GLOBAL DIAGNOSTICS SYSTEM

Preliminary Design Review

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INTRODUCTION AND OVERVIEW

Organization of presentations:

- Introduction and overview (shoemaker)
- Data channels and channel list (sigg)
- diagnostics test tool (sigg)
- Search tool (pratt)
- Vewing tool/recording tool (shoemaker)
- Software design (pratt)
- Hardware implementation and integration (bork)
- Schedule/costs/personpower (shoemaker)

GOALS

- Assist the operators in the control room and in the experimental areas to successfully run the machine.
- Provide immediate answers:
  - What are the quality of the GW data written to disk?
  - Are all of the subsystems working properly?
- Establish & automate diagnostics procedures.
- Give assistance to:
  - learn about the behavior of the instrument,
  - classify abnormal environmental events,
  - identify the exact machine state,
  - correlate the signals of different sensors and,
  - ultimately, reduce the large amount of measured data to a set of relevant and comprehensible statistical quantities.

Allow interferometer scientists to interact with LIGO as they do in the campus labs with prototype interferometers.

DESIGN PRINCIPLES

Scalable

- can grow with users
- can grow with experience
- incrementally useful

Maximally independent modules

- to simplify interfaces within GDS (Global Diagnostics System)
- again, ease staged implementation

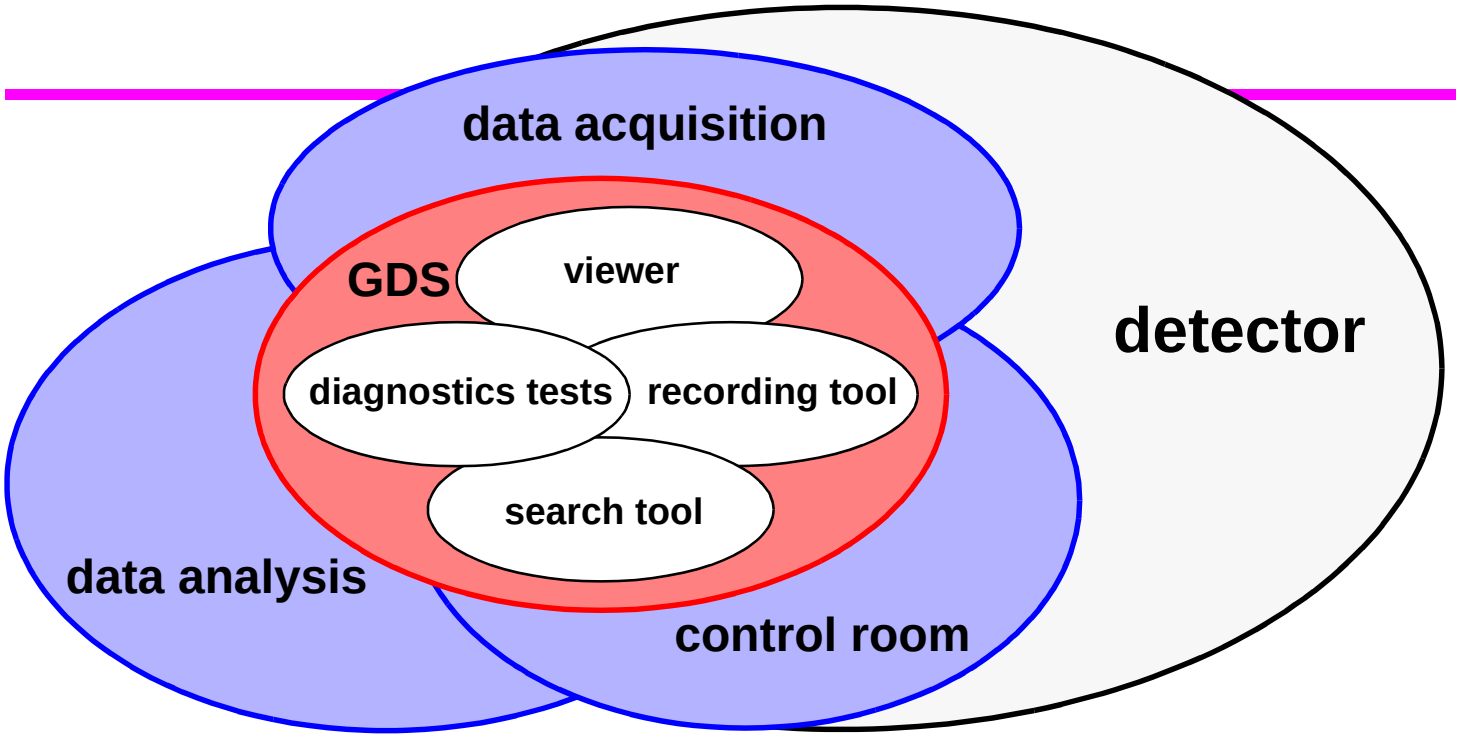
Powerful infrastructure

- access to data
- processing power
- I/O routines and means

Expandable

- seduced datasets
- closed-loop stimulus-response
- system identification/adaptive control

SCOPE

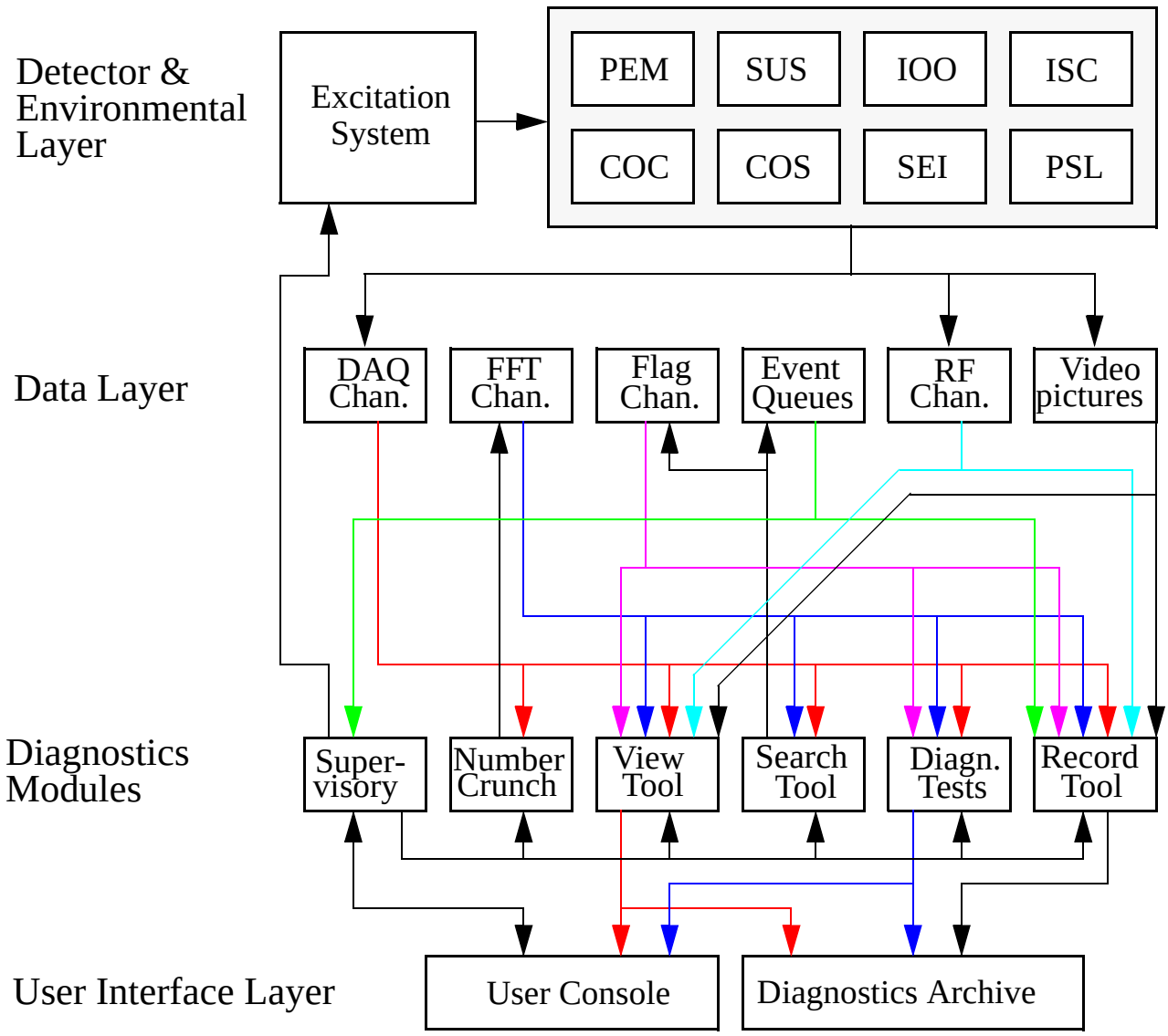


- Viewing tool (possibly shared with DAQS)
- Recording tool (trend frames)
- Diagnostics test tool
- Search tool
- Hardware for real-time analysis, signal generators

Does Not Include

- data acquisition system
- cameras, oscilloscopes, PEM-related equipment
- off-line computing power and workstations

BLOCK DIAGRAM



RAW DATA CHANNELS

- Audio-Frequency Channels
  - IFO data provided by DAQS
  - Audio-output
- RF Channels
  - Snapshots from digitizing oscilloscope
    - e.g. Tektronics TDS 640A
  - High frequency: 10 kHz - 500 MHz
  - Fast transients; 1 ns - 10 μsec.
  - Commercial acquisition & manipulation
    - e.g. GPIB / Nation Instruments LabView
- Video
  - Commercially available stand-alone system
  - NTSC signals available in control room
  - Time stamped video recorder
  - Acquired by CDS

PREPROCESSED DATA CHANNELS

- Channel Reconstruction
  - Length error signals: done by LSC
  - Alignment signals & input beam direction: done by ASC
  - Sum of 4 coil current read-backs describing axial motion: done in hardware by SUS(?)/DAQS
- Fourier Transform
  - 1024 or 16384 point FFT
  - Refresh rate 16, 1, 1/16, 1/256 Hz
  - Windowing
  - substantial amount of fast channels ~10 selectable by operator
  - Scalable compute engine
- Flag Channels
  - Defined by trigger outputs in search tool
  - Data format: real, integer or bit
  - 16kHz maximum; 16 Hz refresh rate maximum
  - Insertion into data stream at front end

CHANNEL LIST IMPORTANT CONSIDERATIONS

- Test Points
  - Finite number, selectable on-the-fly
  - Channels which are not important enough to be acquired continuously can be accessed through test points.
    Example: internal digital servo test point
  - Some channels which normally have a lower sampling rate can be temporarily acquired at a higher rate.
    Example: individual SUS coil read-back
- SUS:
  - sum of 4 coils: 16384Hz
  - individual coils: 2048Hz
  - IOO folding mirrors and mode matching mirrors not saved
- ASC:
  - WFS quadrant signals: 2048Hz, not saved
  - Only alignment error signals saved in frames
- LSC:
  - length error signal: 16384Hz, single precision floats
  - individual diode signals: 2048Hz

CHANNEL LIST
RATE SUMMARY

subsystem	raw rate (kB/s)	frame (kB/s)
LSC	957	797
ASC	371	179
SUS (4k/2k)	684/842	476/582
IOO	379	209
PSL	289	225
SEI	2	1
GDS	1536	0
PEM LHO	889	821
PEM LLO	460	392
Total LHO	**9479**	**4698**
Total LLO	**4676**	**2278**
Total LIGO	**14154**	**6975**

DIAGNOSTICS TESTS REQUIREMENTS

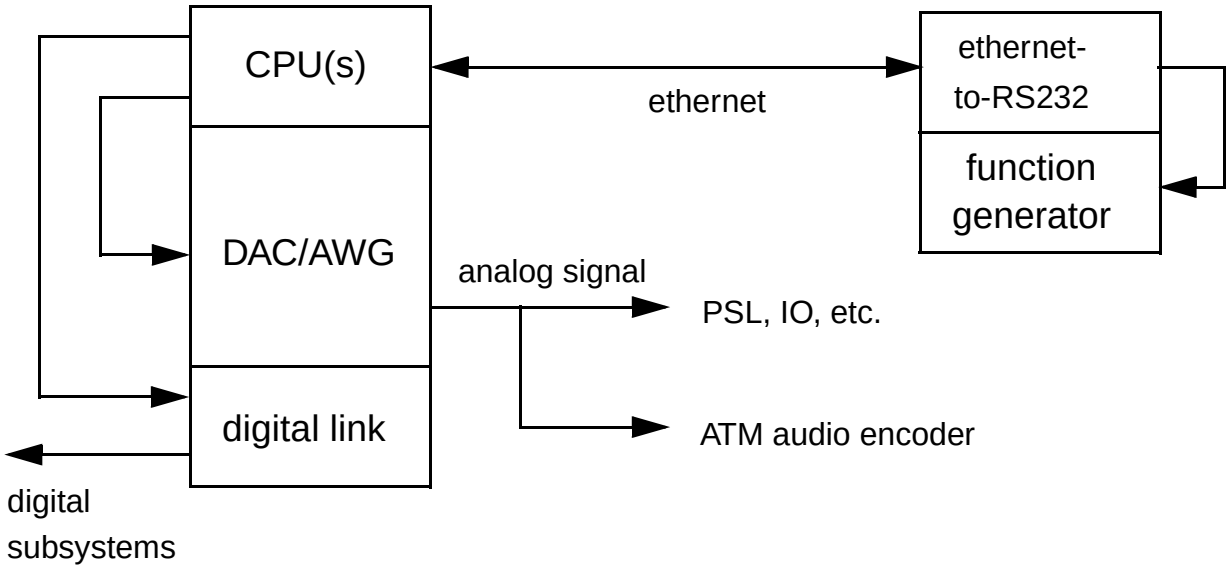
- Scope
  - Characterize the performance of the interferometer by establishing relationships between operating parameters, subsystem performance, and environmental inputs
  - Tasks: passive observation, parametric studies, and active stimulus-response testing
- Requirement
  - Acquire all data which have a significant effect on the interferometer performance, long or short term
  - Provide tools to allow that data to be exploited

DIAGNOSTICS TESTS DESIGN GOALS

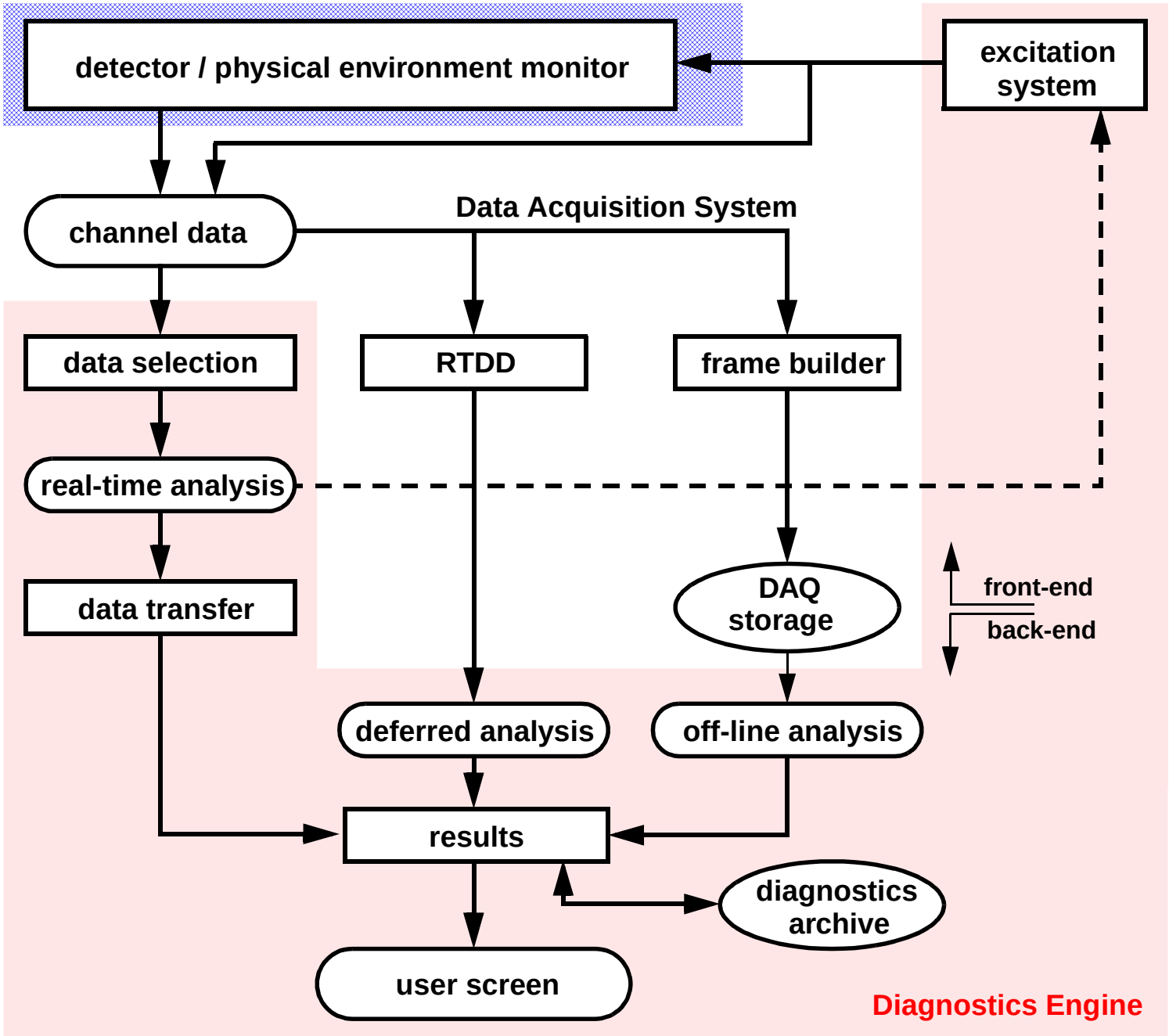
- Give assistance to
  - learn about the behavior of the instrument
  - diagnose problems
  - correlate signals of different sensors
  - actively stimulate a subsystem
- Establish & automate diagnostics procedures
- Provide support for
  - stimulus to the test inputs of the instrument
  - obtain and archive the information in the tested channels
  - analysis algorithms and plotting routines to extract and display test results
  - diagnostics archive
    - track of test results
    - historical trends of detector performance
  - automate diagnostics tests which have proven to be useful
  - test templates

EXCITATION SYSTEM

- Hardware units
  - DS340: remote control via RS232 / ethernet
  - VME based DAC/AWG; ≥4 simultaneous channels
  - Double duty: audio synthesizer
- Software units
  - Software AWG
  - Digital link to LSC, ASC and IOO WFS
- EPICS / MEDM control panel



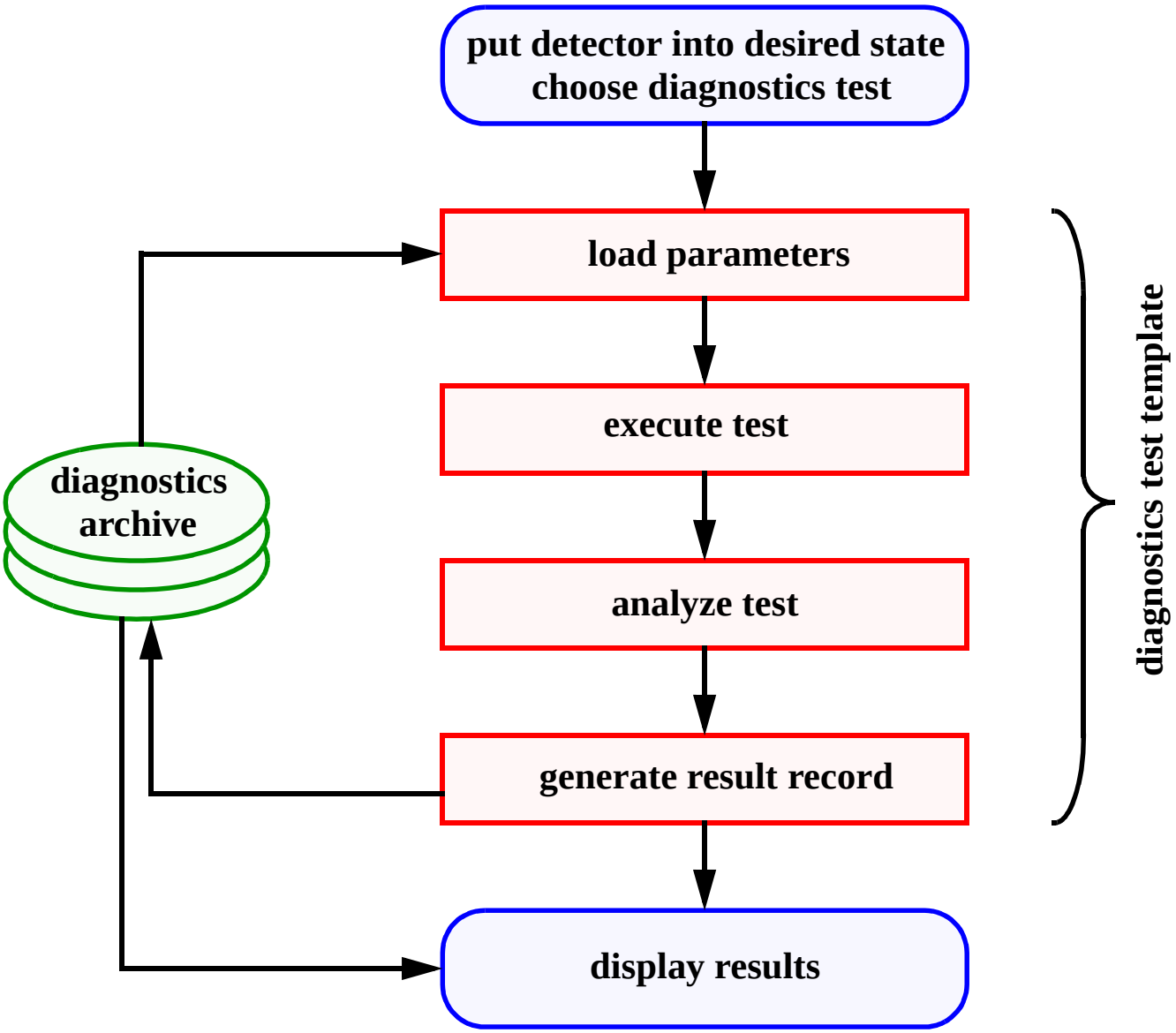
DIAGNOSTICS TEST ENGINE



TEST CLASSIFICATION

- Off-line vs. on-line
  - Develop tests with off-line data
  - Use on-line analysis algorithm to automate tests
- Invasive vs. non-invasive tests
  - invasive: interrupt detection mode
  - non-invasive: can be done in parallel
  - minimally invasive: small pseudo-random excitation
- Subsystem vs. global
  - global: more than one subsystem involved
- Test templates
  - used to separate generic test algorithms from actual tests
  - controlled through parameters
  - tool for automatization

TEST TEMPLATE FLOW CHART



TEST TEMPLATES
BASIC PROPERTIES

- a description of the necessary parameters
- a piece of code which executes the test
- algorithms to analyze the test and obtain the test results and
- a definition of the result record

TEST TEMPLATES
RESULT RECORD

Result record section	Description
Header	header information describing the test (name, class, date, time, etc.)
Detector state vector	describes the state of the detector at the time the test was taken
Test parameters	lists all the parameters used for the test
Raw data	section for storing the measured raw data
Analyzed Data	section to store the test results; divided into:
intermediate steps	subsection to store results from intermediate steps
final result	subsection to store the final results

TEST TEMPLATES OVERVIEW

- Time series measurement
- Power spectrum measurement
- Sine response
- Swept sine response
- Triggered pulse response
- Two-tone intermodulation test
- Harmonic distortion
- Pseudo-random stimulus / power spectrum measurement
- Pseudo-random stimulus / cross spectrum measurement
- Parameter sweep
- Parameter optimization

TEST TEMPLATE: TIME SERIES MEASUREMENT

Parameter (Unit)	Description
TestClass	TimeSeries
TestName	unique identifier
TestDuration (s)	time of measurement
MeasurementChannelN	name or number of the Nth measurement channel; N = 1, 2, 3,... 20
TestAnalysis	none
TestResults	returns the time series of the measured channels

TEST TEMPLATE: POWER SPECTRUM MEASUREMENT

Parameter (Unit)	Description
TestClass	PowerSpectrum
TestName	unique identifier
TestDuration (s)	time of each measurement; default is 10/ bandwidth
FrequencySpan (Hz)	highest frequency; default is 8192 Hz
Bandwidth (Hz)	bandwidth; default is 1 Hz
MeasurementChannelN	name or number of the Nth measurement channel; N = 1, 2, 3,... 20
TestAnalysis	calculates the power spectra and averages over consecutive measurements
AnalysisWindow	Hanning, Flat-top or Uniform
TestResults	returns the averaged power spectra after each step

TEST TEMPLATE: (MULTIPLE) SINE RESPONSE

- Examples:
  - Alignment Sensing Matrix
  - SUS actuator angular calibration
  - Servo loop diagonalization

Parameter (Unit)	Description
TestClass	SineResponse
TestName	unique identifier
TestDuration (s)	time of measurement; default is longest of 100/ StimulusFrequencyM
StimulusChannelM	channel name or number of the Mth test input; M = 1, 2, 3,... 20
StimulusFrequencyM (Hz)	frequency of the Mth stimulus
StimulusAmplitudeM (V)	amplitude of the Mth stimulus
StimulusOffsetM (V)	offset of the Mth stimulus
StimulusWait (s)	time which is waited after applying the stimulus until the test starts default is 10/StimulusFrequency
MeasurementChannelN	name or number of the Nth measurement channel; N = 1, 2, 3,... 20
TestAnalysis	analyzes the measurement channels and calculates both the amplitude and the phase of the signal at each of the applied frequencies
TestResults	returns the power spectra and/or the signal amplitude/phase matrix

USER INTERACTION

- Doing the test:
  - Define test
    - either start medm and type in parameters using the GUI or
    - use text editor to define the parameter file
  - Start test
    - either press start button on medm screen or
    - use command line and specify name of parameter file
  - Do test
    - diagnostics scheduler programs excitation system
    - either diagnostics scheduler programs RTDD and starts receiving task on control room workstation or
    - diagnostics scheduler starts analysis task on front-end CPU which transfers results automatically to the workstation
    - when test is finished, scheduler shuts down excitation system
  - Show results
    - either test results are automatically shown in the viewer or
    - test results are displayed with Matlab/Mathematica or
    - test results have to be analyzed using Matlab/Mathematica

TEST TEMPLATE: SWEPT SINE RESPONSE

- Examples
  - Laser frequency/amplitude noise in the GW band
  - Closed loop servo characterization

Parameter (Unit)	Description
TestClass	SweptSine
TestName	unique identifier
StimulusChannel	channel name or number of the test input
StartFrequency (Hz)	start frequency of the swept sine (for linear and logarithmic sweeps)
StopFrequency (Hz)	stop frequency of the swept sine (for linear and logarithmic sweeps)
StimulusFrequency (Hz)	list of frequencies (for user sweep)
SweptSineType	linear (default), logarithmic or user
SweptSineDirection	upwards or downwards (default)
StimulusAmplitude (V)	amplitude of stimulus; can be a list of (frequency, amplitude) points which is used as an interpolation table (linear interpolation in log-log scale); can be Automatic for auto source level adjustment

StimulusWait (cycles)	time which is waited after applying the stimulus until the test starts default is 0
NumberOfPoints	number of measurement points
MeasurementChannelAN	name or number of the Nth measurement A channel; N = 1, 2, 3,... 20
MeasurementChannelBN	name or number of the Nth measurement B channel; N = 1, 2, 3,... 20
MeasurmentTime (cycles)	time for each measurement point; default is 10 cycles; can be Automatic
MeasurementAverages	number of averages; default is 1.
TestAnalysis	calculates the transfer functions (B/A)
TestResults	returns each measurement point of the transfer function; returns the transfer function at the end of the measurement; returns the coherence spectrum

TEST TEMPLATE: SINGLE TRIGGERED RESPONSE

- Examples
  - Arm cavity loss measurement by ring-down

Parameter (Unit)	Description
TestClass	SingleTriggerResponse
TestName	unique identifier
TestDuration (s)	time of measurement
TestPreTriggerTime	measurement time before the trigger is applied; default is 20% of the total measurement time
StimulusChannel	channel name or number of the trigger input
StimulusType	impulse, step or ramp
StimulusAmplitude (V)	amplitude of the stimulus
MeasurementChannelN	name or number of the Nth measurement channel; N = 1, 2, 3,... 20
TestAnalysis	calculates the decay time of the response
TestResults	returns the time series of the measured channels and the decay constants

TEST TEMPLATE: PERIODIC TRIGGER RESPONSE

- Examples
  - Recycling cavity loss measurement
  - Step response of servo loops

Parameter (Unit)	Description
TestClass	PeriodicTriggerResponse
TestName	unique identifier
TestDuration (s)	time of measurement (trigger to trigger)
TestPreTriggerTime (s)	measurement time before the trigger is applied; default is 20% of the total measurement time
NumberOfTriggers	the number of periodic triggers which are applied to the stimulus channel
StimulusChannel	channel name or number of the trigger input
StimulusType	impulse, step, ramp or triangle
StimulusAmplitude (V)	amplitude of the stimulus
MeasurementChannelN	name or number of the Nth measurement channel; N = 1, 2, 3,... 20
TestAnalysis	averages over repeated measurements; calculates the decay time of the response
TestResults	returns the (averaged) time series of the measured channels and the decay constants

TEST TEMPLATE: TWO-TONE INTERMODULATION

Parameter (Unit)	Description
TestClass	TwoToneIntermodulation
TestName	unique identifier
TestDuration (s)	time of measurement; default is 100/ StimulusFrequency
StimulusChannel1	channel name or number of the first test input
StimulusFrequency1 (Hz)	frequency of the first stimulus
StimulusAmplitude1 (V)	amplitude of the first stimulus
StimulusChannel2	channel name or number of the second test input; default is StimulusChannel1
StimulusFrequency2 (Hz)	frequency of the second stimulus
StimulusAmplitude2 (V)	amplitude of the second stimulus
StimulusWait (s)	time which is waited after applying the stimulus until the test starts default is the longer of 10/StimulusFrequencyM
MeasurementChannelN	name or number of the Nth measurement channel; N = 1, 2, 3,... 20
TestAnalysis	calculates the amplitude of the signals at the sum and difference of the applied frequencies
TestResults	returns the power spectrum and/or the signal amplitude(s)

TEST TEMPLATE: HARMONIC DISTORTION

- Example
  - Angle-length coupling

Parameter (Unit)	Description
TestClass	HarmonicDistortion
TestName	unique identifier
TestDuration (s)	time of measurement; default is 100/ StimulusFrequency
StimulusChannel	channel name or number of the test input
StimulusFrequency (Hz)	frequency of the stimulus
StimulusAmplitude (V)	amplitude of the stimulus
StimulusWait (s)	time which is waited after applying the stimulus until the test starts default is 10/StimulusFrequency
MeasurementChannelN	name or number of the Nth measurement channel; N = 1, 2, 3,... 20
TestAnalysis	analyzes the measurement channels and calculates the strength of each harmonic up to the Nyquist frequency of the data
TestResults	returns the power spectrum and/or the amplitude of the harmonics

Pseudo-Random Stimulus / Power Spectrum Readout

Parameter (Unit)	Description
TestClass	PseudorandomResponse
TestName	unique identifier
TestDuration (s)	time of measurement
StimulusChannel	channel name or number of the test input
StimulusSource	Random (default)
StimulusRMS (V)	r.m.s. value of the stimulus
StimulusFilter	optional filter which is applied to the noise source before being applied to the test input; default none
StimulusWait (s)	time which is waited after applying the stimulus until the test starts; default is 0.
MeasurementChannelN	name or number of the Nth measurement channel; N = 1, 2, 3,... 20
MeasurementAverages	number of averages; default is 10.
TestAnalysis	calculates the power spectra and averages over consecutive measurements
AnalysisWindow	Hanning, Flat-top or Uniform
TestResults	returns the averaged power spectra after each step

Pseudo-Random Stimulus / Cross Spectrum Readout

Parameter (Unit)	Description
TestClass	PseudorandomCrossSpectrum
TestName	unique identifier
TestDuration (s)	time of measurement
StimulusChannel	channel name or number of the test input
StimulusSource	Random (default)
StimulusRMS (V)	r.m.s. value of the stimulus
StimulusFilter	optional filter which is applied to the noise source before being applied to the test input; default none
StimulusWait (s)	time which is waited after applying the stimulus until the test starts; default is 0.
MeasurementChannelAN	name or number of the Nth measurement A channel; N = 1, 2, 3,... 20
MeasurementChannelBN	name or number of the Nth measurement B channel; N = 1, 2, 3,... 20
MeasurementAverages	number of averages; default is 10.
TestAnalysis	calculates the cross spectra (B/A) and averages over consecutive measurements
AnalysisWindow	Hanning, Flat-top or Uniform
TestResults	returns the averaged power spectra after each step

TEST TEMPLATE EXTENSION: PARAMETER SWEEP

- Example: Mode matching

Parameter (Unit)	Description
Sweep	must be yes for enabling a sweep; default is no
SweepType	Linear (default), Logarithmic or User
SweepParameter	Frequency, Amplitude or Offset (default)
SweepChannelN	name or number of the Nth sweep channel; N = 1, 2,... 20
SweepFrequencyN	used only when SweepParameter is not equal Frequency (default 0)
SweepAmplitudeN	used only when SweepParameter is not equal Amplitude (default 0)
SweepOffsetN	used only when SweepParameter is not equal Offset (default 0)
SweepStartN	start value of the Nth sweep parameter (linear and logarithmic)
SweepStopN	stop value of the Nth sweep parameter (linear and logarithmic)
SweepPointsN	number of points of the Nth sweep parameter (linear and logarithmic)
SweepDirectionN	upwards (default) or downwards
SweepValuesN	list of values used for the sweep (user)
SweepWait (s)	(settling) time to wait before each measurement
TestResults	returns the default test results for each step of the sweep, together with the used sweep parameter(s)

TEST TEMPLATE EXTENSION: PARAMETER OPTIMIZATION

- Example:
  - Determine alignment state which maximizes GW sensitivity
    Use SineResponse for diff. length and sweep WFS dc offset

Parameter (Unit)	Description
Optimization	must be yes for enabling an optimization; default is no
FindType	Minimum (sums automatically over a value function which returns a vector), Maximum, Zero, Value, MinimumAbs (minimizes sum of the absolute values), MaximumAbs, MinimumSqr (minimizes the square sum), MaximumSqr
FindValue	specifies the value to be found (if FindFunction = Value)
FindFunction	value function which is used to evaluate the value to be optimized; default is: CoherentRatio for the sine response; HarmonicRatio for the harmonic distortion test, SidebandRatio for the two tone intermodulation test, SpectralDensity for the pseudo-random response, the pseudo-random cross-correlation, the swept sine and the power spectrum measurement TimeSeries for the time series measurement
FindMethod	Scan (default); this method scans through the parameter channels, one after the other, and keeps the best found value for proceeding steps
OptimizationAdjustment	Best for choosing the best parameters at the end of the optimization test (default) or None for setting the parameters back to the values they had before the optimization.
TestResults	returns the default test results at each step of the optimization, together with the used scan parameter(s) and the value function. returns the best test result, together with the best scan parameter(s) and the best value function at the end of the optimization.

SEARCH TOOL GOALS

- Monitor IFO & Environmental Behavior
  - Access to all data all of the time
  - Ability to perform simple analyses on all channels in parallel
  - Low latency
- IFO Health
  - Dead channel monitor
- Performance Monitoring
  - Abnormal behavior
  - Environmental contamination
- Event Handling
  - Identification and archiving
  - Operator notification
  - Reconstruction & offline analysis

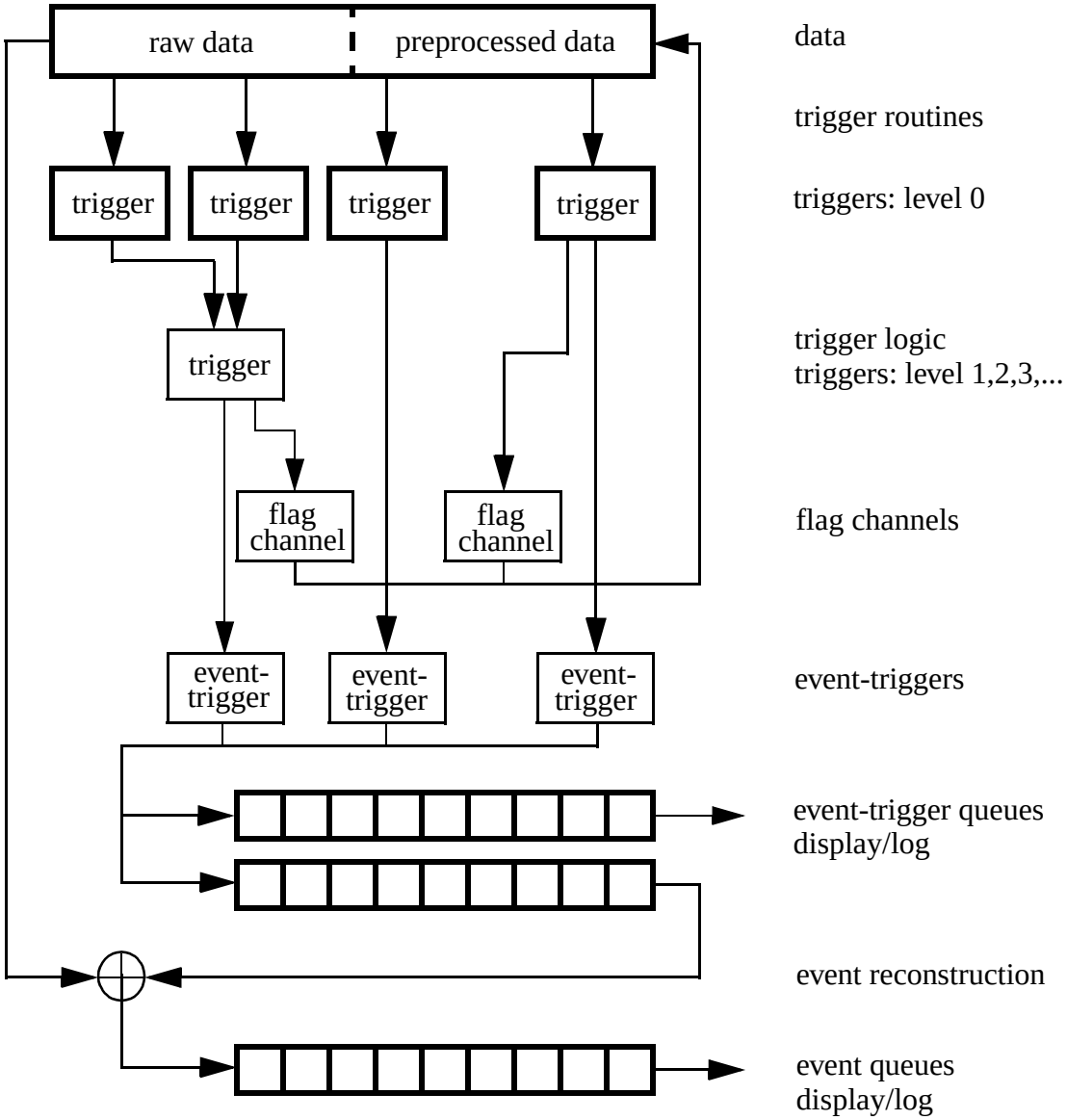
Diagnostic Triggers, Events & Flags

- Events
  - Unusual behavior in data stream
  - Identified by time, type & relevant channels
- Triggers & Vetos
  - Binary output of real-time algorithm
- Data Objects
  - Event
    - Event identifier, e.g. time, type & channel IDs
    - LW data format
  - Event Trigger
    - Event identifier in addition to data blocks
    - LW data format
  - Flag
    - Trigger or filter output
    - Processed data channel

SEARCH TOOL REQUIREMENTS

- Fast Access to Raw Data (16 Hz)
- Compute engine for FFTs
- Channel monitoring
  - Time trace signal level
  - Band limited power
  - New spectral features
  - Time trace rate of change
  - Dead channel (RMS)
- Triggering & Flag channels
  - Highly configurable via trigger banks & levels
  - Simple to complex trigger logic and dependency
  - Flag channels written back to DAQ for archival
  - Event triggers, queues & reconstruction
- Data Capture & Analysis

DIAGNOSTICS SEARCH ENGINE



SEARCH TOOL SPECIFICATIONS

- Data access: all audio channels & FFTs
- Maximum data latency: 125 msec.
- Minimum data history: 2 sec.
- Trigger rate: 16 Hz (fast), 1 Hz (slow)
- Evaluation time for triggers: 50 msec.
- Maximum flag latency: 50 msec.
- Maximum number of triggers: ~1000 / IFO
- Maximum number of event queues: 10 / IFO
- Maximum queue length: 100 events

EVENT TRIGGER PROPERTIES

- ID - trigger identity number
- TYPE - trigger classification
- LEVEL - rank in trigger hierarchy
- TIME - time relative to beginning of trigger interval
- SIZE - amplitude or size of event
- EVALUATION - determines compatability with IFO state
- CONDITION - true / false
- VETO - if true, use veto rather than trigger logic
- EVENT_TRIGGER - specifies output on triggering
- FLAG_CHANNEL - specifies continuous output
- DELAY - delay prior to activation on triggering
- ACTIVE_TIME - active cycles per triggering
- DEAD_TIME - lockout following triggering

PERFORMANCE MONITOR SPECIFICATIONS

- Trigger Rate
  - 16 Hz for GW noise, laser source & SUS coil drivers
  - 1 Hz for remaining monitors
- Priority
  - Normal for 5-20σ events
  - Yellow for events greater than 20σ
  - Red for a factor of 2 or more degradation in GW sensitivity
- Delay
  - 0 sec.
- Dead Time
  - 1 min. for normal priority
  - 15 min. for yellow priority
  - 5 min. for red priority

Broken Channel Specifications

- Trigger Rate
  - 1 Hz
- Trigger Logic
  - Raise if rate is greater than 100 in last 10 min.
- Priority
  - Low for single channel at low rate
  - Normal for single channel
  - Yellow if more than 3 normal priority in last 30 min.
- Delay
  - 0 sec.
- Dead time
  - 10 min. normal priority
  - 20 min. for yellow priority
  - 24 hr. for channels with low alarm rate

TRIGGER EXAMPLES

- Excess GW noise
- Beam intensity
- Laser source AM & FM noise
- Modulation depths & frequencies
- Servo control & error signals
- Narrow band features
- Actuator saturation
- Photodiode temperature, bias & dark current
- Earthquake
- Vibration
- Weather
- Is the excitation system off?

Viewing tool

Top level functions:

- Provide a real-time view of data channels acquired by the DAQ system.
- Provide real-time audio for data channels acquired by the DAQ system.
- Provide monitors of the current performance of the instrument.

Not included (as explicit needs for GDS...)

- off-line visualization
- extensive and flexible analysis tools

Caveat

- system as ‘required’ below not in manpower scope
- both LDAS and GDS in need of system, best unified
    - note, though: GDS has real-time requirement, not LDAS
- zeroth order approach: xvgr/DaDisp, very simple stuff
    - later elaboration as required/possible

Requirements

Maximum delay	200 ms
Channels	DAQ channels FFT channels flag channels
Maximum simultaneous viewing channels	~50
Data preprocessing (audio-frequency channels)	multi-pole filters decimation/smoothing differentiation averaging
Statistical analysis (audio-frequency channels)	histogram mean value, standard deviation, r.m.s., maximum, minimum, highest, lowest
Trigger capability (audio-frequency channels)	simple level trigger flag channel
Storage and print capabilities	snapshots and data traces on user request

Example Viewing trigger

Search for wee dwangies:

- Implemented in search tool using a flag channel

Analysis step	Description
band-pass filer	get rid of the unimportant part of the frequency domain
matched filter	~100 ms to 10 s; look for the wee dwangies
threshold detector	discriminate against non-matches
peak find	find time of occurrence and strength of the wee dwangies
write flag channel	write amplitude of found wee dwangies back as trigger channel data

Visualization:

- trigger viewing tool on flag channel
- choose histogram or time series plot

Viewing tool plot types

Quantities plotted

- Time traces
- Power spectra
- Histograms

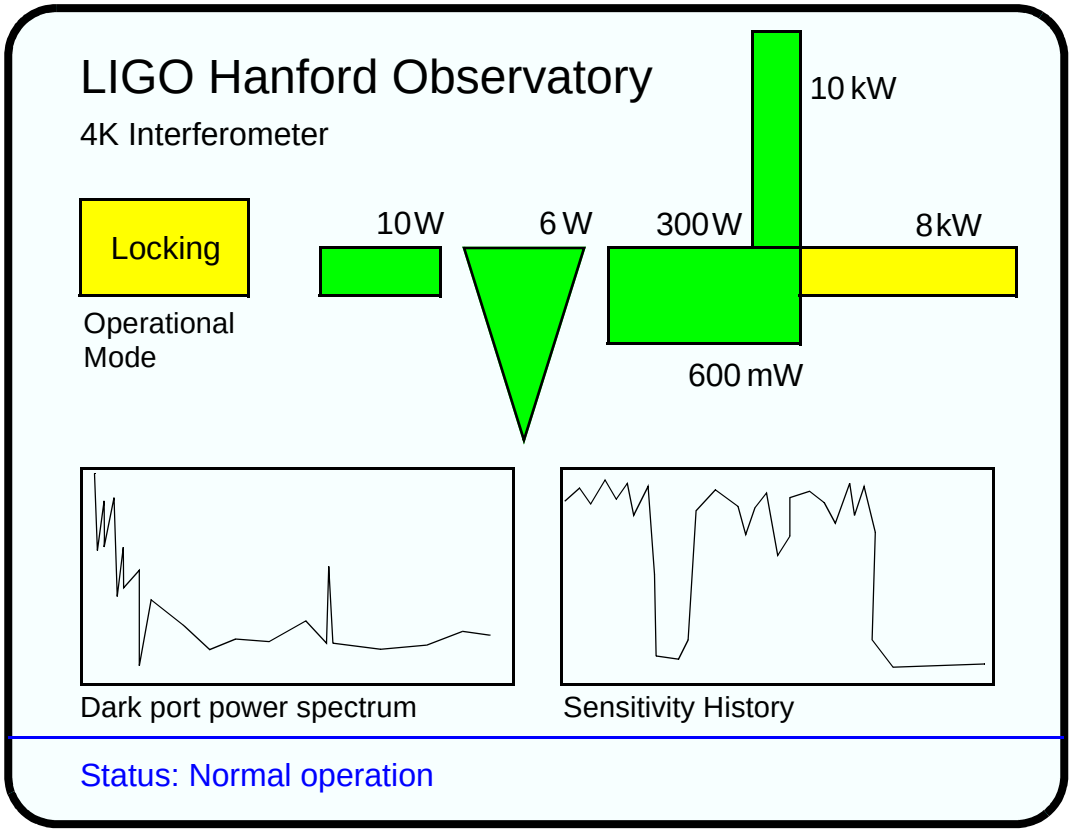
Types of plots

- simple
- roll
- minmax
- persistence
- ...all above with time channel X against time channel Y
- ...all above with multiple (<16) traces
- waterfall

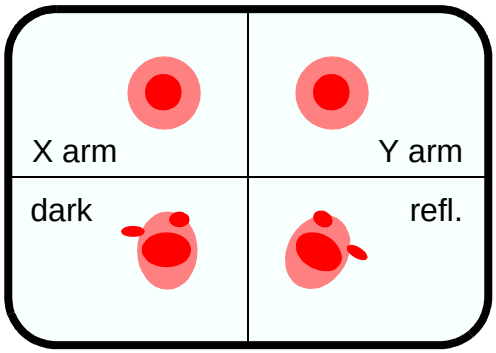
Display functions

Function	Description
Acquisition mode	continuous, single shot, continuously triggered, triggered single shot
Cursor	single/pair of X, Y, X/Y, delta or sideband (with measurement)
Axes	linear, logarithmic
Horizontal zoom	cursors, user defined
Screen dump	postscript to printer/file; traces to display/printer/file
Mouse	get plot values set cursors menu zoom, pan

USER INTERFACE



(a)



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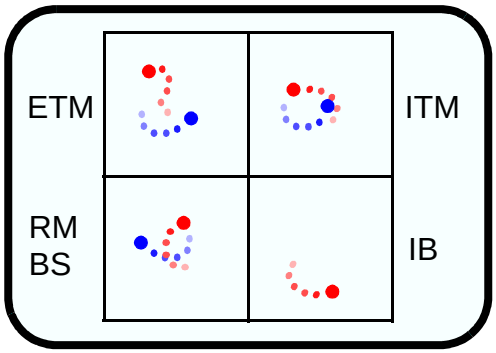


(c)

User interface

Monitor	Description
Operational mode	Large indicator; color code: green: detection mode yellow: locking, going up red: down blue: diagnostics mode
Subsystem status	pictorial representation of the laser, mode cleaner, recycling cavity and the arm cavities; color code: green: locked and running yellow: changing state red: down
Power levels	power level values at the output of the laser, at the output of the mode cleaner, in the recycling cavity, in both arm cavities and at the antisymmetric port
Antisymmetric port FFT	moving average of the power spectrum of the signal measured at the antisymmetric port (histogram updated every second, displayed in persistence mode)
Performance History	Sensitivity history over the last 12 h (trace displayed in roll mode, update every minute)
Length state	The r.m.s. values of the length deviations over the last one second is plotted against time
Alignment state	XY display of the alignment state of all interferometer mirrors and the input beam direction (displayed in persistence mode)
Flag state	The values of some of the flag channels plotted against time
Beam Profiles	video images of the beam in reflection of both arm cavities, at the antisymmetric port and in reflection (color code for intensity)

Miscellaneous

Audio

- same channel access, filtering, as for viewing tool
- ~0.1 sec delay
- 8 kHz BW
- 2 channels maximum

Digital oscilloscopes

- (means for wide-bandwidth signal capture)
- commercial interface software (Labview)
- snapshots or data values visualized or stored

Video cameras

- (simple monitor function)
- images viewable on consoles, storable
- if supported by hardware, capture on trigger using standard tools

Recording Tool

Functions

- writes the diagnostic history archive
- create summaries of environmental history
- enables long-term correlations
- writes log file of events found by search tool

Requirements

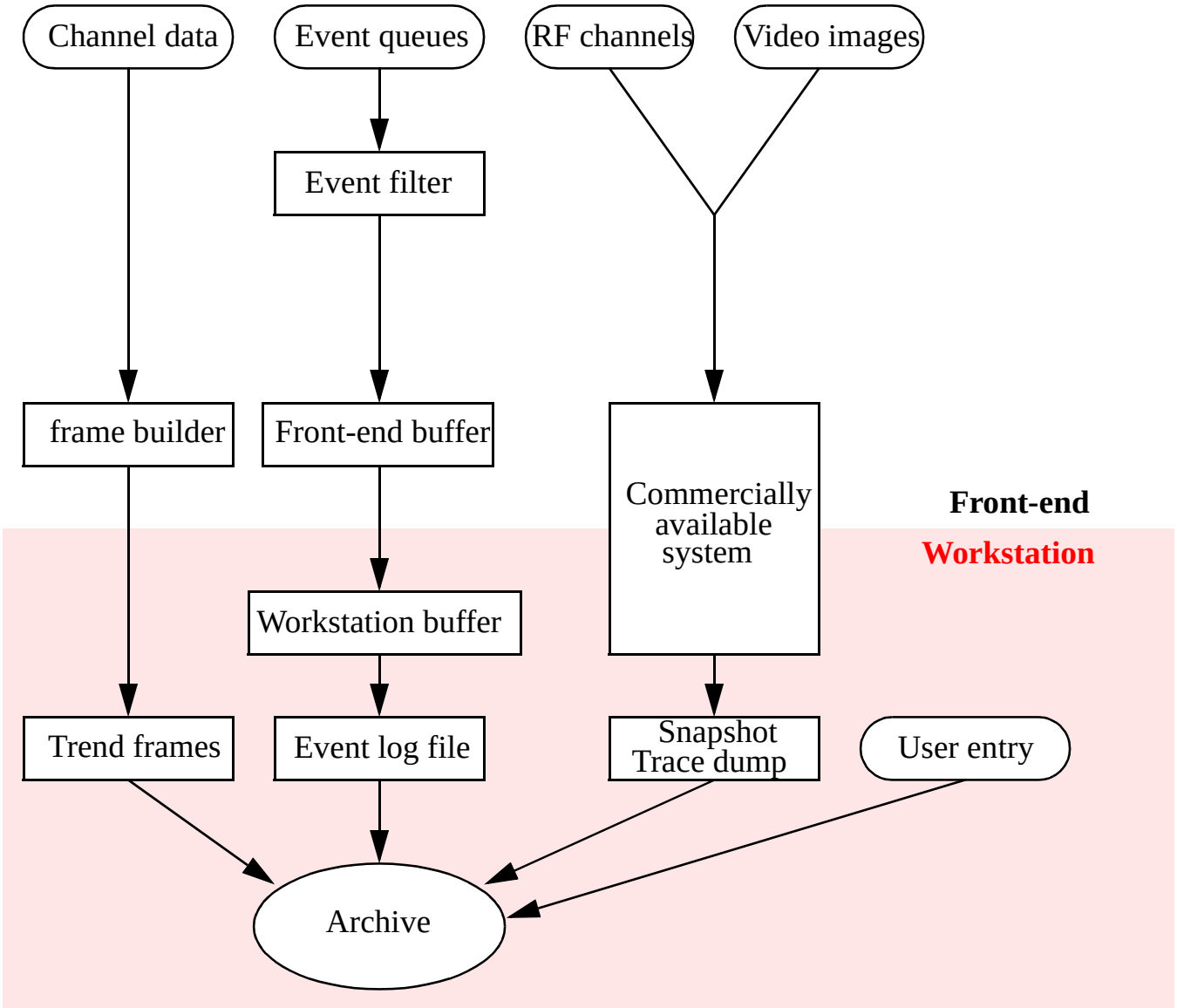
- one year of data on fast-access disk storage
- 1 kB/sec data throughput

Description	Applicable time period	Maximum data rate
Burst data rate	1 minute	1 MB/sec
Short period data rate	1 hour	100 kB/sec
Long period data rate	1 month or longer	1 kB/sec

Data handling

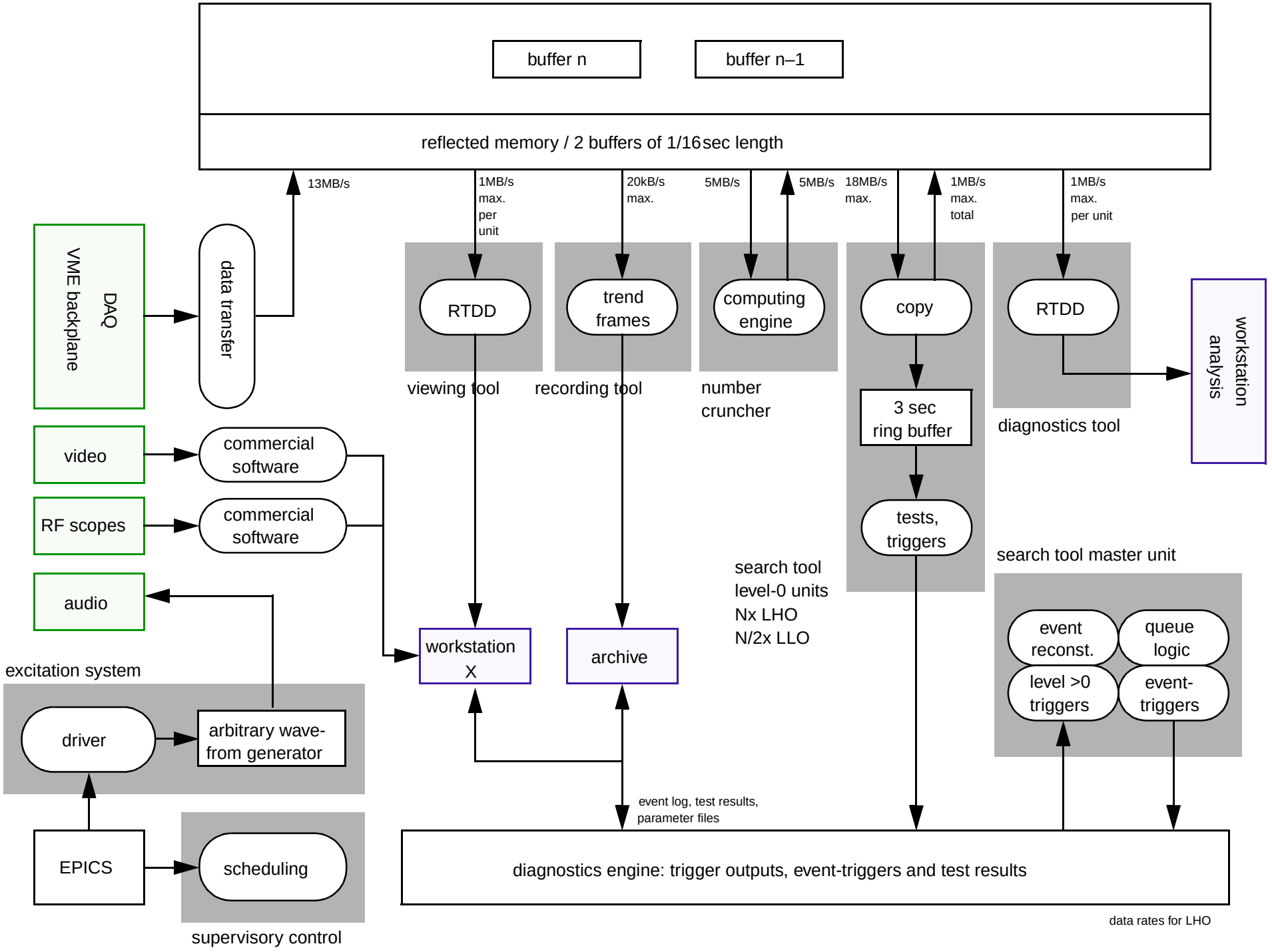
- all channels available to GDS may be recorded
  - › channel, FFT, flag, event queues
- decimation/reduction prescribed for each channel
  - › min/max, EU, rms, peak tracking, LP/HP
- one channel per file, one snapshot per file, one day of events per file

Data flow


Channel data
Event queues
RF channels
Video images
Event filter
frame builder
Front-end buffer
Commercially available system
Front-end
Workstation
Workstation buffer
Trend frames
Event log file
Snapshot Trace dump
User entry
Archive

SOFTWARE DESIGN BASIC CONCEPTS

- Interfaces
  - DAQ, digital subsystems and AWG via reflected memory
  - Back end/Front End & RTDD via CDS ATM network
- Task Scheduling
  - GPS timing
  - Fast processes syncronized to DAQ 16 Hz rate
  - 2/16 sec. maximum delay for inclusion in FB data
- Supervisory Control
  - EPICS MEDM and/or EZCA
- Configuration
  - Parameter files
  - High level configuration via EPICS channels


buffer n
buffer n–1
reflected memory / 2 buffers of 1/16 sec length
13MB/s
1MB/s max. per unit
20kB/s max.
5MB/s
5MB/s
18MB/s max.
1MB/s max. total
1MB/s max. per unit
DAQ
VME backplane
data transfer
RTDD
trend frames
computing engine
copy
RTDD
workstation analysis
viewing tool
recording tool
number cruncher
3 sec ring buffer
diagnostics tool
video
commercial software
RF scopes
commercial software
audio
tests, triggers
search tool level-0 units
Nx LHO
N/2x LLO
search tool master unit
event reconst.
queue logic
level >0 triggers
event-triggers
workstation X
archive
excitation system
driver
arbitrary wave-from generator
event log, test results, parameter files
EPICS
scheduling
diagnostics engine: trigger outputs, event-triggers and test results
supervisory control
data rates for LHO

FRONT END COMMUNICATION

- Reflective Memory Organization => Rolf
- Data rates per IFO
  - transfer from DAQS: 5 MB/s
  - computing engine: 2.5 MB/s (read & write)
  - viewing tools: 1 MB/s (read)
  - search tools: 7.5 MB/s (read), 1 MB/s (write)
  - diagnostics test tool: 1 MB/s (read)
- CDS ATM / ethernet
  - Supervisory communication with back end via EPICS
  - Data transfer via TCP/IP sockets & NFS read/write

FRONT END CPUS

- VME / vxWorks
- Processing Requirements per IFO
  - Computing Engine (FFT on 0.5 # of chns.): ~200 MFLOPS
  - Viewing tool (8th order filter on 50 chn.): ~30 MFLOPS
  - Serach tool (1000 triggers, 2 ops/point): ~ 35 MFLOPS
  - Diagnostics test tool (down-conv. on 10 chn.): ~35 MFLOPS
- Memory Requirements
  - 3 sec. ring buffer of all data (typical)
  - Distributed among search tool processes

BACK END PLATFORMS

- Workstations
  - Unix / Solaris
  - CPU sufficient for deferred analysis
  - Modest memory requirements (~100 MBytes)
- Storage Requirements
  - One year diagnostics test results
  - One month deferred analysis data
  - Parameter files
  - Software executables
  - 100 GBytes (LHO), 50 GBytes (LLO)
  - Video & oscilloscope snapshots

BACK END GUI

- Control Room Consoles
- Remote Login (X session)

GUI	Description
Main diagnostics	Supervisory control Configuration control of diagnostics engine starts diagnostics engine
Alarm handler	shows alarm raised by triggers
Viewing tool	displays plots of data and reconstructed events
Audio	audio-jack to connect a headset
Video	displays images of video cameras
Permanent diagnostics screens	displays permanent diagnostics screens exports permanent diagnostics screen to the web
Diagnostics tests	starts diagnostics tests
Diagnostics analysis & test results	analyzes diagnostics tests and displays results
Parameters editor	Change parameter files
Excitation system	remote-control of a function generator

SOFTWARE LAYERS

- Channel Data Access API
  - Synchronized access to RM
  - Block transfer support
  - Channel address/configuration lookup table
  - CDS DAQ supplied
- Data Archive API
  - Archive index
  - Lightweight data format
    - Plain ASCII
    - ASCII & Binary SDF
  - Parameter files
  - Diagnostic test results
  - Event triggers
  - Video/RF oscilloscope capture (commercial formats)
- Network Transfer API
  - NFS read/write
  - TCP/IP sockets

NETWORK SERVICES

- Real Time Data Distribution
  - Existing API
- Parameter Files
  - NFS files
  - Parameter parsing API
- Recording Tool
  - Trend Frames
  - CDS/LDAS API
- Test Results
  - SDF NFS files
- Events & Event Queues
  - Back end server
  - TCP/IP sockets
- Error Messages
  - Back end server
  - TCP/IP Sockets

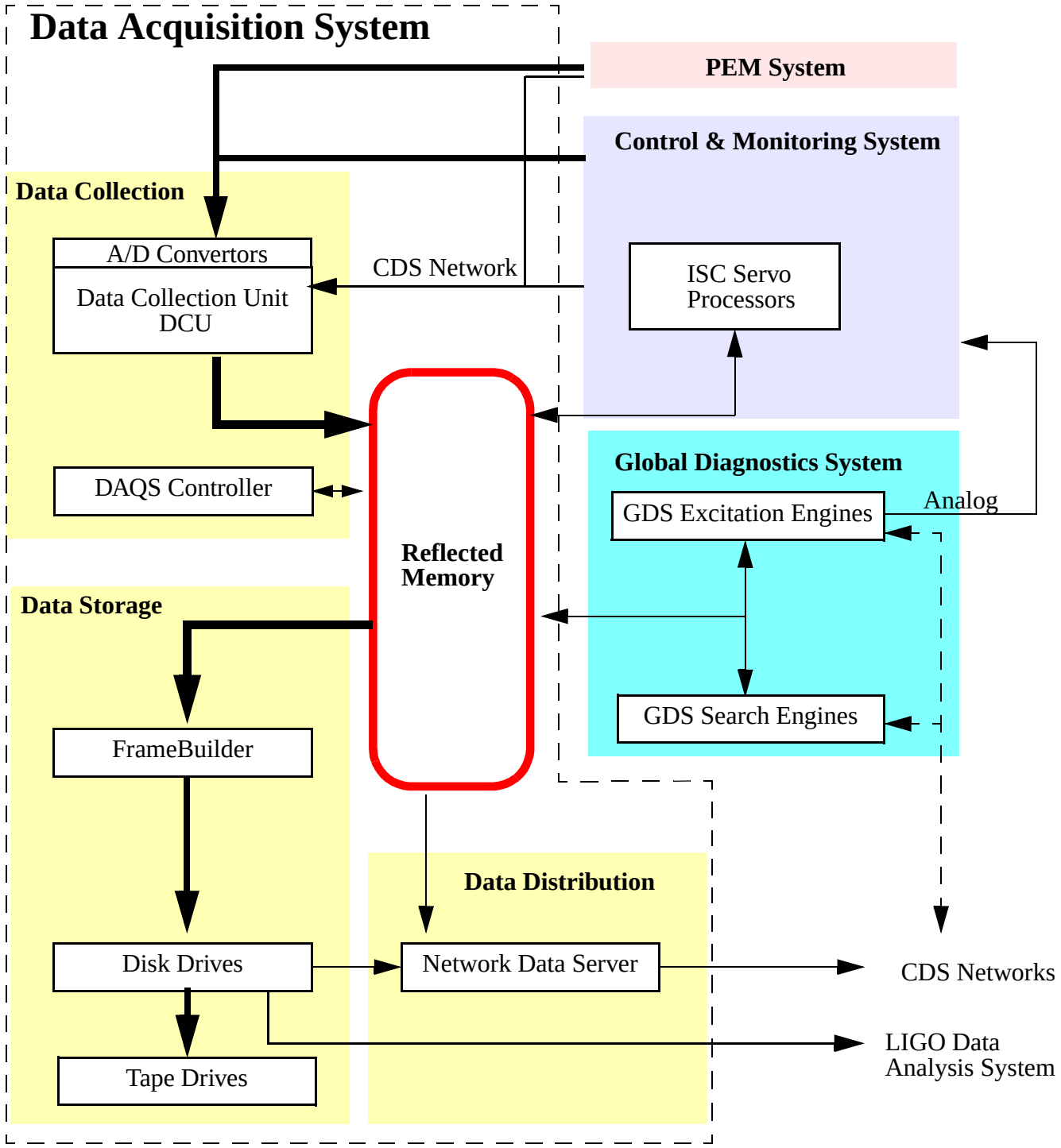
SEARCH TOOL

- Organization
  - Auto-configured with parameter files
  - High level (on/off/reconfigure) control via EPICS
- Operation & Hierarchy
  - Banks of triggers on related channels
  - Low level triggers depend on single channel
  - Higher level triggers operate on lower level triggers
  - Triggers maintain private buffers
- Flag Channels
  - Result of trigger
  - Write back to RM
  - Available as processed data channels to other triggers

EVENT QUEUE MANAGER

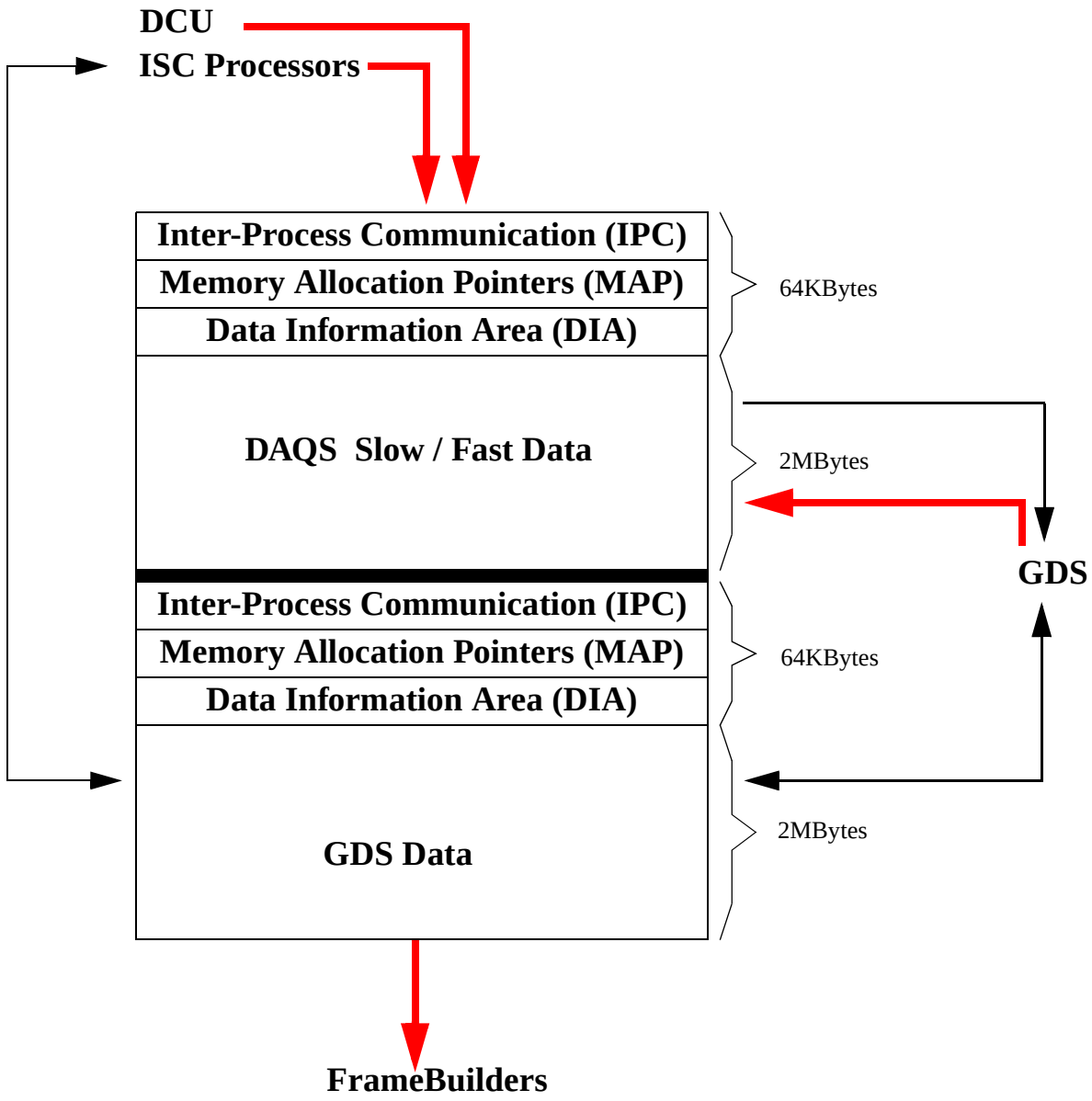
- Back End Server Process
- Evaluates Event for Further Action
  - Notify operator
  - Request data for event reconstruction
  - Event characterization
  - Archive

GDS INTERFACES

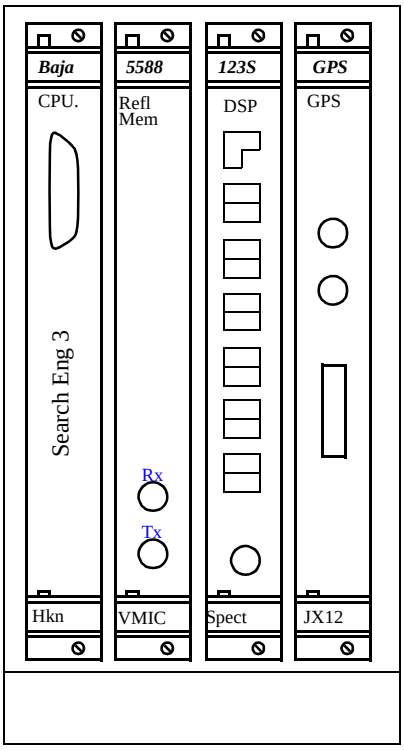


Reflected Memory

- 4MBytes (2 for DAQS, 2 for GDS)
- 30MByte/sec link
- Documented in LIGO T980017-00-C

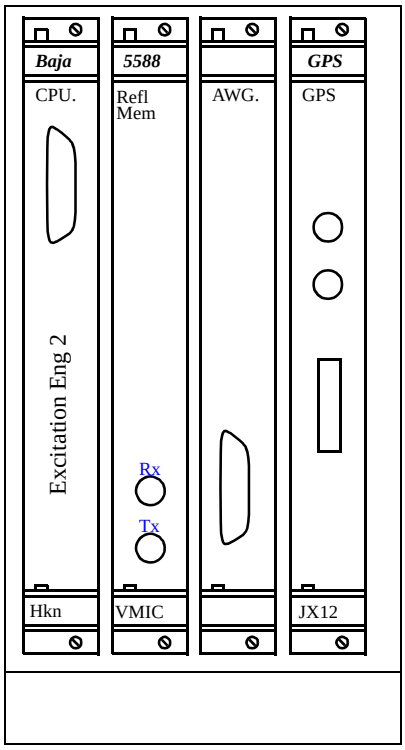


Search Engine



- Real-time system in VME
  - One per IFO
  - One per site for PEM
- MIPS4700 Processor
  - General purpose processing
  - Interface between reflected memory and DSP
- Reflected Memory (4 MByte)
- DSP
  - Spectrum 123S
    - Up to four C40 processors
    - Avg 16K FFT in 1msec (to be tested)
    - Network programming
    - VxWorks interface software to MIPS
    - Extensive optimized math library
  - Alpha Processor ?
- GPS Timing

Excitation Engine



- Real-time system in VME
  - Single unit in LVEA for each IFO
- MIPS4700 Processor
- Reflected Memory (4 MByte)
- Arbitrary Waveform Generator
  - ICS115 DAC
  - 16 bits, 32 individual channels
- GPS Timing