PEM DAQ System General Statements and Requirements

- A combination of commercial and custom instruments and devices are combined to make up the PEM system. It is the job of the PEM DAQ system to provide all the hardware and software necessary to meet the requirements outlined in LIGO T970002.
- All PEM devices are specified and provided by others.
- A detailed reliability analysis has not been conducted. The outcome of the analysis may require changes to the conceptual design presented.

PEM DAQ Supervisory Control and Infrastructure

- Rack Space, CPUs, ADCs

  ››The PEM DAQ system will utilize the existing DAQ system ADC's, VME crates, etc. to as great an extent as possible.
- Communications

  ››The PEM DAQ shall utilize the existing CDS and DAQ network and networking equipment located at the sites.

  ››RS232 and RS485 comms will be handled with MVME162 CPUs and IPs. GPIB comms will use VME-GPIB interface modules.
- Connection of BTE Devices

  ››Temperature and humidity sensors will be 4-20 mA current loop devices connected to corner or midstation with minimum #18 AWG twisted shielded pair cables.

  ››RGA at the BTE mid point will be connected using fiber optic GPIB extender.

PEM DAQ Supervisory Control and Infrastructure (cont'd)

- Connection of PEM Cart

  ››Initial PEM cart will be a stand alone unit.

  ››Cart will be assigned an IP number on CDS network for those times that it is near a CDS network port. This will allow remote control and operation of cart via normal CDS systems.
- Operator Interfaces

  ››Control room interfaces will be developed using standard CDS tools.

  ››Local and portable operator interfaces will be developed using laptop computers, X-windows and standard CDS tools (with the exception of the contamination monitor).
- Time Stamping and Synchronization

  ››Time stamping of data will be better than 10 usec via GPS.

PEM Devices

Table 1: Initial IFO PEM Devices by Model Number

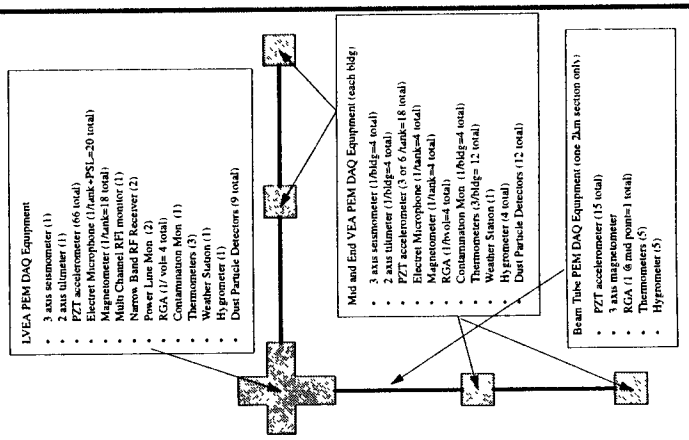
Device	*Model Number*	*Quantity*
Low Freq 3 Axis Seismometers	Guralp CMG-40T Digital Technology Assoc, Inc	5 WA, 3 LA
2 Axis Tiltmeters	Model 520, Biaxial Tiltmeter Applied Geomechanics	5 WA, 3 LA
Accelerometers	Model 7754-1000, Endevco Corp	108 WA, 45 LA
Microphones	Model 33-1067 Radio Shack or model Falcon 4189 Bruel&Kjaer	26 WA, 14 LA
Magnetometers	Model MAG-03MC Bartington Instruments, Ltd	8 WA (initial), 2 LA (initial)
Multi-channel Antenna/Receiver	Model 8902A Hewlett-Packard	1 WA, 1 LA
Narrowband RF Receiver	TBD	2 WA, 1 LA
FMCS Current Monitors	TBD	TBD

G970029-00-D

PEM Devices (cont'd)

Power Line Monitor	Model 8800 Powerscope BMI	2 WA, 1 LA
Residual Gas Analyzers (RGA)	BK M18111, QMG421-3, QMA 430, CP400, IC421 Balzers	9 WA, 5 LA (heads)
Vacuum Contamination Monitor	Model QXM 500 Kurt J. Lesker, Co.	8 WA, 5 LA
Weather Station (Temperature, Humidity, Pressure, Precipitation, Wind Speed and Direction)	Cole Parmer Model 99800-20 or 99800-10	5 WA, 3 LA (1 ea 99800-20 corner bldg, 1 ea 99800-10 other bldgs)
Temperature and Humidity Combined	Omega HX-93	5 WA (BTE)
Temperature Only	TX-92	15 WA, 9 LA (3 /bldg)
Humidity Only	HX-92	4 WA, 2 LA (ea mid and end bldgs)
Dust Particle Detectors	Met One Model 227B	21 WA, 13 LA
Acoustic Noise Generator	TBD	TBD
RFI Generator	TBD	TBD
Magnetic Field Generator	TBD	TBD

PEM Device Locations (WA site)



Low Frequency 3 Axis Seismometer

- One per building, 5 total WA, 3 total LA
- Guralp CMG-40T and CMG-DM16, Digital Technology Assoc., Inc.

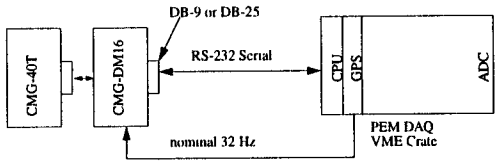


Table 1: Summary of 3 Axis Seismometer Specifications

Voltage Range	*Resolution*	*Sample Rate*
RS232 communications	16 bits	32 samples per second per axis

2 Axis Tiltmeter

- One per building, 5 total WA, 3 total LA
- Model 520, Biaxial Tiltmeter, Applied Geomechanics.

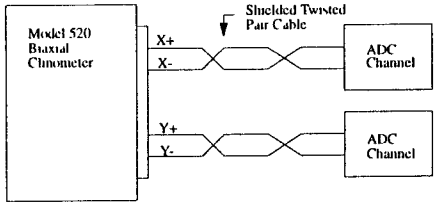


Table 1: Summary of 2 Axis Tilt Meter Specifications

Voltage Range	*Resolution*	*Sample Rate*
+/- 7 Volts (+/- 100 urad/volt for gain setting 1)	16 bits	32 samples per second per axis

Accelerometers

- Located in VE Chambers, beam tube, PEM Cart, 108 total WA, 45 total LA
- Model 7754-1000, 2793M1, Endevco Corp.

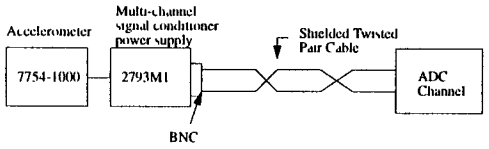
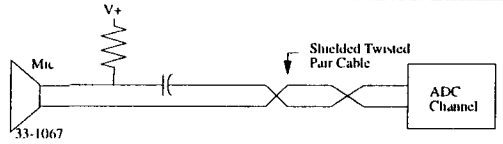


Table 1: Summary of PZT Accelerometer Specifications

Voltage Range	*Resolution*	*Sample Rate*
+/- 5 Volts (+/- 5 G)	16 bits	512 samples per second per axis

Microphones

- Located on tanks, near PSL/IOO, PEM Cart, 26 total WA, 14 total LA
- Model 4198, 2639/69, Bruel & Kjaer or Model 33-1067, Radio Shack



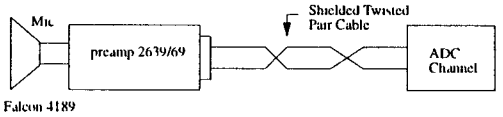


Table 1: Summary of Electret Microphone Specifications

Voltage Range	*Resolution*	*Sample Rate*
+/- 5 Volts (+/- TBD dBA)	16 bits	2048 samples per second per microphone

Magnetometers

- Located on core optics tanks, PEM Cart and outside LVEA, 8 total WA, 2 total LA
- Model MAG-03MC, MAG-03M power supply, Bartington Instruments, Ltd.

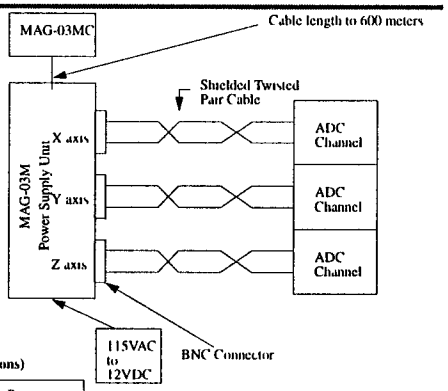
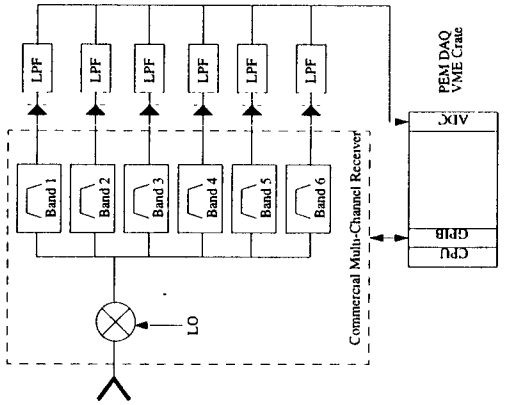


Table 1: Summary of Magnetometer specifications)

Voltage Range	*Resolution*	*Sample Rate*
+/- 10 Volts (+/-70 uT) each axis	16 bits	2048 samples per second per axis

Multi-Channel Receiver



Multi-Channel Receiver (cont'd)

- One per site
- Model 8902A, Hewlett Packard.

Table 1: Summary of Multi-channel Antenna/Receiver Specifications

Voltage Range	*Resolution*	*Sample Rate*
TBD	16 bits	2048 samples per second per axis

Narrowband RF Receiver

- Located near AS photodiode, one per modulation frequency, 2 total WA, 1 total LA
- Design/manufacturer TBD

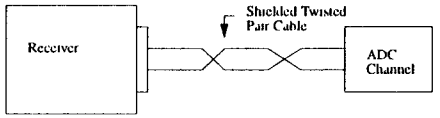


Table 1: Summary of Narrowband RF Receiver Specifications

Voltage Range	*Resolution*	*Sample Rate*
Receiver Output TBD	16 bits	2048 samples per second per receiver

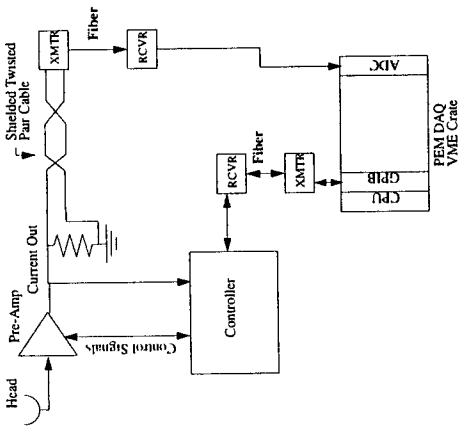
FMCS Current Monitor

- Located on power mains for buildings and provided as part of the civil construction. Total for WA and LA TBD
- Manufacturer TBD
- Requirements TBD

Power Line Monitor

- Used to monitor technical power voltage and current waveforms.
- 2 total WA, 1 total LA
- Model 8800 Power Scope, BMI
- Software will be developed to provide:
  - ››Reading of voltage and current RMS value
  - ››Voltage frequency
  - ››Basic setup of instrument including trigger thresholds
  - ››Reading of captured waveform data.

Residual Gas Analyzers



Residual Gas Analyzers (cont'd)

- One head per isolatable volume, one per PEM Cart, one at BTE mid point, 9 total WA, 5 total LA
- BK M18111, QMG421-3, QMA 430, CP400, IC421, Balzers
- RGA @ BTE midpoint will be connected using fiber optic bus extender and fiber links.

Table 1: Summary of RGA Specifications

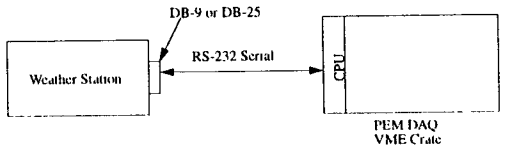
Voltage Range	*Resolution*	*Sample Rate*
RGA Current Output TBD	16 bits	2048 samples per second

Vacuum Contamination Monitor

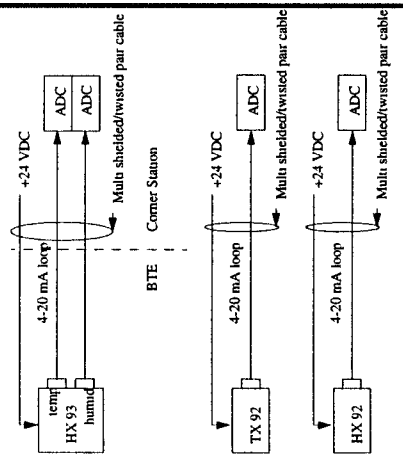
- The vacuum contamination monitor does not connect directly to the PEM DAQ system. It is a stand alone unit to which a controller and portable RGA is connected at approximately monthly intervals. Data collected from the controller and RGA are then analyzed off line to determine the extent of material deposition on the contamination monitor head.
- CDS will provide a means by which data can be collected from the controller and portable RGAs. It is currently envisioned that this will consist of a laptop computer loaded with the software necessary to communicate with the contamination system equipment.
- Manufacturer TBD

Weather Station

- Located in each building, 5 total WA, 3 total LA
- Model 99800-20 and/or 99800-10, Cole Parmer
- Used to measure temp, RH, press precipitation, wind speed and direction
- Reading updated once per minute



Thermometers and Hygrometers



Thermometers and Hygrometers (cont'd)

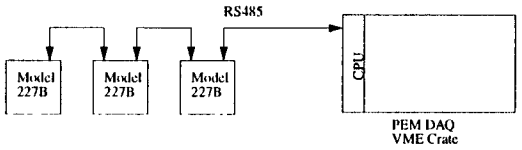
- Located in BTE, inside buildings and outside buildings
- Several models used as follows:

Model	Measurement	Total Quantity
Omega HX-93	WA BTE Temp, RH	5 total WA
Omega HX-92	Mid & End Building RH (inside)	4 total WA, 2 total LA
Omega TX-92	Outside Temp	15 total WA, 9 total LA

Table 1: Summary of Thermometer/Hygrometer Specifications)

Current Range	*Resolution*	*Sample Rate*
Temp 4-20 mA or 0-1V (-20 to +75 C) Humidity 4-20 mA or 0-1V (3 to 95% RH)	16 bits	2 samples per second per measured parameter

Dust Particle Detectors



- Located in optics labs, vac prep. areas, VEAs, portable clean rooms, 21 total WA, 13 total LA
- Model 227B, Met One
- Software will be developed to:
  - Control each monitor
  - poll each monitor on approximately 10 minute intervals
  - monitor internal alarms and status registers
  - Start and stop monitor

Excitation Sources

- Acoustic Noise Generator
- Magnetic Field Generator
- RFI Generator
- Fixed Seismic Excitation
- These systems are currently being designed by PEM. As the systems and requirements for test sequences, control and monitoring and data acquisition become available, PEM DAQ hardware and software will be designed.

PEM Cart

- The PEM Cart has a mixture of devices connected to various communications buses and ADC channels.

Table 1: Summary of PEM Cart Devices Connected to Communications Buses

Device Type	*Interface Type*
Acoustic Noise Generator	GPIB
Magnetic Field Generator	GPIB
RFI Generator	TBD
Seismic Excitation	TBD
Multichannel RF Antenna/ Receiver	GPIB
RGA	GPIB

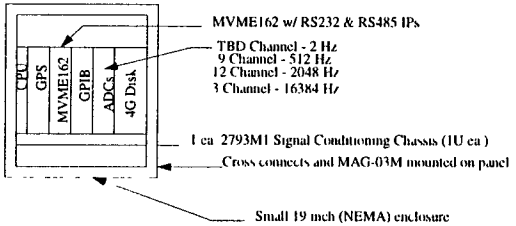
PEM Cart (cont'd)

Table 1: Summary of PEM Cart Devices Connected to ADCs

Device Type	*Voltage Range & Scaling*	*Sample Rate (Samples/sec)*	*Total Sample Rate*
PZT Accelerometer (3 each)	+/- 5 Volts = +/- 5 G	512	(3 x 3) x 512 = 4 5K
Magnetometer (1 each)	+/- 10 Volts = +/- 70 uT	2048	1 x 3 x 2048 = 6K
Microphone (2 each)	TBD	2048	2x 2048 = 4K
Multi-channel RFI Antenna/ Receiver (1 each, 6 channels)	TBD	2048	6 x 2048 = 12K
RGA Controller (1each)	TBD	2048	1 x 2048 = 2K
Temperature Sensors (TBD each)	4-20 mA or 0-1V (-20 to +75 C)	2	TBD x 2 = TBD
Humidity Sensors (TBD each)	4-20 mA or 0-1V (3 to 95% RH)	2	TBD x 2 = TBD
Acoustic Noise Generator Monitor	TBD	16384 (intermittent)	
Magnetic Field Generator Monitor	TBD	16384 (intermittent)	
RFI Generator Monitor	TBD	16384 (intermittent)	
Seismic Excitation	TBD	TBD	
		Total	28 5K samples/sec

PEM DAQ Cart Conceptual Design

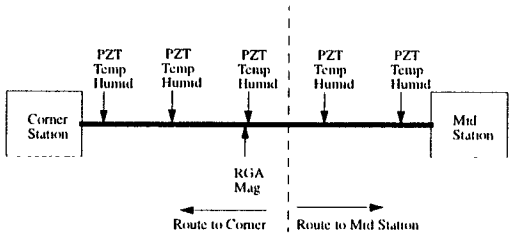
- It is proposed that the PEM DAQ portion of the PEM cart be a stand alone VME based solution.



- Power Requirements: 115 VAC, ~ 1 KWatt
- Space Requirements: Clear footprint ~2 ft. x 2 ft. x 3 ft. tall
- As time and the design of the PEM system progress, additional carts and/or subsets of the cart will be developed.

BTE Devices

- BTE devices will be controlled and monitored from the corner station and the mid station.



- Cables will be routed inside the BTE and secured using TBD method.

Corner Station PEM DAQ

- The Corner Station has a mixture of devices connected to various communications buses and ADC channels.

Table 1: Summary of Corner Station PEM Devices Connected to Communications Buses

Device Type	*Location*	*Interface Type*
3 Axis Seismometer	LVEA Slab (TBD)	RS232
Multichannel RF Antenna/ Receiver	TBD	GPIB
Power Line Monitor	TBD	GPIB/RS232
RGA	1 ea isolatable volume - 4 total (TBD) 1 ea BTE Volume	GPIB/RS232
Weather Station	TBD	RS232
Dust Particle Detector	1 ea - 3 Portable Clean Room 1 ea - OSB Optics Lab, OSB Vac Prep Room 2 ea - LVEA 2 ea = PSL/IOO	RS485

Corner Station PEM DAQ (cont'd)

Table 1: Summary of Corner Station PEM Devices Connected to ADCs

Device Type	*Locations*	*Voltage Range & Scaling*	*Sample Rate (Samples/sec)*	*Total Sample Rate*
BTE Temperature Probe	1 ea - BTE0, BTE500, BTE1000	4-20mA = -20 to +75 C	2	3 x 2 = 6
BTE Humidity Probe	1 ea - BTE0, BTE500, BTE1000	4-20mA = 3 to 95% RH	2	3 x 2 = 6
Outside Temperature Probe	3 ea - outside corner station	4-20mA = -20 to +75 C	2	3 x 2 = 6
Inside Humidity Probe	1 ea - inside LVEA	4-20mA = 3 to 95% RH	2	3 x 2 = 6
2 Axis Tiltmeter	1 - LVEA Slab (TBD)	+/- 2 Volts = +/- 20 degrees	32	2 x 32 = 64

Table 1: Summary of Corner Station PEM Devices Connected to ADCs

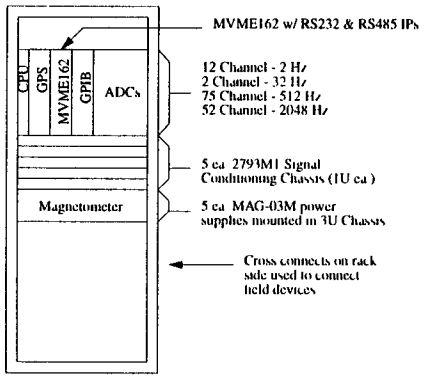
Device Type	*Locations*	*Voltage Range & Scaling*	*Sample Rate (Samples/sec)*	*Total Sample Rate*
PZT Accelerometer	3 ea - PSL1, PSL2, HAM1, HAM2, HAM3, HAM4, HAM5, HAM6, HAM21, HAM22, HAM23, HAM24, HAM25, HAM26, BSC1, BSC2 ITM21, ITM22 3 ea - BTE0, BTE500, BTE1000 6 ea - ITM1, ITM2	+/- 5 Volts = +/- 5 G	512	(21 x 3) + (2 x 6)= 75 devices 75 x 512 = 37 5K
Magnetometer	1 ea - RM1, BS1, ITM1, ITM2 1ea BTE1000 1 ea outside LVEA 3 axis each device	+/- 7 Volts = +/- 70 uT	2048	6 x 3 x 2048 = 32K
Microphone	1 ea - PSL1, PSL2, HAM1, HAM2, HAM3, HAM4, HAM5, HAM6, HAM21, HAM22, HAM23, HAM24, HAM25, HAM26, BSC1, BSC2 ITM21, ITM22, ITM1, ITM2	TBD	2048	20 x 2048 = 40K
Multi-channel RFI Antenna/Receiver	1 ea - LVEA (TBD) 6 channels each device	TBD	2048	6 x 2048 = 12K

Table 1: Summary of Corner Station PEM Devices Connected to ADCs

Device Type	*Locations*	*Voltage Range & Scaling*	*Sample Rate (Samples/sec)*	*Total Sample Rate*
Narrowband RF Receiver	2 ea - HAM6, HAM26	TBD	2048	4 x 2048 = 8K
RGA	1 ea. LVEA isolatable volume - 4 total (TBD) 1 ea BTE1000	TBD	2048	5 x 2048 = 10K
			Total	139 5K samples/sec

Corner Station PEM DAQ Conceptual Design

- One of the existing DAQ racks located in the corner station will be used
- Some of the BTE devices will be monitored and controlled from the corner station rack.
- Communications to RS 232 and RS 485 devices will be via MVME162 with IP comms cards.
- Communications to GPIB devices via VME GPIB interface card



Mid Station PEM DAQ

- The Mid Station has a mixture of devices connected to various communications buses and ADC channels.

Table 1: Summary of Mid Station PEM Devices Connected to Communications Buses

Device Type	*Location*	*Interface Type*
3 Axis Seismometer	VEA Slab (TBD)	RS232
RGA	1 ea isolatable volume - 4 total (TBD)	GPIB/RS232
Weather Station	TBD	RS232
Dust Particle Detector	1 ea - 1 Portable Clean Room 1 ea - Optics Lab 1 ea - VEA	RS485

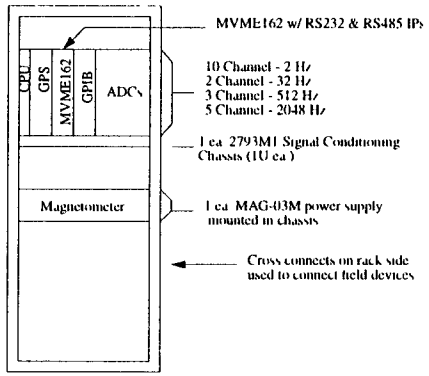
Mid Station PEM DAQ (cont'd)

Table 1: Summary of Mid Station PEM Devices Connected to ADCs

Device Type	*Locations*	*Voltage Range & Scaling*	*Sample Rate (Samples/sec)*	*Total Sample Rate*
BTE Temperature Probe	1 ea - BTE1500, BTE2000	4-20mA = -20 to +75 C	2	2 x 2 = 4
BTE Humidity Probe	1 ea - BTE1500, BTE2000	4-20mA = 3 to 95% RH	2	2 x 2 = 4
Outside Temperature Probe	3 ea - outside mid station	4-20mA = -20 to +75 C	2	3 x 2 = 6
Inside Humidity Probe	1 ea - inside VEA	4-20mA = 3 to 95% RH	2	3 x 2 = 6
2 Axis Tiltmeter	1 - LVEA Slab (TBD)	+/- 2 Volts = +/- 20 degrees	32	2 x 32 = 64
PZT Accelerometer	3 ea - chamber	+/- 5 Volts = +/- 5 G	512	3 x 512 = 1.5K
Magnetometer	1 ea - chamber 3 axis each device	+/- 7 Volts = +/- 70 uT	2048	1 x 3 x 2048 = 6K
Microphone	1 ea - chamber	TBD	2048	1x 2048 = 2K
RGA	1 ea isolatable volume - 1 total (TBD)	TBD	2048	1 x 2048 = 2K
			Total	11.5K samples/ sec per mid station

Mid Station PEM DAQ Conceptual Design

- One of the existing DAQ racks located in the mid station will be used
- Some of the BTE devices will be monitored and controlled from the one mid station rack.
- Communications to RS 232 and RS 485 devices will be via MVME162 with IP comms cards
- Communications to GPIB devices via VME GPIB interface card



End Station PEM DAQ

- The End Station has a mixture of devices connected to various communications buses and ADC channels.

Table 1: Summary of End Station PEM Devices Connected to Communications Buses

Device Type	*Location*	*Interface Type*
3 Axis Seismometer	VEA Slab (TBD)	RS232
RGA	1 ea isolatable volume - 4 total (TBD)	GPIB/RS232
Weather Station	TBD	RS232
Dust Particle Detector	1 ea - LVEA 1 ea - Optics Lab 1 ea - VEA	RS485

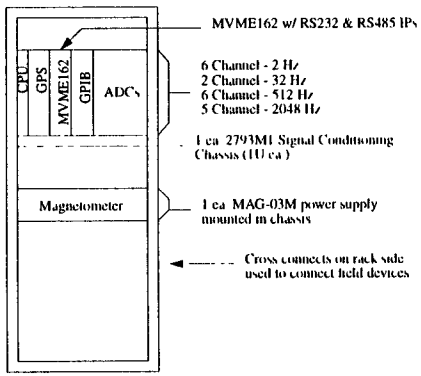
End Station PEM DAQ (cont'd)

Table 1: Summary of End Station PEM Devices Connected to ADCs

Device Type	*Locations*	*Voltage Range & Scaling*	*Sample Rate (Samples/sec)*	*Total Sample Rate*
Outside Temperature Probe	3 ea - outside end station	4-20mA = -20 to +75 C	2	3 x 2 = 6
Inside Humidity Probe	1 ea - inside VEA	4-20mA = 3 to 95% RH	2	3 x 2 = 6
2 Axis Tiltmeter	1 - LVEA Slab (TBD)	+/- 2 Volts = +/- 20 degrees	32	2 x 32 = 64
PZT Accelerometer	6 ea - ETM chamber	+/- 5 Volts = +/- 5 G	512	6 x 512 = 3K
Magnetometer	1 ea - chamber 3 axis each device	+/- 7 Volts = +/- 70 uT	2048	1 x 3 x 2048 = 6K
Microphone	1 ea - chamber	TBD	2048	1x 2048 = 2K
RGA	1 ea isolatable volume - 1 total (TBD)	TBD	2048	1 x 2048 = 2K
			Total	13K samples/sec per end station

End Station PEM DAQ Conceptual Design

- One of the existing DAQ racks located in the mid station will be used
- Communications to RS 232 and RS 485 devices will be via MVME162 with IP comms cards
- Communications to GPIB devices via VME GPIB interface card.



PEM DAQ Outstanding Issues and Requirements

- Requirements definition for:
  - ››Acoustic Noise Generators, RFI Generators, Magnetic Field Generators, Fixed Seismic Excitation Systems.
  - ››Vacuum Contamination Monitoring
  - ››Multi-Channel Receivers- sequences, functions, etc
  - ››Narrow Band RF Receiver
  - ››FMCS Current Monitors
  - ››Power Line Monitors- sequences, functions, etc.
  - ››Thunderstorm Monitoring
- Final placement of all instruments and devices
- System reliability, availability requirements

PEM DAQ Preliminary Design Phase

- Software driver development for:
  - ››Low Frequency Seismometers
  - ››Multi-Channel Receivers
  - ››Power Line Monitors
  - ››RGAs
  - ››Weather Stations
  - ››Dust Particle Detectors
- Additional requirements definition for:
  - ››All excitation sources
  - ››Thunderstorm monitoring
- Detailed designs and procurements for cart hardware and software in order to meet summer delivery must start immediately.

PEM DAQ Cost, Schedule, Technical Risk

- Cost
  - ››Baseline Cost Estimate:
    - —Design Manpower: $135K
    - —Prototype hardware: $20K
    - —WA Equipment. $35K manpower + $290K hardware = $325K
    - —LA Equipment $23.5K manpower + $306K hardware = $329K
    - —Total = $809K
  - ››Estimate to Complete:
    - —Design Manpower. $252K
    - —WA Equipment. $318K
    - —LA Equipment: TBD
    - —Total = $252K + $318K = $570K (WA only)

PEM DAQ Cost, Schedule, Technical Risk

- Cost (cont'd)
  - ››Analysis:
    - —Baseline: Design + WA Equipment = $480K (full up PEM)
    - —ETC: Design + WA Equipment = $570K (initial PEM only)
    - —Major difference between baseline and ETC is that the baseline was mostly hardware with little software while the current system has approx. the same hardware and more software development (~1 manyear w/o LA). The baseline was also for the full PEM while the ETC is for a reduced system
  - ››Cost Risk: Medium-
    - —Complex test sequences or increased functionality for instruments could increase software manpower requirements.
    - —Space constraints in the DAQ racks and VME crates may require purchase of additional VME hardware, reflective memory, etc.
    - —Possible use of redundant systems, etc., dictated by availability may increase cost and complexity

PEM DAQ Cost, Schedule, Technical Risk

- Schedule
  - ››PEM DAQ schedule is being reworked as part of the on going replan exercise. Current schedule calls for:
    - —Preliminary design complete: Aug 97
    - —Final design complete: Nov 97
    - —WA equipment procured: Feb 98
    - —WA software development complete: Feb 98
  - ››PEM Cart Operation by Summer 97 could be a problem given current CDS staffing
  - ››Schedule Risk: High- CDS resources will need to be diverted from other tasks to have a chance of meeting the schedule. Definition of test sequences, etc. for excitation sources and the cart in general are needed ASAP Procurement of components for cart must start immediately.

PEM DAQ Cost, Schedule, Technical Risk

- Technical
  - ››Most devices are commercially available and the interfaces are well defined.
  - ››Excitation Sources could be technically challenging if test sequences are complex.
  - ››Definition is needed for Thunderstorm monitoring.
  - ›› Location of RGA at BTE mid point could be problem given the ambient environment.
  - ››Technical Risk: Low to Medium