LOS and SOS CDS Final Design Review

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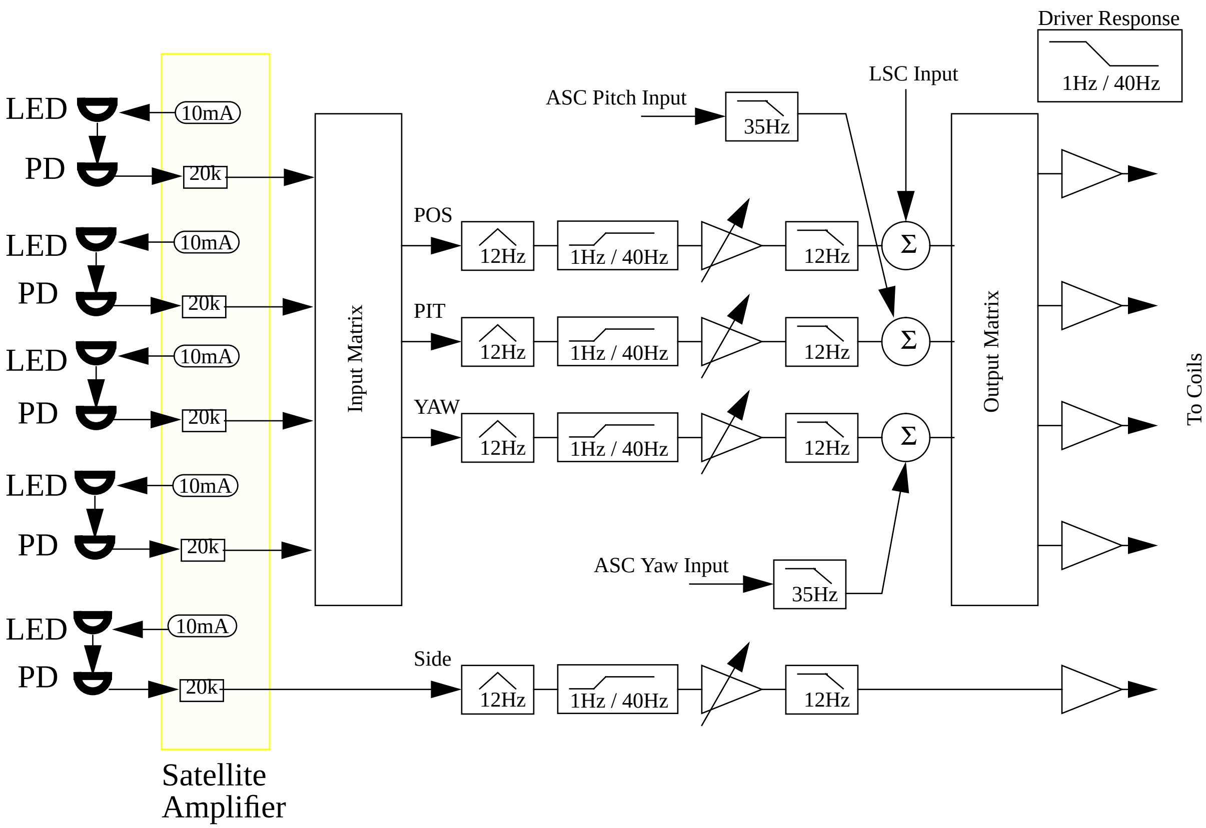
Suspension System Block Diagram



Changes Since PDR

- The input matrix that was proposed to be removed at the time of the PDR has been retained at the request of the PDR committee.
- Due to the change in the requirements for the SOS controllers needed for the IOO it was determined that a flat response versus frequency could be used. In addition, it was determined that different versions of the SOS controller could be used to more effectively match the capabilities of the coil driver to the requirements.
- The noise requirement for the LOS controller has been relaxed in an effort to keep the range of the contoller at the 20 ump-p level. If in the course of the LSC commissioning it is determined that the range requirement can be relaxed, components in the coil driver circuit can be changed to meet the noise requirement. (See LIGO T960151-02 for details of requirements change).
- The simulink models for each suspension system have not been updated since they are still valid. The only difference between the model results and the actual controller responses that are required are in the areas of controller voltage gain and acquisition/detection mode compensation. These differences and how to adjust the model results to determine the required controller responses are discussed in the appropriate sections of the final design document.
- A coil current sum channel has been added to the design.
- The interface to the DAQ system will be via a daughter card mounted in the controller chassis. This daughter card will meet all interface requirements for DAQ/GDS.

LOS Controller Requirements

- Detailed requirements are listed in T960151-02

Table 1: LOS Controller Dynamic Range and Output Noise

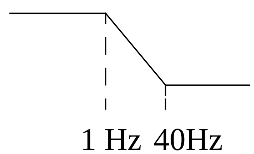
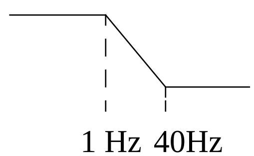
	Mode of Operation	*Dynamic Range*[a]	*Output Noise*[b]
Local Damping and Control	Local damping and control mode	$20\ \mu m_{p\text{-}p}$ 	$5x10^{-20}\left(\frac{f}{40}\right)^{-2}(m/(\sqrt{Hz}))$ f > 40 Hz
ASC Pitch Input to Optic	All modes	$500\ \mu rad_{p\text{-}p}$, 	$1x10^{-17}((rad)/(\sqrt{Hz}))$ f > 40 Hz

Table 1: LOS Controller Dynamic Range and Output Noise

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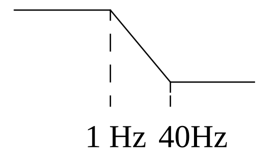
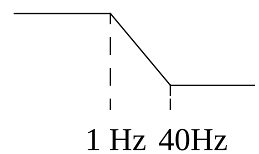
ASC Yaw Input to Optic	All modes	500 $\mu rad_{p\text{-}p}$, 	$1x10^{-17}((rad)/(\sqrt{Hz}))$ f > 40 Hz
LSC Input to Optic	LSC Acquire	>100 $\mu m_{p\text{-}p}$ Flat response	N/A
LSC Input to Optic	LSC Locked	20 $um_{p\text{-}p}$ 	$5x10^{-20}\left(\frac{f}{40}\right)^{-2}(m/(\sqrt{Hz}))$ f > 40 Hz

a. Memo L960728-00-D, “Requirements of the LOS Suspension Driver”, S. Kawamura, outlines the dynamic range and noise requirements for the LOS controller and the trade-off that can be made between the number of actuator coil windings, the maximum output current drive and the output referred current noise.

b. It has been decided (4/1/98 meeting between Whitcomb, Heefner, Coyne, Shoemaker and ISC Group) that the number of turns on the sensor/actuator head should remain at the current number (~400). With the present coil driver design this implies that the noise requirements can not be met. The actual noise will be $\sim 9x10^{-20}\left(\frac{f}{40}\right)^{-2}(m/(\sqrt{Hz}))$. It, at some future date it is determined that the range requirements for the LOS can be relaxed, the exisiting circuitry could be modified to reduce the noise to the required numbers.

Coil Driver and Number of Coil Turns

The following table details a few design examples that meet both the noise and dynamic range requirements.

Table 1: LOS Coil Driver Design Examples

Turns Reduction Ratio	*Series Resistance*	*Detection Mode Range*	*Acquisition Mode Range*[a]
1.0	25 Kohm	5.8 ump-p	110 ump-p
1.85	7.3 Kohm[b]	11 ump-p	59 ump-p
3.54	2.0 Kohm	20.5 ump-p	31 ump-p
4.33	1.333 Kohm	25 ump-p	25 ump-p

a. Note that in these examples the acquisition mode range is being traded for detection mode range and noise.
b. Present series resistance

LOS Controller Requirements

- ASC Input
  - 25μrad/Volt at DC
  - 35 Hz, forth order, 4 dB passband ripple 60 dB stopband attenuation elliptic
  - Input noise less than $(1\mu V)/(\sqrt{Hz})$ for f<40Hz, less than $(80nV)/(\sqrt{Hz})$ for f>40Hz
- LSC Input
  - 1μm/Volt at DC
  - 1 Hz pole, 40 Hz zero
  - Input noise less than $(1\mu V)/(\sqrt{Hz})$ for f<40Hz, less than $(80nV)/(\sqrt{Hz})$ for f>40Hz
  - Modes:
    - Locked
    - Acquire
    - Off

SOS Controller Requirements

- Detailed requirements are listed in T960151-02.

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 28 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
SM1, SM2 (2Km IFO only)	SOS	500 um p-p 28 mrad p-p	$5x10^{-16}\left(\frac{f}{40}\right)^{-2}(m/(\sqrt{Hz}))$ f > 40 Hz
MMT3[a]	SOS	40 um p-p 1 mrad p-p	$5x10^{-16}\left(\frac{f}{40}\right)^{-2}(m/(\sqrt{Hz}))$ f > 40 Hz

a. MMT3 is a large optic, but due to the requirements a SOS controller can be used in the design. This will simplify the IOO suspension system design and implementation.

SOS Controller Requirements

- ASC Input
  - 35 Hz, forth order, 4 dB passband ripple 60 dB stopband attenuation elliptic
  - Input noise less than $(1 \mu V)/(\sqrt{Hz})$ for f<40Hz, less than $(80 nV)/(\sqrt{Hz})$ for f>40Hz
- LSC Input
  - Flat Response for f<10KHz
  - Input noise less than $(1 \mu V)/(\sqrt{Hz})$ for f<40Hz, less than $(80 nV)/(\sqrt{Hz})$ for f>40Hz
  - Modes:
    - Locked
    - Acquire
    - Off

SOS Controller Requirements

- ASC and LSC Input Transfer Function.

Table 1: SOS LSC Input to Output Transfer Function

Optic	*LSC Transfer Function (at DC)*	*ASC Transfer Function (at DC)*
MMT1, MMT2 SM1, SM2	$(25um)/(Volt)$	$(1340urad)/(Volt)$
MMT3	$(2um)/(Volt)$	$(25urad)/(Volt)$
MC1, MC2, MC3	$(1.4um)/(Volt)$	$(75urad)/(Volt)$

IO SOS Suspension Controls

- 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

Test Results

- Prototypes have been built and tested for LOS and SOS controllers and Satellite Amplifier.
- Testing shows that the units can meet or exceed all requirements.
- All tests were conducted using the drafts of the test plans to be used for the production modules.
- The test plans verify performance and test all functions of each of the modules, including:
  - ››Transfer functions- ASC Input, LSC Input, Local Damping
  - ››On/Off, Enable/Disable
  - ››Run/Acquire Mode
  - ››Noise
  - ››etc.

Status

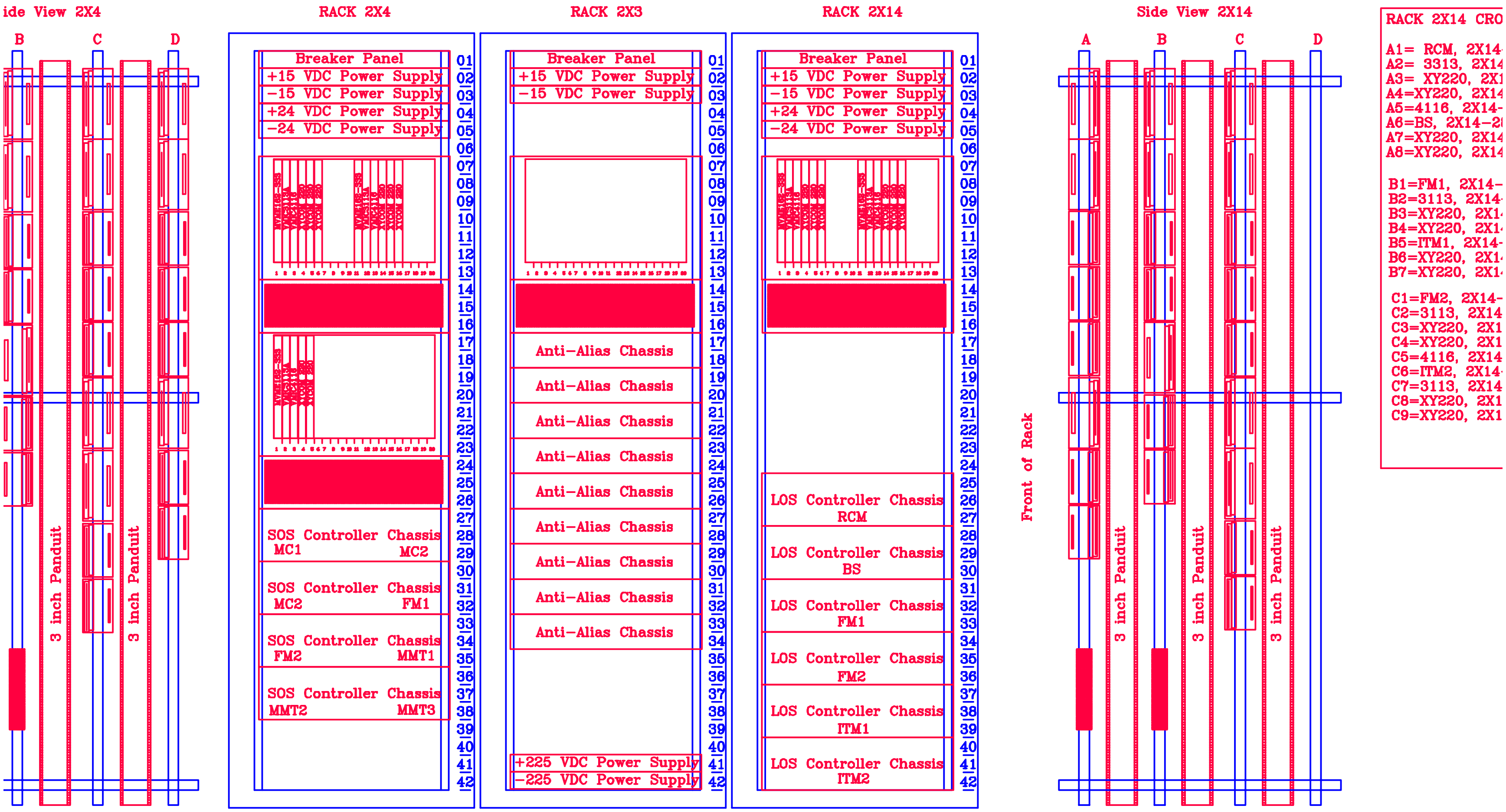
- Oliver is in the process of building the sensor actuator heads for WA 2K IO. They should be complete by 5/30/98.
- SOS controller prototype tests are complete, final layout is complete and the fab contract for 25 units will be awarded within 2 weeks. Prototype chassis have been tested. Final designs are being completed.
- LOS controller fabrication has been started. Prototype chassis have been tested. Final designs are being completed.
- Satellite module prototype tests are complete, final layout is in process fabrication of final units should begin within the next 2 weeks.
- DAQ daughter card layout has been started.
- 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 sites.
- WA 2K LVEA CO cross connect wiring has been started.
- 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.

Status

- VME IO modules and processors for IO have been ordered or received.
- System wiring diagrams are done using Protel which allows automatic generation of cross connect list, wiring lists and bill of materials. It will also allow rapid replication of system drawings using cut, copy, paste, etc.
- Outstanding question:

  ››What type of whitening is required on the coil driver and sum channel monitors for DAQ?

Suspension Rack Layout



SS CONNECT BLOCK ASSIGNMENTS

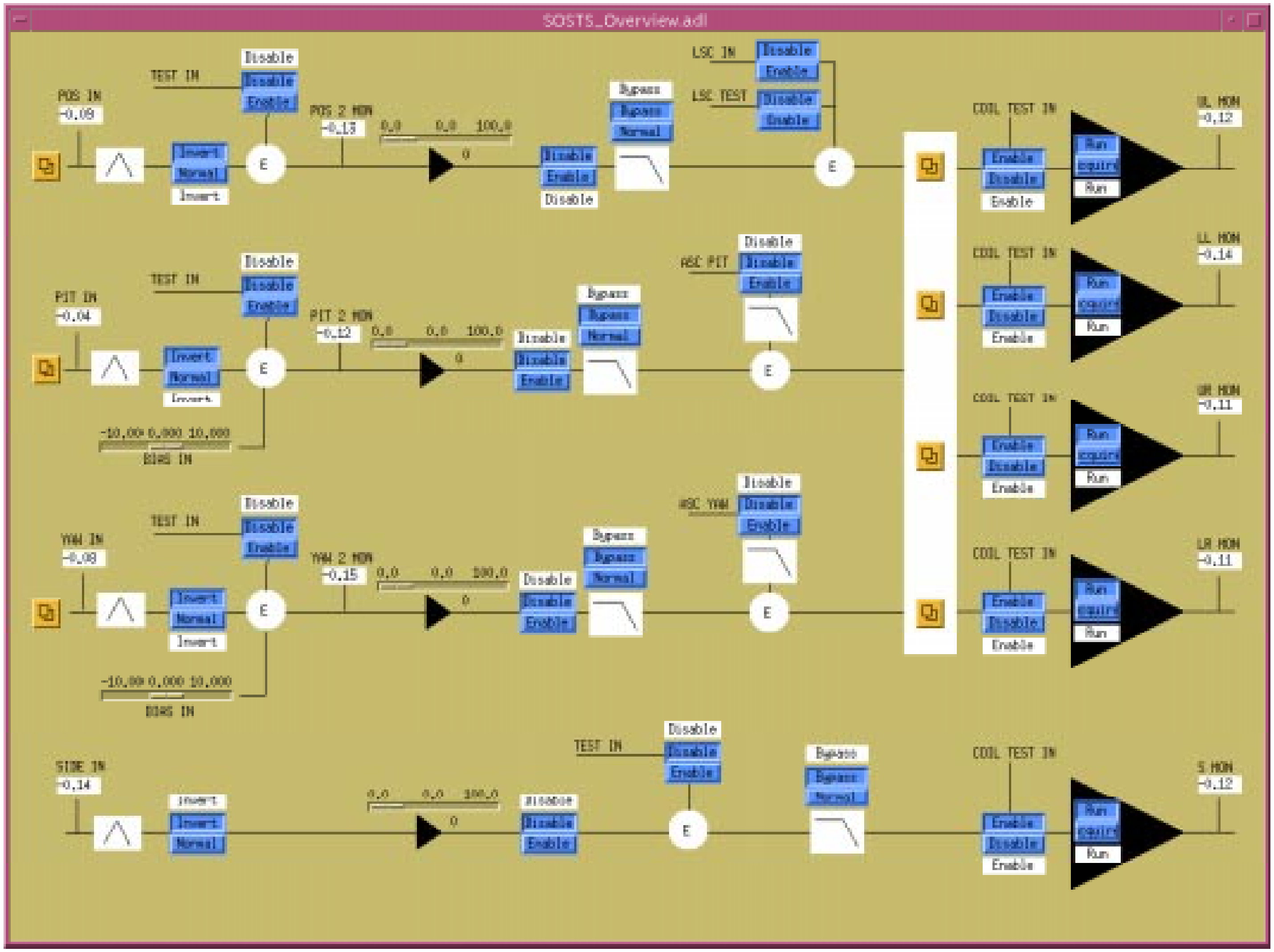
-27A
-7-2 P4
4-7-4 JK1
-7-4 JK2
7-3
-7B
-7-5 JK1
-7-5 JK2

B1=MC3, 2X4-30A
B2=3113, 2X4-7-2 P3
B3=XY220, 2X4-7-6 JK1
B4=XY220, 2X4-7-6 JK2
B5=FM2, 2X4-33A
B6=XY220, 2X4-7-15 JK1
B7=XY220, 2X4-7-15 JK2

C1=FM1, 2X4-30B
C2=3113, 2X4-7-12 P4
C3=XY220, 2X4-7-14 JK1
C4=XY220, 2X4-7-14 JK2
C5=4116, 2X4-7-13
C6=MMT1, 2X4-33B
C7=3113, 2X4-7-12 P3
C8=XY220, 2X4-7-16 JK1
C9=XY220, 2X4-7-16 JK2

D1=MMT2, 2X4-36A
D2=3113, 2X4-17-2 P4
D3=XY220, 2X4-17-4 JK1
D4=XY220, 2X4-17-4 JK2
D5=4116, 2X4-17-3
D6=MMT3, 2X4-36B
D7=XY220, 2X4-17-5 JK1
D8=XY220, 2X4-17-5 JK2

Operator Screen Example



Schematics and Test Plans (to date)

Table 1: Suspension Electronics Test Plans

Document	*Number*
LOS and SOS Controller Test Plan	T980042
Satellite Module Test Plan	T980TBD
Suspension System Electronics Hardware and Software Test Plan	T980TBD

Table 2: Suspension Schematics

Schematic	*Number*
LOS Controller	D980013
SOS Controller	D980181
Satellite Amplifier	D961289
Suspension Controller DAQ Daughter Board	D980234
WA 2K Suspension Rack Drawing	D980211
WA 2K Core Optics Suspension Wiring	TBD
WA 4K Suspension Rack Drawing	TBD

Cost, Schedule, Technical Risk

- Cost

Table 1: LOS and SOS Hardware Costs

System	Baseline Estimate (94 $)	Jan 98 Estimate to Complete
WA 4K IFO LOS and SOS	$204K	$268.3K
WA 2K IFO LOS and SOS	$235K	$303.2K
LA 4K IFO LOS and SOS	$204K	$268.3K
TOTAL	$643K***	$839.8K

*** Cost numbers estimated from baseline IOO and COS cost book entries

›› Analysis

– Noise and dynamic range requirements have increased the cost of the controllers from the initial baseline number.

›› Risk: Low (Jan 98 ETC)

– Jan 98 estimate from actual catalog costs and production costs of prototypes.

Cost, Schedule, Technical Risk

- Schedule (from 2k integration schedule)
  - ››Test stands for Hanford: 7/7/98 (UF needs by 8/98)
  - ››WA 2K IO SUS install: 8/17/98
  - ››WA 2K CO SUS install: 1/11/99
- Analysis:
  - ››Dates are reasonable with the possible exception of the Hanford test stand. In the event that there were a problem supplying production units, the prototypes could be used initially. The actual need date of 8/1/98 can be met.
- Risk: Low

Cost, Schedule, Technical Risk

- Technical risk: Low

  ››Been there done that, with the exception that ultra-low noise performance has not been demonstrated on an operational IFO.