# LIGO Data Analysis System (LDAS)

## Status

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PAC Meeting
LIGO Livingston Observatory (LLO)
23 - 24 April 1998

LIGO-G980062-00-E

LIGO
CALIFORNIA INSTITUTE OF TECHNOLOGY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

# Data Analysis System for LIGO I
## Status

- Design Requirements Review completed 12/97
  - Provide on-line analysis at the observatories; data distribution from on-line cache -- diagnostics.
  - Process and reduce the raw LIGO datasets at the off-line center to prepare the data for archival storage and retrieval.
  - Provide computational and storage resources for off-line analysis using the archived data
  - Provide a flexible design which can be reconfigured to reflect new analysis or computational requirements as they evolve.
  - Provide access to LIGO data from all LIGO Laboratory sites and also from member institutions of the LIGO Scientific Collaboration for the LIGO I search.

# Data Analysis System for LIGO I
## Status

- MOU drafted [LIGO-M980029]
  - Under review by LIGO (Barish) and CACR (Messina)
  - CACR would be an institutional member of the LSC
  - Identifies specific areas of mutually beneficial collaborative research:
    - Data archival and retrieval
      - > 20TB systems
      - > 20MB/s throughput
    - Linux/PC (Dec Alpha?) based compute cluster development
      - Low cost supercomputers
      - ~ 20 GFLOPS
      - ~ 32 - 64 nodes
      - Fast ethernet dedicated interconnection
      - MPI-based parallel computation
    - Data server/data distribution over the net
    - Use of CACR supercomputer resources for advanced LIGO data analysis going beyond LIGO computing resources
      - Resources will be made available to LIGO Laboratory (all sites) and members of LSC involved in LIGO I search
    - Mutual commitment to developing future research programs/ proposals to expand resource base as data analysis needs grow

# Data Analysis System for LIGO I
## Status: Testing & Prototyping

## 1. Networking & Storage Systems

- A list of networks and storage facilities being investigated for use by LIGO:
  - **HIPPI**: High Performance Parallel Interface.
    - 800Mb/s "super computer" network at Caltech (CACR).
    - HIPPI-FP Framing Protocol: Low level HIPPI protocol used when superior performance to vendor supplied TCP/IP is required (often an order of magnitude).
  - **ATM**: Asynchronous Transfer Mode.
    - 155Mb/s fibre based network being adopted by LIGO.
  - **100BaseT**: Twisted pair Ethernet.
    - 100Mb/s Ethernet wire used to network "pile-of-PCs".
  - **HPSS**: High Performance Storage Solution.
    - Hierarchical Storage Management (HSM) system being investigated as the primary archive for LIGO data.

# Data Analysis System for LIGO I
## Status: Testing & Prototyping

## 2. Point-to-Point Bandwidth Tests

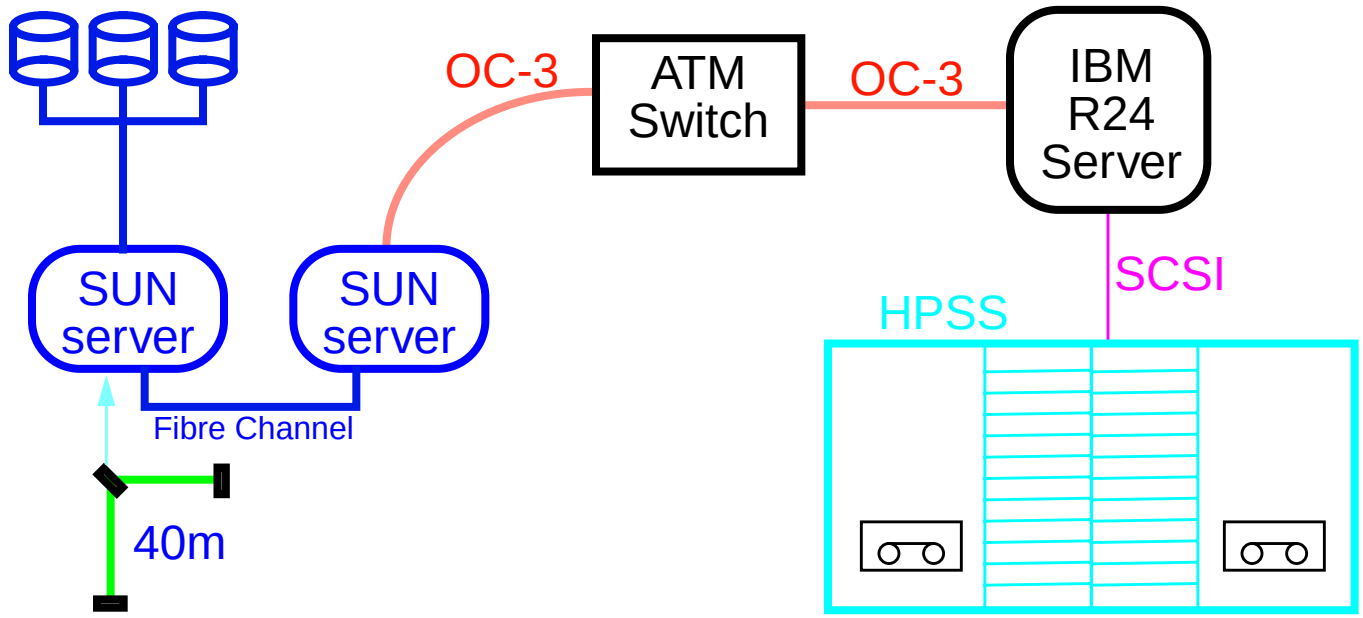
- **ATM ⇔ ATM**
  - **Sun ⇔ Sun**: 12MB/s
  - **Sun ⇔ IBM**: 6-14MB/s (TCP vs UDP)
  - **IBM ⇔ IBM**: 10-15MB/s (TCP vs UDP)
  -
- 100BaseT ⇔ 100BaseT
  - **Pile-of-PCs ⇔ IBM**: 4.5-6MB/s
- HIPPI ⇔ HIPPI
  - **IBM ⇔ IBM**: 8.5MB/s (TCP)
  - **Paragon ⇔ Paragon**: 0.6-2MB/s (TCP)
  - **Paragon ⇔ Paragon**: 65MB/s (interface nodes HIPP-FP)
  - **Paragon ⇔ Paragon**: 30MB/s (generic nodes HIPP-FP)
  - **Paragon parallel filesystem ⇔ IBM**: 30MB/s
- ATM ⇔ HIPPI (using Gigarouter)
  - **Sun ⇔ IBM**: 1MB/s
  -

- Note: single connection bandwidths.
  - Some rates suffer from relatively high software latencies and may be significantly improved by running multiple parallel connections.

# Data Analysis System for LIGO I
## Status: Testing & Prototyping

## 3. 40m Data Transmission Tests

- Data rate of 2.4MB/s has been obtained in archiving 40m frames into HPSS.
  - 600kB/s for sequential transfer (presently relatively small) 705 kB frame files
  - Data transfer occurs in bursts of 2.4MB/s as verified with larger files
  - Could (presumably) be obtained for small files with multiple concurrent ftp sessions
  - Current performance is limited by the sequential aspect of the HPSS ftpd.
    - Will be overcome by changing from ftp to fptp once additional ATM switching hardware is installed at CACR.



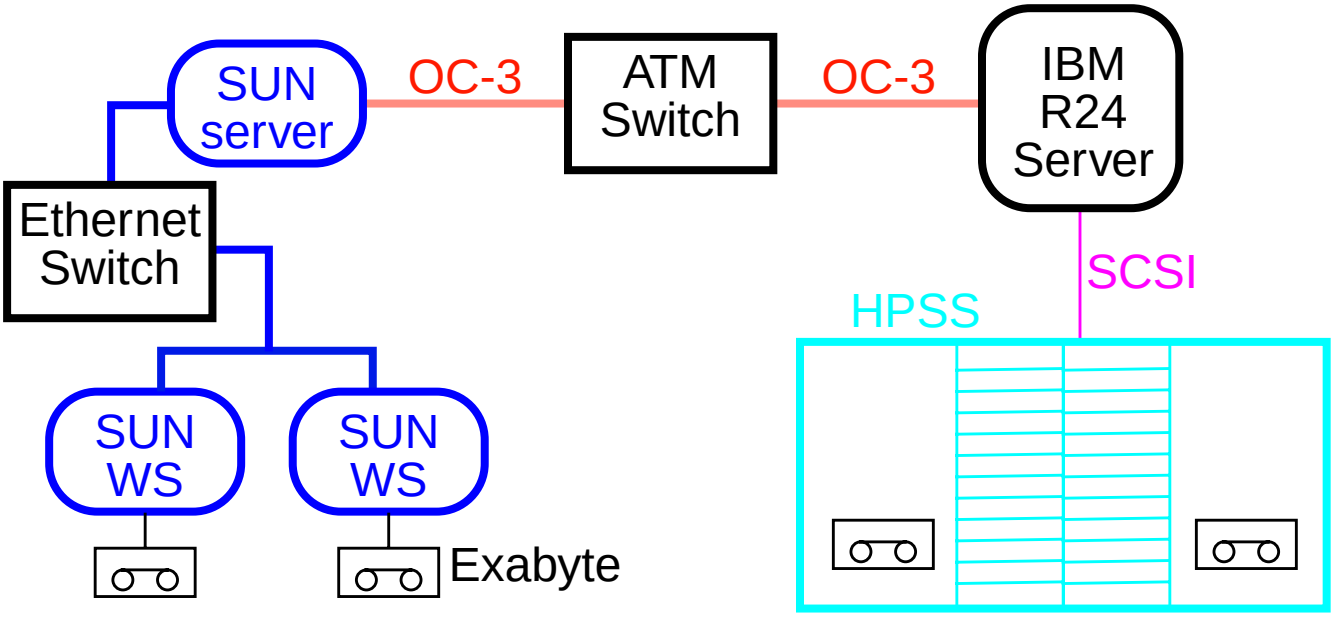



LIGO-G980062-00-E

# Data Analysis System for LIGO I
## Status: Testing & Prototyping

## 4. Radio Pulsar Tests

- As a test in robustness and as an interim data set until the 40m network connectivity was finalized in April 1998, 1 TB of radio pulsar data has been archived into HPSS.
  - During the transfer of 1,016,304,861,184 Bytes as 3041 separate files several bugs in HPSS, ftp, and the HIPPI driver have been isolated and have been or are planned to be fixed by IBM.



# Data Analysis System for LIGO I
## Status: Testing & Prototyping

## 5. Fourier Transform Tests

- Small (1K complex): single node
  - PentiumPro 200MHz (FFTW): 105MFLOP/s
  - Ultra II 300MHz (FFTW): 275MFLOP/s
  - PA8000 180MHz (VECLIB): 255MFLOP/s
  - RS6000 132 (ESSL): 344MFLOP/s
- **Medium (1M complex):** single node
  - PentiumPro 200MHz (FFTW): 40MFLOP/s
  - Ultra II 300MHz (FFTW): 87MFLOP/s
  - PA8000 180MHz (VECLIB): 193MFLOP/s
  - RS6000 132MHz (ESSL): 196MFLOP/s
- Large (1G complex): multiple node
- 512 node Delta: 1GFLOP/s (hypercube code)
- 16 node Exemplar: 620MFLOP/s (1 hypercube)
  - HP's parallel FFT library does not work well on multiple hypernodes (16 processors each) by design.
  - Note, the MPI version of FFTW is under testing as a possibility for a portable large in-core FFT library. However, the current version has uncovered a bug in the Intel implementation of MPI.
- Extra Large (1TB): multiple node + disk
  - Work in progress on porting existing code to CACR Beowulf (rewrite as a portable MPI library?)

# Data Analysis System for LIGO I
## Status: Testing & Prototyping

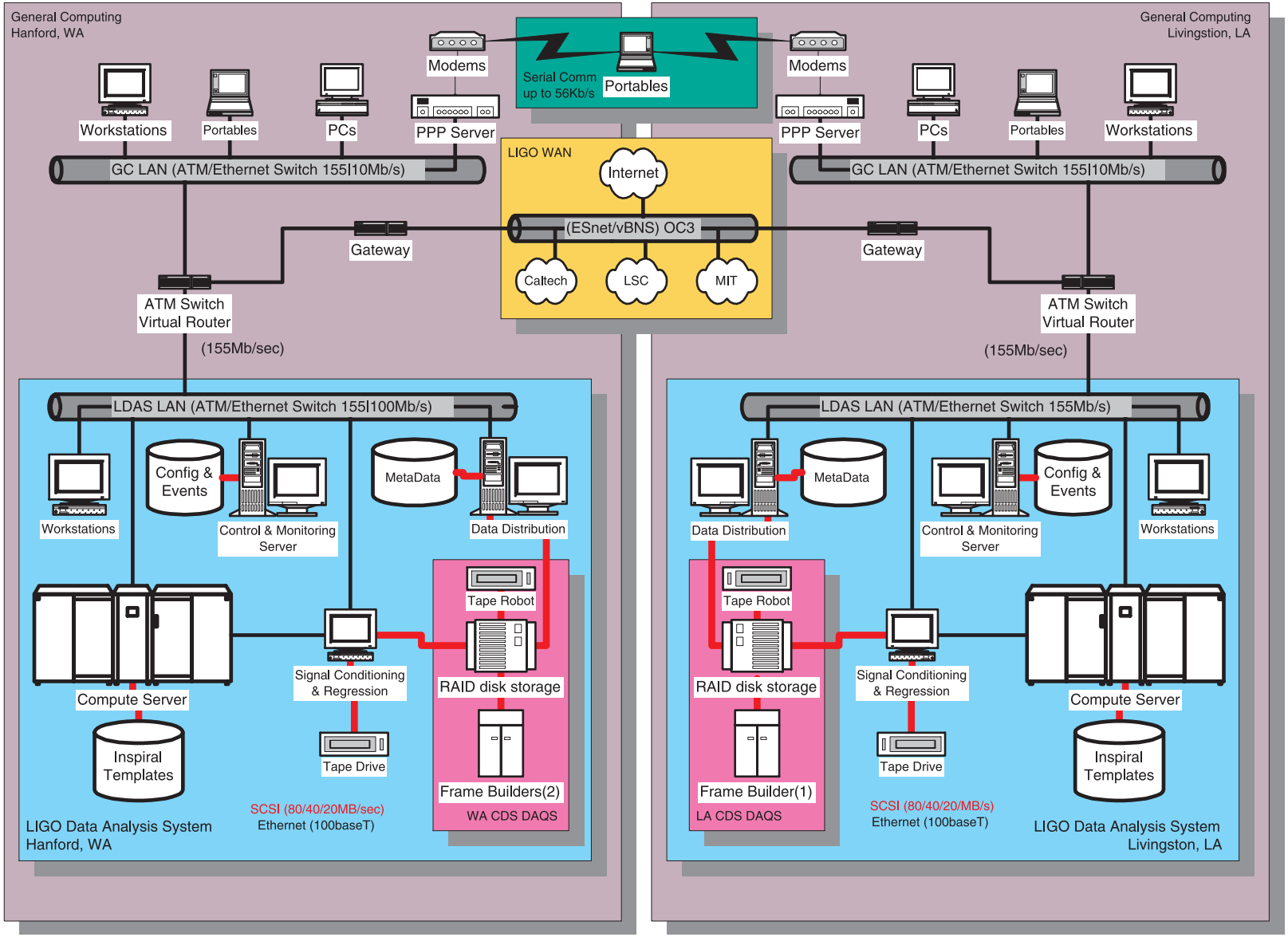
## 6. Data distribution server

- 50GB RAID system (seamlessly extensible to 250 GB)
  - Will be back end of 40m DAQS prototype
  - Serves as interface to LDAS - per architecture plan
  - Hardware at 40m lab; awaiting availability of servers & personnel to implement
  - Two 300 MHz UNIX servers ordered to stage data of RAID system via SCSI interfaces
    - Replaces present pathway from 40m DAQS to CACR/HPSS
- Example web client interface built by CACR staff
  - Limited distribution of data at present
  - Available for downloading/viewing/listening to 40m data
  - Starting to develop a metadata catalog model for summary descriptors which will be used for LIGO frame data

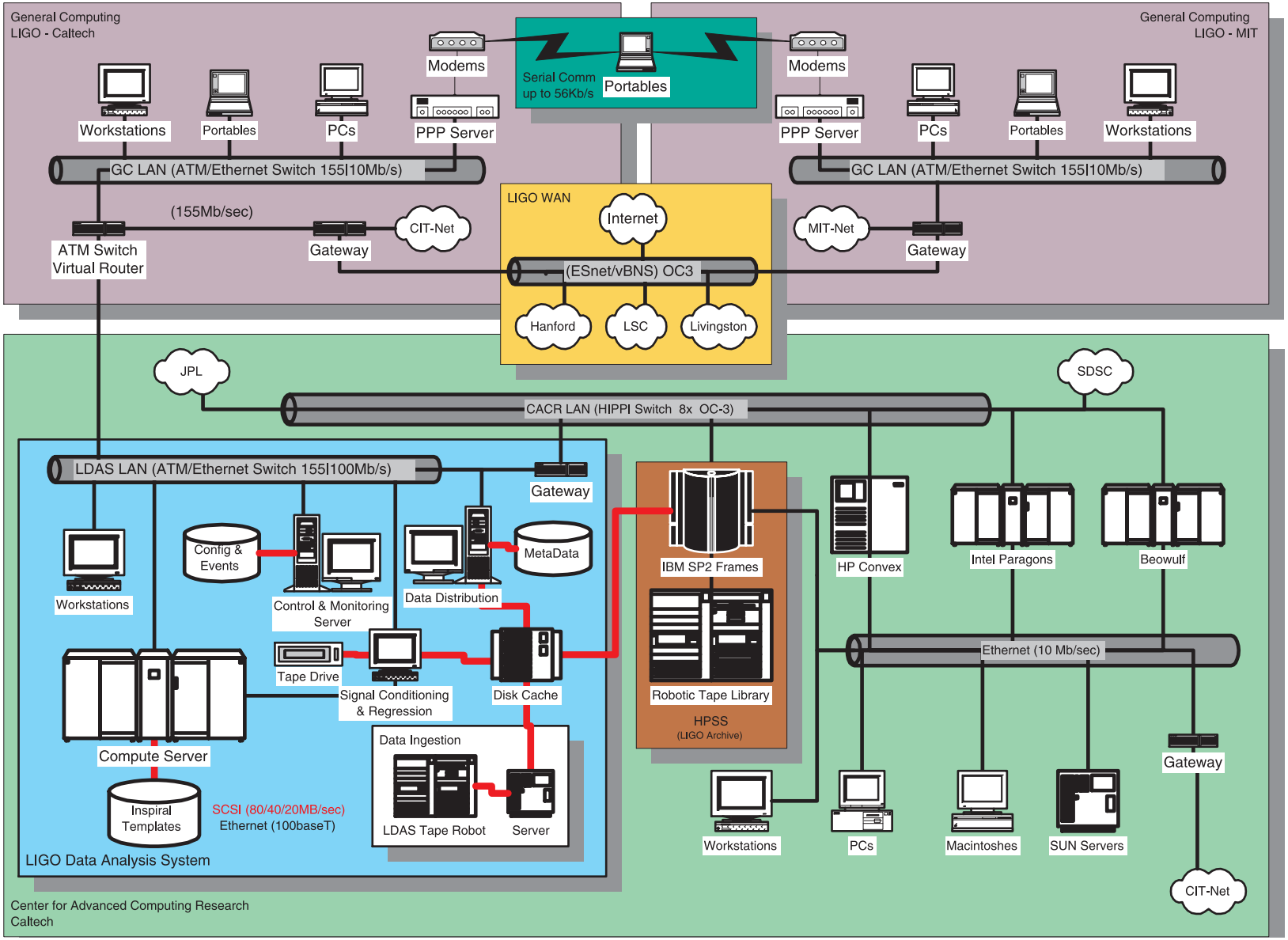
## 7. Linux PC compute cluster

- In-house development deferred in favor of data transmission and data distribution activities
  - Prototyping will likely first take place at U. Wisc. (Allen) as an LSC-based activity.

# LIGO Data Analysis System
## On-line architecture



# LIGO Data Analysis System
## Off-line Architecture



# Data Analysis System for LIGO I
## Status: Design

- Software system design

**Data analysis -- scope: LSC + LIGO Laboratory**

- Data analysis flows - sizing of requirements:
- Data analysis software prototyping - GRASP code
- Data usage model

**Data management -- scope: LIGO Laboratory**

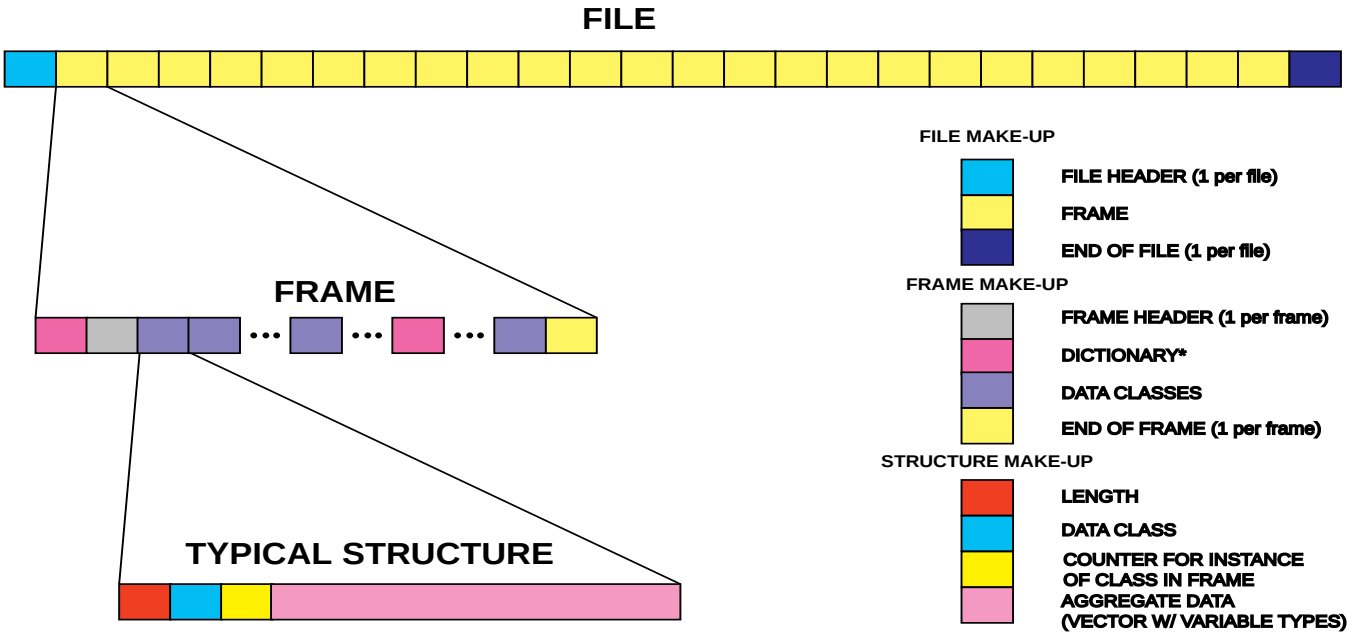
- Design and definition of architecture & components:
- Data distribution & access
  - Storage systems & archives
  - Data transmission & downloading
- Metadata creation/archival/retrieval
- API design/development
  - Data ingestion (incorporation of new/recent data)
  - LDAS command language
  - Interprocess communications -- LDAS distributed data analysis manager
  - Disk cache management
  - Access to data libraries - Frame/LW/Metadata/Event
  - Filtering/MPI/Conditioning
  - Control/Reporting

# LIGO Data Analysis System
## Software Design

### *DATA FORMAT STANDARDS*

**FRAMES:**

- Developed by VIRGO (Benoit Mours)
- Standardization defined by LIGO and VIRGO *(LIGO-T970130-B)*
- Accepted by GEO600 and TAMA
- Primarily developed for data acquisition and data archival
- Frame data attributes grow out of C language structures
- Frame I/O library (in C) and documentation available from Web see *(http://lapphp.in2p3.fr/virgo/FrameL)*
- MATLAB I/O interface to Frames also available
- C++ version of library and API under development at LIGO & VIRGO




*** Dictionary structure behavior is unique in that:**
**1. It preceeds header for first frame of file;**
**2. Dictionary is built up incrementally as addititional structures are incorporated into frame**
**3. It is valid for entire file (persistent)**

## *DATA FORMAT STANDARDS*

**Light-Weight Format:**

- Candidates - SDF being developed by CACR (John Salmon) CDL/NetCDF developed by Unidata Program Center
- Primarily intended as an easy to use data format
- May also be used for communication of data between distributed processes

**Other Data Formats:**

- Meta Data - data about data; candidates include database solutions, distributed, accessible through web browsers
- Event Data - data about events (analysis/filter results) includes triggers, diagnostic filters, GW filters
- MPI Data - data communicated between MPI processes (MPI standard)

# Data Analysis System for LIGO I
## Metadata (Partial List)

| | | | Basis of size estimate | | | |
|---|---|---|---|---|---|---|
| **SOURCE** | **Data** | **Data Types** | **#Parameters #Bins #Pixels #Samples/s** | **#Bytes** | **#/Hr** | **Data Volume/Year [GB]** |
| **LIGO - Interferometer** | Machine state vector | Text: Parameters | 1000 | 4 | 10 | **0.4** |
| | Snapshots | Video | 2500 | 1 | 10 | **0.3** |
| | | Audio | 40000 | 1 | 0.002 | **3** |
| | | Spectra; fast scopes | 1024 | 4 | 100 | **4** |
| | Frame Data Catalog | Text/Strings | 1024 | 1 | 10 | **0.1** |
| | Operator Logs | Text/Strings | 512 | 1 | 20 | **0.1** |
| | | Graphics | 250000 | 1 | 20 | **50** |
| | | Spectra | 2048 | 4 | 20 | **2** |
| | Diagnostics - Calibrations | Spectra | 2048 | 4 | 20 | **2** |
| | Diagnostics - Triggers | Matrices/coefficients | 100 | 4 | 1 | **0.004** |
| | | Text: Model parameters | 1024 | 1 | 1 | **0.01** |
| | | Discrete logic | 100 | 4 | 3600 | **14** |
| **LIGO - PEM** | Facilities state vector | Text: Parameters | 512 | 1 | 3600 | **18** |
| | Seismometers | Spectra | 1024 | 4 | 360 | **15** |
| | Magnetometers | Spectra | 2048 | 4 | 360 | **29** |
| | Tiltmeters | Time Series | 0.016666667 | 2 | 3600 | **0.001** |
| | Microphones | Spectra | 10000 | 2 | 360 | **72.0** |
| | Diagnostics - Calibrations | Matrices/coefficients | 100 | 4 | 1 | **0.004** |
| | Diagnostics - Triggers | Text: Model parameters | 1024 | 1 | 1 | **0.01** |
| | | Discrete logic | 100 | 4 | 3600 | **14** |

# Data Analysis System for LIGO I
## Metadata (Partial List)

### LDAS Metadata List - Preliminary

| SOURCE | Data | Data Types | Basis of size estimate: #Parameters #Bins #Pixels #Samples/s | #Bytes | #/Hr | Data Volume/Year [GB] |
|---|---|---|---|---|---|---|
| **Non-LIGO** | Seismic | Text: Parameters | 512 | 1 | 10 | **0.1** |
| | Electromagnetic storms | Text/Strings | 256 | 1 | 100 | **0.3** |
| | Astrophysics - GRBs | Text/Strings/Parameters | 256 | 1 | 0.04 | **0.00** |
| | Astrophysics - neutrinos | Text/Strings | 256 | 1 | 0.04 | **0.00** |
| | Astrophysics - visible | Text/Strings | 256 | 1 | 0.0416667 | **0.00** |
| | Astrophysics - gravitational | Text/events | 2048 | 1 | 10 | **0.2** |
| **LDAS Events** | Event Lists | Text: Parameters | 2048 | 1 | 10 | **0.2** |
| | | GW channel snap shots | 1638400 | 2 | 2 | **66** |
| | | Images/Graphics | 500000 | 1 | 10 | **50** |
| **LDAS Specific** | Catalogs | Text | | | | **0.0** |
| **Total Metadatabase == >** | | | | | | **341** |

# LIGO Data Analysis System
## Software Design

### *SOFTWARE STANDARDS*

**Languages:**

- ANSI C++ will be primary development language for compiled components to be maintained and supported by LIGO
- ANSI C will be used where wrappers are needed to bind C++ components with C, FORTRAN and TCL components
- TCL (Tool Control Language) will be used in the LDAS components responsible for controlling the LDAS software system
- TK will be used for the Graphical User Interface components
- Tclets (TCL/TK plug-ins) will be used for web browser connectivity into the LDAS software system.
- A TBD database will be used to integrate metadata into the LDAS software system

**Communications**:

- TCL layer sockets will be used to communicate commands and messages between components (processes) of the LDAS
- C++ socket class library will be used to communicate data between components (processes) of the LDAS

**Libraries**:

- C++ Class Libraries, numerical libraries, I/O libraries will be dynamically linked and built as shared libraries on supporting platforms for efficient use of hardware resources

## *VERSION CONTROL*

**Software Development:**

- Development cycle will include CVS (Concurrent Version System) as the software management system
- LIGO will be responsible for the LDAS CVS software repository
- A secure CVS shell will allow remote check-ins and check-outs from the LIGO LDAS repository

**Software Style:**

- The LIGO systems integration team has written a recommended software style guide *(LIGO-T970211-00-E)*

**Releases:**

- Releases of the LDAS software system will be in the public domain and available via FTP and WWW
- User Interfaces to the LDAS (shells and GUIs) will be available via FTP and WWW
- New releases will be announced over the Web and via email

## *SOFTWARE ARCHITECTURE*

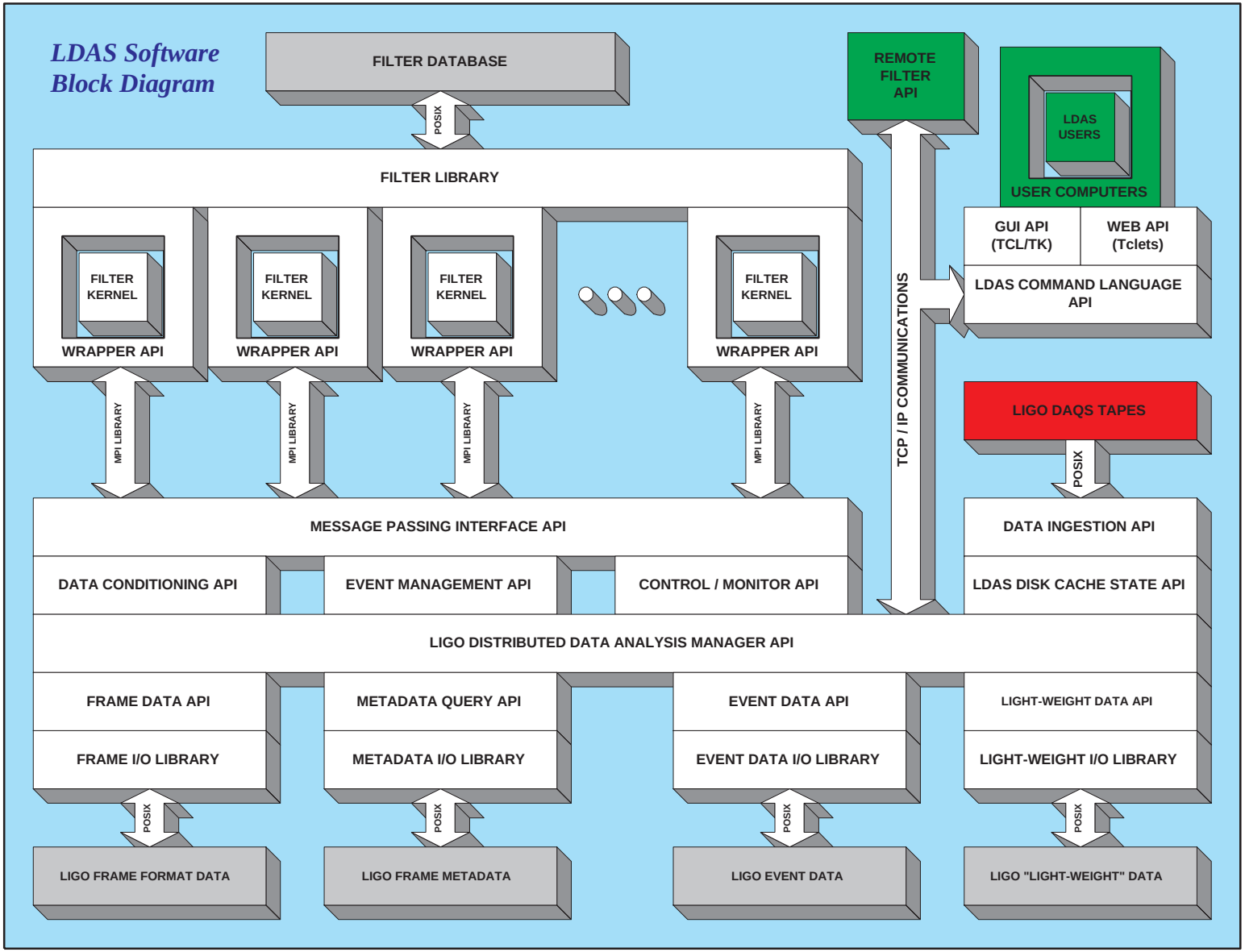
**Distributed Components:**

- Software components will in integrated into a distributed system using MPI and sockets for inter-process communications
- A distributed software manager will act as the master, serving users and coordinating the connections between all system components
- User interfaces based on TCL/TK will act as clients, making requests for services from the LDAS system through the distributed software manager

**API Components:**

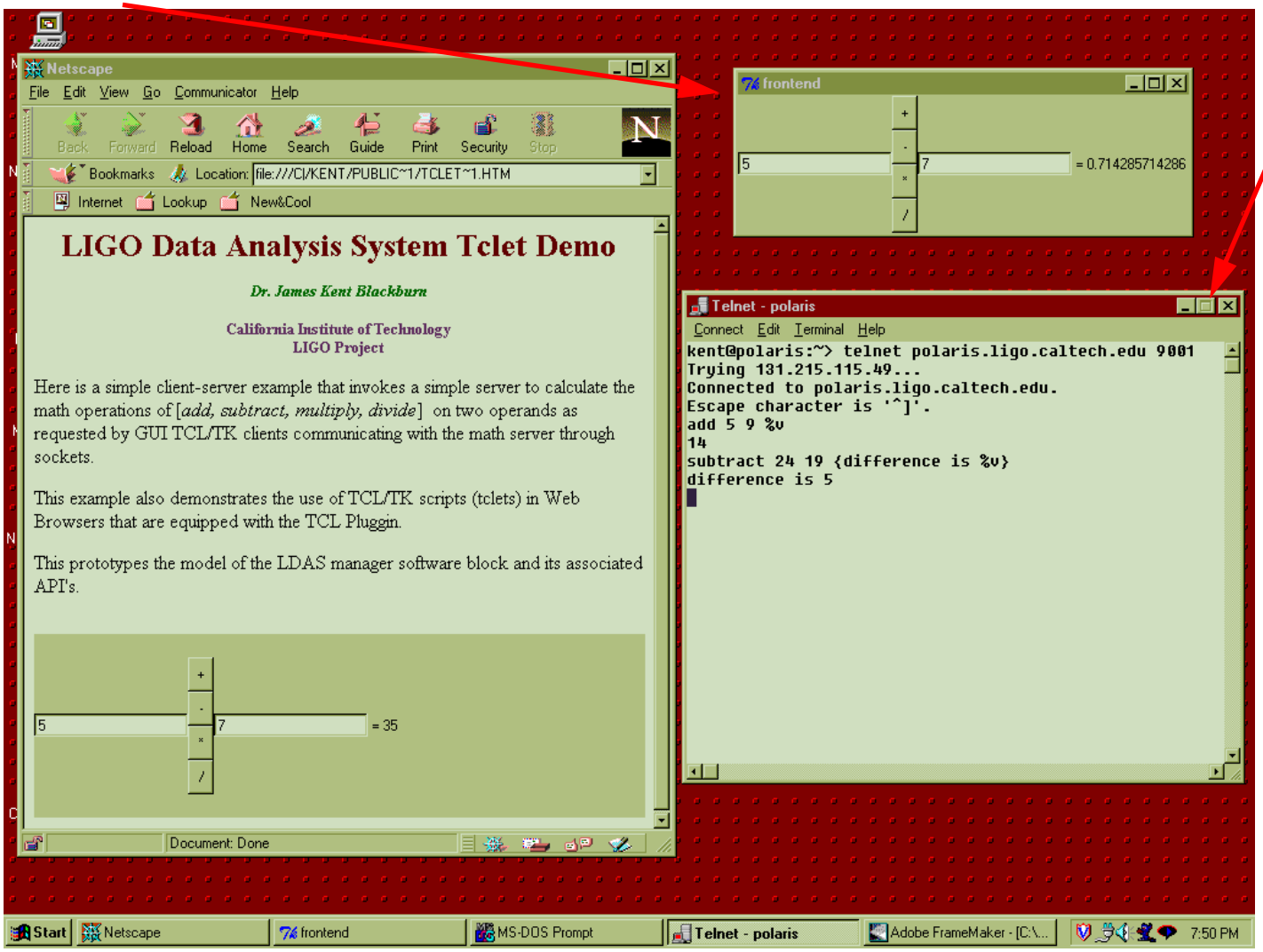
- The manager will see a standard interface(API) to all the software components

# LIGO Data Analysis System
## Software Design

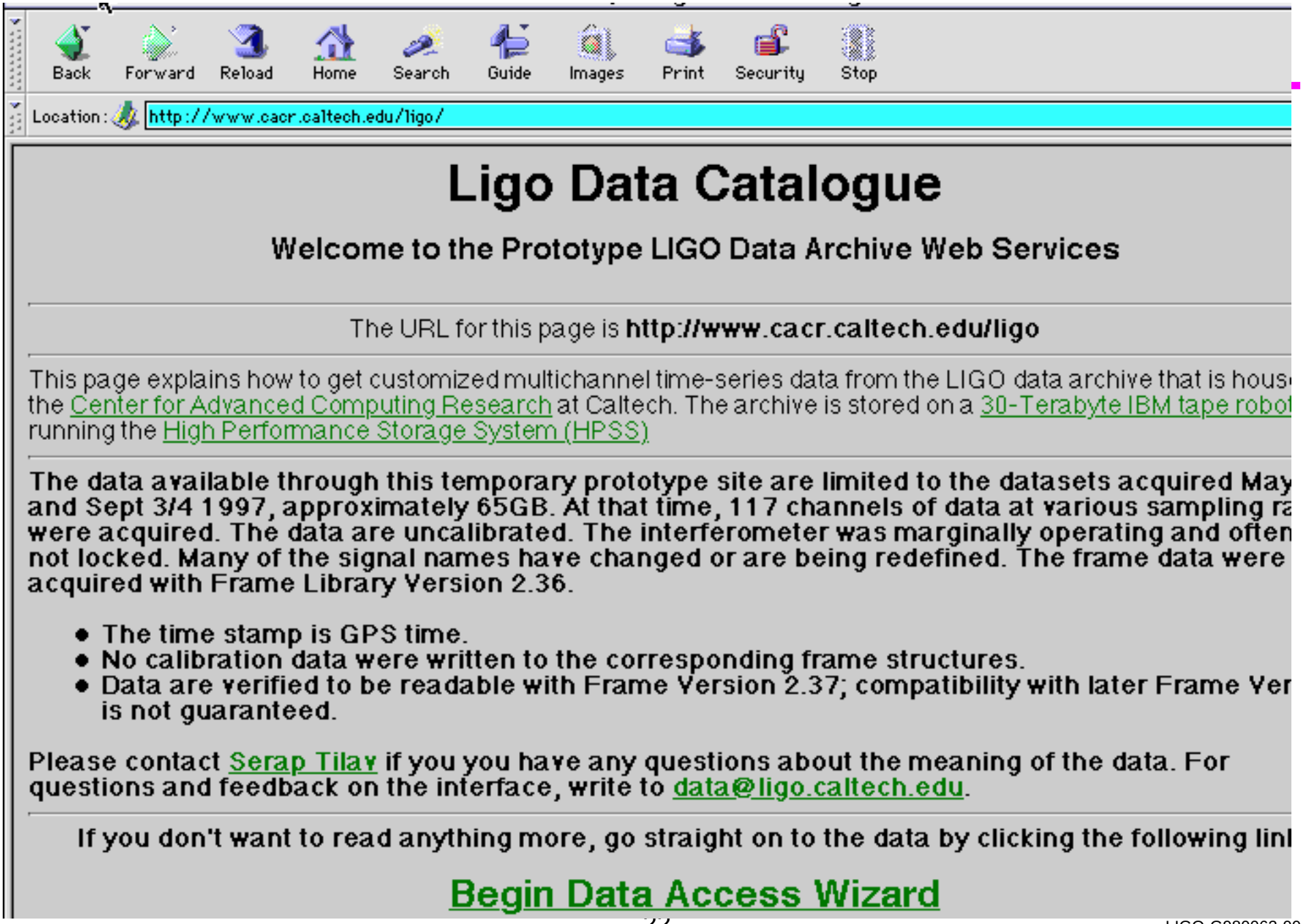


# LDAS SOFTWARE DESIGN
## Software Prototyping: TCL/TK Layer

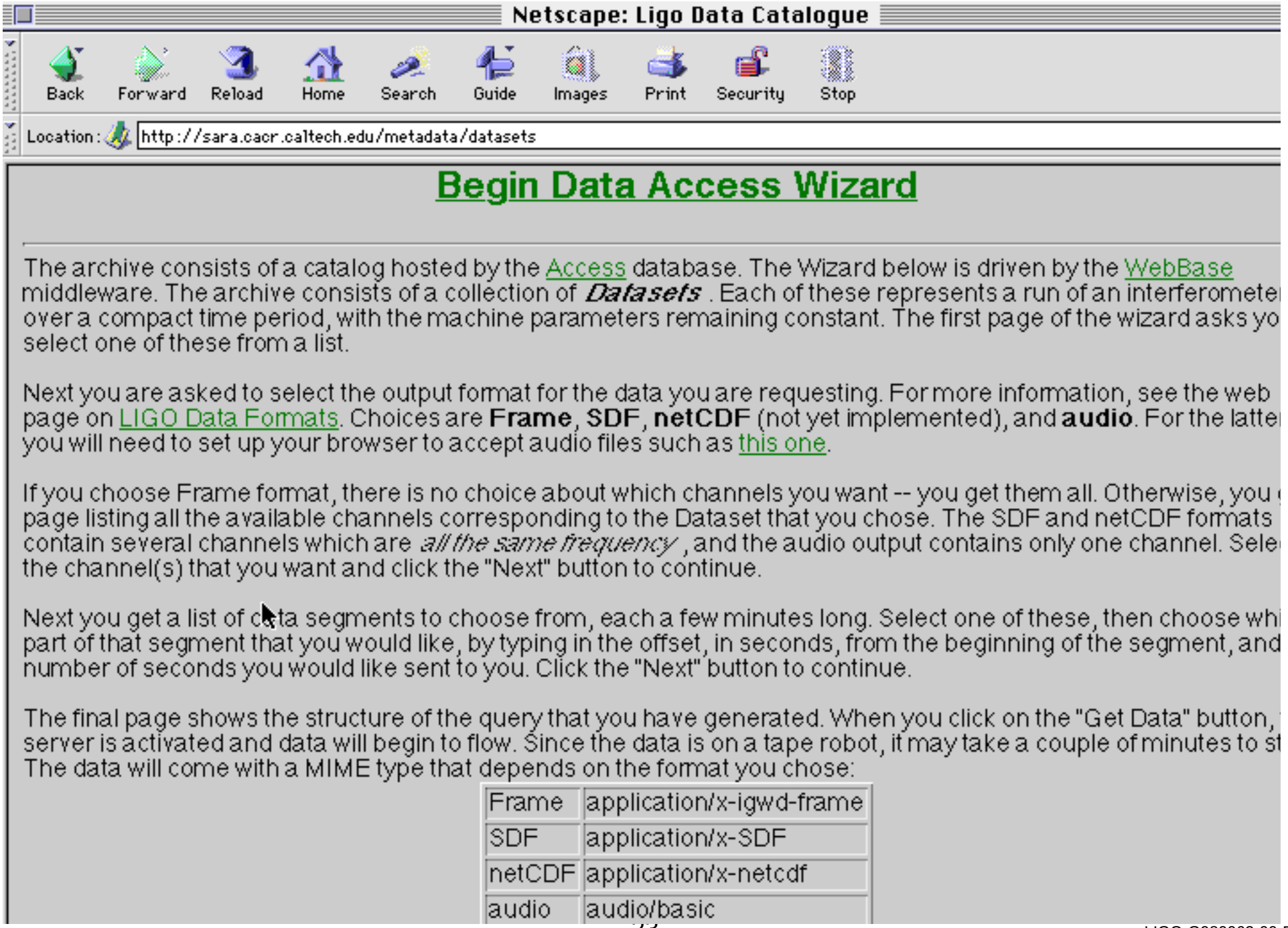
**Demo:** TCL Calculator Engine *(server)* running on a Sun Workstation computes for TCL/TK clients running in ***netscape*** and a ***wish shell*** on a PC...also a keyboard interface to the server's socket using the ***telnet session!***



# S/W Prototyping: Data Server Model



# S/W Prototyping: Data Server Model



## LIBRARIES LINKED ON LDAS HARDWARE

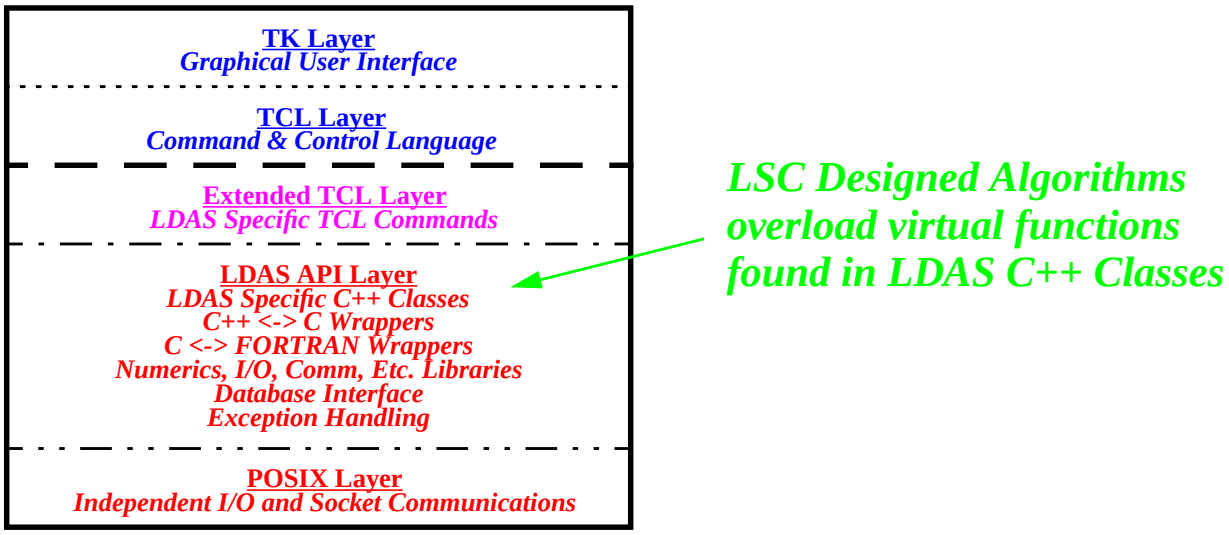
| | libmpi.a | libframe.a | libmeta.a | libevent.a | libsdf.a | libfilter.a | libposix.a |
|---|---|---|---|---|---|---|---|
| Computer Server | X | | | | X | X | X |
| Control & Monitor Server | | | | X | X | | X |
| Data Distribution Server | | X | X | | X | | X |
| User Interface | | | | | X | | |
| Data Ingestion Server | | X | | | X | | X |
| Data Conditioning Server | | X | | | X | | X |

## LIBRARIES LINKED TO LDAS SOFTWARE

| | libmpi.a | libframe.a | libmeta.a | libevent.a | libsdf.a | libfilter.a | libposix.a |
|---|---|---|---|---|---|---|---|
| Filter Wrapper Class | X | | | | X | X | X |
| MPI API | X | | | | | | X |
| Data Conditioning API | | | | | X | | X |
| Event Management API | | | | | X | | X |
| Control & Monitor API | | | | | X | | X |
| Frame Data API | | X | | | X | | X |
| Meta-Data API | | | X | | X | | X |
| Event Data API | | | | X | X | | X |
| SDF API | | | | | X | | X |
| Filter Kernel | Inherits | | | | Inherits | Inherits | Inherits |
| GUI User Interfaces | | | | | TCL | | |
| Remote Filter API | | | | | X | X | X |
| LDAS Command API | | | | | TCL | | |
| Data Ingestion API | | X | | | X | | X |
| LDAS Disk Cache API | | | | | X | | X |
| LDAS Manager API | | | | | X | | X |

# LIGO Data Analysis System
## Software Design

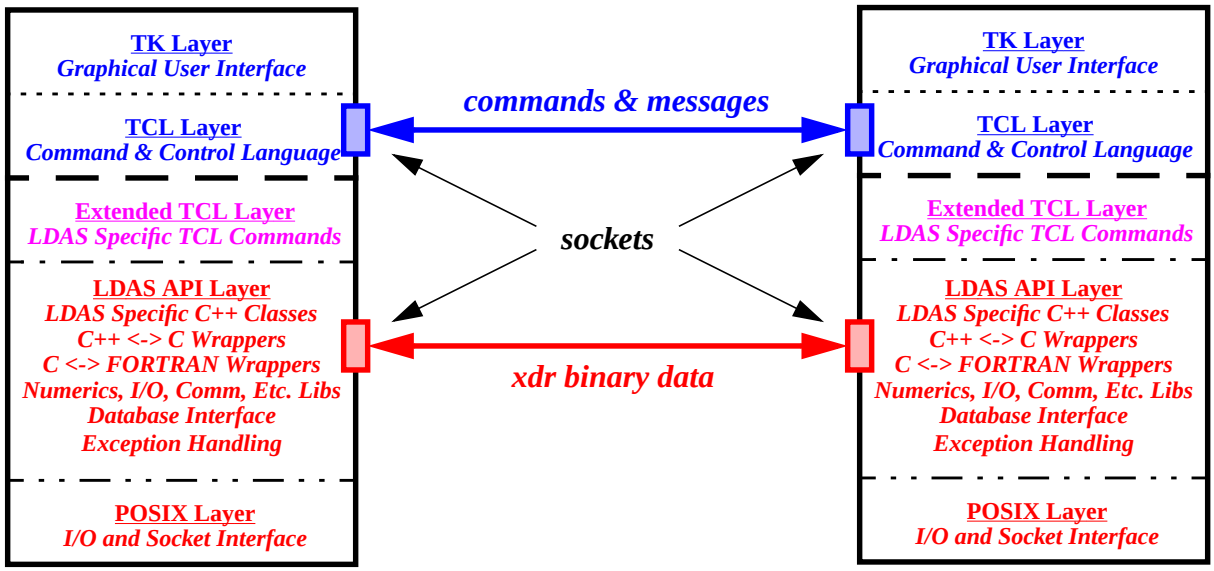
### APIs *"GENERIC"* LAYERED COMPOSITION




| *APIs* | *TK (GUI)* | *TCL (Control)* | *Extended TCL(LDAS)* | *LDAS Applications* |
|---|---|---|---|---|
| **Message Passing Interface** | OPTIONAL | YES | YES | YES |
| **Data Conditioning** | YES | YES | YES | YES |
| **Event Manager** | YES | YES | YES | YES |
| **Control & Monitor** | YES | YES | YES | YES |
| **Frame Data** | OPTIONAL | YES | YES | YES |
| **Meta-Data** | OPTIONAL | YES | YES | YES |
| **Event Data** | OPTIONAL | YES | YES | YES |
| **Simple Data Format** | OPTIONAL | YES | YES | YES |
| **LDAS Command Language** | GUI Front Ends | YES | OPTIONAL | YES |
| **Remote Filter API** | OPTIONAL | YES | YES | NO |
| **Data Ingestion** | YES | YES | YES | YES |
| **LDAS Disk Cache** | YES | YES | YES | YES |
| **LDAS Manager** | YES | YES | NO | NO |

# LIGO Data Analysis System
## Software Design

### APIs "*TWO-LEVEL*" SOCKET COMMUNICATIONS

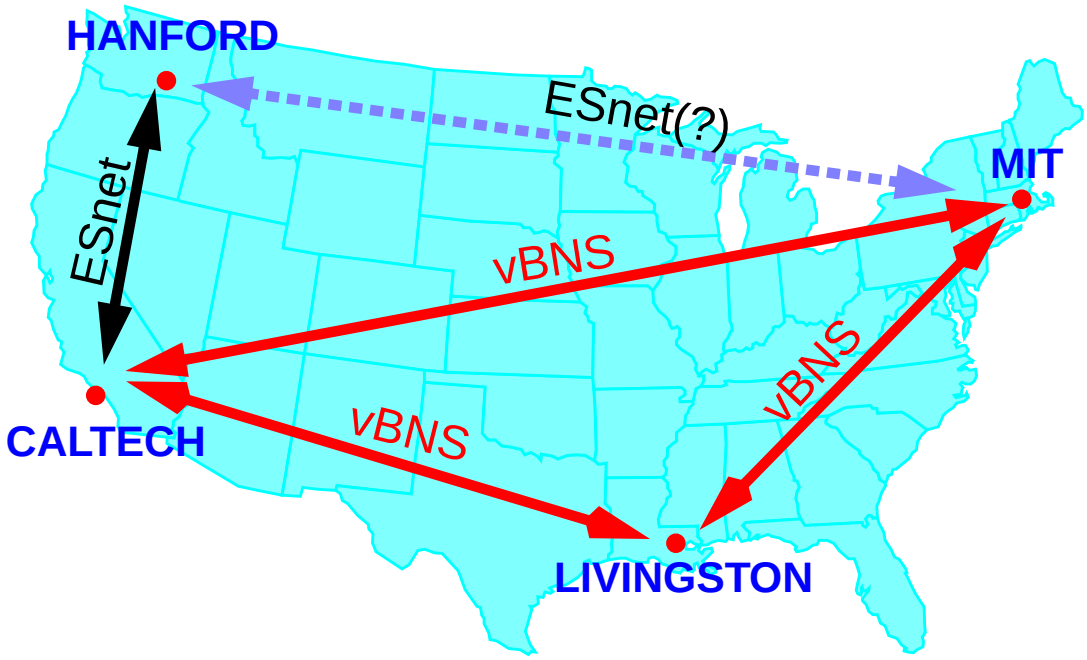



*Yellow boxes below indicate option to use SCSI*

| ***API*** | **FW** | **MPI** | **DC** | **EM** | **CM** | **FD** | **MD** | **ED** | **SDF** | **FK** | **COM** | **DI** | **DCS** | **MAN** | **RF** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **FW** | | mpi | | | | | | | | inherit | | | | | |
| **MPI** | mpi | mpi | socket | socket | socket | | | | | inherit | | | | | |
| **DC** | | socket | | | socket | socket | socket | | socket | | | | | socket | socket |
| **EM** | | socket | | socket | socket | | | socket | socket | | | | | socket | socket |
| **CM** | | socket | socket | socket | | socket | socket | socket | socket | | | | | socket | socket |
| **FD** | | | socket | | socket | | | | socket | | | | socket | socket | |
| **MD** | | | socket | | socket | | socket | socket | socket | | | | socket | socket | |
| **ED** | | | | socket | socket | | socket | socket | socket | | | | | socket | |
| **SDF** | | | socket | socket | socket | socket | socket | socket | | | | | socket | socket | socket |
| **FK** | inherit | inherit | | | | | | | | | | | | | |
| **COM** | | | | | | | | | | | | | | socket | |
| **DI** | | | | | | | | | | | | | socket | | |
| **DCS** | | | | | | socket | socket | | socket | | | socket | | socket | |
| **MAN** | | | socket | socket | socket | socket | socket | socket | socket | | socket | | socket | | socket |
| **RF** | | | socket | socket | socket | | | | socket | | | | | socket | |

# LIGO Wide Area Network

## Plan




**WAN/LAN Connectivity among LIGO Laboratory Sites**

| *Site* | *Livingston, LA* | *Hanford, WA* | *MIT* | *Caltech* |
|---|---|---|---|---|
| *Caltech* | vBNS(OC3) | ESnet (4 X T1) <-> vBNS(OC3) | vBNS(OC3) | OC3/ATM 100BT |
| *MIT* | vBNS(OC3) | MIT<->Caltech<->Hanford<br>ESnet (4 X T1) <-> vBNS(OC3) | 100BT OC3/ATM(?) | |
| *Hanford, WA* | ESnet (4 X T1) <-> vBNS(OC3) | OC3/ATM 100BT | | |
| *Livingston, LA* | OC3/ATM 100BT | | | |

# LIGO Wide Area Network

## Status

- LIGO proposed & drafted an MOU between NSF/DOE to provide access to ESnet at Hanford
  - Final MOU complete: awaiting signatures at NSF, DOE
  - Proceeding to implement initial (T1) capability; requested up to 4 x T1 BW (cost is an issue).
  - SOW/PO with PNNL & Lockheed-Martin to procure switching & routing equipment almost complete
  - Cross-over between ESnet and vBNS takes place at SDSC
  - Routing: LHO-PNNL-SDSC-CACR-LIGO/Caltech
    - Awaiting IP address space release by ESnet
    - Testing has been done to establish quality of service between SDSC & PNNL: excellent.
    - Will conduct similar testing between CACR and SDSC - no surprises expected
  - MIT may be added later as a separate addendum to MOU (reduce to several 2-body problems!)

# LIGO Wide Area Network

## Status

- Issue: ESnet link is not extensible beyond ~ 2 x T1 due to costs (we have requested extensibility to 4 x T1)
  - WSU/Pullman (~ 100km NE) awarded an NSF grant to establish a vBNS hook-up
  - UW/Seattle (~350 km W) has vBNS at present
  - LIGO is exploring the possibility of a consortium to propose to NSF a direct vBNS hookup in Tri-Cities area with PNNL (EMSL: R. Bair) and WSU/Richland extension campus (J. Judy)
    - Follows model in place at Livingston
  - Interest is “moderate”
    - EMSL needs better connectivity to Seattle, Caltech, SDSC
    - WSU/Richland has no present high-bandwidth connection to internet -- small budgets
  - LIGO is an “outsider” and would like a local advocate who knows Washington state telecommunications infrastructure (State and commercial sectors)
  - Not obvious 31 July 1998 deadline for proposal to NSF can be met

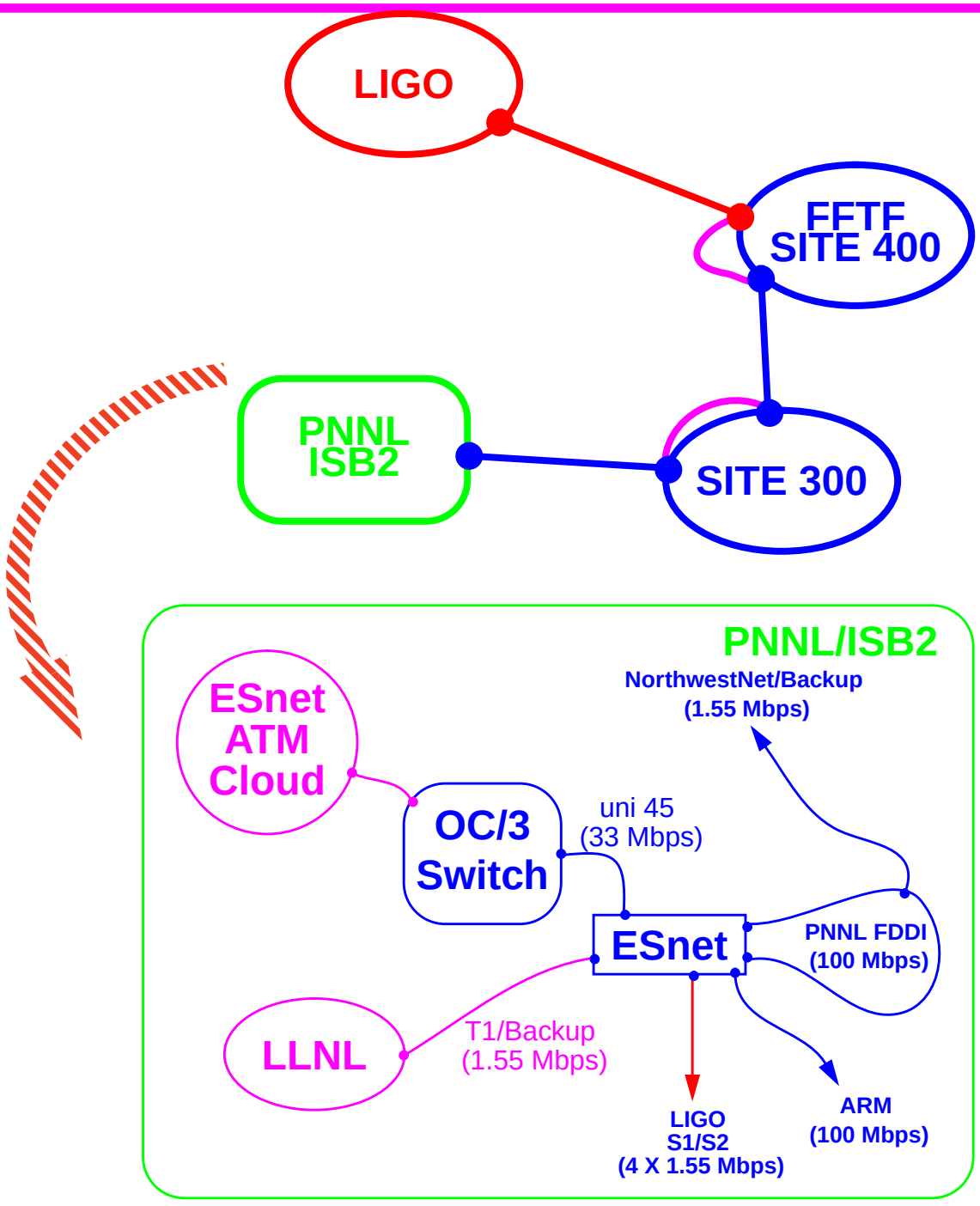
# LIGO Wide Area Network

## Status

- T1 link to Livingston Observatory is in place
  - LSU provides gateway service
  - Recent proposal by LSU to NSF for vBNS connection includes LIGO access at Livingston
  - Future FO link from observatory to campus via Bell South switch near Livingston [present link uses Cu].

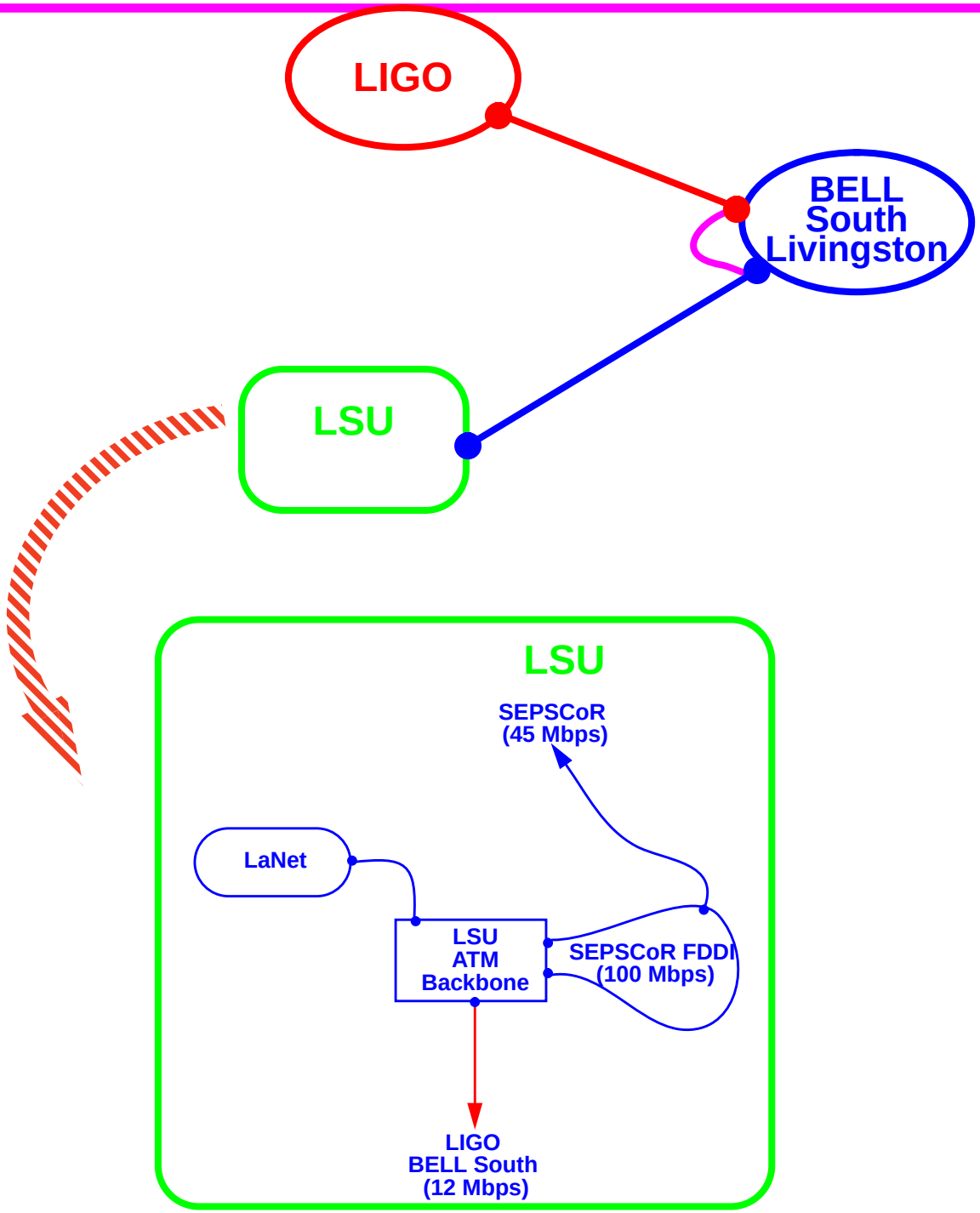
# LIGO Hanford WAN

## Link to ESnet



# LIGO Livingston WAN

## Link to LSU/vBNS



# LIGO Data Analysis System
## To-Do List

- Design & definition
  - Data -- channel lists/frame contents/types of frames/...
  - Metadata -- contents/environment
  - Algorithms -- hierarchical searches/periodic searches/f-t processing/wavelets/...
  - Events -- definition
  - LDAS architecture -- complete design/definition
- Development & prototyping
  - LDAS command language syntax
  - Scripting language implementation -- interprocess control & communication
  - Data distribution -- 40m implementation
  - Compute server -- BEOWULF cluster; integrate ~8 node cluster
  - Algorithms -- same as above
  - Benchmarks -- algorithms; data distribution;...
  - Visualization tools
    - Applets
    - Plug-ins
    - AP Interfaces to commercial/extant products
      - Matlab, IDL, Triana(GEO), ...
  - Data transmission -- quantify WAN performance/ limitations

# LDAS Development
## Timeline

- Highest priority: staged implementation of on-line systems to support detector commissioning:

| Detector Milestone: | Date | LDAS Need |
|---|---|---|
| ›› Data Acquisition System, 2km: | 9/98 | Min. data dist. |
| ›› PSL/Input Optics | 2/99 | “ |
| ›› Vertex Michelson, first light | 7/99 | Full data dist. |
| ›› 2km operational | 6/00 | On-line system |

- 4 km interferometers staggered in time by 3 & 6 mos.
- Staged installation at CACR of off-line system in period 6/99 - 12/01
  - .

# Data Analysis System for LIGO I
## Summary of Recommendations from PAC Report of 11/97

- Data Model
  - ›› Have started prototyping an acess/filter/retrieval example session
  - ›› Cooperating with CDS/Diagnostics group
    - Ensuring uniformity of software (where reasonable)
    - Data acess & retrieval
    - Data type definition
  - ›› Developing metadata list
  - ›› Revised interface to CDS/Detector tape storage
    - CDS to provide on-line large RAID disk system
    - LDAS to provide tape writing capability to ensure seamless compatibility with tape archiving system at CACR
  - ›› Frame format specification under configuration control
    - see URL http://docuserv.ligo.caltech.edu/~prince/data_dump.html; document # T970130.pdf
  - ›› C++ class library definition/design in process
  - ›› CACR MOU under review
  - ›› Data archive system (e.g., HPSS) still under evaluation
    - May consider a “home-grown” *datawulf* system
  - ›› Data compression will be implemented when needed
  - ›› Have begun hiring necessary programming staff to carry forth implementation