Input Optics CDS Preliminary Design

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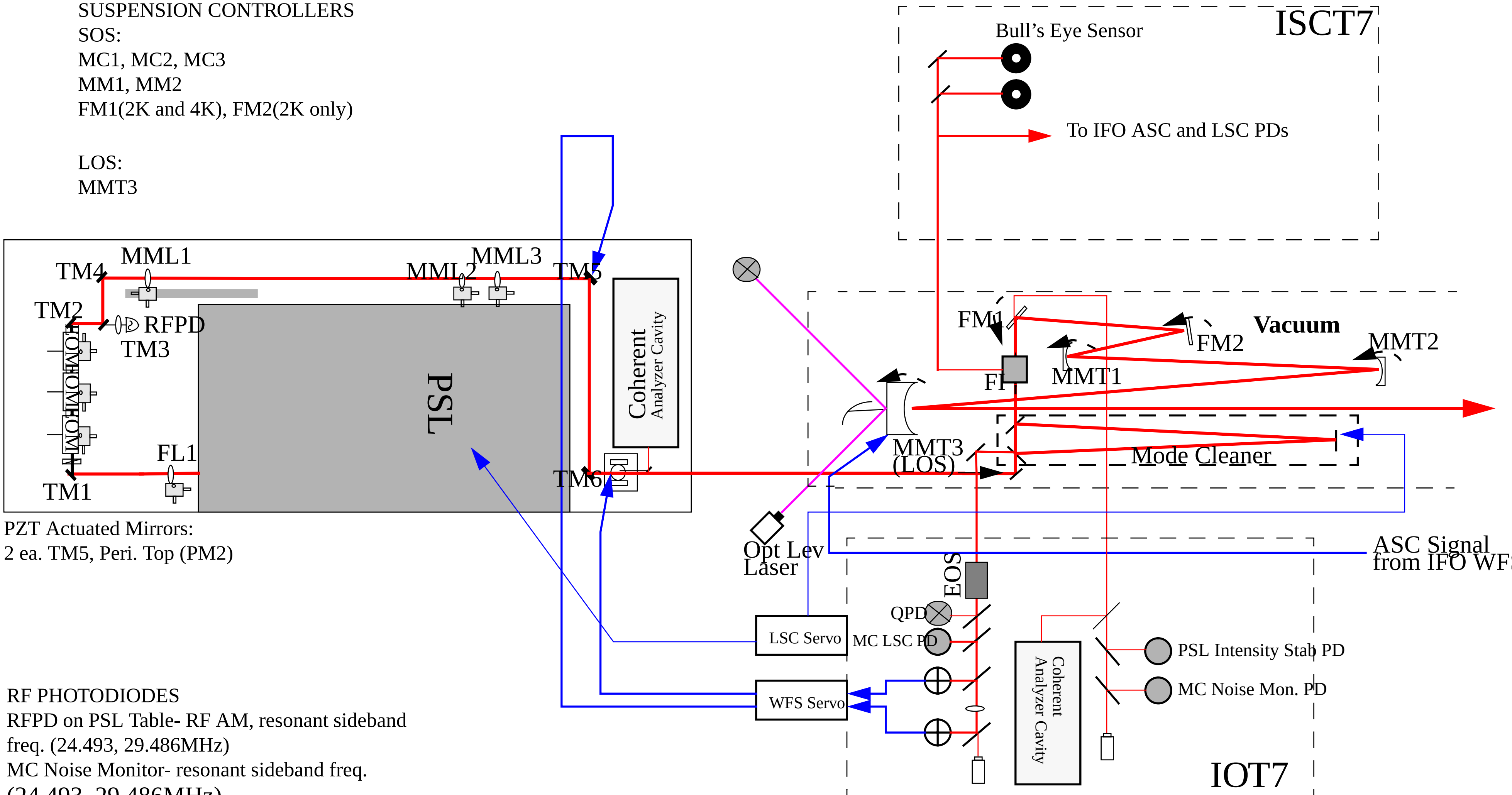
IOO Devices

- The IOO has many types of devices/systems that need to be controlled and monitored:
  - Suspension Controllers
  - Mode Cleaner Alignment Controls
  - Mode Cleaner Length Controls
  - Optical Levers
  - Cameras
  - Mode Matching Controls
  - Analyzer Cavities
  - RF Photodetectors

SUSPENSION CONTROLLERS
SOS:
MC1, MC2, MC3
MM1, MM2
FM1(2K and 4K), FM2(2K only)

LOS:
MMT3



PZT Actuated Mirrors:
2 ea. TM5, Peri. Top (PM2)

RF PHOTODIODES
RFPD on PSL Table- RF AM, resonant sideband freq. (24.493, 29.486MHz)
MC Noise Monitor- resonant sideband freq. (24.493, 29.486MHz)

IOO Suspension Control Requirements

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Table 1: IOO Suspension Controller Noise and Dynamic Range Requirements

Optic	*Type of Controller*	*Dynamic Range Length and Angle*	*Noise*
MMT1, MMT2	SOS	500 um p-p >5 mrad p-p	$5x10^{-16}\left(\frac{f}{40}\right)^{-2}(m/(\sqrt{Hz}))$ f > 40 Hz
MC1, MC2, MC3	SOS	27 um p-p 1.5 mrad p-p	$3.8x10^{-18}\left(\frac{f}{40}\right)^{-2}(m/(\sqrt{Hz}))$ f > 40 Hz
FM1, FM2 (2Km IFO only)	SOS	500 um p-p > 5 mrad p-p	$5x10^{-16}\left(\frac{f}{40}\right)^{-2}(m/(\sqrt{Hz}))$ f > 40 Hz
MMT3	LOS	40 um p-p 1 mrad p-p	$5x10^{-16}\left(\frac{f}{40}\right)^{-2}(m/(\sqrt{Hz}))$ f > 40 Hz

IOO Suspension Controls Design

- Suspension Controllers will have a flat response from DC to >10KHz for the LSC input
- MMT3 will use an SOS controller in order to simplify the system
- The max drive current and predicted noise will be:

Table 1: Coil Driver Series Resistance vs. Controller

Controller	*Series Resistance*	*Max. Drive Current*	*Predicted Noise*
MMT1, MMT2, FM1, FM2	430 ohms	58 mAp-p	$1.6x10^{-17}\left(\frac{f}{40}\right)^{-2}(m/(\sqrt{Hz}))$ f > 40Hz
MC1, MC2, MC3	7.82K ohms	3.20 mAp-p	$3.8x10^{-18}\left(\frac{f}{40}\right)^{-2}(m/(\sqrt{Hz}))$ f > 40 Hz
MMT3	227 ohms	110 mAp-p	$5.2x10^{-19}\left(\frac{f}{40}\right)^{-2}(m/(\sqrt{Hz}))$ f > 40 Hz

IOO Suspension Status

- FDR scheduled for 5/20/98.
- Oliver is in the process of building the sensor actuator heads for WA 2K IO. They should be complete by 5/30/98.
- SOS controller prototype tests are complete, final layout is complete and the fab contract for 25 units will be awarded within 2 weeks.
- Satellite module prototype tests are complete, final layout is in process fabrication of final units should begin within the next 2 weeks.
- WA 2K IO rack cross connect wiring is complete and has been shipped to Hanford.
- WA and LA SUS test stand cross connect wiring is complete and has been shipped to the sights.
- Software and displays from Caltech test stands will be copied and modified to be used as WA 2K software, i.e. tag name changes, etc.

IOO Vacuum Cabling and Feedthroughs

- Vacuum cabling used for the input optics suspension systems will MDC model KAP-R25-300 cable with MDC model D25-PCC 25 pin D connectors on each end.
- Vacuum feedthroughs will be MDC model 633002-1000.
- Vacuum port assignments will be as shown in T980040.
- Vacuum feedthroughs, cables and ports, etc. for IO have been received or will be delivered in the near future.
- L. Jones is designing the clamps, etc. for stack cabling.

  »Ribbon cable clamps have been designed and 12 assemblies are due by the end of May.

  »HAM seismic stack cable form is also due by end of May. This will be used to test cable assemblies, mountings, etc. prior to installation into vacuum system.

Mode Cleaner Alignment Requirements

- Maintain mode cleaner alignment to better than 2 x 10^{-5} rad
- The modulation frequencies for the 2 Km and 4 Km IFOs shall be as shown in the table below.

Table 1: IOO ASC Modulation Frequencies

IFO	*WFS Modulation Frequency*
2 Km	26.7 MHz
4 Km	33.3 MHz

- mirrors used for mode cleaner alignment control (PM2 and TM5) are actuated using Physik Instruments SI-330 PZT actuated mirrors and controller

Mode Cleaner Alignment Controls

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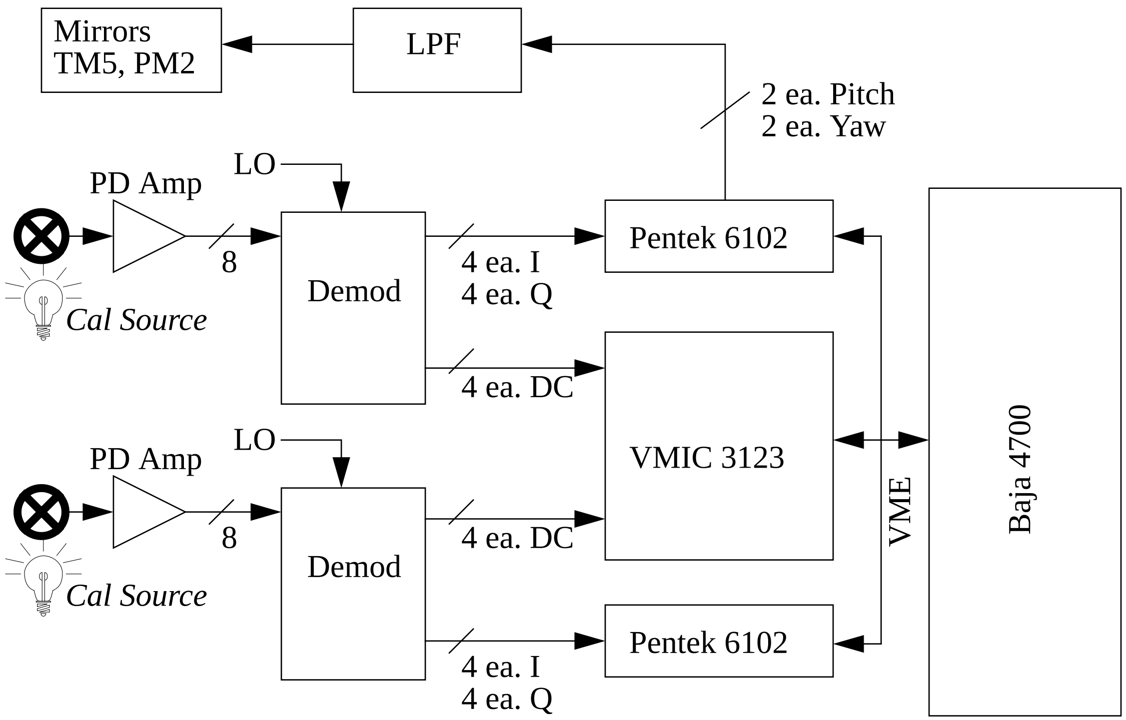

Figure 1: Mode Cleaner Alignment Controls

Mode Cleaner Alignment Controls

- The mode cleaner alignment controls will be used as a prototype for the IFO ASC system.
- The system could be done using analog hardware with an EPICS interface.
- WFS demodulator boards, photodetectors, ADC/DAC modules are identical to those used in the IFO ASC system.
- The sample rate for the ADCs and DACs will be 2048 and 8192, respectively.

Mode Cleaner Alignment Control Software

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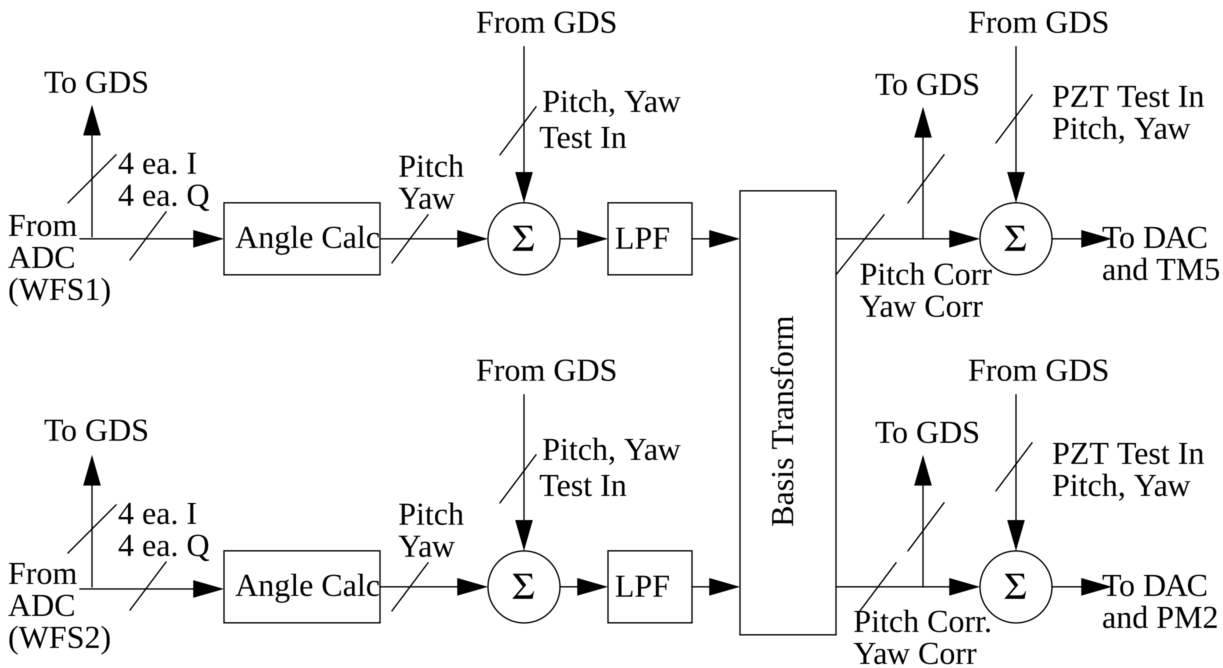


Mode Cleaner Alignment Software

- The servo filter will be a single pole LPF at 0.1Hz.
- The basis transform will be:

$$TM5_{yaw} = A_{TM5yaw} \times WFS1_{yaw} + B_{TM5yaw} \times WFS2_{yaw}$$

$$TM5_{pitch} = A_{TM5pitch} \times WFS1_{pitch} + B_{TM5pitch} \times WFS2_{pitch}$$

$$PM2_{yaw} = A_{PM2yaw} \times WFS1_{yaw} - B_{PM2yaw} \times WFS2_{yaw}$$

$$PM2_{pitch} = A_{PM2pitch} \times WFS1_{pitch} - B_{PM2pitch} \times WFS2_{pitch}$$

where:

$$1 \cong A_{xx} \cong B_{xx}$$

- The interface to the GDS system will be via reflective memory as described in T9700172 and T980026.

Mode Cleaner Alignment Software

››Operator interfaces and software will be developed that will allow the operator to view:

›› PD outputs

››demodulator outputs

››PZT outputs

››adjust servo gains

››enable the servo loops

››monitor and adjust transformation matrix coefficients

››monitor the status of the test inputs from GDS, i.e. which test inputs are active.

Mode Cleaner Alignment Status

- Prototype servo software for test stand at Caltech has been written and tested. GDS interface and functions need to be added. CDS is currently working on an architecture that allows the front end servo functions to be de-coupled from the GDS/DAQ functions. This will involve multiple processors, but will minimize the impact of changes on either side of the interface.
- The WFS to VME cross connect chassis needs to be designed.
- WFS demod and PD boards for use on first IO system are ready.
- VME components for first IO system are in house.
- Alignment system wiring diagrams have been started.

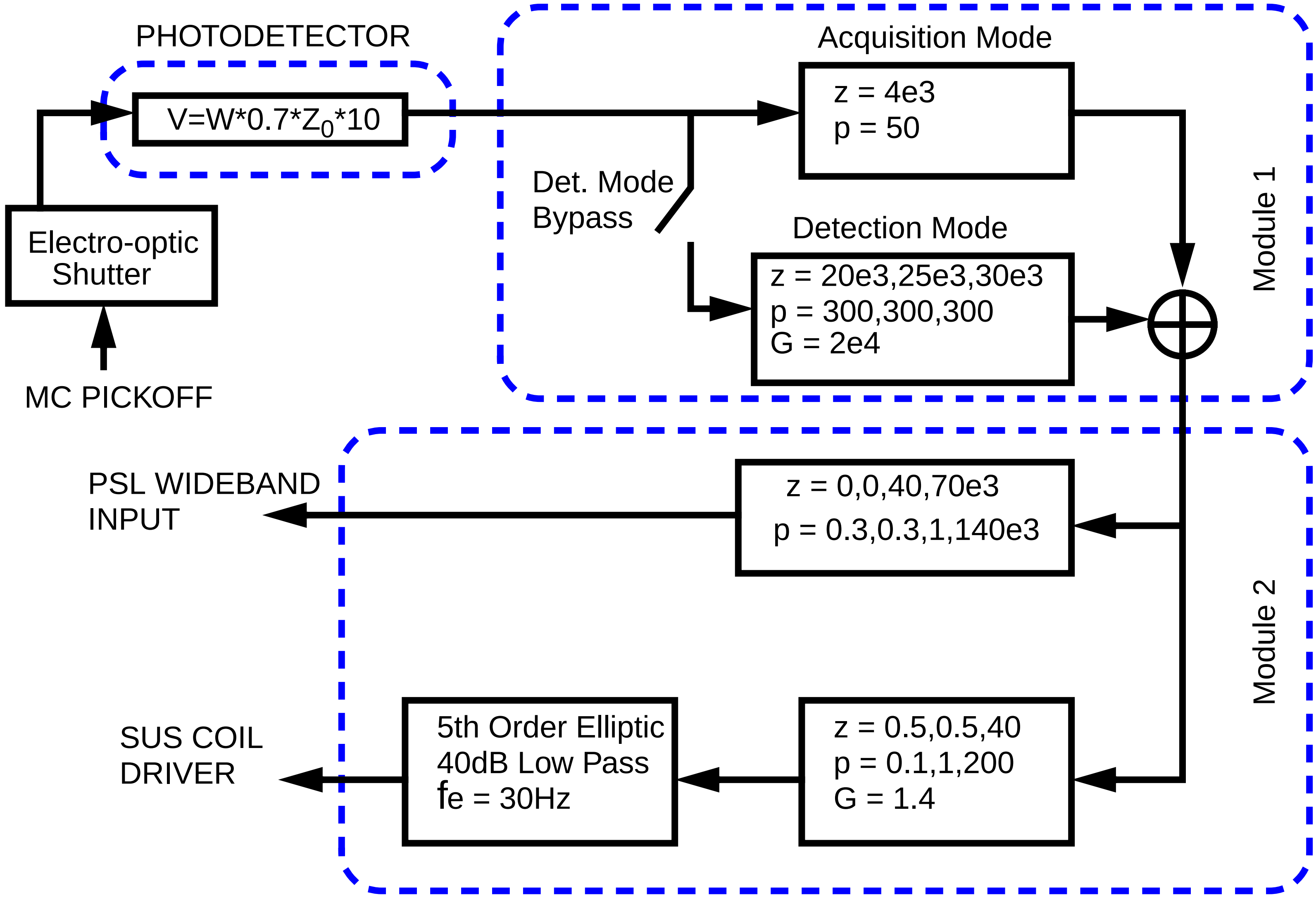
Mode Cleaner Length/Frequency Control

- MC Servo must keep the mode cleaner resonant with the input light.
- It must suppress the frequency fluctuations of the input light to the required level.
- The Mode Cleaner length shall be controlled such that it deviates from the perfectly resonant length by no more than $10^{-13} m_{rms}$.
- Input referred noise at PD preamp shall be less than 7 nV/rtHz above 40 Hz in order to be at least 20dB lower than shot noise.
- The requirements for the Mode Cleaner are given in LIGO T970218.

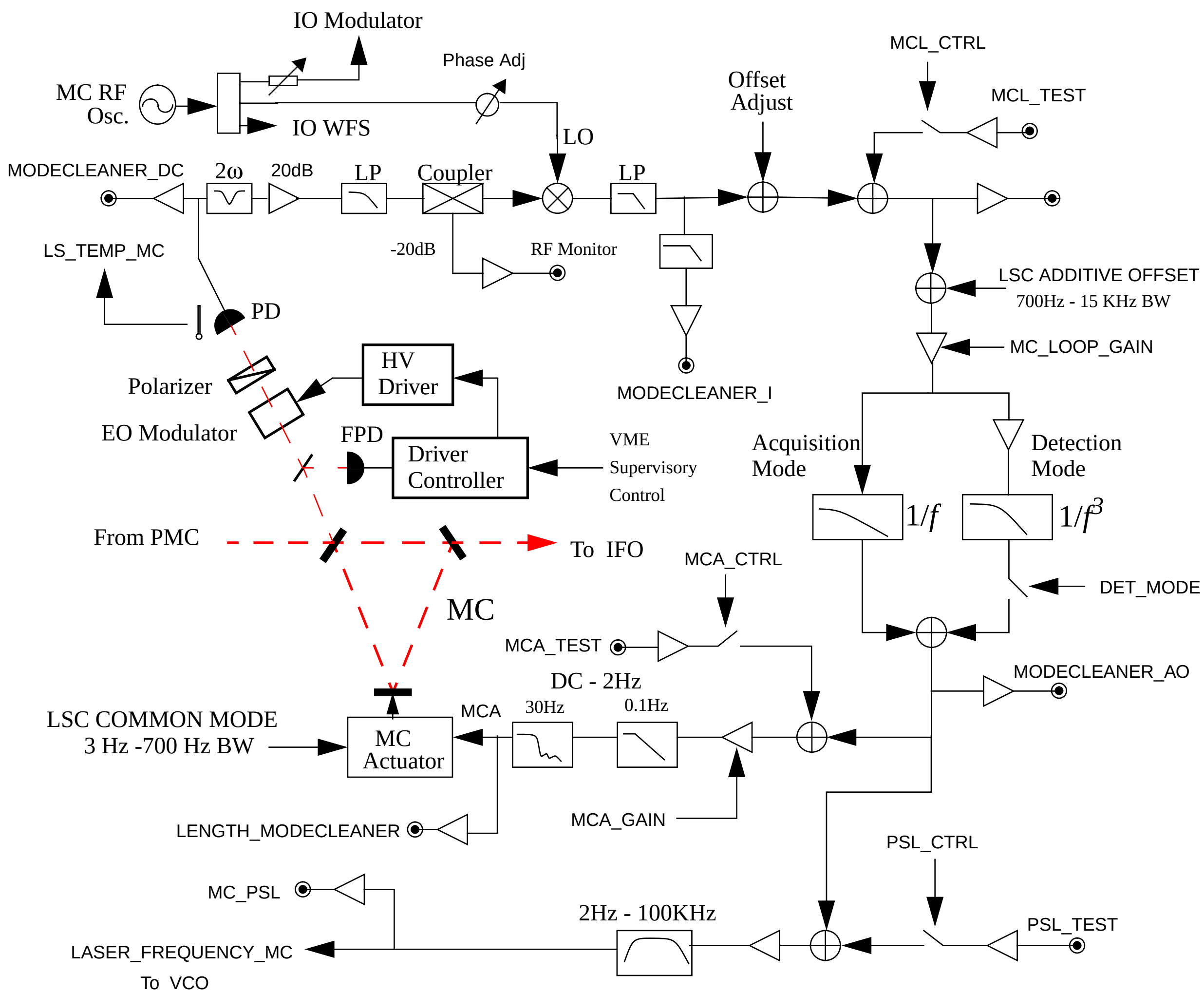
Mode Cleaner Length/Frequency Control

- Because of the high bandwidth requirements of the MC servo we use an analog implementation.
- The photodetector used is the same as in the LSC subsystem.
- Below about 2Hz the feedback is mainly to the length actuator. Above 2Hz feedback is mainly to the wideband input to the PSL.
- During Acquisition Mode the controller uses relatively low gain with a simple filter. In Detection Mode a high gain bypass is switched in with an aggressive filter in order to achieve a frequency noise suppression at 7KHz of 1.6×10^{-5} Hz/rtHz.

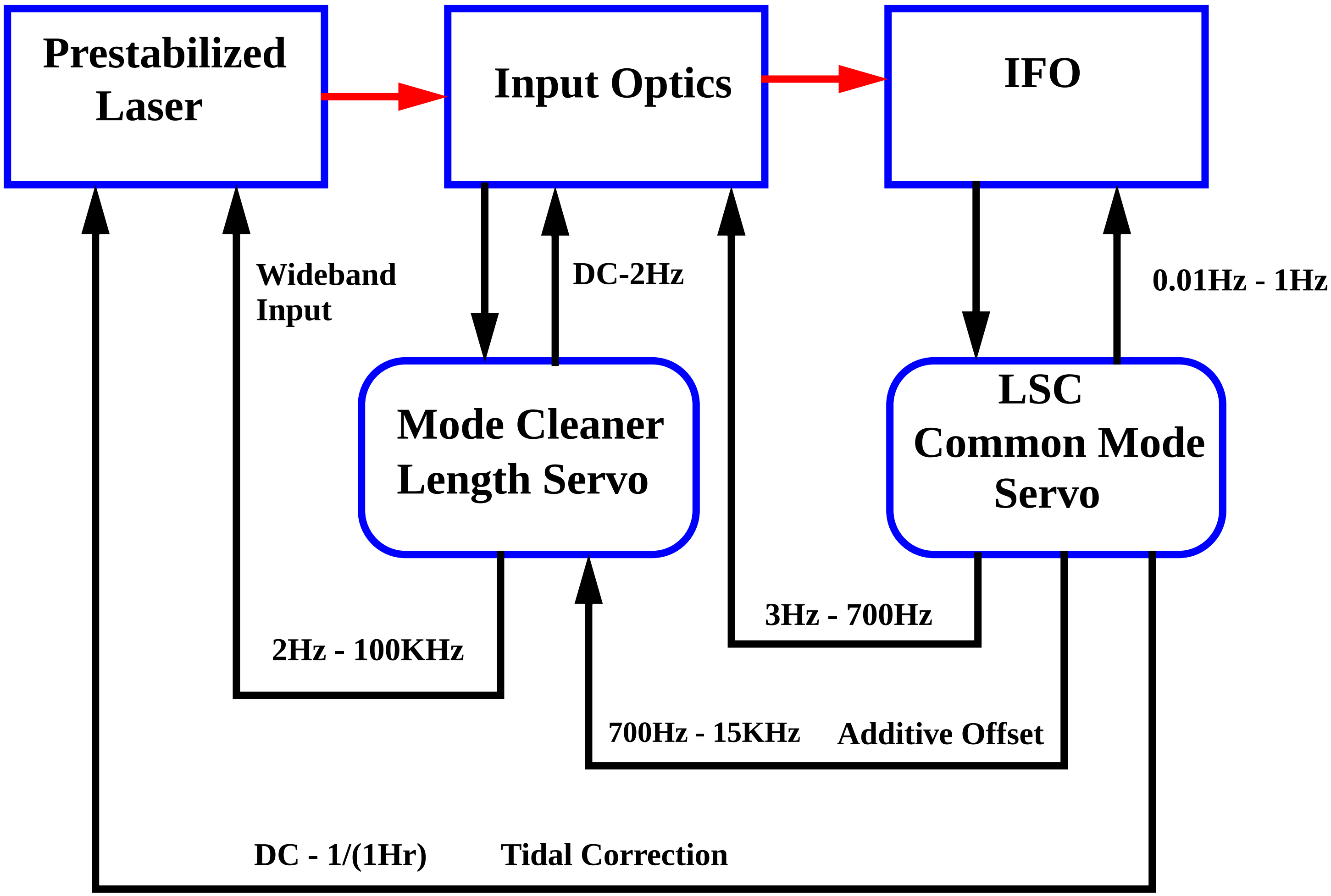
MC Length/Frequency Control Components



Mode Cleaner Length/Frequency Servo



MC Length Servo Subsystem Interface



Photodetector Characteristics

- The load for the photocurrent is the impedance of a parallel resonant circuit tuned to the Mode Cleaner resonant sideband frequency f_{mc}.
- A trap at $2f_{mc}$ is included in front of the preamp to keep this frequency component from saturating the preamp.
- The preamp is a low-noise wideband opamp operating from 5V supplies. The voltage gain is nominally set at 10.
- A DC output is provided for monitoring the diode current.
- A negative-resistance bias circuit provides a constant voltage across the diode over the full range of photocurrent. It also provides thermal shutdown should the bias circuit overheat, a status bit to indicate shutdown status, an enable pin that allows the bias supply to be shutdown remotely and a built in current limit.
- A sensor is provided to monitor the photodiode temperature.

Photodetector Parameters

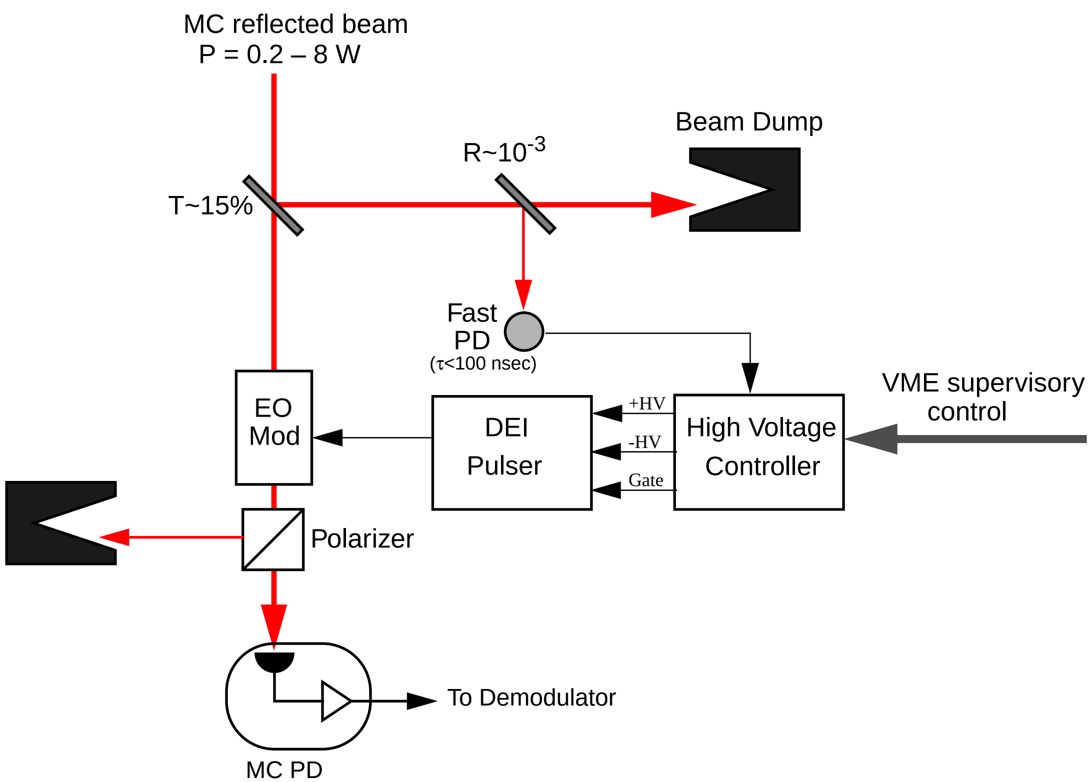
Parameter	*2 Km*	*4 Km*
Modulation Frequency	26.7 MHz	33.3 MHz
Photodiode capacitance	85 pF	85 pF
Photodiode series resistance	9 Ohms	9 Ohms
Photodiode pole frequency	3.4 MHz	5.4 MHz
Resonant load	550 Ohms	350 Ohms
Preamp gain	10	10
Photodetector transimpedance (resonant load x gain x 0.5 for back termination)	2750 Ohms	1750 Ohms

Mode Cleaner Grounding Scheme

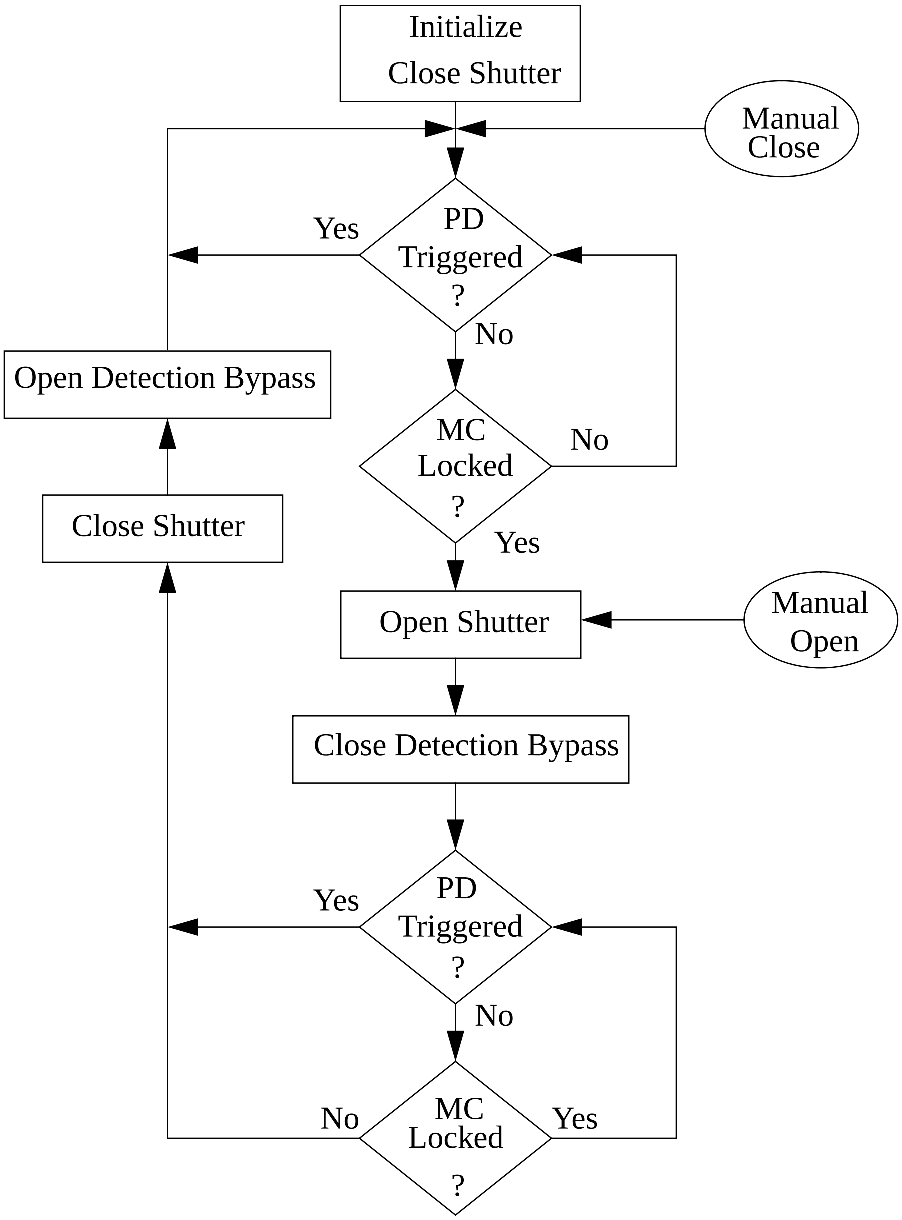
- To eliminate the possibility of ground loops all photodetector signal and power cables will be connected to the same EUROCARD crate. No ground connection will be made to the optics table.

- The high voltage pulser for the electro-optic shutter will be located near the optics table but will get its ac power from the IO electronics rack and will not connect to the optics table ground. The electro-optic shutter should be isolated from the optics table.

Electro-optic Shutter Control



Electro-optic Shutter Operation



Mode Cleaner Length Controller Status

- Beta version of photodetector is being tested now. Minor revisions will be implemented before production run.
- Demodulator circuit is being prototyped now. Both controller modules should be completed by August.
- Electro-optic shutter controller is being prototyped now. A high voltage pulser from DEI is being tested at MIT. High voltage power supplies from Ultravolt will be tested in the controller prototype.

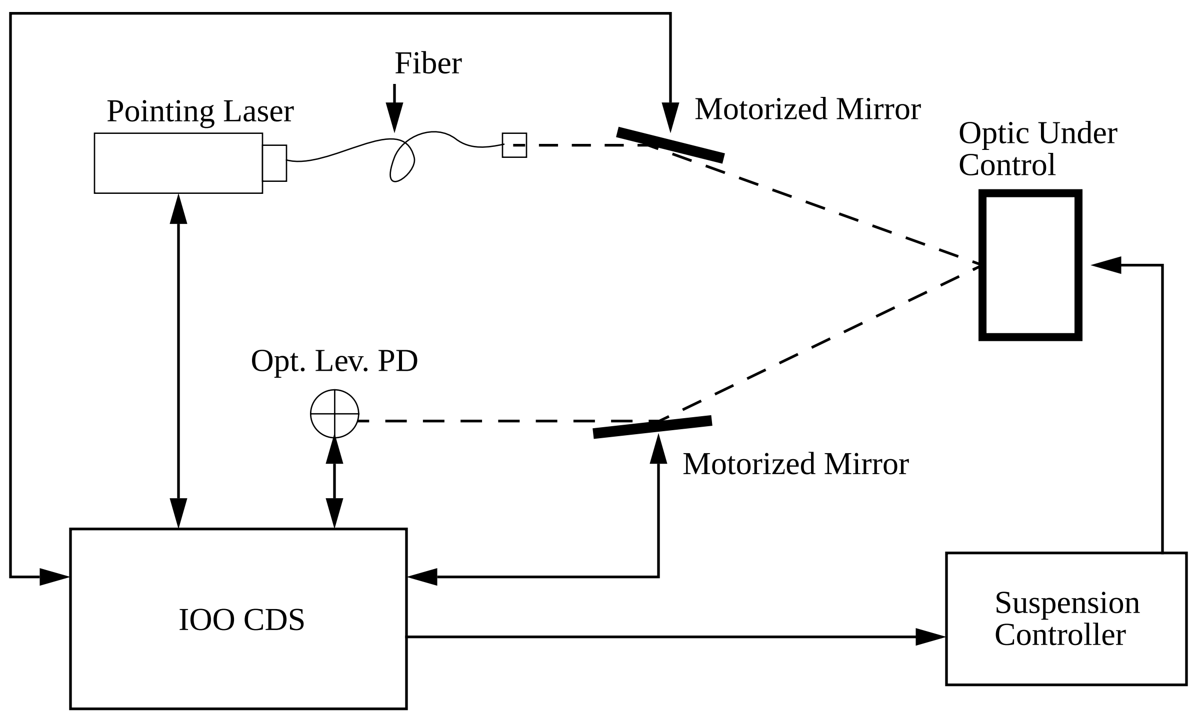
Motorized Mirror and Lens Fine Actuator Controls

- CDS to provide all necessary hardware and software to control motorized mirrors and lenses.
- No motorized mirrors on PSL table, TBD on ISCT7 and two on IOT7.
- New Focus model 8852 with a New Focus model 8732 multi-axis driver
- Operator control via RS232 and MVME162-333 processor.
- Status: Software not started and awaiting priority, but should not be difficult as it will be similar to that used to communicate with the SUS controllers.

Optical Lever Requirements

- Provide all electronics hardware and software required for optical lever control and monitoring, including:
  - Operator displays
  - Control of motorized mirrors
  - Photodetector electronics for Centronics QD100-0 photodiode
  - Position/Angle calculation
- MMT3 is the only mirror in the IOO with an optical lever system

Optical Lever Design



Optical Lever Design

- Position/Angle calculation performed in software at a min. 3 Hz rate.
- Operator control of mirrors via RS232 and MVME162-333 processor.
- Photodetector transimpedance nominally 1Kohm, but will be adjusted during initial commissioning.
- Status: PD amplifier design has been started. Software, etc. not started and is awaiting priority.

IOO Camera Requirements

- Camera locations are TBD
- CDS to provide all HW and SW to allow operator to view camera outputs.
- There are no image processing requirements
- Chamber illumination lamps are Waldmann model HGKW-70-24V.

Camera Systems

- Design
  - AVA-300 and the SVA software are available from Nemesys Research Ltd.
  - Each AVA-300 will handle as many as six video inputs. There will be one AVA-300 in each VEA and multiple units in the LVEA.
  - LVEA cameras will be routed to the AVA-300 through video multiplexers. The multiplexers will be controlled via CDS VME crates/processors.
- Status
  - Camera system has been tested at Hanford.
  - Multiplexers will not be required for IO.

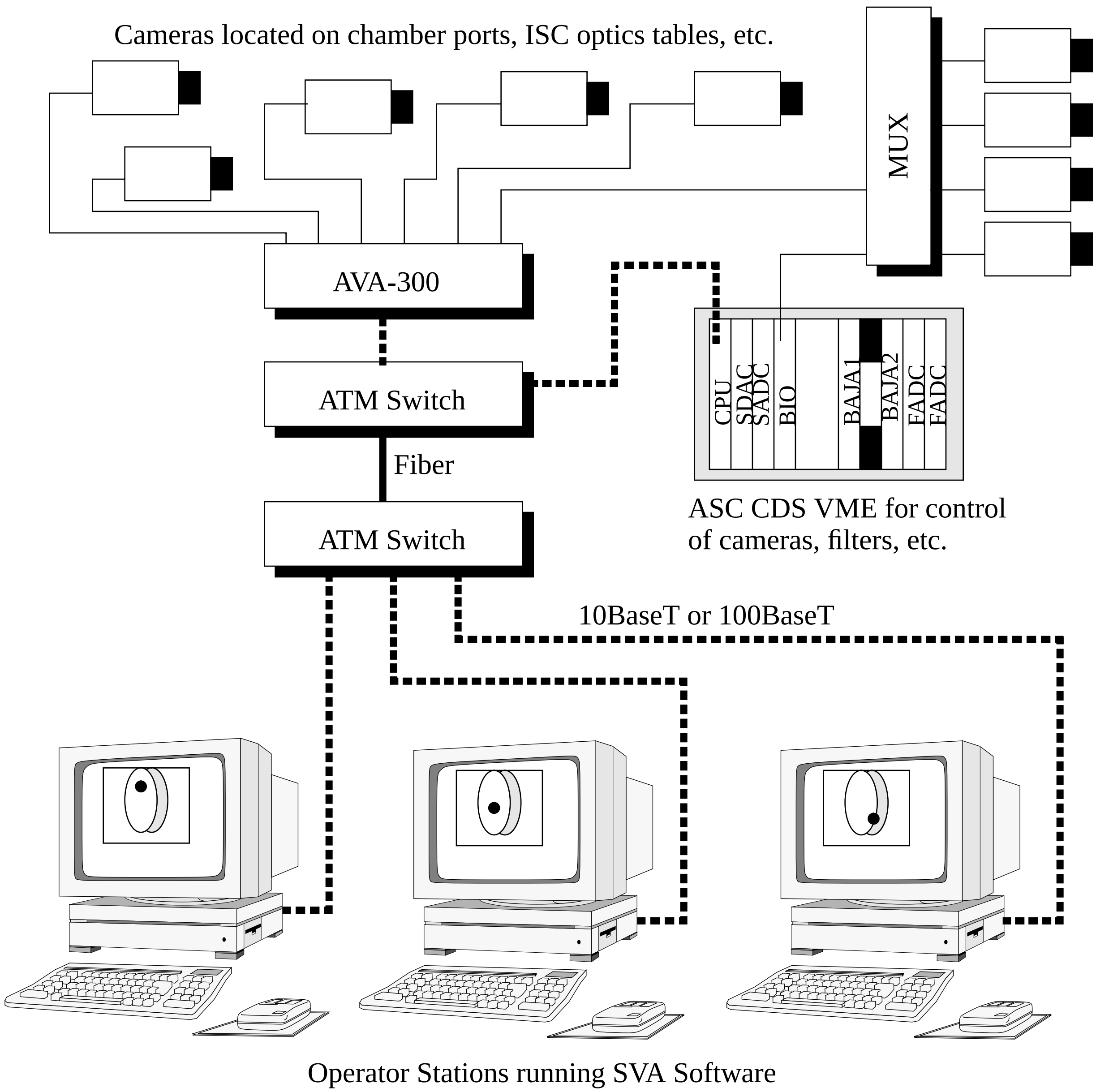
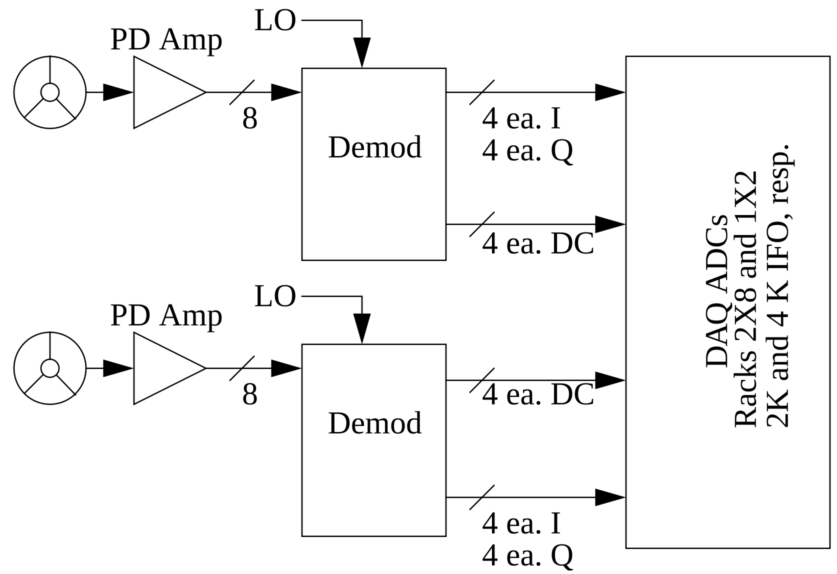


Figure 1: ASC CDS Camera Connections

Mode Matching Wavefront Sensing

- ASC WFS PD and demodulator electronics.
- The algorithm is TBD and performed by GDS.
- The sample rate will be 256 Hz for I&Q signals and 16 Hz for DC signals.
- Status: additional demod boards and PD amps need to fab'd



Analyzer Cavity Monitoring

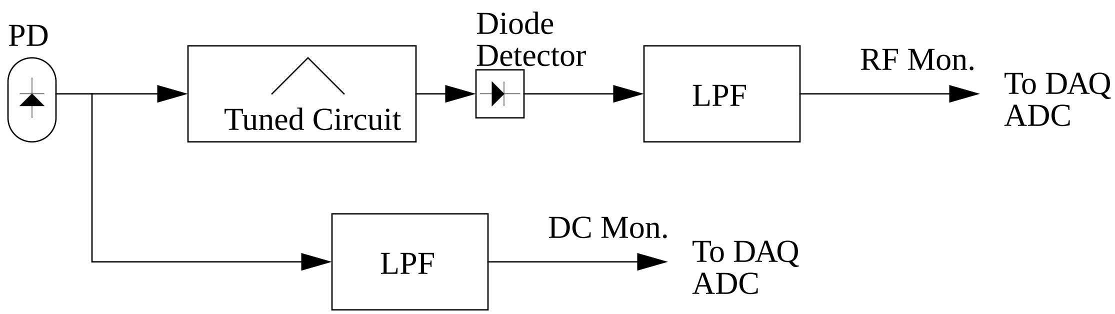
- There two analyzer cavities in the IOO. One on the PSL table and one on IOT7.
- Cavities are Coherent model 216 with model 251 controllers.
- The analyzers only provide a sweep trigger signal and cavity output signal all other controls are front panel knobs and switches
- The controller will need to be modified to provide a sweep voltage output and an on/off control.
- Operator displays, etc. will be developed for viewing of output versus sweep voltage

RF Photodetectors Used for Diagnostics

- Two types of detectors:
  - RFAM monitor
    - located on PSL table
    - used to monitor RFAM at LSC resonant sideband frequency
    - fractional sensitivity better than 10e-6
    - sample rate 1 Hz
  - MC Noise Monitor
    - located on IOT7
    - used to monitor noise in GW band at LSC resonant sideband frequency
    - sample rate 16384 Hz

RF Photodetectors

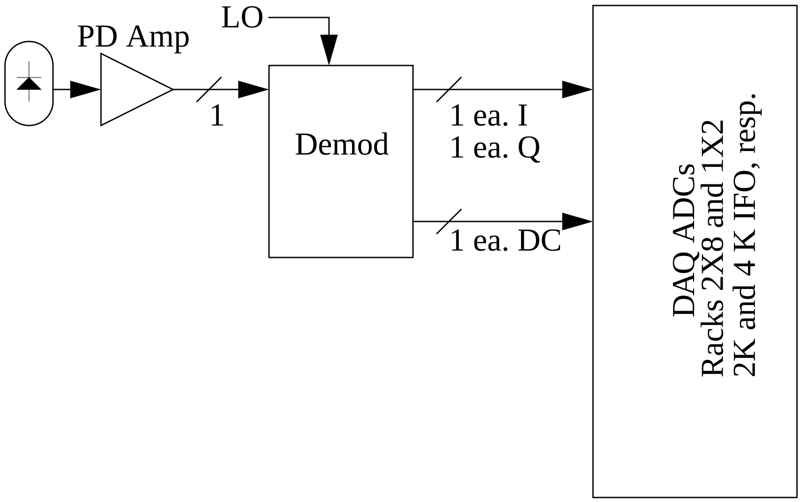
- RFAM Monitor



- Circuit tuned to 29.486 MHz and 24.493 MHz for 2K and 4K IFOs, respectively
- Outputs passed directly to DAQ/GDS for analysis and display

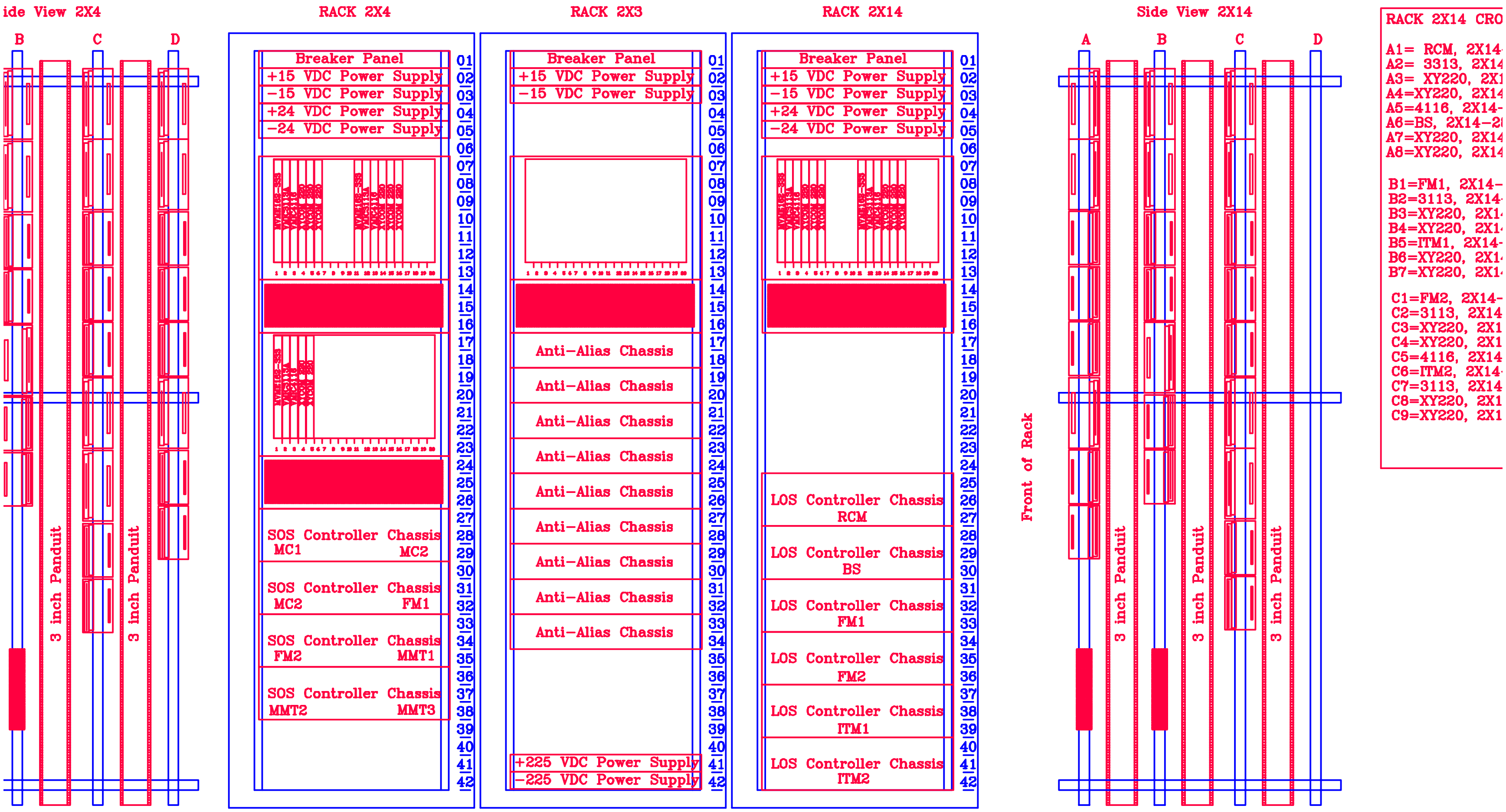
RF Photodetectors

- MC Noise Monitor



- PD and demodulators identical to MC LSC.
- Outputs passed directly to DAQ/GDS for analysis and display

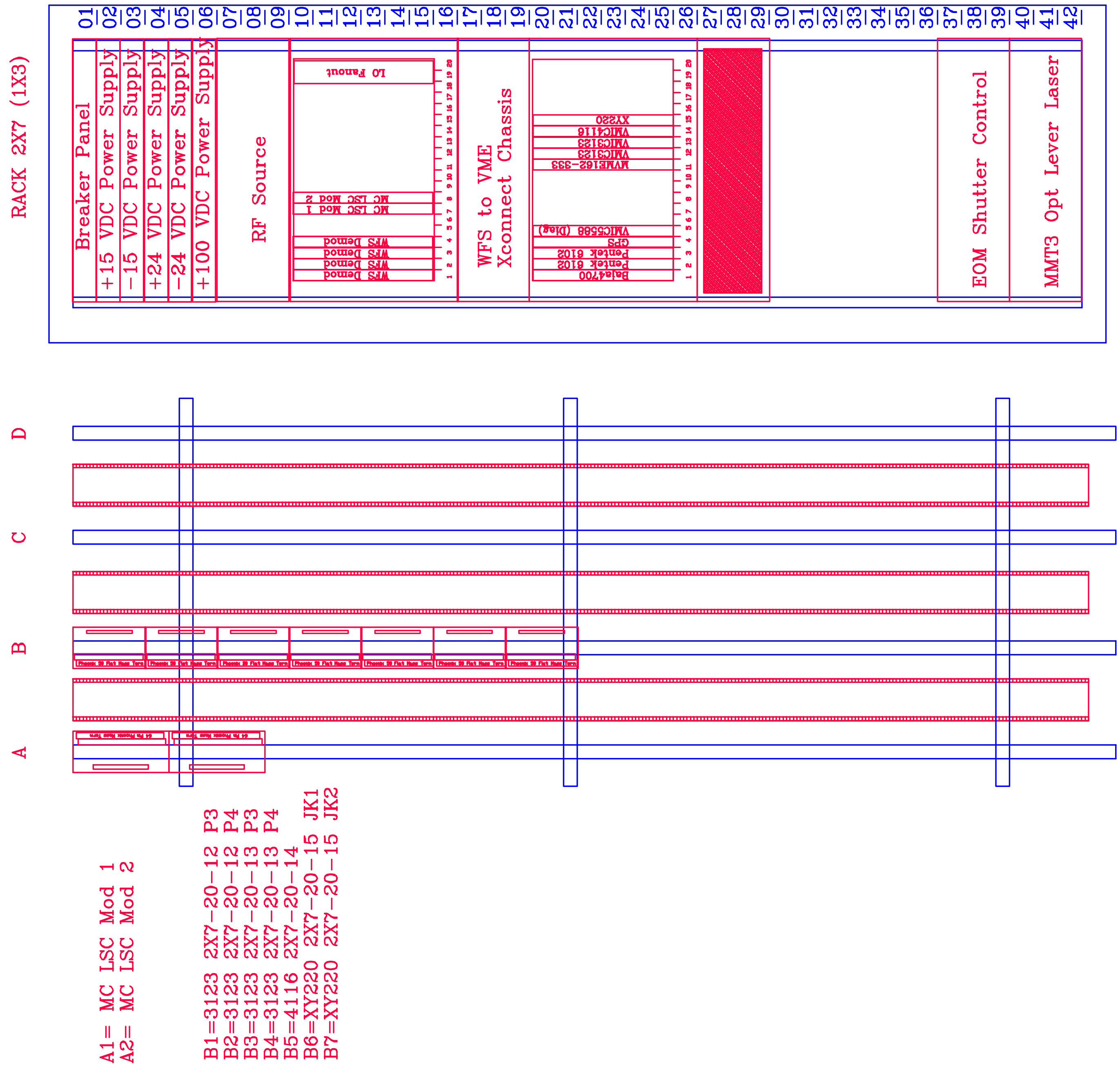
Suspension Rack Layout



S CONNECT BLOCK ASSIGNMENTS

27A	B1=MC3, 2X4-30A	C1=FM1, 2X4-30B	D1=MMT2, 2X4-36A
-7-2 P4	B2=3113, 2X4-7-2 P3	C2=3113, 2X4-7-12 P4	D2=3113, 2X4-17-2 P4
4-7-4 JK1	B3=XY220, 2X4-7-6 JK1	C3=XY220, 2X4-7-14 JK1	D3=XY220, 2X4-17-4 JK1
-7-4 JK2	B4=XY220, 2X4-7-6 JK2	C4=XY220, 2X4-7-14 JK2	D4=XY220, 2X4-17-4 JK2
7-3	B5=FM2, 2X4-33A	C5=4116, 2X4-7-13	D5=4116, 2X4-17-3
7B	B6=XY220, 2X4-7-15 JK1	C6=MMT1, 2X4-33B	D6=MMT3, 2X4-36B
-7-5 JK1	B7=XY220, 2X4-7-15 JK2	C7=3113, 2X4-7-12 P3	D7=XY220, 2X4-17-5 JK1
-7-5 JK2		C8=XY220, 2X4-7-16 JK1	D8=XY220, 2X4-17-5 JK2
		C9=XY220, 2X4-7-16 JK2	

IOO Rack Layout



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DAQ/GDS Interfaces

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Table 1: DAQ and GDS Signals

Signal	*Type*	*Sample Rate*	*Analog/Digital*
All Suspension Local PD read backs	Output to DAQ	2048	Analog
All SUS coil currents	Output DAQ	2048	Analog
Sum Coil currents	Output to DAQ	16384	Analog
All MC ASC demodulated PD signals I & Q	Output to DAQ	IOO ASC sample freq.	Digital
All MC ASC output signals	Output to DAQ	IOO ASC sample freq	Digital
All MC ASC PD DC outputs	Output to DAQ	1	Digital
All MC LSC demodulated PD signals I & Q	Output to DAQ	16384	Analog
MC LSC output signal (MC length)	Output to DAQ	256	Analog
MC LSC output signal (PSL freq)	Output to DAQ	16384	Analog
MC LSC PD DC output	Output to DAQ	1	Analog

Table 1: DAQ and GDS Signals

Signal	*Type*	*Sample Rate*	*Analog/Digital*
MC LSC PD Temp.	Output to DAQ	1	Analog
Bull's Eye Sensor demodulated PD signals	Output to DAQ	256	Analog
RFAM PD	Output to DAQ	1	Analog
Noise Monitor RFPD demodulated signals I & Q	Output to DAQ	16384	Analog
MC Misalign/shift test input	Input from GDS	IOO ASC sample freq	Analog
MC ASC PD Test Inputs	Input from GDS	IOO ASC sample freq	Analog
MC LSC Test input at error summing junction	Input from GDS	16384	Analog
MC LSC Test input before feedback split MC/laser	Input from GDS	16384	Analog

IOO CDS Cost, Schedule, Technical Risk

- Cost
  - ››Baseline Cost (hardware only 1994 $):
    - –WA 4K- $98.1K, WA 2K- $98.1K, LA 4K- $98.1K
    - –Total = 3 x 98.1= $294.3K
  - ››ETC (Jan 98)
    - –Total = 3 x 254= $762K
- Analysis
  - ››The cost of SOS controller went from 2.5K to 6K- total=28K per IFO
  - ››Original estimate of mode cleaner design was too simplistic. It only included a two simple servo modules (analog) and no digital servos.
  - ››VME component costs increased due to complexity of system
- Cost Risk - Low (Jan 98 ETC)

IOO CDS Cost, Schedule, Technical Risk

- Schedule (per 2K integration schedule)
  - ››Key milestones
    - –Begin installation of IO SUS electronics- 8/17/98
    - –IO installation complete - 10/8/98
    - –IO ready to commission - 12/7/98
  - ››Analysis
    - –SOS controllers being fab'd, satellite modules being fab'd, rack wiring for WA 2K, WA and LA test stands complete and sent to sights.
    - –ASC (MC) prototype being assembled, LSC (MC) prototypes being fab'd
    - –at this time the dates look reasonable
  - ››Schedule Risk- Medium: manpower shortages in CDS due to work load and travel could present a problem. These manpower shortages will be mostly in the area of software development for the systems (both real time and EPICS). Delays in the installation and commissioning of the WA 2K IOO could impact other IFO/CDS deliveries.

IOO CDS Cost, Schedule, Technical Risk

- Technical

  ›› No systems within the IO are pushing the state of the art.

  ›› Prototype tests of suspension controllers on the 40 meter and in the lab have verified performance predicted in simulations.

  ›› Technical Risk: Low to Medium

  – The interface between the IO alignment control system and the GDS will have to be carefully managed to make certain that the close coupling of the front end servos to the DAQ/GDS systems do not jeopardize the performance of the servo.

  – All other components for the IO controls are either commercially available or standard electronics/software that has been supplied for many other systems in the past.