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LIGO Data Acquisition System Final Design

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1 INTRODUCTION

The LIGO observatory systems will generate large amounts of continuous data (approximately 14MBytes/sec for the Hanford site). These data must be stored in such a way that they may be recovered at a later time for off-line data analysis and distributed to various on-line ananlysis and diagnostic systems. The process of collecting, storing and , to a limited degree, distributing LIGO data is to be performed by the Data Acquisition System (DAQS).

1.1. Purpose

This technical note presents the final design for the LIGO Data Aquisition System (DAQS). This design has been produced in direct response to the *LIGO DAQS Design Requirements Document (DRD), LIGO T960009-C* and reflects an update to the preliminary design presented in *CDS Data Acquistion Preliminary Design, LIGO-T970136-00-C*. Since it is early in the design phases of LIGO, it is understood that more requirements will be placed on the system over time, particularly as data reduction methods are devised. Therefore, it is the intent of this document to present a baseline design which is flexible enough to incorporate new features in the future.

All designs presented in this document will use technology available at the time of writing. However, the field of data acquisition is rapidly expanding as new technologies become available, and this may open the design to better, faster, cheaper options in the future. Therefore, where possible, some degree of flexibility has been included into the design in allow future developments to be incorporated into the design where ever it is applicable. Also, while specific manufacturers and model numbers of equipment are shown as part of the design in this document, they may not necessarily be the ones used, but rather are meant to be representative of the equipment to be used.

1.2. Scope

A LIGO DAQS is to be developed which meets the requirements set forth in the DRD. The DAQS shall provide the facilities to:

- Acquire LIGO data from various LIGO control and monitoring systems, either via direct analog connections or network connections.
- Format the acquired data into defined data blocks, known as frames.
- Store data frames to short term storage media.
- Provide data on request via computer networks from either its short term storage devices or “live” data every 1/16 second.
- Provide operator views into the acquisition processes.
- Configure the DAQS and its acquisition, storage and distribution processes.

Specifically not considered to be within the scope of the DAQS are:

- Data networks for the distribution of DAQS data to other systems (networks are to be provided by CDS under control and monitoring and by LIGO site general computing).
- Mass storage units, processors and software necessary to read and distribute data from tapes or other long term storage media (considered to be the responsibility of data analysis systems and/or LIGO general computing).

- Tape duplication and distribution facilities.
- Gravitational wave analyis hardware or software.

1.3. Changes to Preliminary Design

This document reflects several changes since the publication of the preliminary design document. A few of the key changes are:

- The DAQS will now provide the short term mass storage system necessary to meet LIGO requirements and the LIGO Data Analysis System (LDAS) will provide the tape or other long term storage media.
- The DAQS reflected memory network has been extended to connect the GDS. This allows data to be acquired and analyzed in real-time by the GDS, allow the GDS in turn to return data to the DAQS and provide a mechanism for GDS to stimulate Interferometer Sensing and Control (ISC) servo processors directly. This network has also been extended directly into Unix workstations (previously only real-time processors).
- ISC processors now directly write some of their data directly as digital information into the DAQS reflected memory network. Previously, DAQS provided separate, parallel Analog to Digital Convertors (ADC). Note that this change also moves the scope of providing necessary whitening and overvoltage detection onto these systems for their signals.
- The formatting of data into frames has been moved from real-time (VxWorks) processors to Unix workstations.

1.4. Definitions

1.4.1. VME.

Versa Module Eurocard, a bus based crate system allowing card based modules to communicate with each other via an arbitrated bus. Most LIGO front end systems are based on VME systems.

1.4.2. Real-Time Software.

Real-time software is that software which is deterministic in its task scheduling and duration. Throughout this document, this term refers to software which runs on a VME micro-processor under control of a real-time operating system (VxWorks).

1.4.3. Non-Real-Time Software.

Non-real-time software refers, in this document, typically to that software which runs under the UNIX operating system. This is due to the non-deterministic scheduling and task duration under this operating system.

1.5. Acronyms

ADC: Analog to Digital Convertor

ADCU: Analog Data Collection Unit

API: Application Programmer’s Interface

ATM: Asynchronous Transfer Mode

CA: Channel Access (EPICS Control and Monitoring system network protocol).

CDS: Control and Data System

CMS: Control and Monitoring System (that portion of CDS which specifically performs these functions)

DAQS: Data Acquisition System

DIA: Data Information Area (of reflected memory)

DRD: Design Requirements Document

DCU: Data Collection Unit (generic)

DMA: Direct Memory Access

EDCU: EPICS Data Collection Unit

EDSU: EPICS Data Server Unit

EPICS: Experimental Physics and Industrial Control System.

FCR: Facility Control Room

FIFO: First In First Out

FFT: Fast Fourier Transform

GDS: Global Diagnostics System

GPS: Global Positioning System

GUI: Graphical User Interface

Hz: Hertz

IFO: Interferometer

IP: Internet Protocol.

ISR: Interrupt Service Routine

LDAS: LIGO Data Analysis System

LVEA: Laser and Vacuum Equipment Area

MAP: Memory Allocation Pointer (reflected memory)

MSR: Mass Storage Room

MTBF: Mean Time Before Failure

MTTR: Mean Time To Repair

NDS: Network Data Server

OSB: Operations Support Building

PEM: Physical Environment Monitoring

RAID: Removeable Array of Independent Drives

RAM: Random Access Memory

SCSI: Small Computer Standard Interface

TBD: To Be Determined

TCP: Transport Control Protocol.

UDP: User Datagram Protocol.

1.6. Applicable Documents

1.6.1. LIGO Documents

- CDS Control and Monitoring Design Requirements Document LIGO-T950054-01-C
- CDS Control and Monitoring Final Design LIGO T960171-C
- Global Diagnostics Preliminary Design LIGO T970172-00-D
- Global Diagnostics Reflective Memory Organization LIGO T980020-00-D
- Specification of a Common Data Frame Format for Interferometric Gravitational Wave Detectors (IGWD) LIGO-T971030-00-E
- 40m Data Acquisition System Quick Reference LIGO-T970126-00-C
- DAQS Reflected Memory Network Design LIGO T980017-00-C
- Hanford Site DAQS Rack Layouts and Signal Connections LIGO T980030-00-C
- Livingstion Site DAQS Rack Layouts and Signal Connections LIGO T980036-00-C
- Data Acquisition Daemon Program Design LIGO T980025-00-C
- Data Acquisition Daemon Client-Server Communication Protocol LIGO T980024-00-C
- A Reference of Data Server Library for DAQS LIGO T980023-00-C
- LIGO Channel Count LIGO T980004-00-D

1.6.2. Non-LIGO Documents

- Interactive Circuits and Systems (ICS) Ltd., ICS-110B 24-bit Data Acquisition Board technical white paper No. 24, Rev. A dated December, 1997.

2 GENERAL DESCRIPTION

2.1. Product Perspective

The LIGO CDS is divided into three functional components, which must be tightly integrated, as shown in Figure 1: CDS Components. These components are defined as:

- Control & Monitoring Systems (CMS): Provides for the control and monitoring of LIGO interferometers and other scientific instruments, along with the LIGO vacuum systems. It also provides the basic infrastructure for the CDS, which includes such functions as networks, timing, and operator stations. The current design for this system is documented in CDS Control and Monitoring Final Design LIGO T970171-C.
- Data Acquisition System (DAQS): Provides for the acquisition of all LIGO data integral to gravitational wave analysis and data for use by the GDS.
- Global Diagnostics System (GDS): Provides on-line processing and display of data from the control & monitoring and data acquisition systems for the purposes of diagnosing, characterizing and improving interferometer performance; provides various automated test routines and virtual test instruments. This system is described in the GDS Preliminary Design LIGO T970172-00-D.

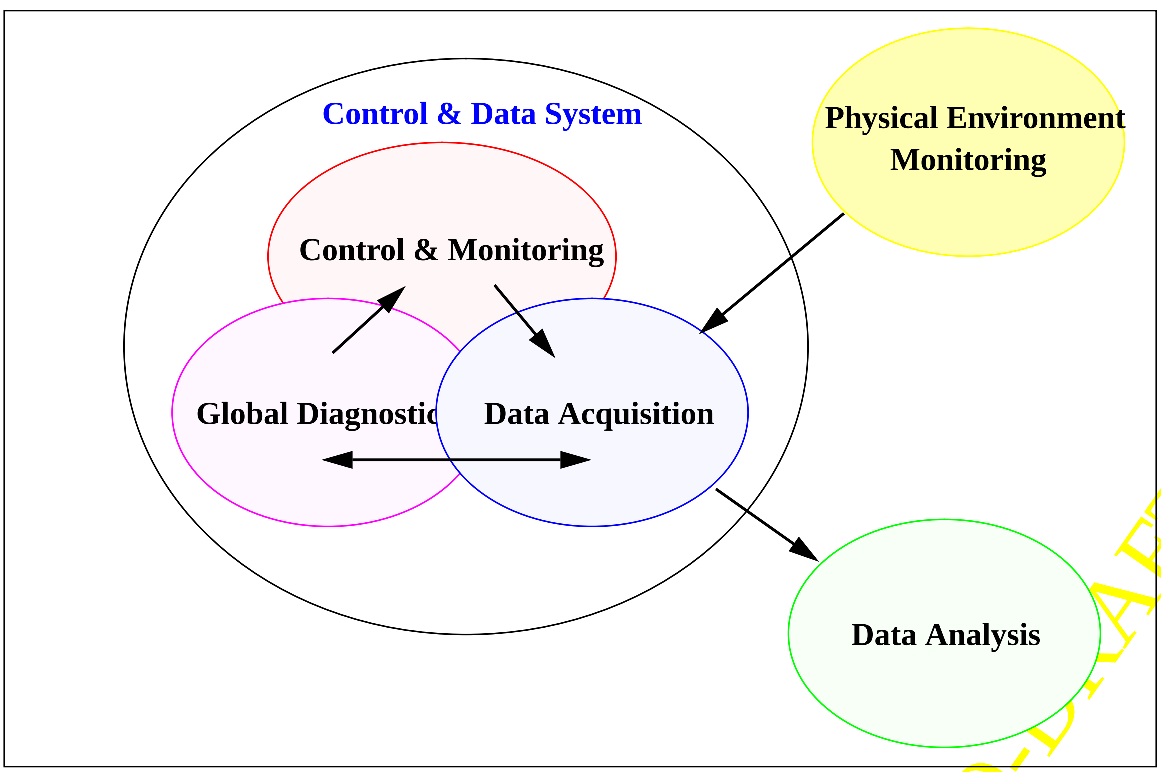

Figure 1: CDS Components

2.2. General Requirements

The specific requirments which this system must meet are given in the DRD, LIGO-T960009-C. The primary requirements on the system, which heavily drives the design which follows, is to be able to:

- Acquire analog data at high rates (up to 16K samples/sec) directly from various points throughout the LIGO facility (up to 4km from the central OSB)
- Acquire slow data (1 sample/sec/channel) from CMS via CDS networks.
- Transport all of this data to a central location, format it, and store it to long term and short term storage devices for later analysis (~6Mbytes/sec/interferometer).

Given the data channel counts and rates listed in LIGO Channel Count LIGO T980004-00-D, the DAQS must be capable of managing the data summarized in Table 1: DAQS Data Channels / Rates.

Table 1: DAQS Data Channels / Rates

System	*DAQS Network*		*Data Storage*	
	Channels	*Rate (MByte/sec)*	*Channels*	*Rate (MByte/sec)*
LHO-4K	510	4.22	300	1.88
LHO-2K	548	4.37	332	1.99
LHO-PEM	204	0.89	204	0.89
LHO-VAC	500	0.01	500	0.01
LHO-GDS	133	2.45		
LLO-4K	515	4.22	305	1.89
LLO-PEM	95	0.46	95	0.46
LLO-VAC	300	0.01	300	0.01
LLO-GDS	76	0.89		

While the current idea is to store all acquired data channels continuously, the design of the DAQS must also provide flexibility, such that if various data reduction methods are considered and approved in the future, the DAQS is capable of providing those facilities. Examples of some data reduction methods which have been discussed are:

- Storing only a limited data set unless event triggers are generated by on-line analysis, at which time all data channels are recorded for a limited time frame around the event.
- Full data sets are only recorded when not vetoed by abnormal interferometer conditions.

3 DESIGN OVERVIEW

3.1. System Architecture

The general architecture of the DAQS is shown in Figure 2: DAQS Overview. Key components of the DAQS are:

- Data Collection Units (DCU):
  - Analog Data Collection Units (ADCU) perform the digitization of analog signals from Control and Monitoring Systems (CMS) and the Physical Environment Monitoring (PEM) system. Note that the DAQS does not provide any sensors itself.
  - Collect slow data (1Hz) from CMS and PEM digitally via the CDS networks. This is done via a special DCU, named the EPICS Data Collection Unit (EDCU).
  - Performs any necessary data decimation and synchronously places this data into a reflected memory network for transport to other DAQS and GDS processors.
- DAQS Controller:
  - Configures, starts and synchonizes operation of DCU.
  - Controls the DAQS reflected memory network.
  - Performs DAQS diagnostics.
  - Signals FrameBuilders and GDS when data is available.
- Data Storage
  - Collects the data from the reflected memory and formats it into LIGO/VIRGO standard frame formats.
  - Stores the DAQS data to disk.
- Data Distribution Server (DDS):
  - Distributes data, on request, within the realm of the CDS networks (Network Data Server).
  - Places trend or other slow/decimated data back into an EPICS database for distribution to EPICS alarm manager(s).

Specific DAQS equipment rack layouts, signal lists and cost estimates are given in Hanford Site DAQS Rack Layouts and Signal Connections LIGO T980030-00-C and Livingston Site DAQS Rack Layouts and Signal Connections LIGO T980036-00-C. A summary cost estimate for the DAQS hardware is given in Appendix A.

3.2. Software Components

The primary software components of the DAQS are shown in Figure 3: DAQS Software Components. These components are discussed in further detail in following subsections on the design of each of the DAQS major subsystems.

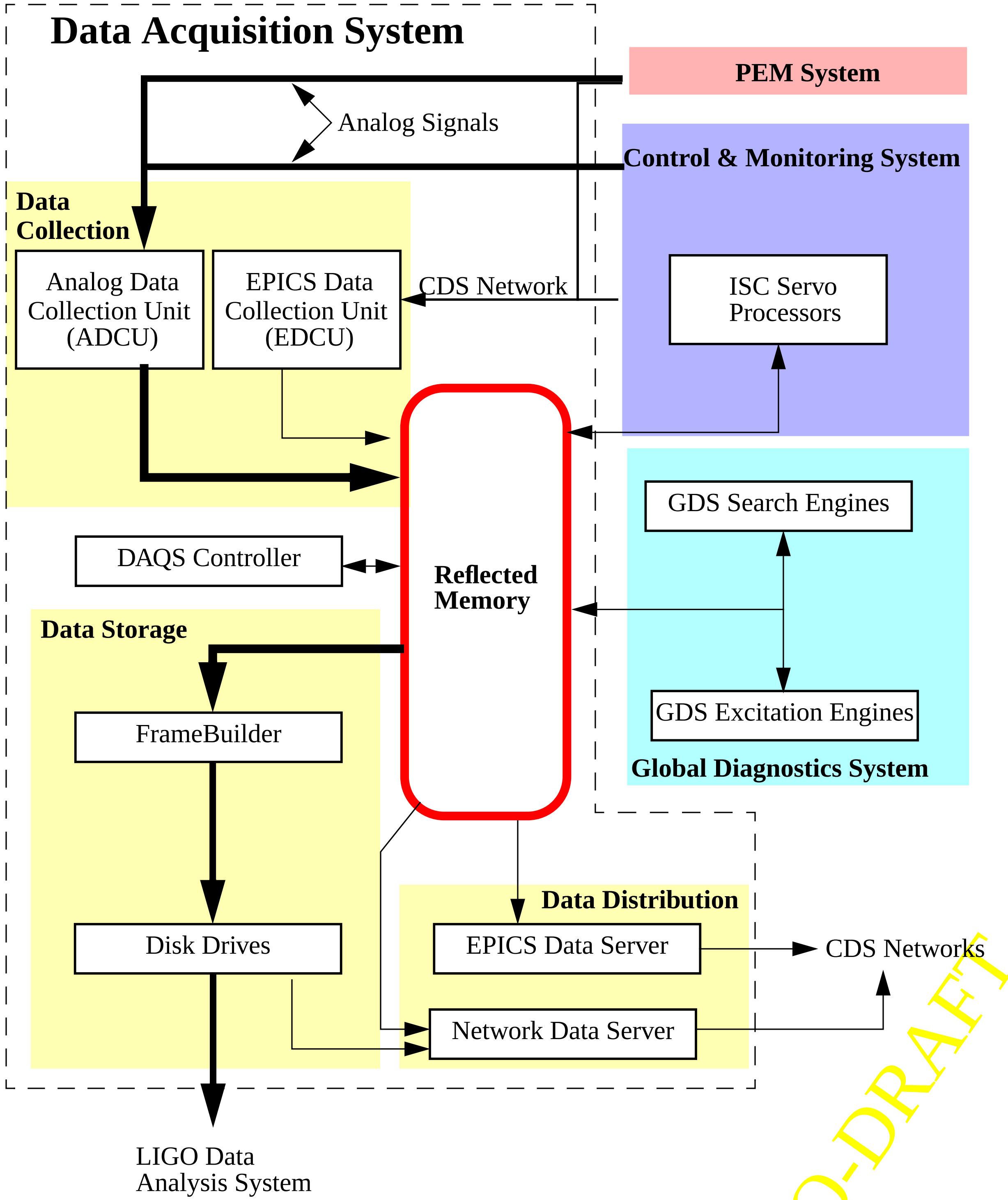

Figure 2: DAQS Overview

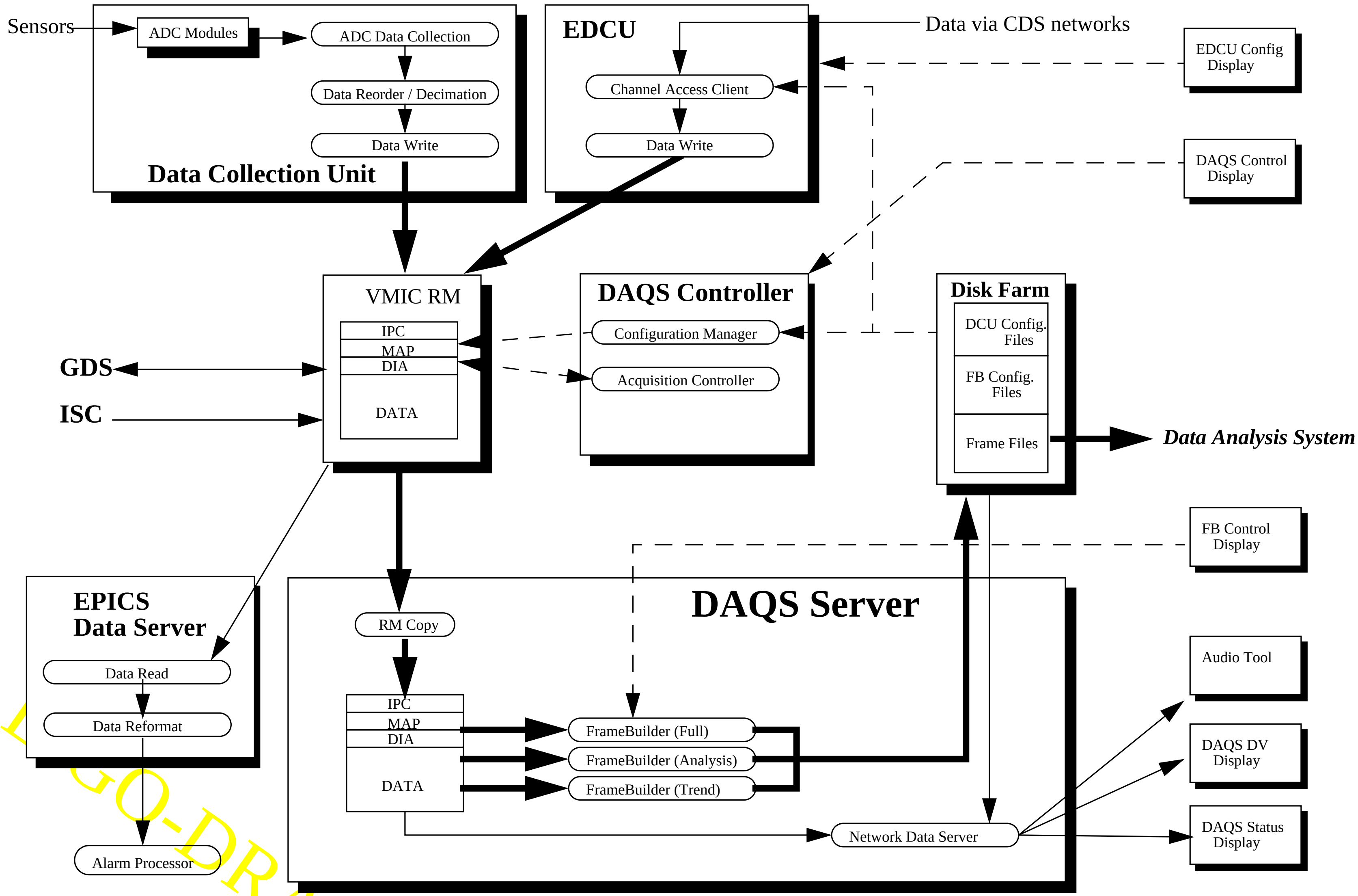

Figure 3: DAQS Software Components

3.3. Interfaces

The interfaces to the DAQS are shown in Figure 4: DAQS Interfaces.

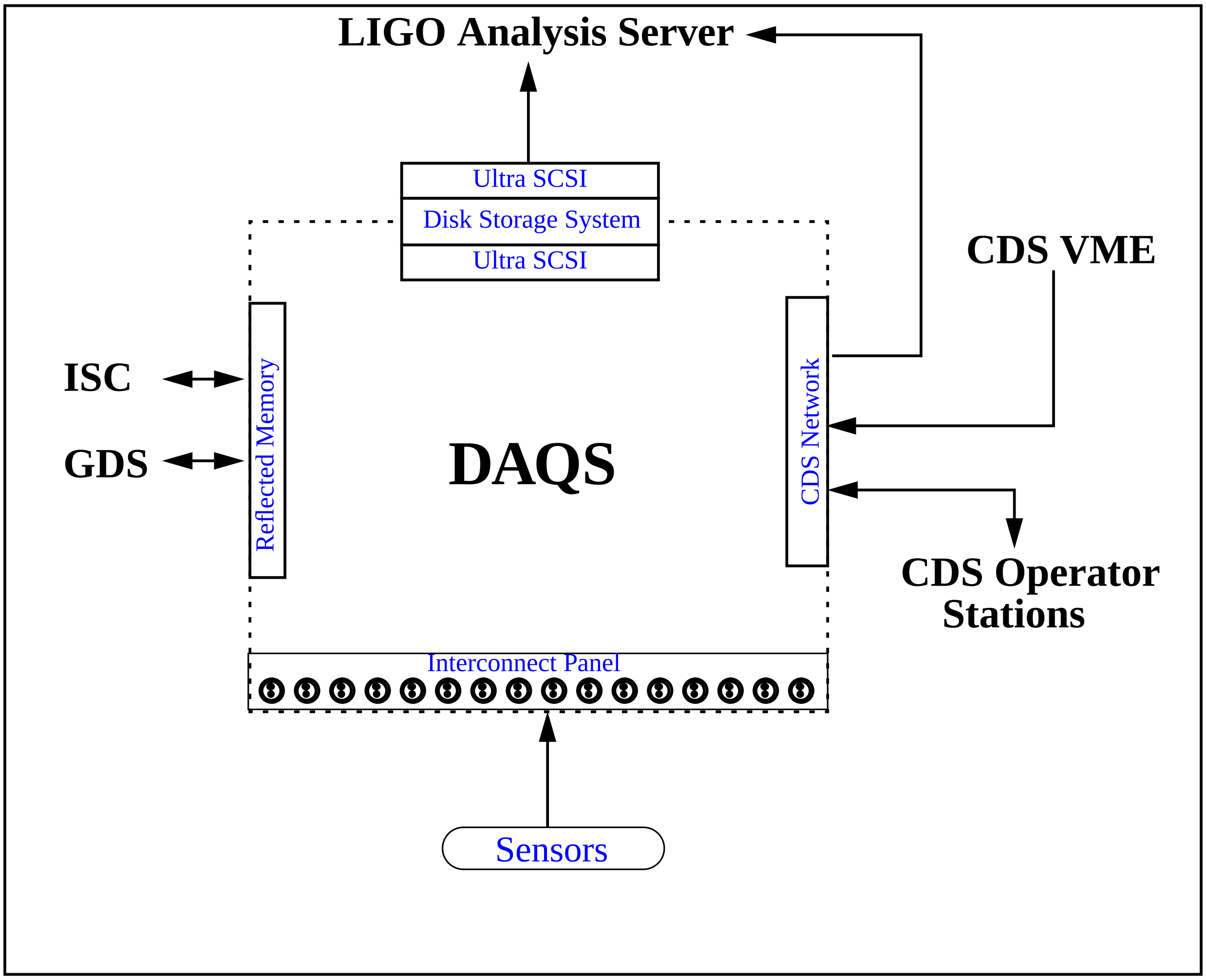

Figure 4: DAQS Interfaces

3.3.1. Sensors

The various sensors from which data is to be acquired are provided as part of other LIGO systems. The common interface is at differential LEMO (signals from control subsystems) and BNC (from PEM) connectors at the front panel of DAQS provided interconnection panels.

3.3.2. LIGO Data Analysis Systems

Computer and software systems for the analysis of LIGO data are to be provided by the LIGO data analysis group. The primary interface to these systems will be at a second Ultra SCSI disk controller in the DAQS storage system. This will allow a data analysis server to directly connect to the DAQS file system. In addition, a network connection via the CDS network infrastructure will be provided to pass data file and configuration information.

3.3.3. CDS VME

Slow data (1Hz) is to be monitored from various CDS VME crates. This interface will be the CDS network backbone, using EPICS channel access software to access the control system information.

In addition, direct links onto the DAQS reflected memory network will be provided to ISC VME processors for fast data (>1Hz, up to 16KHz).

3.3.4. CDS Operator Stations

Operator consoles and additional compute servers are to be provided as part of the control and monitoring function of CDS. Connection to these components will be via the CDS network backbone.

3.3.5. Global Diagnostic System (GDS)

The GDS is to be connected directly to the DAQS by connection onto the DAQS reflected memory networks, thereby providing high speed, independent data access for interferometer diagnostic software.

4 DATA COLLECTION

Sensor signals enter the DAQS for acquisition via a number of means:

- Directly as analog signals.
- Indirectly in digital form from control and monitoring systems which have performed the analog to digital conversion. Digital information enters the DAQS either through EPICS channel access on CDS networks (slow data) or directly on the DAQS reflected memory network (fast data).

To directly input analog signals, the DAQS provides Analog Data Collection Units (ADCU), which provide for analog to digital conversion. For the input of slow digital data, the DAQS provides an EPICS Data Collection Unit (EDCU). These are described in the following sections.

4.1. Analog Data Collections Units (ADCU)

The functions of the ADCU are to:

- Input analog signals into the DAQS, providing necessary anti-aliasing and gain.
- Synchonously digitize these input signals from various LIGO sensors.
- Read data from the ADC modules and send the data to the framebuilders over reflected memory.

The layout for a typical DCU VME crate is shown in Figure 5: ADCU Components and Connections. Full equipment rack layouts are shown in Appendix A, Figures 1 thru 4. Layouts and locations, including quantities of ADC modules, are based on the present signal list provided in LIGO T980004-00-D LIGO Channel Count.

It should be noted that primarily ancillary data channels appear as analog inputs to the DAQS ie many key signals, such as the gravity wave channel and other ISC signals, are digitized (or occur only in digital format) and are passed to the DAQS via reflected memory. How these signals are filtered, whitened and otherwise processed prior to being introduced into the DAQS is described in the design documentation for ISC subsystems. Additionally, most analog channels that do enter directly into the DAQS are outputs from control and monitoring systems (such as suspension controllers) and have passed through various analog circuitry prior to output to the DAQS. Again, the specifics of these analog data channels are described in various CDS subsystem design documentation.

4.1.1. ADCU Hardware

The following subparagraphs describe the various electronic components which comprise an ADCU.

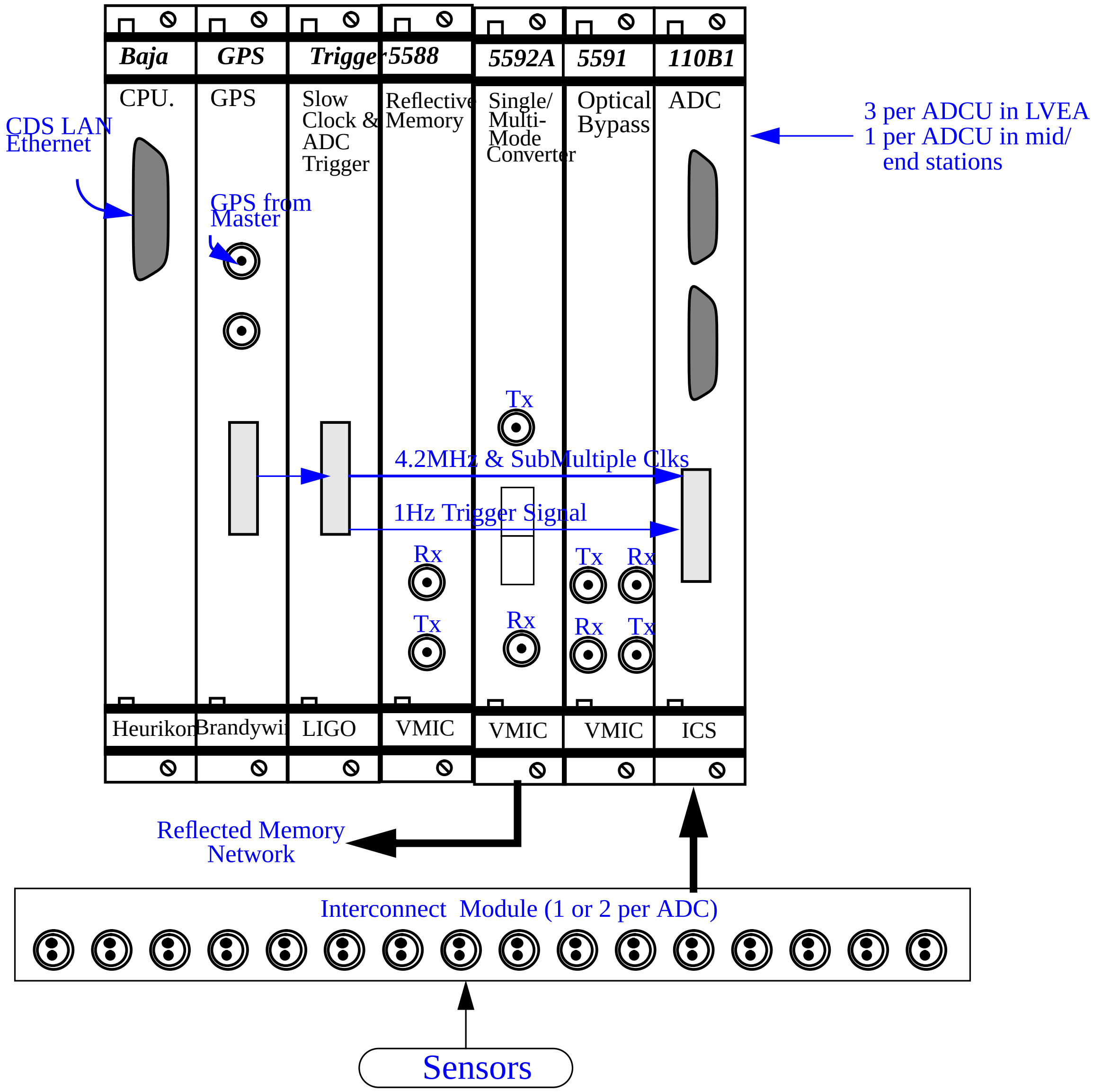

Figure 5: ADCU Components and Connections

4.1.1.1 ICS110B1 32 channel 24 bit ADC

The ICS ADC module (or similar) will be used to digitize signals acquired by the DAQS. The ICS110B1 provides both ADC and anti-aliasing / signal conditioning. Technical documentation of this unit can be found at http://www.ics-ltd.com/tech_notes.htm (Interactive Circuits and Systems (ICS) Ltd., ICS-110B 24-bit Data Acquisition Board technical white paper No. 24, Rev. A dated December, 1997). A subset of the specifications of this module are:

ADC Section:

- 32 individual sigma delta, differential input, 24-bit, no missing codes, sigma delta ADC (DAQS will run this unit in 16bit mode)
- Input range: 2Vpp differential

- 64K sample onboard FIFO.
- A32 D32 BLT Slave VME data readout (Data access @ 32 bits/210 nsec).
- VME interrupt generation when FIFO is half-full.
- Gate delay: $34/F_o$

Filter Section:

- Max input level: +/-5V differential
- Lowpass Filter: 2 pole butterworth
- Programmable Gain: -95.0db to +31.5db in 0.5db steps

These ADC units are to be clocked by the GPS to provide outputs at 16KHz. For signals to be acquired at slower rates, the ADCU CPU will decimate the readouts down using averaging prior to entering the data onto the DAQS reflected memory network.

Since these units use sigma-delta conversion, the gate delays will introduce delay of the output readings. Control servos, from which data will be received directly after digitization, will not use sigma delta convertors, as these delays can not be tolerated in the loops. Therefore, data from the ADC in the servos and the DAQS ADC will be offset in time. This offset will be taken out (data realigned) as described in section 4.1.2. Operational Overview.

4.1.1.2 Analog Signal Interface Chassis

To provide the interconnection between LEMO or BNC input cable connections and the 44 pin D connector of the ADC modules, an analog signal interface chassis will be provided. This unit consists of:

- 1U high front panel with either 32 LEMO or 16 BNC connections.
- One (for BNC) or two (for LEMO) 44 pin D printed circuit board mounted output connectors.
- A printed circuit board with traces to match the input and output connectors.

4.1.1.3 Global Positioning System (GPS) Module

Timing and synchronization for the DAQS is to be provided from the GPS, with an antenna and receiver located at each LIGO site building. The present choice of the GPS module is the model VME-Syncclock32 from Brandwine Corp. This unit is based on their standard module, but has been modified by the manufacturer to provide output clock rates of 2^n for clocking DAQS ADC modules. These units have a time accuracy of 1usec and a timing synchronization of 100nsec to the GPS 1Hz clock.

From receiver units, time information will be passed on to other slave timing modules within various VME crates over IRIG-B via a star fanout configuration. The time code carried on this link will be UTC.

Time readout over the VME backplane from the GPS receivers/slaves is also in the UTC time standard. Software is to be provided to convert this to GPS time (as part of the Frame Library), which will be used as the time standard for time stamping DAQS data. Since processors receiving time data over IRIG-B will not have year and leap second information, this will be made available by the DAQS via EPICS channels accessible over LIGO networks.

4.1.1.4 Slow Clock / Synchronization Module

The clock output of the GPS module is 4194304Hz (16384 x 256), which is the clock frequency necessary for ADC modules to provide an output of 16384 samples/sec. This module provides down counters to reduce this frequency for other CDS ADC modules which use lower rates.

In addition, this module provides the trigger for the ADC modules. A software command to start acquisition is ANDed with the GPS 1Hz trigger such that all ADC modules begin digitization on the GPS 1Hz boundary.

4.1.1.5 CPU

The present choice for the CPU is a Heurikon Baja4700. This model is also being extensively used in the CDS control and monitoring systems. It is based on a MIPS 4700 processor, running at 175MHz, with 32MBytes of Random Access Memory (RAM). This CPU has been used in various CDS systems for the past year, selected at the time for price/performance and the fact that it provides two PCI Mezannine Card (PMC) slots for direct plug in of various PMC interface modules.

4.1.1.6 Reflective Memory

The network media for the DAQS is to be reflected memory over fibre optic links. Shown in Figure 5: ADCU Components and Connections are three module types employed in implementing this system. These are:

- VMIC 5588 Reflected Memory Module, which provides the actual network interface.
- VMIC 5591 Optical Bypass Module, used in VME units to maintain link continuity if one VME crate in the network loop is powered down/fails.
- VMIC 5592, a Multimode to Single Mode fibre optic convertor, used to extend the network out to mid and end stations.

This network and its components are further described in Section 6 and LIGO T980017-00-C DAQS Reflected Memory Network Design.

4.1.2. Operational Overview

An overview of the ADCU operation, module connections and reflected memory layout is shown in Figure 6: DCU Operational Overview.

1) Sensors are connected to the ADCU via differential LEMO or BNC connectors at the interconnect module.

2) After processor boot, the ADCU CPU receives configuration information and startup commands from the DAQS controller via a designated header area of reflected memory.

3) On receipt of a start acq. command from the DAQS controller, the ADCU control software writes a start command to the Trigger/Clock VME module.

4) On the next 1Hz clock output from the GPS module, the Trigger/Clock module sends a trigger signal to the ADC modules to start acquisition.

5) The 4.2MHz clock from the GPS module is provided to the various ADC modules.

6) The ADC modules digitize the sensor signals and accumulate data in an onboard FIFO. Since the ADC modules have a gate delay of 34/Fo (i.e. signal present at ADC input at T_0 does not appear on the ADC module output until sample number 35), after ~ 3msec of acquistion, the CPU will read out 34 samples and discard them to synchronize the output data back to T_0.

7) When the FIFO is half full (1024 samples, every 1/16 sec), an interrupt is generated by the first ADC module in each ADCU and acknowledged by an Interrupt Service Routine (ISR) in the CPU.

8) The ISR signals a data transfer thread, which copies the half FIFO of data (1024 points x 32 channels) from the ADC to the defined locations in reflected memory, performing any required decimation.

9) The data transfer thread, when complete, will increment the cycle counter in the reflected memory header. This, along with the data, is automatically transferred to the reflected memory located in the remaining units of the DAQS.

4.1.3. ADCU Configuration, Control and Monitoring

Configuration of a DCU primarily pertains to the setup of what data channels to collect, how fast, and where to put the data in reflected memory. This information is made available to the DCU in the Memory Allocation Pointer (MAP) and Data Information Area (DIA) of the reflected memory network. This is described in detail in LIGO T980017-00-C DAQS Reflected Memory Network Design.

4.1.4. Prototype Performance

Testing on the DAQS prototype indicates the an ADCU can maintain the required acquisition rates with 96 channels (3 ADC modules). To read a single ADC module every 1/16 sec (62.5msec), 17msec is required to read the data, perform decimation and diagnostic checks and write the data to reflected memory, for a total of 51 msec for three ADC modules. This is the time required when the CPU moves all of the data in a serial fashion. Since the reflected memory module has master DMA capability, it should be possible to increase the performance by making the data transfers a more parallel process by having the refected memory module collect one ADC block of data from the CPU memory while the CPU is performing any decimation tasks, etc. on the next ADC block of data.

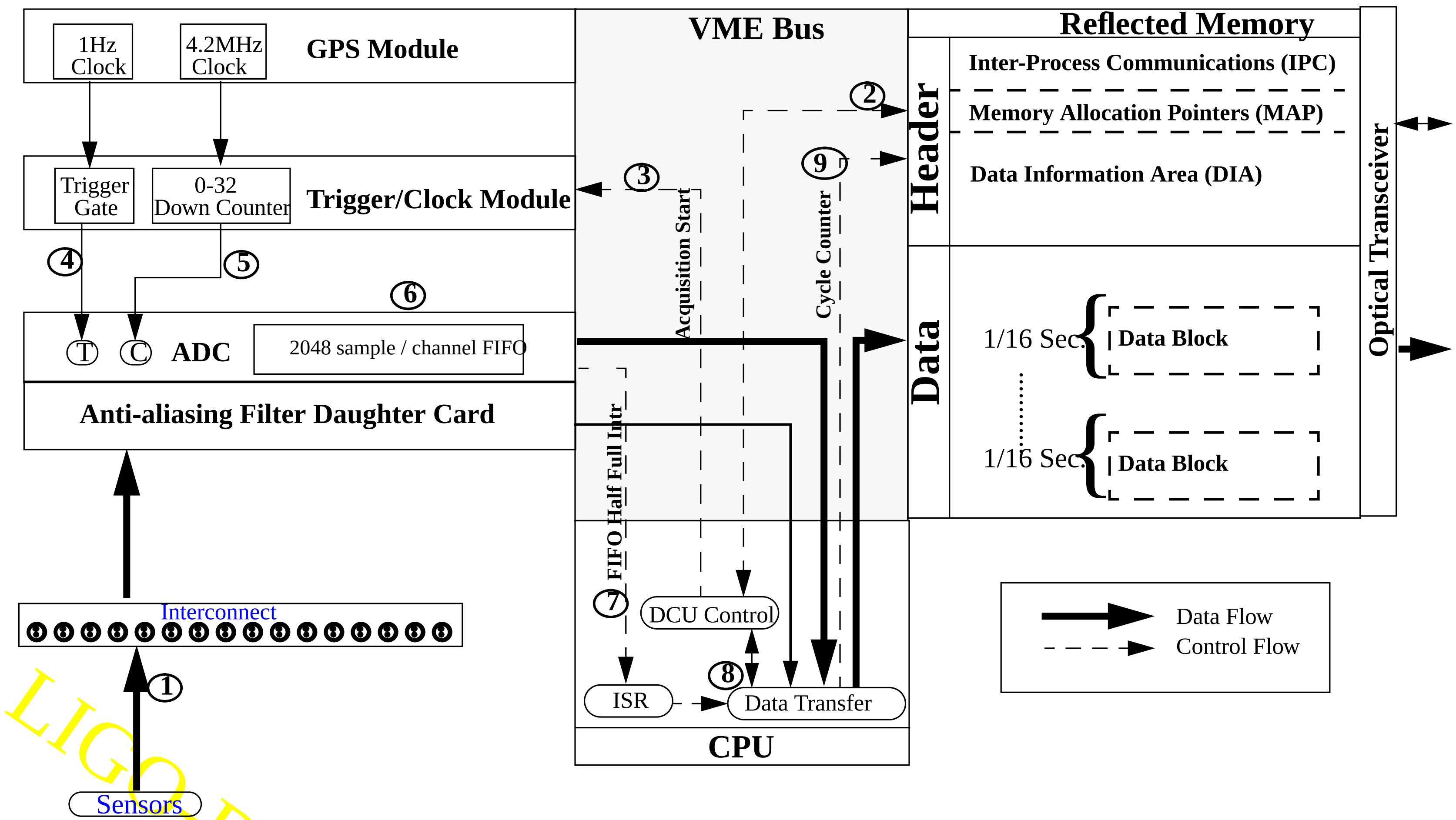

Figure 6: DCU Operational Overview

4.1.5. EPICS Data Collection Unit (EDCU)

The EDCU contains no ADC modules, but rather collects data from control and monitoring systems at low rates (1Hz) over the CDS networks. This data is primarily composed of control system settings and slow data, from such systems as vacuum controls. Since it is collecting data at lower rates than the ADCU, it will collect one second blocks of data and only place it into the reflected memory at the 1Hz time markers from the GPS. (***NOTE***: The EDCU only collects data channels at 1Hz, but the individual data channels can be data arrays ie not required to be single value signals).

Along with collecting data from the control systems directly, the secondary function of the EDCU is to accept data from operators that is not available electronically. This includes such items as switch settings on some PEM and other equipment, manual vacuum valve settings and other information that the CDS cannot directly access by electronic means. To allow these types of information to be stored by the DAQS, the EDCU will be set up with an EPICS database, accessible by operators via EPICS GUI on operator consoles.

4.1.6. Fast Digital Data Collection

4.1.6.1 ISC Processors

Processors involved with ISC will provide data to the DAQS directly as digital information on the DAQS reflected memory network. There will be three processors connected in this fashion for each LIGO interferometer. For purposes of data acquisition, these processors will be synchronized and configured through the same header area of reflected memory as the standard DCU.

4.1.6.2 GDS Processors

Primarily, GDS processors receive data from the DAQS. However, the GDS processors do provide some data back to the DAQS in the form of triggers and events. This is described in detail in LIGO T970172 GDS Preliminary Design and LIGO T980020 GDS Reflective Memory Organization.

4.2. DAQS Data Network

Once data is collected by the DCU and ISC processors, this data is moved to other backend processors via a private reflected memory network. This network is described in detail in LIGO T980017-00-C DAQS Reflected Memory Network Design. Reflected memory was chosen as the data network for the following reasons:

- High aggregate data rates (30MBytes/sec)
- High individual CPU to network data transfer rates (up to 15MBytes sec from CPU to/from reflected memory using DMA)
- Deterministic data delivery
- No CPU involvement in actual data transfer to other network nodes (on board CPU handles all data transmission)
- Ease of software development (appears as simple memory locations)
- Data is required to be delivered to multiple processors in the system and externally to GDS processors. Reflected memory automatically copies data to all nodes on the network in a

"multi-cast" fashion, thereby not requiring multiple data sends by each CPU to multiple clients on the network.
- Long distance transmission capabilities (to 10km between nodes)

4.3. DAQS Controller

4.3.1. Hardware

The DAQS controller is a VME unit, configured as shown in Figure 7: DAQS Controller VME Crate. This unit will be housed in a rack in the Mass Storage Room (MSR) of the Operational Support Building (OSB).

Components of this unit are:

- MIPS 4700 processor
- Two reflected memory modules (4MBytes each)[1]
- GPS Timing Module
- Two single mode to multi-mode fiber optic convertors (Note: latest versions of reflected memory modules appear to come with multi-mode or single mode options, thereby negating the need for additional modules to provide this transition).

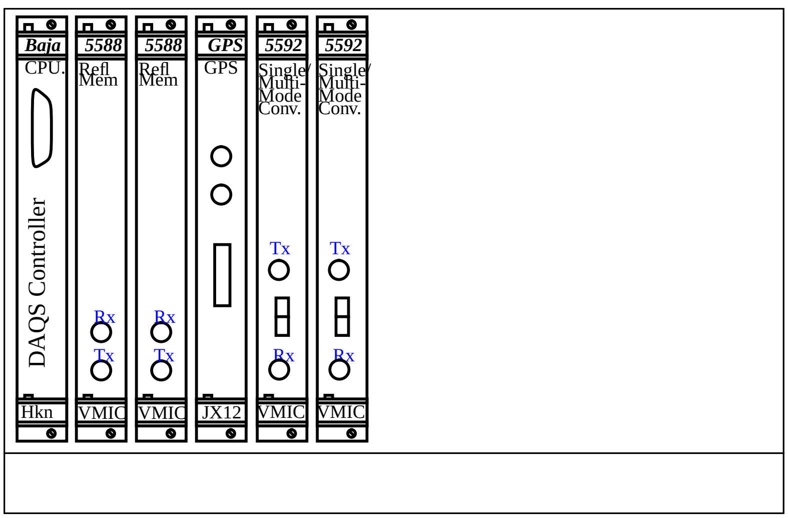

Figure 7: DAQS Controller VME Crate

4.3.2. Software

The software for the DAQS controller consists of two primary components, as shown in Figure 8: DAQS Controller Software / Interfaces:

1. Hanford site; Livingston site has only one reflected memory network

- Configuration Manager, which loads the information necessary for DCU to acquire and send data to reflected memory.
- Acquisition Controller, which initiates and monitors the data collection tasks.

4.3.2.1 Configuration Manager

The DAQS controller defines the data which is to be acquired by the system and maintained in reflected memory. It is anticipated that this data collection configuration will not change frequently. A separate configuration table is kept by the framebuilders as to what data to retrieve from the reflected memory and store to disk (discussed in a later section).

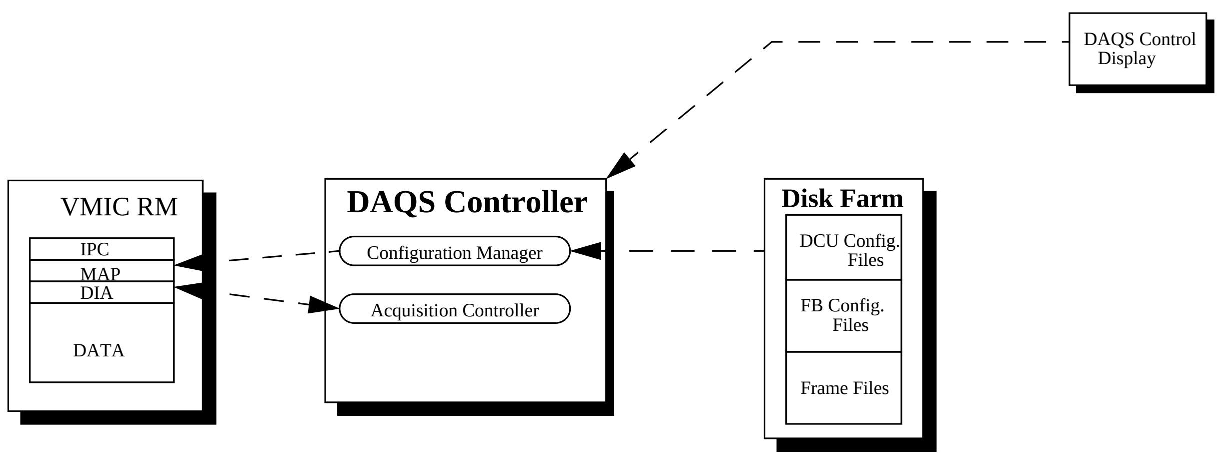

Figure 8: DAQS Controller Software / Interfaces

The DAQS controller configures the DAQS reflected memory, which in turn provides information to all DCU on which data to acquire, how fast and where to write that data. This configuration data is described in the reflected memory design document.

The DAQS configuration is kept in the form of ASCII files. A user interface is provided to select the appropriate configuration file and command the DAQS controller to load the system with parameters from this file. The basic sequence is:

- Operator selects configuration file from browser.
- Operator selects load command.
- DAQS controller changes status in reflected memory, indicating that the MAP/DIA is undergoing changes (this is to flag new processes requesting information on reflected memory pointers that the system configuration is not valid).
- The MAP/DIA are changed to reflect the new data collection configuration.
- Commands are sent to all DCU that there is a new configuration pending.
- DCU search MAP/DIA for new configuration information and perform their setup routines to accomodate the new configuration. Each then sets their status to indicate when they are ready to comply.

- Once DAQS controller receives ready indication from all DCU, it will command DCU to switch to new configuration on next 1Hz GPS pulse. It will also notify the framebuilders and other client tasks that they need to check the MAP/DIA for new data pointers.

Note that the data collection process is not suspended during a reconfiguration cycle. Each DCU still collects data in accordance with the previous configuration until such time as the controller commands them to switch to the new configuration.

4.3.2.2 Acquisition Controller

The acquisition controller task(s) performs the functions of:

- System monitoring and diagnostics
- Data validation
- Signalling data ready to client (data consumer) processes

The basic data collection sequence is shown in Figure 9: Data Collection Timing. At time zero, ADC units of a ADCU begin digitization. After 1024 points have been digitized (1/16 second), the ADC produces an interrupt, which causes the DCU processor to read in the FIFO and move the data into reflected memory. At a point prior to the next 1/16 second mark, the DAQS controller will verify that all DCU have responded by setting their data into the reflected memory. If a given ADCU has not responded, all data for that ADCU will be marked as invalid by the controller task. Once verified, the controller will then issue interrupts (via reflected memory) to all data client reflected memory modules, thereby enabling processing of framebuilders, etc. Since the ADCU are alternately writing to two 1/16 data blocks, data clients have 1/16 to collect data before it will be overwritten on the next cycle.

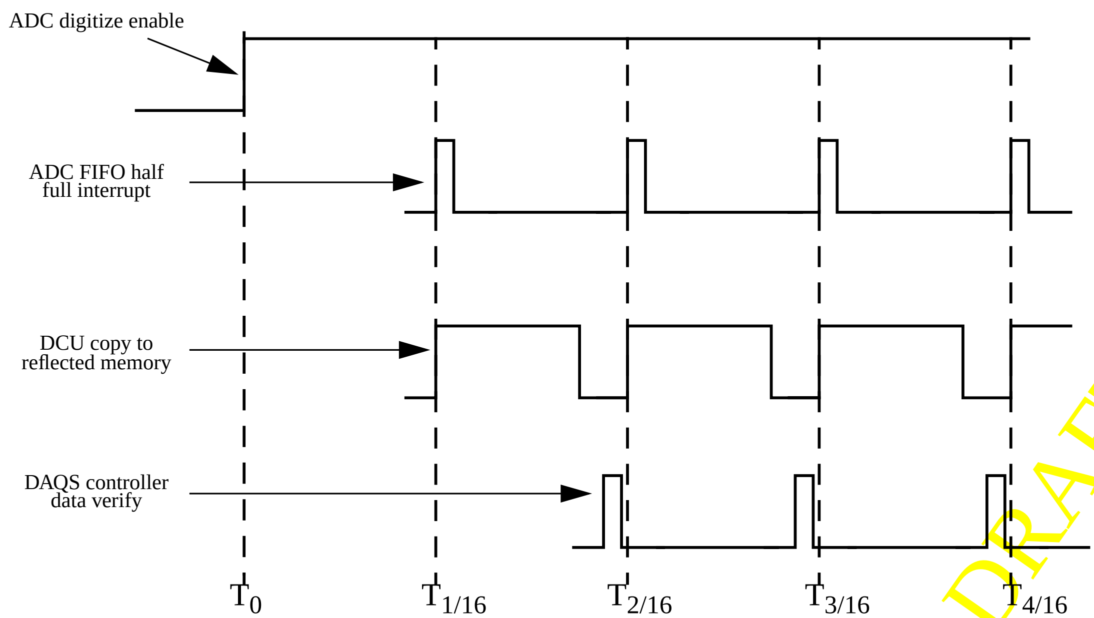

Figure 9: Data Collection Timing

5 DATA STORAGE

5.1. Hardware

The data storage subsystem hardware includes processors and disk storage systems as necessary to perform the functions of data formatting and short term storage.

5.1.1. Data Processing

These units are to be Sun UltraSparc 60 Unix workstations. Each unit consists of:

- Two UltraSparc IIi 300MHz processors
- 512 MByte RAM
- Two 4MByte PCI reflected memory modules
- PCI ATM network interface
- Ethernet interface
- Ultra SCSI interface

In normal operation, one Ultra60 is framing and storing data, while the other performs the function of the Data Distribution Server (DDS). In the event of a failure in the unit building frames, the DDS unit automatically takes over the framebuilding tasks.

5.1.2. Short Term Data Storage

The requirement for each site is that short term random access disk storage be provided which can accomodate a minimum of 16 hours of data. Given the present data estimates, this equates to ~288GByte of disk storage. Therefore, to accomodate this load and additional space for databases, etc., the DAQS will initially provide a 372GByte RAID storage system. This unit contains 42 drive slots (initially each slot with 9GByte drives, or 24GByte drives if available in time) and a single controller with 4 host Ultra SCSI ports.

Of the four SCSI ports, two will be connected to the DAQS Ultra60 units for data read/write. The other two will be connected to LDAS machines as the primary data interface to DAQS.

The DAQS disk drive system will be partitioned as follows:

- Full Frame Partition: Will contain data directories to support a circular buffer arrangement for up to 16 hours of LIGO data in full data frame formats.
- Analysis Frame Partition: Identical to above, but set up for analysis frames.
- Trend Frame Partition: Again, setup as above, but will contain a minimum of 1 month of trend information.
- Database Partition: Supports the database server.

DAQS operational software will be maintained on the CDS server system and not reside on this disk system.

5.1.3. Long Term Storage

The LIGO LDAS will provide tape or other media for long term storage.

5.2. Software

The primary software components associated with data storage/distribution subsystem is shown in Figure 10: Data Storage/Distribution Software.

- FrameBuilder Controller: Controls operation of the unit, including configuration information for the data to be stored.
- Mem Copy: This process, on interrupt from the DAQS controller each 1/16 second, copies data from the reflected memory into a larger (4 second) internal memory block. This process also signals the other framebuilder tasks when a new one second of data is available in the internal memory.
- FrameBuilder (3): Performs the function of formatting the data into frames and storing that data to disk.
- Network Data Server: Distributes data to on request to the CDS network.

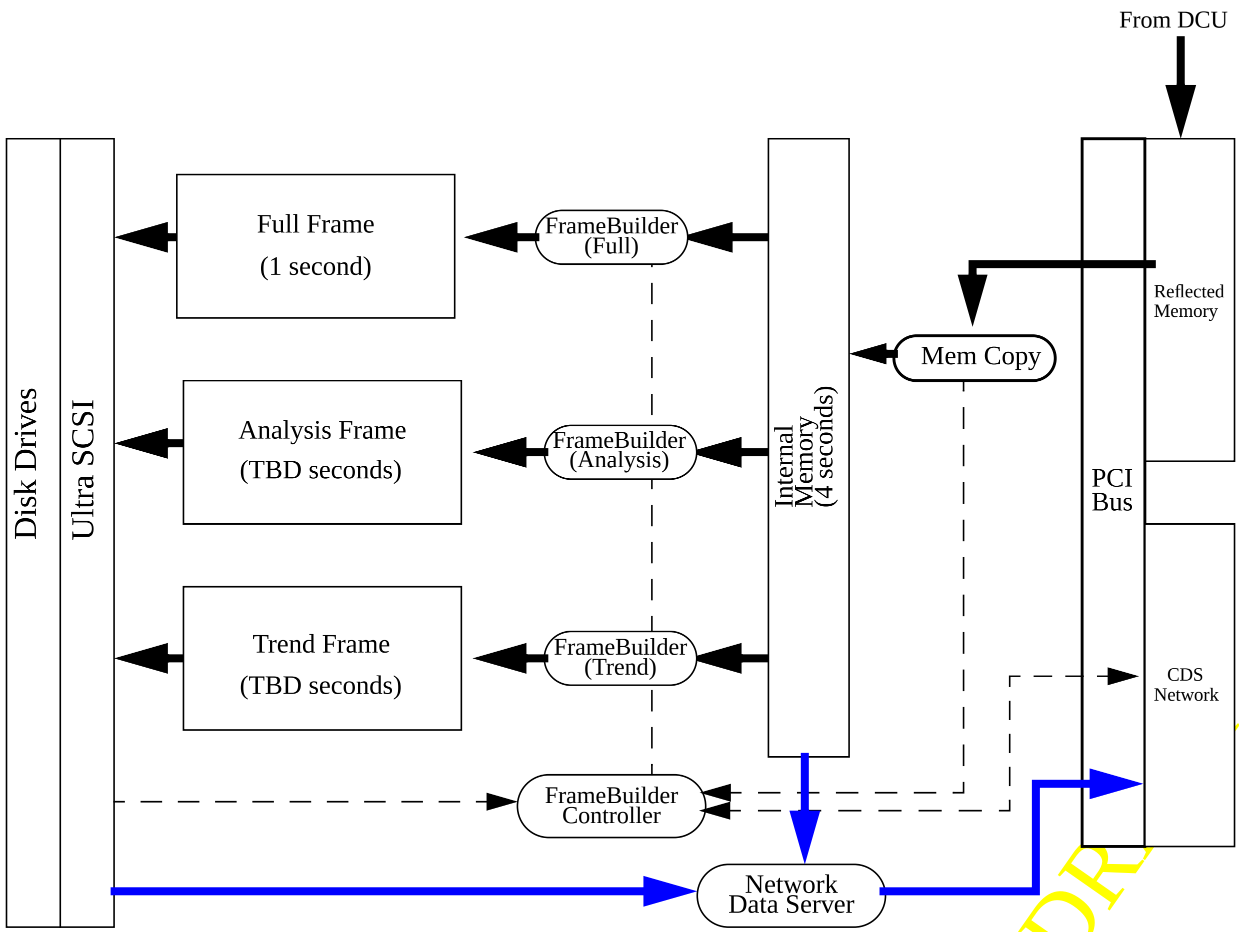

Figure 10: Data Storage/Distribution Software

5.2.1. Framebuilder

5.2.1.1 Processes

The DAQS framebuilders format the data received from the ADCUs into a standard frame format, as described in *LIGO-T971030-00-E Specification of a Common Data Frame Format for Interferometric Gravitational Wave Detectors (IGWD)*.

Three types of frames are produced by the framebuilders:

- Full Frame: Contains a full set of data channels being acquired by the DAQS.
- Analysis Frame: Contains a selected subset of data channels, typically those of primary interest in first glance gravity wave analysis.
- Trend Frame: Contains all slow data channels (1Hz) and summary information (max, min, average, ...) of all other data channels for a 1 second period. This allows for many hours of trend information to be quickly retrieved and displayed without the need to sift through all of the larger full and analysis data frames.

All full frames produced by the framebuilders are one second in duration. The analysis and trend frame durations are TBD pending final testing.

One process is tasked with building each type of frame. A set of these tasks then frames data for each interferometer and for site data. 'Site' data is data which is independent of an interferometer, such as PEM, Vacuum Equipment (VE) and Facility Monitoring and Control System (FMCS) data[1]. For the Hanford site, these tasks are shown in Figure 11: Hanford Data Framing Tasks. Note that there are no 'Analysis' frames written for 'site' information.

1. Connection to the FMCS is to be made at a later date.

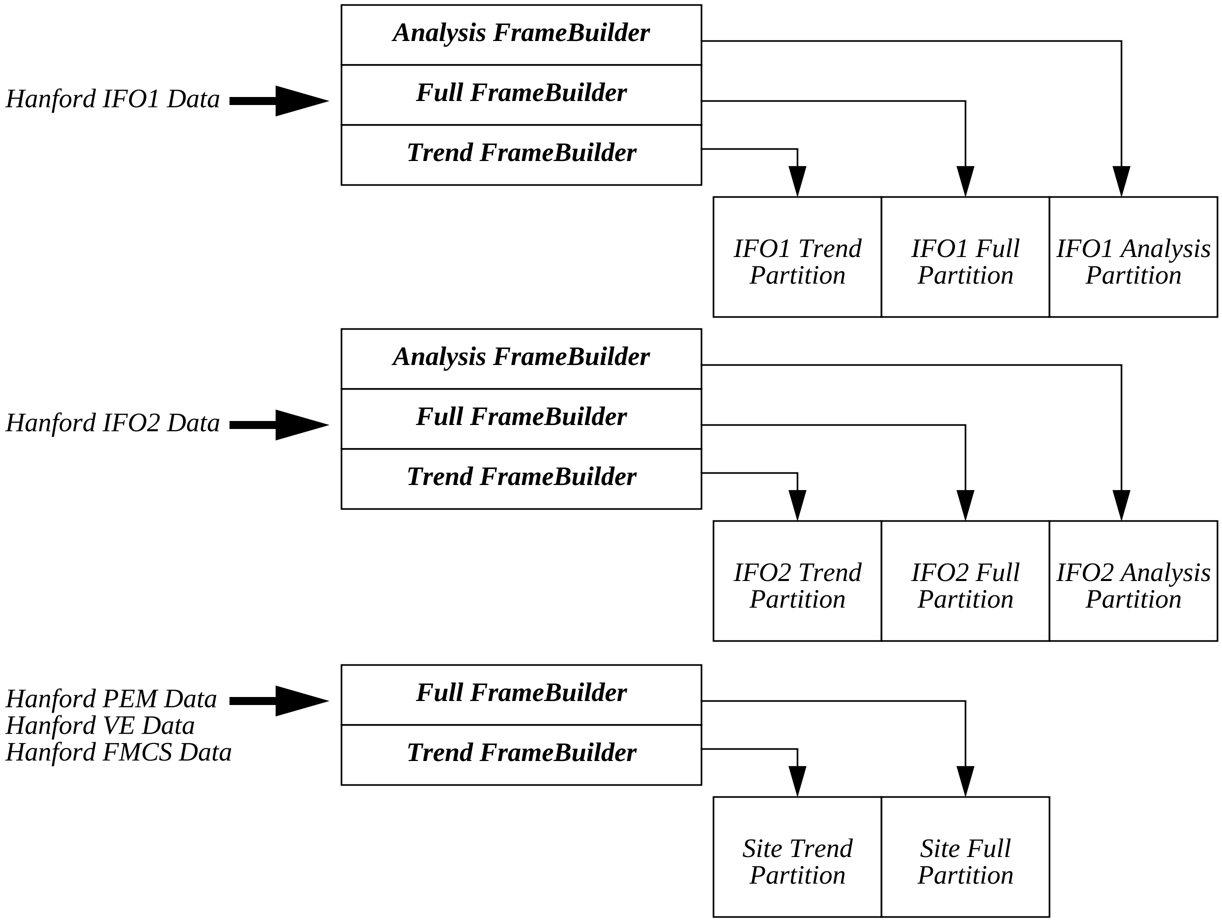

Figure 11: Hanford Data Framing Tasks

5.2.1.2 Frame Structure

The structure of a typical data frame is shown in Figure 12: Standard Frame Structure. The overall frame layout uses LIGO/VIRGO standard frame components. The timestamp in the frame will be in GPS time (seconds).

Since there is no standard ‘Slow Data’ type, this will be setup as follows:

- Static data structures, with pointers to VectData will be used to store the slow data channel names and engineering units (most of this data has been preprocessed).
- A single ADC structure will be used to hold all of the slow channel data.

Therefore, the lookup of a data value for a slow channel will require searching for the name in the static data structure, then use the index of the name as the pointer to the data in the slow ADC structure e.g. if the name of channel x is the fifth element of the static data structure, its value will appear as the fifth element in the ADC structure.

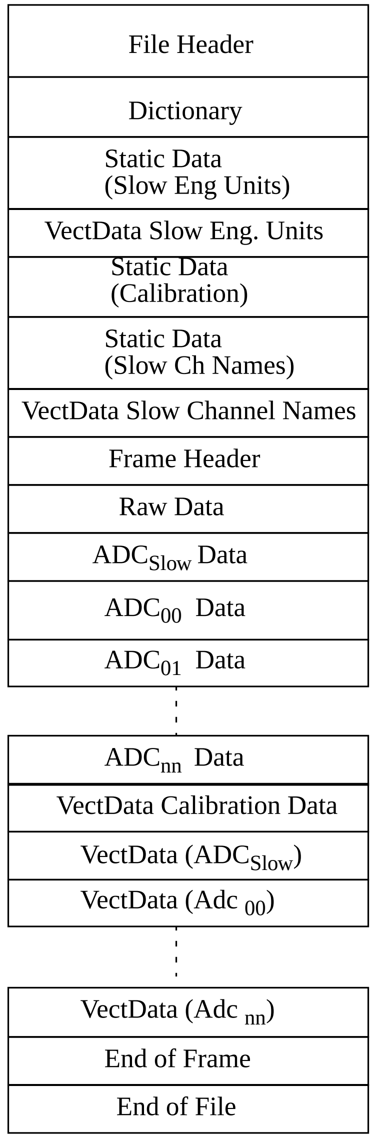

Figure 12: Standard Frame Structure

5.2.1.3 File Structure

These data frames are then written into frame files in directory partitions. A possible layout is shown in Figure 13: Data Storage File Structure. This is a concept which would be dependent on the actual disk drive system which is finally procured for this system, as to how it can be partitioned, etc. However, this figure indicates the basic concept for the Hanford site.

At the top of the directory structure is a directory for each interferometer (H1, H2) and one for site wide information (HS), which contains PEM, vacuum and similar data. Below this level are directories for the three frame types. Within the Full and Analysis sections, there are 16 one hour directories with one hour of data frame files within each. Since trend frames are smaller and kept for longer durations, the sub-directories within the Trend area are by day.

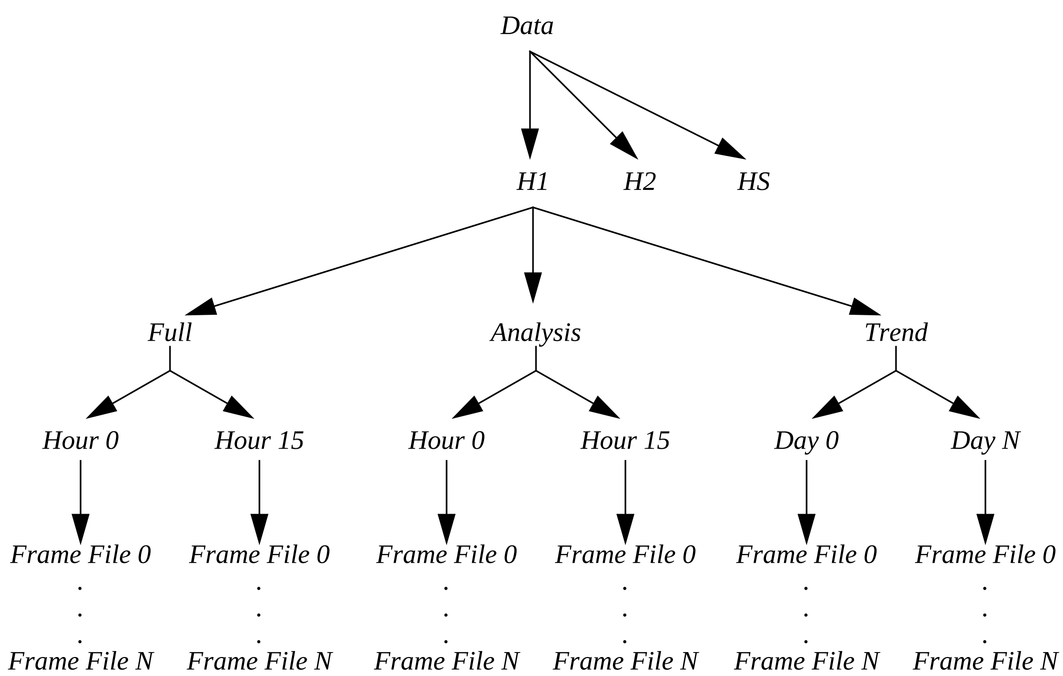

Figure 13: Data Storage File Structure

Frame files will be written with a standard naming convention, such as H1-97378923.F, with the following fields:

- First character denotes the site, with:
  - • C = Caltech
  - • M = MIT
  - • H = Hanford
  - • L = Livingston
- Second character denotes the interferometer (1,2,3, etc.) or 'S', for site wide data.
- Third character is a '-'.
- Characters between '-' and '.' denote start time (in GPS seconds) of the data within the frame file.
- Character after '.' denotes frame type:
  - •.F indicates a full data frame file
  - •.A denotes an analysis frame file
  - •.T denotes a trend frame file

5.2.2. FB Controller

The FB Controller software provides communication, configuration and coordination functions for the framebuilders. This module provides a Java interface, as shown in Figure 14: Framebuilder Operator Interface, for operator control.

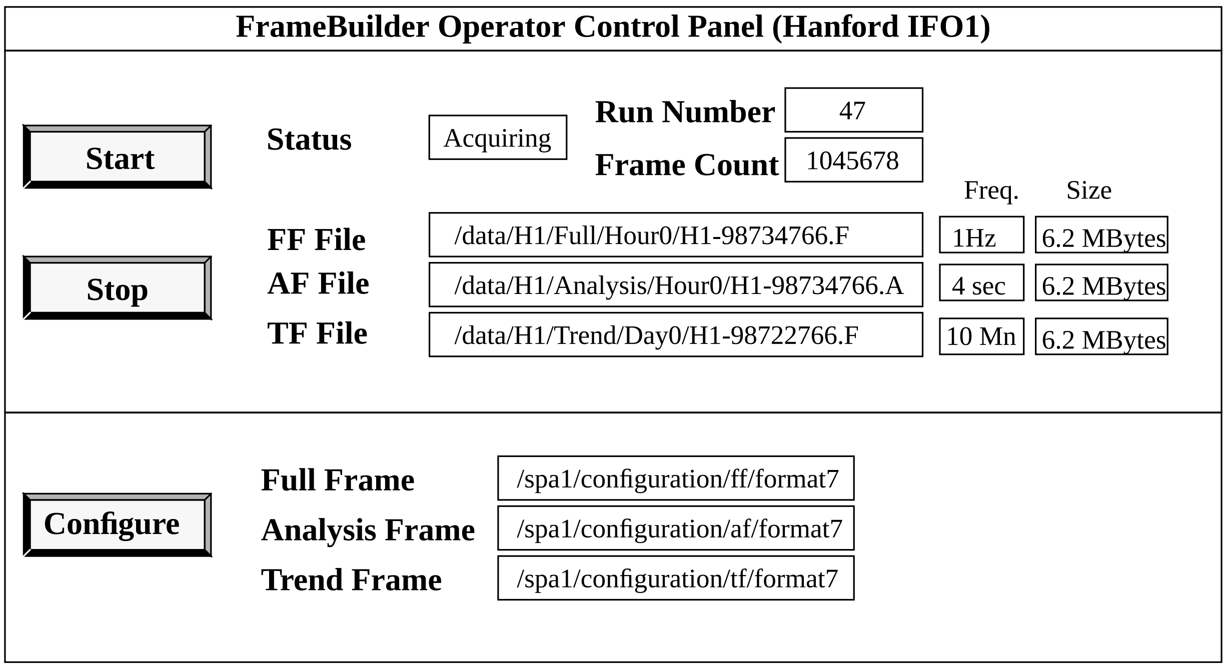

Figure 14: Framebuilder Operator Interface

5.3. Database Server

While the bulk of information necessary to perform gravitational wave analysis will be contained within each standard data frame, there is anticipated to be a not insignificant amount of information about the configuration of LIGO interferometers and its data channels which may be impractical to store in every data frame. This is data which does not change very often (days, months), but is necessary to note for later analysis. Some examples of this type of information are:

- Additional information describing the data channels, such as normal ranges, calibrations, conversions, etc.
- Electronic module serial numbers and calibrations and related component maintenance/ replacement at the time of data taking.
- Electronic module or other interferometer settings/parameters which are unavailable to the DAQS, either directly or through the CDS, and must be noted by operators into an electronic log.
- Operator logs and observations.

Further defining this information set and where/how to store it will be coordinated with the LDAS and presented in the LDAS design documents.

6 DATA DISTRIBUTION AND VISUALIZATION

6.1. Network Data Server (NDS)

Data is distributed within the LIGO CDS system by a Network Data Server (NDS) process. Distribution is to be over the CDS networks using TCP/IP sockets. This server provides data in both the form of arrays and as frames. Further descriptions of the NDS and user API are provided in the following documents:

- LIGO T980024-00-C Data Acquisition Daemon Client-Server Communication Protocol
- LIGO T980025-00-C Data Acquisition Daemon Program Design
- LIGO T980023-00-C Network Data Server Reference Library

6.2. EPICS Data Server Unit (EDSU)

The Global Diagnostic System will provide certain event flags and other information that is to be used to alert operators as to abnormal operating conditions. Since the EPICS software package already provides alarm monitoring and presentation capabilities, the DAQS will make use of this rather than developing a new system for this purpose. This then requires that certain data from the DAQS be exported to EPICS records in order to connect with the EPICS alarm and presentation tools. For this purpose, the DAQS will provide a processor and software in a shared VME crate with the EDCU. This processor will have direct access to all data on the DAQS reflected memory network.

6.3. Visualization Tools

Presently, data visualization tools are being developed around two primary software packages:

- xmgr for real-time operator display
- Java, for DAQS control panels and slow data presentation, such as in the netscape web browser.

The work done to date with xmgr is described in the 40m Data Acquisition System Quick Reference document (LIGO T-970126-02-C). The software developed around the xmgr package provides the capability to display up to 16 channels in real-time (16Hz refresh) as both time series and FFT in separate subwindows or overlayed in a single window. This software will continue to be extended to meet the requirements as set forth in the Global Diagnostics Preliminary Design document (LIGO T970172) for data visualization.

Java will be used as the primary interface into DAQS software running on UNIX stations, such as control and monitoring of the framebuilder software. Additionally, Java has been used to provide live data displays on the internet in netscape browers. The GEO project is also developing a visualization tool based on Java which will be evaluated for use in LIGO.

APPENDIX 1 DAQS COST ESTIMATE

Table 1: Summary Cost Estimate / Baseline Comparison

DAQS Subsystem	*Location*	*Cost*
Hanford DAQS / PEM		
H4KDAQS1 & H4KDAQS2	LVEA	$137,950
H4KDAQS3	Right End	$50,850
H4KDAQS4	Left End	$50,850
H2KDAQS1	LVEA	$55,350
H2KDAQS2 & 3	LVEA	$121,950
H2KDAQS4	Right Mid	$50,850
H2KDAQS5	Left Mid	$50,850
DAQS Cntrl / EDCU / EDSU	OSB MSR	$74,250
Server System	OSB MSR	$157,770
LSC/ASC support	LVEA	$57,600
HPEM1 & HPEM-2	LVEA	$140,850
Hanford DAQS/PEM EAC		**$949,120**
Hanford DAQS/PEM Baseline		$1,125,000
Hanford Baseline - EAC		$175,880
Livingston DAQS / PEM		
L4KDAQS1 & 2	LVEA	$137,950
L4KDAQS3	Right End	$50,850
L4KDAQS4	Left End	$50,850
DAQS Cntrl / EDCU /EDSU	OSB MSR	$57,450
Server System	OSB MSR	$157,770
LSC/ASC Support	LVEA	$28,800
LPEM-1	LVEA	$76,850
Livingston DAQS/PEM EAC		**$560,520**
Livingston DAQS/PEM Baseline		$723,700
Livingston Baseline - EAC		$163,180