirement associated with the reprocessing 10% of the raw data is the need to store that amount of raw data in the US. This storage requirement, as will be discussed below, implies that such activities are probably best concentrated at the Tier 1 center.

- Data mining: This is the process performed on ESD or AOD resulting in reduced and/or reorganized ESD or AOD data sets. These sets are better suited in terms of compactness and efficiency of reading for the highly iterative analysis phase of data processing. Data mining is generally a highly I/O intensive process and is not expected to produce a compute load which is large compared to or even clearly distinguishable from the analysis requirement. Data mining is of particular importance for data residing on tertiary storage. The serving of data from both online and tertiary storage is discussed below.

- Data serving (Online storage): This is making the data immediately available for efficient use by processing, compiling, or displaying systems. The data to be served includes documents, code, calibrations, and various levels of event data. It is the serving of the event data that defines the quantitative requirements of the systems. Data serving can be either Local or Wide Area. In the absence of effective differentiated Wide Area Network services, even when there is adequate bandwidth between sites, latency can be a problem. This is particularly true for I/O intensive activities, such as analyses working from database event stores, in which successive reads may be widely separated in storage. It is therefore the goal in US ATLAS computing to have sufficient online storage (disk) Local Area connected to processors, doing any type of computing, so that all of the data being processed can be cached locally and there is little network latency induced inefficiency.

Document and code libraries need to be locally cached but the data volumes associated with this are small and the AFS system handles the caching in an effective way. The capacity defining data to which direct online assess is desired includes all of the TAG, AOD, and ESD for both real and simulated data. Since ATLAS estimates the ESD data volume for 2005 to be of order 100 Tbytes this alone would result in a large cost for disk given that there are 6 Tier 2 as well as a Tier 1 center. US ATLAS physicists are expected to be involved in only a subset of the ATLAS physics analyses and correspondingly in need of frequent access to the associated ESD data. Therefore a model has been used here in which all of the ESD data is available at the US Tier 1 center on tertiary storage but only 50% of it is resident on disk at any time. Calculation based on the above shows that about 100 Tbytes of installed disk would be required to support the complete US ATLAS data serving requirement at the Tier 1 center. In addition significant processing power will be located at the 6 Tier 2 centers, each of which will require significant local disk caches in order to keep its processors *and physicists* operating efficiently. These caches will include additional relatively static subsets of the TAG and AOD, corresponding to the particular analyses concentrated at each site, as well as more dynamic caches of ESD data and other TAG and AOD data. In all, it is estimated that Tier 2 centers may each require as much as 15% of the disk capacity required at the Tier 1 center.

- Nearline storage (Tertiary storage): Tertiary storage will be required to retain copies of all data on disk plus ESD data not on disk and the 10% of raw data for which local re-reconstruction is required each year. This results in a data volume, which is of order 300 Tbytes in 2005. In addition to the automated media library, which stores and manipulates the recording media, there are drives, which do the actual reading and writing. The number and performance of these drives determine the access bandwidth to the data store. An estimate of the bandwidth requirement for access to these data is obtained by estimating that one would want to be able to make passes through the ESD data not on disk at least once a week so 50 Tbytes/ 7 days or ~100 Mbytes/sec. Assuming that the aggregate throughput for all other activities is comparable, the installed tertiary I/O bandwidth must be of order 200 Mbytes/sec. The US ATLAS model is that tertiary storage with the associated high personnel requirements of hierarchical storage system hardware and software management will be limited to the Tier 1 center.

- Analysis: This is a highly iterative process to extract physics significance from a data set by the adjustment of selection criteria and display variables. This activity is most commonly interactive in nature with the physicist actually sitting and waiting for the result. For this reason the requirement is defined by peak demands where the peaks occurring during the workday hours of geographical locations where large concentrations of ATLAS collaborators are found. ATLAS has estimated a requirement for 130 kSPECint95 of capacity for such analysis. The US ATLAS community is distributed across a 3-hour range in time zones and so for 6-8 hours each day there is likely to be heavily overlapped use of these facilities by almost all active US ATLAS collaborators and therefore the demand very peaked. The rule of thumb indicates that US ATLAS resources should include 20% of the total analysis capacity. However, because of this strong peak in demand and since this is the compute capacity that directly supports US ATLAS physicists in the extraction of results for the physics channels they are studying, the requirement for analysis has been raised to twice the guideline or 40%. This produces an estimate for analysis of 2 x 20% x 130x10^3 SPECint95 = ~50x10^3 SPECint95 of installed capacity. This function is well suited to Tier 2 centers and is expected to be distributed there with a substantial descoping of this activity at the Tier 1 center.

- Data import & export: ATLAS has estimated that the required data transfer rate between CERN and a Tier 1 Regional Center could be satisfied by a dedicated OC3 connection. The required connectivity for bulk data transfer between multiple Tier 2 centers and the US Tier 1 is expected to be at a comparable bandwidth. Since OC3 connectivity is already becoming common within the US and is expected to be available to CERN soon, the use of physical media to export and import data is unlikely to be necessary and so has not been included in this model.

- Desktops: Functionally this includes Email, web browsing, document preparation, image display, etc. which are currently the purview of the individual physicists desk top workstation or PC. This activity is largely independent of the scale of the project on which the physicist works. While it involves

Information Technology it is more of an infrastructure appliance such as the telephone and so is assumed to exist but is not considered a part of the US ATLAS computing requirement proper.

- Network: Connectivity between CERN and the Tier 1 center was estimated to require at least an OC3 connection. While OC3 allows for the time averaged bulk transfer of data from source sites to other required centers, US ATLAS feels that it is marginal in terms of dealing with peak demand situations. It will further put an unacceptable premium on managing data flow in the dynamic world of replicated data bases being simultaneously manipulate at multiple sites. US ATLAS therefore estimates that by the time ATLAS operations begin, OC12 connectivity for US ATLAS to CERN well be required. By the same logic, connectivity between the Tier 1 center and Tier 2 centers will also require OC12.

- Infrastructure Software: There are a large number of functionality requirements, which impact software more than hardware. Such software requirements can result in significant license and maintenance cost as well as staffing cost related to development, integration, and operations efforts. A few of the more important items included in these requirements are: data management tools such as an OODBMS, wide area network transparency, software development tools and utilities, code and document repository management utilities, and the cyber security of user data and facility resources.

3. Technology and Technology Projections

Virtually all of the cost driving components of the US ATLAS facilities plan are evolving dramatically as a function of time. This means that any projection of cost for a specified level of performance at a time five years in the future is going to have large uncertainties associated with it. The following describes the technology choices and costing assumptions of these major facility cost-driving components.

- Compute intensive (CPU): The requirement for large quantities of inexpensive compute cycles has been most effectively met over the course of the last 20 years by farms of semi-commodity (workstations) and more recently commodity (personnel computer) computers. The decrease in the cost of CPU cycles from these commodity systems has continued at the rate of at least a factor of two every 18 months for more than 15 years and shows no sign of stopping. It is therefore clear that in the near term such farms will play a part in ATLAS computing and it is seems likely that this will remain to be the case into initial LHC running. Computing of this type is extremely well suited to the simulation and reconstruction component of the ATLAS computing requirement. Farms of this type based on Intel processors running the Linux operating system are currently in wide use and are the costing basis for this type of computing.

- Online storage (Disk): While various other technologies have shown promise, magnetic disk with a decrease in cost of approximately a factor of 2 every 18 months has remained the primary form of Online storage for several decades. There are strong indications that it will retain its rate of improvement in cost effectiveness and remain the principal online storage medium for the near term. It replacement by another technology would be a result of the technology improving even more rapidly so estimating costs on the basis of magnetic disk technology is a conservative approach. Fibre Channel connected RAID disk is the costing base here for this type of storage.

- Nearline (tertiary) storage (Robotic tape): While the rate of improvement in cost effectiveness for tape storage has not been as dramatic as that of CPU and disk, its improvement has been significant during the last few years. A number of tape technology advances in capacity and bandwidth currently predicted offer the possibility that over the next couple years it price performance improvements may approach those of disk and CPU, factors of two in 18-24 months. The management of the large volumes of data stored in an automated tape storage system requires the use of complex software for both bookkeeping and operations. This software usually couples the automated tape library, the tape drives, and a front-end disk cache into a unified hierarchy of storage. The High Performance Storage System (HPSS), a Hierarchical Storage Management system distributed by IBM, is currently perhaps the only highly scalable HSM commercial used in particle physics and so is a reasonable default for the US ATLAS model. It allows for reasonably accurate estimation costs and staffing requirements.

- Network: The introduction of first fast Ethernet and then Gigabit Ethernet have resulted in dramatic improvement in both performance and price/performance over the course of the last few years for local area networking. The network requirements within US ATLAS facilities seem to be well within the capacity of such technology. In the case of wide area networking the situation is less clear. The cost of wide area networking is currently substantial, especially between the US and Europe. Simple extrapolations of existing technology are used to estimate the availability and cost of this capability.

- Servers: Medium to large scale SMP's with their high speed back planes and their capability of supporting large numbers of peripherals and network connections are available from SUN, IBM, and SGI. All make SMP's commonly used in HEP as server machines. Such severs are also frequently used to support I/O intensive activities such as data mining or some types of analysis. While such system are experiencing improvement in price/performance at approximately the same rate as commodity computers, their price is offset higher by a factor of 5 to 10 so it is important that they not be used for simple CPU intensive activities. These systems fill the large-scale server niche in the US ATLAS facilities model. One of the major server functions of these SMP's, that of serving RAID disk, may be usurped by dedicated serving engines, so called network appliances, over the course of the next few years. However since this will only occur if the new technology is more cost effective than the continued use of SMP servers, the conservative costing based on SMP's is used here.

4. Architecture

As discussed briefly above the model for US ATLAS facilities is that of a transparent hierarchical distributed grid of computing resources. The simplest form of the model is one in which the only significant concentration of resources that exist outside of CERN would be at the Tier 1 center. This degenerate form of the model might occur in a limited funding scenario. It would quite efficiently address the basic requirements but would make less effective use of desktop or other institutional or base program supplied resources and would, with the associated need for formal centralize resource allocation, reduce the autonomy of individual technical and scientific work groups.

At the other end of the model spectrum is one where comparable capacities exist at each level of the hierarchy. While the utilization of such more distributed resources will be less efficient, it is expected to be offset by the ability to utilize institutional, desktop and other base program supported equipment more effectively. Effective utilization of such a full function hierarchy requires more technical support and in particular the use of analytic and predictive tools such as those being developed in MONARC and the successful execution of advance GRID computing projects such as the Particle Physics Data Grid and Apogee. The result would be a computing environment with more technical capacity local to individual institutions, thus putting more functionality into hands of individual physicists and granting significantly more autonomy to technical and scientific work groups.

The US ATLAS facilities plan focuses on a computing hierarchy in which there are significant resources at all levels. However attention has been paid to assuring that the overall design will work efficiently in the absence of certain intermediate levels. This would require quantitative changes in the composition of the remaining levels of the hierarchy but would not require dramatic changes in architecture or changes in the fundamental capabilities at any level.

Although it is not immediately obvious, for a computing facility offering a full range of services, the primary cost associated with supplying computing service is almost always the cost of the personnel required to operate the facility rather than the cost of the computing hardware in it. A quick evaluation of the US ATLAS case leads to this same conclusion. Therefore one of the guiding principles in developing the model for US ATLAS computing facilities has been an effort to limit the scale of personnel requirements. One way to address the personnel problem in a multi-center facilities plan is to make only one of those centers a full function center in need of a full complement of expertise. The second is to enforce a high level of uniformity across the various centers so that a solution developed for one is immediately applicable to the others. Both of these approaches are part of the plan for a multi-center U.S. ATLAS computing facilities architecture.

The Tier 1 regional center for US ATLAS located at Brookhaven National Laboratory will contain all elements of US ATLAS facilities and will supply full support services including mirrors of the ATLAS code and documentation repositories at CERN. The Tier 2 centers will focus on simulation and analysis compute capabilities with sufficient local disk cache to efficiently support these activities. They will specifically not include tertiary storage systems, depending on high performance connections and GRID computing infrastructure to make us of such capabilities at the Tier 1 center.

5. Facility Components

There are three basic cost driving components to US ATLAS facilities. The first is the Tier 1 center at BNL. The second is the set of Tier 2 facilities. The third is the network. The Tier 1 facility is already coming into operation and will serve as the initial test bed for US ATLAS facilities, their configuration and how they interact with users. The Tier 2 facilities will be phased in. On the assumption that it takes two years to achieve fully operational status, the first, serving as the Tier 2 testbed will be established in 2001, the second in 2002, and the remaining 4 in 2003 so that all will be fully operational going into 2005. The second Tier 2 center, established in 2002 would probably be the one at CERN. The 2005 projected capacities of the Tier 1 Center and a typical Tier 2 center are indicated in the tables below.

Table 1

Tier 1 Center in Context of Tier 2's

	CERN Disk	CERN Tape	US Fractions		US ATLAS Disk	US ATLAS Tape
Annual Data Storage Estimate						
Raw - Tbytes		1000	10%			100
ESD - Tbytes	100	100	100%		50	100
AOD+ETD - Tbytes	11	11	100%		11	11
Simulated - Tbytes	11	111			6	21
10% Tape Staging & Caching - Tbytes					23	
Total Storage for 2005 Data - Tbytes	122	1222			90	232
Legacy Sim & T-beam Data ('99-'04) - Tbytes					10	75
Total Installed Capacity in 2005 - Tbytes					100	307

	GLOBAL ATLAS	US Fraction	US ATLAS
Installed CPU Estimate			
Simulation - kSPECint95	50	20%	10
Reconst. - kSPECint95	70		
US Reconst. - kSPECint95		10%	7
Analysis - kSPECint95	130	20%	26
Total CPU - kSPECint95	250		43

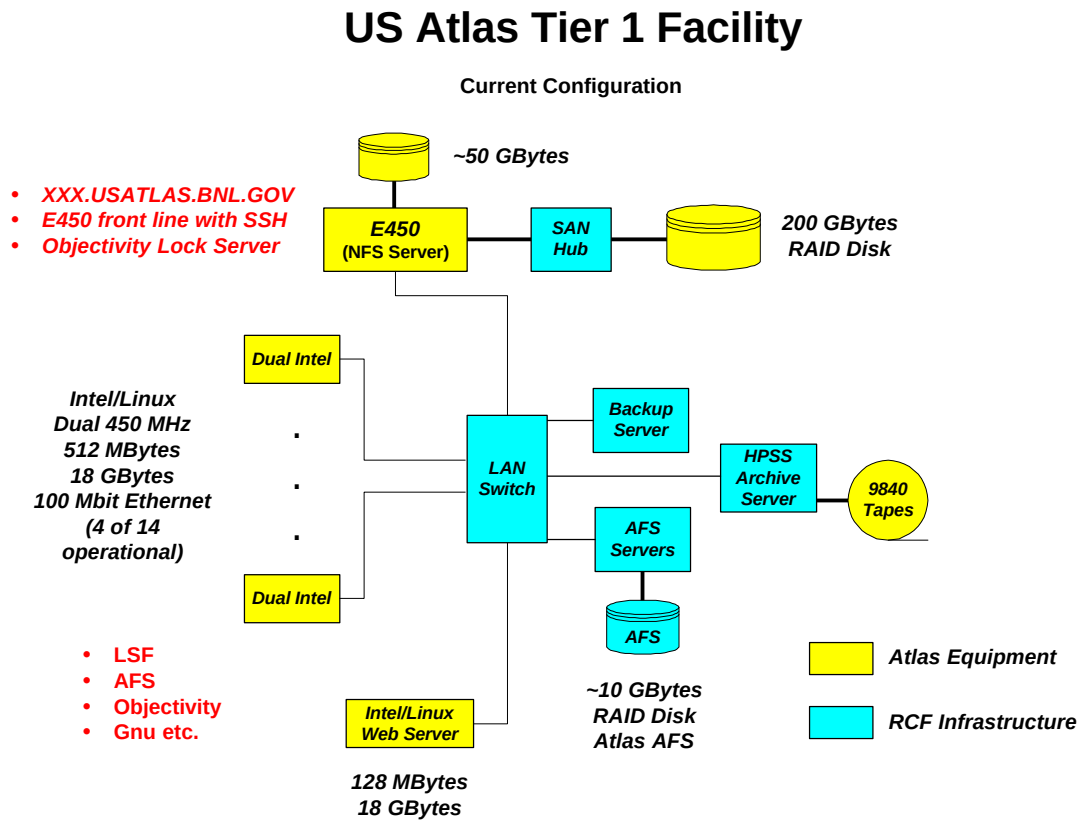
	Comment		Band-width
CERN connectivity - Mbits/sec	OC3		155
User connectivity - Mbits/sec	50	Users	50
US Tier 2 connectity - Mbits/sec	5	OC3 SITES	775

Typical 1 of mutiple Tier 2 Centers			
	Comment		
CPU			
Simulation - kSPECint95	20%	of above US	4
Analysis - kSPECint95	20%	of above US	10
Disk			
AOD-EOT Subsets - Tbytes	50%	of Total	6
Network-Tape Stage & Cache - Tbytes	3%	of US Tape	9
Network			
Tier 1 connectivity - Mbits/sec	Dedicated OC3		155
User connectivity - Mbits/sec	20%	of US users	20

Table 2

The Tier 1 facility at BNL is currently operational with several of the basic components but with very limited capacity in each. The facility currently consists of a Sun server, Fibre Channel connected RAID disk, a small farm of dual processor Intel systems running Linux, and a web server. The facility shares physical space and external network connectivity with the RHIC Computing Facility (RCF). It also has shared access to a low priority HPSS class of service for the archiving of data and shares use of an AFS server at the level of about 10 GBytes of storage. A schematic is shown below.

Fig. 2



There is currently one FTE's of system administration effort being directed to its support, which is covered by BNL LDRD funding. The current installed capacities are summarized as follows:

Table 3
Current U.S. ATLAS Tier 1 Capacities

Compute	28 CPU's	500 SPECint95
Disk	Fibre Channel	250 Gbytes
Sun Server / NIC	2 CPU's	100 Mbit/sec

6. Capabilities and Cost

The following table describes the projected US ATLAS computing capacities as a function of US Fiscal year for CPU, Online (Disk) Storage, and Nearline (Tertiary) Storage. The table shows the break down between the Tier 1 center and Tier 2 centers.

Table 4

US ATLAS Facilities Integrated Capacities

	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006
Operational Tier 2 Facilities	-	-	1	2	6	6	6	6
CPU - kSPECint95								
Tier 1	0	2	5	9	16	30	50	80
Tier 2	-	-	1	4	20	48	91	156
Total CPU	**0**	**2**	**6**	**13**	**37**	**77**	**141**	**235**
Disk - TB								
Tier 1	0	1	4	12	24	54	100	168
Tier 2	-	-	1	3	20	52	89	145
Total Disk	**0**	**1**	**5**	**15**	**44**	**106**	**189**	**313**
Robotic Tape Storage (Tier 1) - TB								
Total Robotic Tape	**1**	**5**	**17**	**35**	**62**	**116**	**319**	**622**

The personnel requirements for the Tier 1 and Tier 2 facilities in 2005, presumably near the steady state operating mode, and how they are imagined to be distributed according to function are indicated in the following table. While the detail is probably not correct, it is felt that integrating over the details will produce estimates that are reasonably accurate. As has been discussed elsewhere, the goal with the Tier 2 centers has been to limit the required staffing and to try to leverage existing facilities and expertise at institutions in site selection. For this reason, while it is felt that not fewer than 3 FTE's are required to operate such a facility, at least one of those three is expected to be supported out of the local base program or by some other institutional contribution. Therefore only 2 FTE's per Tier 2 site are expected to contribute to the final project costs.

Table 5

US ATLAS Facilities FY 2005 Staffing Estimate Details

Function	Typical Tier 2 (FTE's)	Multi-center Tier 1 (FTE's)	Total 6 x Tier 2 (FTE's)
Simulation/Reconstruction System	0.3	2.5	1.8
Data Serving System	0.5	4	3.0
Analysis System	0.4	2.5	2.4
Computing Environment	0.5	4	3.0
Data Access	0.5	6	3.0
Network	0.2	3	1.2
Physical Infrastructure	0.1	1	0.6
Facility Management	0.5	3	3.0
Total	**3**	**26**	**18**
	Assume 1 FTE is contributed from base		Total of 6 FTE's are contributed from base

The funded staffing profile for each type of center and integrate across all centers is shown by year in the following table.

Table 6

US ATLAS Facilities Staffing (FTE's)

	FY '99	FY '00	FY '01	FY '02	FY '03	FY '04	FY '05	FY '06
Tier 1								
Tier 1 Total	3	5	8	11	13	19	26	26
Tier 2								
Initial Year Center	-	-	1	2	2	2	2	2
Second Year Center	-	-	-	1	2	2	2	2
4 Final Year Centers	-	-	-	-	4	8	8	8
Tier 2 Total	-	-	1	3	8	12	12	12
US ATLAS Facilities Total	3	5	9	14	21	31	38	38

Network costs will be a significant contribution unless they are funded out of some other source. Since adequate network capacity is critical to the US ATLAS Facilities plan an estimated cost of the required network capacity as summarized below has been included.

Table 7

Network Cost Estimate

	1999	2000	2001	2002	2003	2004	2005	2006
Tier 1 to CERN Link					T3	OC3	OC12	OC12
Annual CERN Link Cost	0	0	0	0	100	250	400	300
Number of Tier 2 to Tier 1 OC3 Links	0	0	1	2	5	4	0	0
Number of Tier 2 to Tier 1 OC12 Links	0	0	0	0	0	1	5	5
Estimate annual cost of a domestic OC3	300	240	192	154	123	98	79	63
Estimate annual cost of a domestic OC12	600	480	384	307	246	197	157	126
Total Domestic WAN Cost	0	0	192	307	614	590	786	629
Total WAN Cost	0	0	192	307	714	840	1186	929

The following table summarizes the total US ATLAS facilities costs as a function of U.S. Fiscal Year. It should be noted that certain items which are usually separated out from equipment, such as power and maintenance costs are here included in the Equipment, etc. line.

Table 8

US ATLAS Facilities Annual Costs (FY2000 k$)

	FY '99	FY '00	FY '01	FY '02	FY '03	FY '04	FY '05	FY '06
Tier 1								
Equipment, etc.	110	520	960	1,090	1,330	2,050	2,110	2,150
Personnel	100	700	1,120	1,540	1,820	2,650	3,630	3,630
Tier 1 Total	220	1,220	2,070	2,630	3,150	4,700	5,740	5,780
Tier 2								
Equipment, etc.	-	-	190	470	1,630	2,030	2,050	2,140
Personnel	-	-	140	420	1,120	1,680	1,680	1,680
Tier 2 Total	-	-	330	890	2,740	3,710	3,720	3,820
Network								
Network Total	-	-	190	310	710	840	1,190	930
US ATLAS Facilities Total	**200**	**1,200**	**2,600**	**3,800**	**6,600**	**9,300**	**10,600**	**10,500**

7. Milestones and Deliverables

The deliverables associated with the facilities component of the US ATLAS computing project are most simply defined as the capacities projected for each year in Table 4 above. To these one must add appropriate network connectivity and properly installed and maintained infrastructure software as well as the required tools, utilities and libraries. There are in addition qualitative aspects to these requirements, which have at this point not been fully defined but need to be reflected in the ultimate list of deliverables. Certainly the notion of transparency of use of facilities in this distributed model is an important qualitative aspect of this type. Others will include ease of use and general uniformity in look and feel. A different class of deliverable is represented by the required support of US ATLAS physicist in their use of the facilities. Since requirements will change over the course of the next five years, it is necessary that the deliverables be adjusted to meet those revised requirements.

Milestones associated with the facilities component of the computing project are also complex and not yet fully defined. The milestones will include the making of technical and managerial decisions, demonstration of developed and procured technical capabilities, and the establishing of levels of capacity. Table 9 below contains a strawman list of potential milestones.

Table 9

Draft Facilities Milestone List

Milestone Description	Date
Selection of 1st Tier 2 site	01-Oct-00
Procure dedicate Automate Tape Library (ALT)	01-Jun-01
Demo Tier 2 transparent use of Tier 1 ATL	01-Jan-02
Establish dedicated Tier 1 / CERN link	01-Jan-02
Select remaining Tier 2 sites	01-Jan-03
Mock Data Challenge I (25% turn-on capcity)	01-May-03
Final commit to HSM	01-Oct-03
Demo full hierarchy transparent operation	01-Apr-04
Mock Data Challenge II (50% turn-on capacity)	01-Jun-04
Achieve turn-on capacities	01-Jan-05

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