LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

LIGO Laboratory / LIGO Scientific Collaboration

LIGO-E040136-01-D *ADVANCED LIGO* 20 May 2004

Seismic Isolation System (SEI)
Payload Mass Properties

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LIGO Science Collaboration

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of the LIGO Project.

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Revision 00: Mar 2004, Initial draft release

Revision 01: Release in conjunction with E030179-A for the AdL SEI structural design requirements.

1 Purpose

The purpose of this memo is to document the mass property limits for the payloads on the SEI platforms for advanced LIGO, which will be defined in the interface control document (ICD, which is to be written). This document provides the basis for establishing the requirem ents for the AdL SEI structural design requirements. Parameters had to be estimated for the purpose of establishing a set of interface requirements. As the designs mature, the interface requirements can be re -evaluated based upon better design information and the basic methodology and considerations given in this document.

A companion document, will be used to track the current estimates of payload mass properties and compare them to the ICD limits.

2 Layouts

Layouts are depicted in the attached Figures.

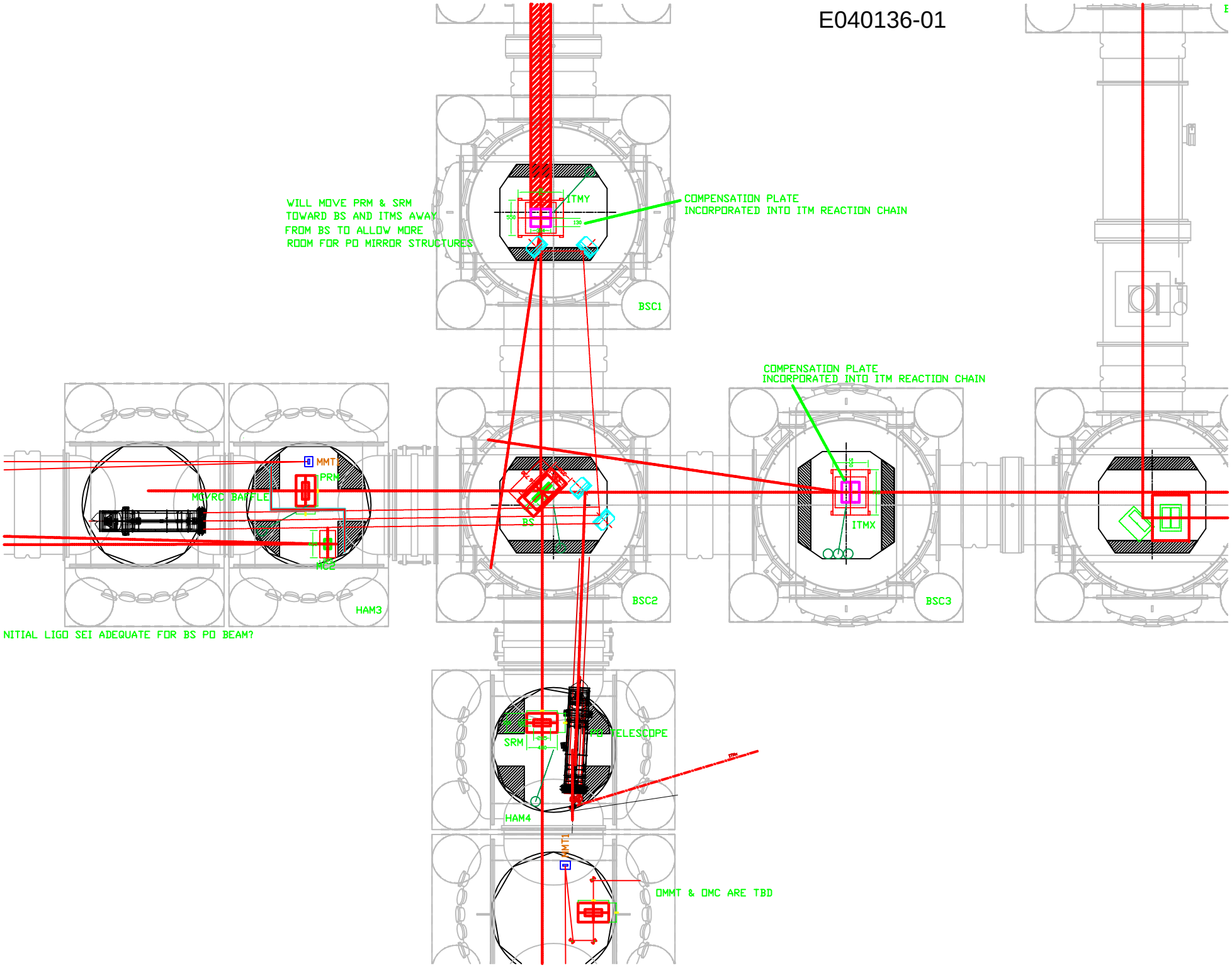
3 Assembly Mass Properties

The assemblies that comprise the AdL in -chamber payload are listed in the following Table, with their estimated masses. These mass estimates for the individual assembly/component items are used with the layouts to estimate the mass pr operties of the payload ensembles for each optics table (particularly the total mass and the first moments of mass about the table center).

4 Optics Table Mass Properties

The mass properties for each chamber are listed in the following Tables. The payloads a re separated into HAM Chamber and BSC chamber payloads.

E040136-01


WILL MOVE PRM & SRM
TOWARD BS AND ITMS AWAY
FROM BS TO ALLOW MORE
ROOM FOR PO MIRROR STRUCTURES
ITMY
COMPENSATION PLATE
INCORPORATED INTO ITM REACTION CHAIN
BSC1
COMPENSATION PLATE
INCORPORATED INTO ITM REACTION CHAIN
MMT
PRM
MCVRC BAFFLE
MC2
BS
ITMX
HAM3
BSC2
BSC3
NITIAL LIGO SEI ADEQUATE FOR BS PO BEAM?
SRM
TELESCOPE
HAM4
ITMMT
OMMT & OMC ARE TBD

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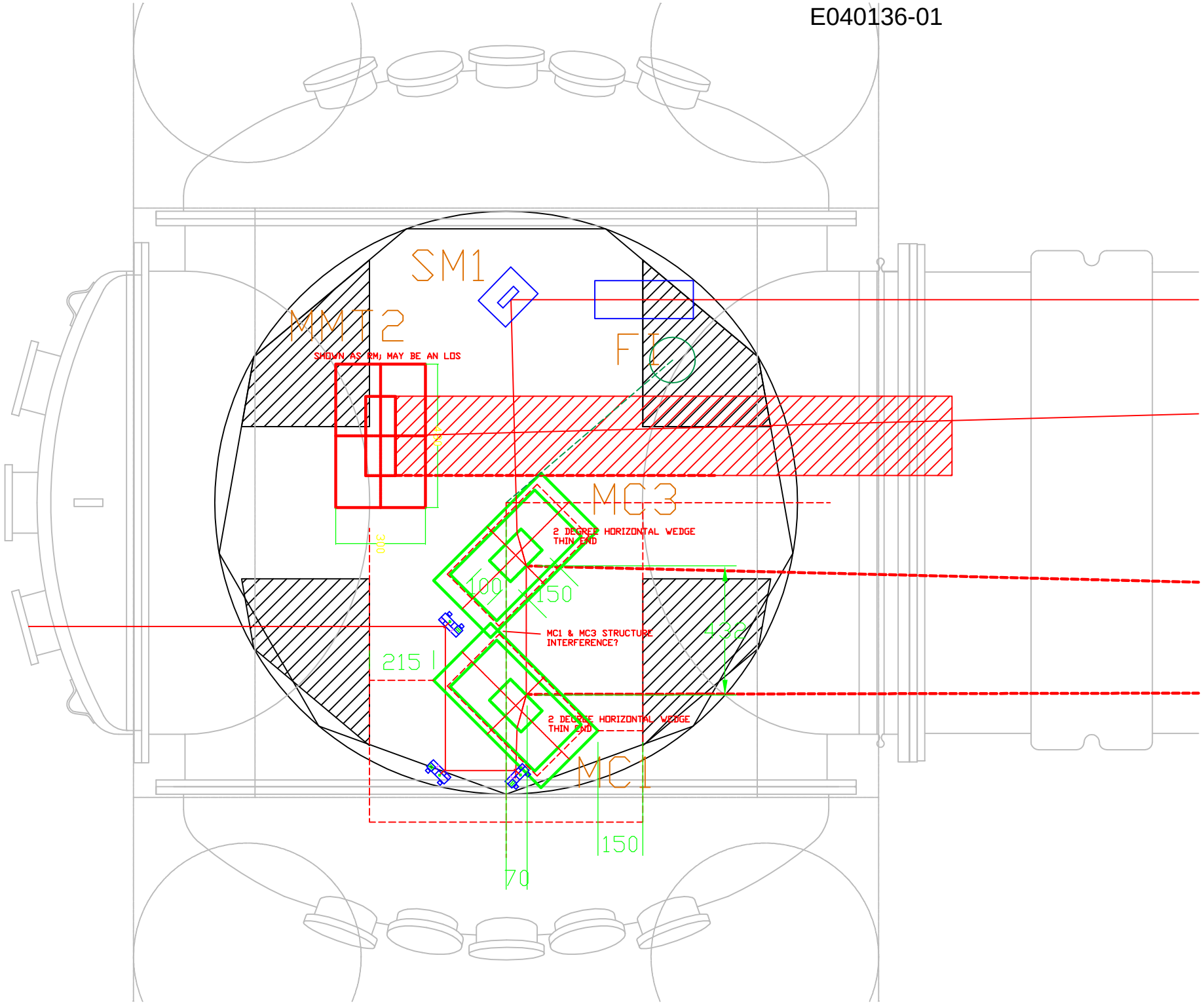
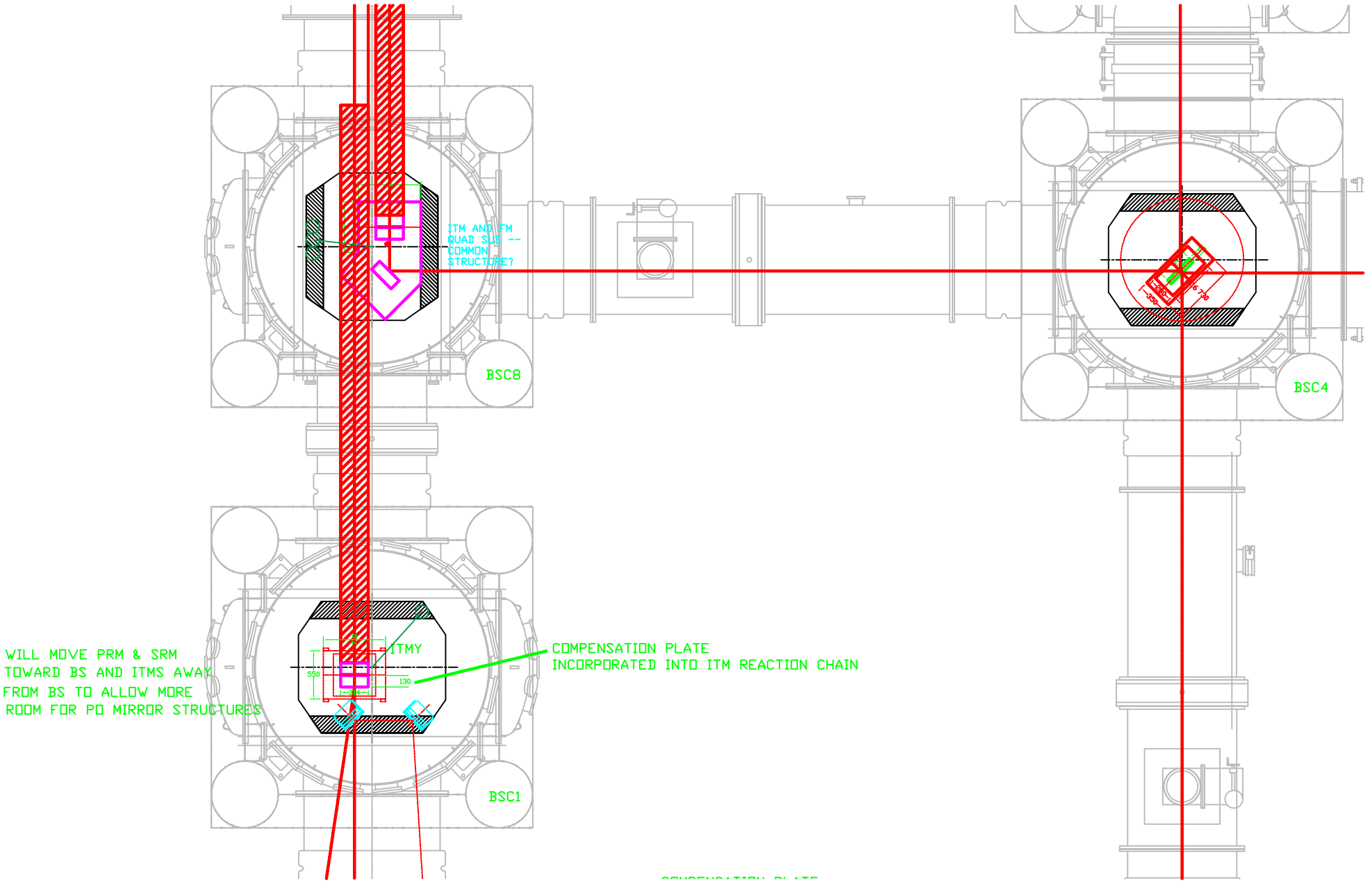

SM1
MMT2
SHOWN AS RM; MAY BE AN LOS
FI
MC3
2 DEGREE HORIZONTAL WEDGE
THIN END
100
150
MC1 & MC3 STRUCTURE
INTERFERENCE?
432
215
2 DEGREE HORIZONTAL WEDGE
THIN END
MC1
150
70


ITM AND FM
QUAD SUS --
COMMON
STRUCTURE?
BSC8
BSC4
ITMY
550
130
384
BSC1
WILL MOVE PRM & SRM
TOWARD BS AND ITMS AWAY
FROM BS TO ALLOW MORE
ROOM FOR PO MIRROR STRUCTURES
COMPENSATION PLATE
INCORPORATED INTO ITM REACTION CHAIN

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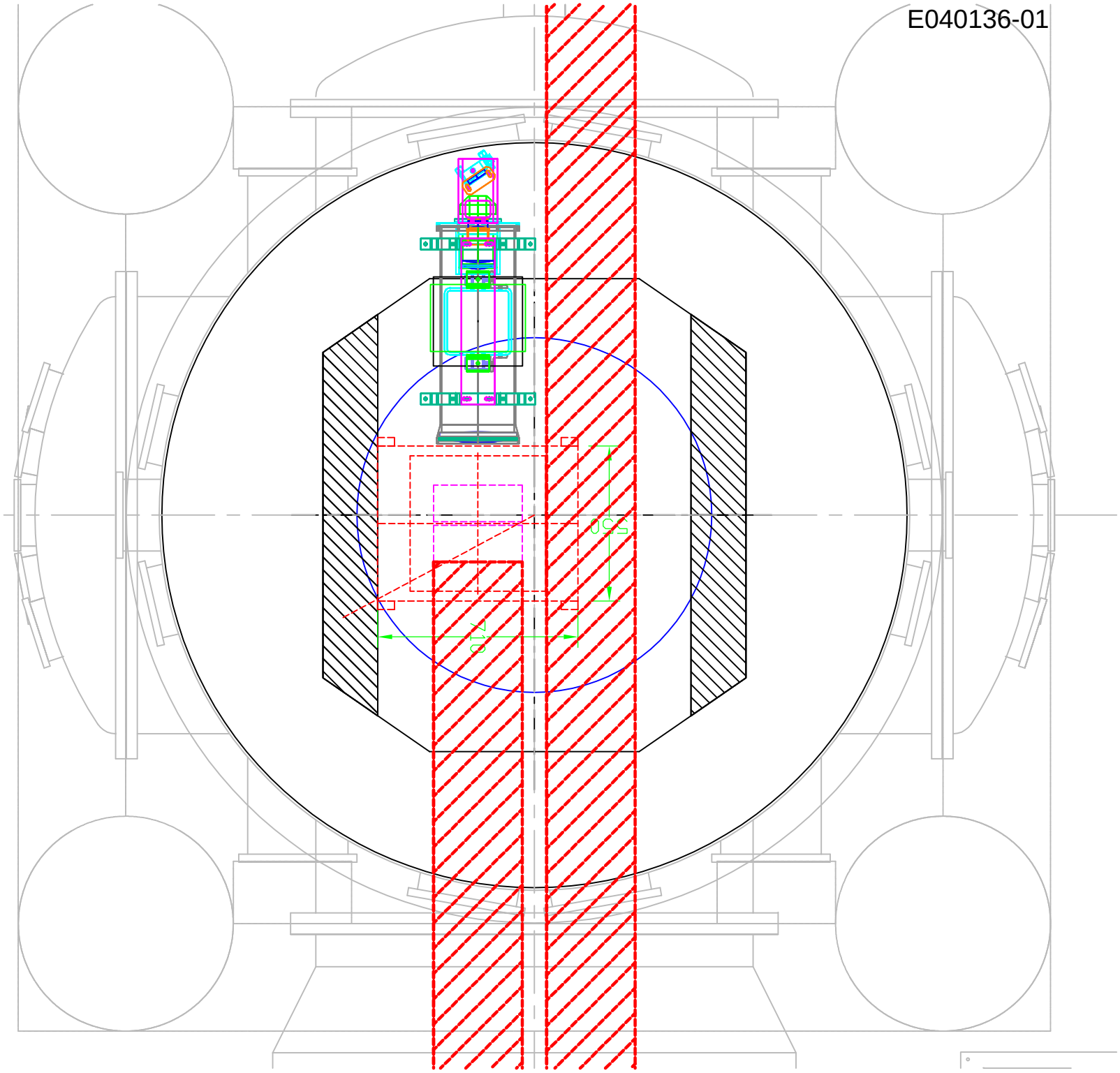

ADVANCED LIGO			Total	Nonsusp	Nonsusp		Budget Mass (kg)		Optics	
Component	**Subsystem**	**Mass (lbs)**	**Mass (kg)**	**Mass (kg)**	**Z cg (mm)**	**Conting**	**Total**	**Nonsuspended**	**Thk, mm**	**Comment**
DLC Mount & Mirror	AOS	2.2	1.0	1.0		10%	1.1	1.1	5.0	same as L1 DLC Mount & Mirror
MC	SUS		65.0	56.0	385.0	25%	81.3	70.0	75.0	C. Torrie estimate from SolidWorks model (2/26/2003 email). However the structural modes are low; a stiffer/heavier structure is needed. Coyne estimates another 25 kg is needed
SM	SUS	30.0	13.6	0.3	180.0	20%	16.3	0.4	25.0	modified L1 SOS
MMT1	SUS	30.0	13.6	0.3	180.0	20%	16.3	0.4	25.0	modified L1 SOS
MMT2	SUS	152.0	68.9	44.9	265.0	20%	82.7	53.9	100.0	modified L1 LOS
HAM periscope	AOS	10.0	4.5	4.5	(1) 152, (1) 304	30%	5.9	5.9	0.0	guess
IO FI	IO	10.0	4.5	4.5	140.0	30%	5.9	5.9	N/A	based on L1 COS FI
OO FI	AOS	10.0	4.5	4.5	140.0	30%	5.9	5.9	N/A	based on L1 COS FI
SUS-PD	SUS	26.0	11.8	11.3	180.0	30%	15.3	14.7	25.0	based on L1 SOS
SRM	SUS	220.0	96.3	60.3	345.0	25%	120.4	75.4	100.0	large triple pendulum estimated by J. Romie & C. Torrie
PRM	SUS	220.0	96.3	60.3	345.0	25%	120.4	75.4	100.0	large triple pendulum estimated by J. Romie & C. Torrie
ETM Trans Tel	AOS		67.0	38.0	-855.0	30%	87.1	49.4	N/A	same as L1 but with long stiff structure to support at proper height; Coyne rough estimate for suspended & scaled initial LIGO version
MC baffle	AOS	7.0	3.2	3.2		30%	4.1	4.2	N/A	
IO beam dump	AOS	7.0	3.2	3.2		30%	4.1	4.2	N/A	
RM beam dump	AOS	10.0	4.5	4.5		30%	5.9	5.9	N/A	
RC baffle	AOS	10.0	4.5	4.5		30%	5.9	5.9	N/A	
PO mirror	AOS		64.0	41.0	-1000.0	25%	74.3	51.3	60.0	Need to extend the L1 PO mirror considerably; Probably single suspension with eddy current damping
cabling & clamps	SEI	40.0	18.1	18.1	-100.0	25%	22.6	22.6	N/A	estimate per chamber (connector bracket, cabling, fasteners)
Comp Plate SUS	AOS/SUS		189.4	150.0	-1000.0	30%	246.2	195.0	75.0	incl. Thermal corrector. WAG based on 3/5/2003 telecon with M. Zucker, D. Ottaway, G. Billingsley
								0.0		
PO TEL	AOS	160.8	72.9	72.9	365.0	30%	94.8	94.8	N/A	redesigned L1, same length, larger diameter, estimate 1.3 x L1 weight
ETM	SUS		384.0	136.0	-570.0	25%	418.0	170.0	130.0	N. Robertson estimate (2/26/2003 email): primary chain assuming FS optics: 22,22, 40,40 plus reaction chain: 22,22, 40,40 L. Jones 3/6/2003 email: quad structure sketch design 114 kg, hase 145 Hz 1st resonance by analysis, so take 120 kg as structure mass Note by L. Jones: the 120 kg needs further increase to account for other nonsuspended items: coils, tablecloth, etc.: 25 kg? 2 Sep 2003 T030137-04
ITM	SUS		384.0	136.0	-570.0	25%	418.0	170.0	130.0	N. Robertson estimate (2/26/2003 email): primary chain assuming FS optics: 22,22, 40,40 plus reaction chain: 22,22, 40 2 Sep 2003 assume thermal compensator is at the bottom of the ITM reaction chain and the ITM = ETM
FM & ITM & CP	SUS		638.0	290.0	-570.0	25%	710.5	362.5	118.0	N. Robertson estimate of optic masses 4 x 25 kg primary chain plus 3 x 25 kg reaction chain (2/26/2003 email) P. Willems (3/14/2003): no need for reaction chain on the FM
BS	SUS		236.1	170.0	-570.0	30%	306.9	221.0	60.0	Coyne's WAG 7,7,12.7,12.7 plus reaction chain 7,7,12.7, plus larger structure mass than quad, say 150 kg

HAM Payload Summary

			Payload							
			Total	Suspend	Non-Susp	Moments (kg-m)				
IFO	Chamber	COC	Mass (kg)	Mass (kg)	Mass (kg)	Mx	My	min Mz	max Mz	
Non-Folded	H1	IO	496.3	83.8	412.5	0.0	0.0	72.6	92.1	
	H3	PRM	345.5	72.3	273.2	0.0	0.0	55.0	70.2	
	H4	SRM	545.2	56.3	488.9	0.0	0.0	119.1	144.9	
	H5	Detector	TBD							
	H6	OO								
Folded	H7	IO								
	H9	PRM								
	H10	SRM								
	H11	Detector								
	H12	OO								
		"MAX"	545.2	83.8	488.9	0.0	0.0	55.0	144.9	
			510.0	75.0	435.0	kg		55.0	145.0	kg-m
			1124.4	165.3	959.0	lbm		4773.8	12585.4	lbm-in
			Requirements							

CHAMBER: HAM1
Layout 1: IMC1, IMC3, IMMT2

	Local Coordinate Frame (table center)			Total	Nonsusp	C.G. Position Uncertainty (mm)					
Components (with contingency)	X (mm) TM	Y (mm) TM	Z (mm) NM	MASS (kg)	MASS (kg)	- X	+ X	- Y	+ Y	- Z	+ Z
MC1	32.0	-678.5	385.0	81.3	70.0	-100.0	100.0	-100.0	100.0	-50.0	50.0
MC3	32.3	-176.0	385.0	81.3	70.0	-100.0	100.0	-100.0	100.0	-50.0	50.0
SM1	16.0	679.3	180.0	16.3	0.4	-100.0	100.0	-100.0	100.0	-50.0	50.0
MMT2	-419.9	223.9	158.4	82.7	53.9	-100.0	100.0	-100.0	100.0	-50.0	50.0
IO FI	465.7	679.3	150.0	5.9	5.9	-100.0	100.0	-100.0	100.0	-50.0	50.0
suspended photodiode	-400.0	0.0	150.0	15.3	14.7	-100.0	100.0	-100.0	100.0	-50.0	50.0
2 L2 HAM periscopes	-400.0	0.0	300.0	11.8	5.9	-100.0	100.0	-100.0	100.0	-50.0	50.0
MC baffle			150.0	4.1	4.2	-100.0	100.0	-100.0	100.0	-50.0	50.0
IO beam dumps			150.0	4.1	4.2	-100.0	100.0	-100.0	100.0	-50.0	50.0
cabling			100.0	22.6	22.6	-100.0	100.0	-100.0	100.0	-50.0	50.0
10 DLC mounts & mirrors	-400.0	0.0	150.0	11.0	1.1	-200.0	200.0	-200.0	200.0	-50.0	50.0
System contingency (10%)	0.0	0.0	180.0	33.6	33.6	0.0	0.0	0.0	0.0	0.0	0.0
total payload cg (w/o balance mass)	-112.8	-96.7	269.2	370.1	286.3	-167.5	-14.3	-184.2	-31.0	205.9	274.1
						-167.5		-184.2			
						Max (Abs(Xcg))		Max (Abs(Ycg))			
						249.0		-132.3			
						Radius (mm)		Angle (deg)			
Balance mass (on optics table)	491.2	540.0	107.7	126.2	126.2	730.0		47.7			
N.B.: Balast (Z) mass not indicated		total mass (sans balast), kg		496.3	412.5						

Mass moments (kg-m):	+/- X	+/- Y	Zmin	Zmax
TotalPayload Mass	62	68		
Non-Suspended Payload Mass			59	78.5
Optics Table Balance + Payload Mass	0	0	73	92.1

CHAMBER: HAM3
Layout 1: IMC2, IMMT1, PRM

	Local Coordinate Frame (table center)			Total	Nonsusp	C.G. Position Uncertainty (mm)					
Components (with contingency)	X (mm) TM	Y (mm) TM	Z (mm) NM	MASS (kg)	MASS (kg)	- X	+ X	- Y	+ Y	- Z	+ Z
MC2	292.8	-425.1	385.0	81.3	70.0	-100.0	100.0	-100.0	100.0	-50.0	50.0
PRM	-49.3	222.0	345.0	120.4	75.4	-100.0	100.0	-100.0	100.0	-50.0	50.0
PRM beam dump	253.6	222.0	180.0	5.9	5.9	-100.0	100.0	-100.0	100.0	-50.0	50.0
MMT1	12.7	679.3	180.0	16.3	0.4	-100.0	100.0	-100.0	100.0	-50.0	50.0
CABLING	-400.0	0.0	100.0	22.6	22.6	-100.0	100.0	-100.0	100.0	-50.0	50.0
5 DLC mounts & mirrors	-400.0	0.0	150.0	5.5	5.5	-200.0	200.0	-200.0	200.0	-50.0	50.0
System contingency (10%)	0.0	0.0	180.0	25.2	25.2	0.0	0.0	0.0	0.0	0.0	0.0
total payload cg (w/o balance mass)	30.0	16.5	301.1	277.2	204.9	-10.2	151.3	-64.2	97.3	249.0	323.0
						151.3		97.3			
						Max (Abs(Xcg))		Max (Abs(Ycg))			
						179.9		32.7			
						Radius (mm)		Angle (deg)			
Balance mass (on optics table)	-614.0	-394.8	58.3	68.3	68.3	730.0		212.7			
N.B.: Balast (Z) mass not indicated		total mass (sans balast), kg		345.5	273.2						

Mass moments (kg-m):	+/- X	+/- Y	Zmin	Zmax
TotalPayload Mass	42	27		
Non-Suspended Payload Mass			51	66.2
Optics Table Balance + Payload Mass	0	0	55	70.2

CHAMBER: HAM4
Layout 1: IMC1, IMC3, IMMT2

	Local Coordinate Frame (table center)			Total	Nonsusp	C.G. Position Uncertainty (mm)					
Components (with contingency)	X (mm) TM	Y (mm) TM	Z (mm) NM	MASS (kg)	MASS (kg)	- X	+ X	- Y	+ Y	- Z	+ Z
OMC2	297.2	-528.3	385.0	81.3	70.0	-100.0	100.0	-100.0	100.0	-50.0	50.0
SRM	-179.7	473.8	345.0	120.4	75.4	-100.0	100.0	-100.0	100.0	-50.0	50.0
SRM beam dump	-179.7	830.6	345.0	5.9	5.9	-100.0	100.0	-100.0	100.0	-50.0	50.0
PO telescope	350.5	584.2	453.6	94.8	94.8	-100.0	100.0	-100.0	100.0	-50.0	50.0
2 periscopes	375.9	-330.2	301.8	11.8	11.8	-100.0	100.0	-100.0	100.0	-50.0	50.0
CABLING	-609.6	-177.8	300.0	22.6	22.6	-100.0	100.0	-100.0	100.0	-50.0	50.0
5 DLC mounts & mirrors	-400.0	0.0	150.0	5.5	5.5	-200.0	200.0	-200.0	200.0	-50.0	50.0
System contingency (10%)	0.0	0.0	180.0	34.2	34.2	0.0	0.0	0.0	0.0	0.0	0.0
total payload cg (w/o balance mass)	61.5	176.6	360.2	376.5	320.2	11.8	172.5	117.3	277.9	296.1	376.7
						172.5		277.9			
						Max (Abs(Xcg))		Max (Abs(Ycg))			
						327.1		58.2			
						Radius (mm)		Angle (deg)			
Balance mass (on optics table)	-384.9	-620.3	144.0	168.7	168.7	730.0		238.2			
N.B.: Balast (Z) mass not indicated		total mass (sans balast), kg		545.2	488.9						

Mass moments (kg-m):	+/- X	+/- Y	Zmin	Zmax
TotalPayload Mass	65	105		
Non-Suspended Payload Mass			95	120.6
Optics Table Balance + Payload Mass	0	0	119	144.9

BSC Payload Summary

				Payload								
			Layout	Total	Suspend	Non-Susp	Moments (kg-m)				Required Scenario for
IFO	Chamber	COC	#	Mass (kg)	Mass (kg)	Mass (kg)	Mx	My	min Mz	max Mz	AdL SEI Structural Design
Non-Folded	B1	ITMy	1	659.0	304.0	355.0	81.3	124.4	-231.6	-231.6	X
			2	755.5	299.2	456.3	148.2	199.7	-328.5	-328.5	X
	B2	BS	1	525.9	131.9	393.9	28.8	47.6	-254.6	-254.6	X
			2	525.9	131.9	393.9	119.6	28.1	-203.4	-203.4	X
	B3	ITMx	1	495.7	258.0	237.7	13.6	77.1	-121.7	-121.7	X
			2	755.5	299.2	456.3	19.0	124.2	-328.5	-328.5	X
	B9	ETMx	1	580.5	285.7	294.8	194.2	92.5	-167.8	-167.8	X
	B10	ETMy	1	580.5	285.7	294.8	116.4	55.6	-167.8	-167.8	X
Folded	B4	BS	TBD								
	B7	ITMx, FMx	TBD								
	B8	ITMy, Fmy	1	806.4	348.0	458.4	126.8	22.3	-245.5	-245.5	X
	B5	ETMx	TBD								
	B6	ETMy	TBD								
			"MAX"	806.4	348.0	458.4	194.2	199.7	-328.5	-121.7	
			kg	800	350	450	194.2	199.7	-328.5	-121.7	kg-m
			lbm	1764	772	992	16852.4	17329.4	-28513.0	-10562.6	lbm-in
			Requirements				**Reference Only**				

CHAMBER: BSC1

Layout 1: ITMy/CP Combined, 2 BS POMs (nominal layout)

	Local Coordinate Frame (table center)			Total	Nonsusp	C.G. Position Uncertainty (mm)					
Components (with contingency)	X (mm) TM	Y (mm) TM	Z (mm) NM	MASS (kg)	MASS (kg)	- X	+ X	- Y	+ Y	- Z	+ Z
ITMy with integral CP	-200.0	-81.0	-570.0	428.0	170.0	0.0	0.0	0.0	0.0	0.0	0.0
POM_BS1	-259.0	-549.0	-1000.0	74.3	51.3	0.0	0.0	0.0	0.0	0.0	0.0
POM_BS2	523.0	-549.0	-1000.0	74.3	51.3	0.0	0.0	0.0	0.0	0.0	0.0
						0.0	0.0	0.0	0.0	0.0	0.0
CABLING, misc	-678.2	-363.2	-100.0	22.6	22.6	0.0	0.0	0.0	0.0	0.0	0.0
System contingency (10%)	0.0	0.0	-500.0	59.9	59.9	0.0	0.0	0.0	0.0	0.0	0.0
total payload cg (w/o balance mass)	-123.4	-188.8	-652.4	659.0	355.0	-123.4	-123.4	-188.8	-188.8	-652.4	-652.4
non-suspended c.g.	-100.9	-220.4	-652.4	355.0		-123.4		-188.8			
suspended c.g.	-149.8	-151.8	-635.1	304.0		Max (Abs(Xcg))		Max (Abs(Ycg))			
						225.5		-123.2			
						Radius (mm)		Angle (deg)			
Balance mass (on optics table)	383.1	585.9	-181.2	212.3	212.3	700.0		56.8			
N.B.: Balast (Z) mass not indicated		total mass (sans balast), kg		871.4	567.4						

Mass moments (kg-m):	+/- X	+/- Y	Zmin	Zmax
TotalPayload Mass	81	124		
Non-Suspended Payload Mass			-232	-231.6
Optics Table Balance + Payload Mass	0	0	-270	-270.1

Layout 2: ITM & CP separate, no POMs

	Local Coordinate Frame (table center)			Total	Nonsusp	C.G. Position Uncertainty (mm)					
Components (with contingency)	X (mm) TM	Y (mm) TM	Z (mm) NM	MASS (kg)	MASS (kg)	- X	+ X	- Y	+ Y	- Z	+ Z
ITMy	-200.0	-81.0	-570.0	418.0	170.0	0.0	0.0	0.0	0.0	0.0	0.0
CP	-200.0	-640.0	-1000.0	246.2	195.0	0.0	0.0	0.0	0.0	0.0	0.0
						0.0	0.0	0.0	0.0	0.0	0.0
CABLING, misc	-678.2	-363.2	-100.0	22.6	22.6	0.0	0.0	0.0	0.0	0.0	0.0
System contingency (10%)	0.0	0.0	-500.0	68.7	68.7	0.0	0.0	0.0	0.0	0.0	0.0
total payload cg (w/o balance mass)	-196.1	-264.3	-719.9	755.5	456.3	-196.1	-196.1	-264.3	-264.3	-719.9	-719.9
						-196.1		-264.3			
						Max (Abs(Xcg))		Max (Abs(Ycg))			
						329.1		-126.6			
						Radius (mm)		Angle (deg)			
Balance mass (on optics table)	417.2	562.1	-303.1	355.2	355.2	700.0		53.4			
N.B.: Balast (Z) mass not indicated		total mass (sans balast), kg		1110.7	811.5						

Mass moments (kg-m):	+/- X	+/- Y	Zmin	Zmax
TotalPayload Mass	148	200		
Non-Suspended Payload Mass			-329	-328.5
Optics Table Balance + Payload Mass	0	0	-436	-436.2

CHAMBER: BSC2

Layout 1: BS SUS and 2 POMs for BS & ITMx POs (nominal layout)

	Local Coordinate Frame (table center)			Total	Nonsusp	C.G. Position Uncertainty (mm)					
Components (with contingency)	X (mm) TM	Y (mm) TM	Z (mm) NM	MASS (kg)	MASS (kg)	- X	+ X	- Y	+ Y	- Z	+ Z
BS	-150.0	172.3	-570.0	306.9	221.0	0.0	0.0	0.0	0.0	0.0	0.0
POM BS3	784.0	-223.0	-1000.0	74.3	51.3	0.0	0.0	0.0	0.0	0.0	0.0
POM ITMx	431.0	263.0	-1000.0	74.3	51.3	0.0	0.0	0.0	0.0	0.0	0.0
						0.0	0.0	0.0	0.0	0.0	0.0
CABLING, misc	-678.2	-363.2	-100.0	22.6	22.6	0.0	0.0	0.0	0.0	0.0	0.0
System contingency (10%)	0.0	0.0	-500.0	47.8	47.8	0.0	0.0	0.0	0.0	0.0	0.0
total payload cg (w/o balance mass)	54.8	90.6	-646.4	525.9	393.9	54.8	54.8	90.6	90.6	-646.4	-646.4
						54.8		90.6			
						Max (Abs(Xcg))		Max (Abs(Ycg))			
						105.9		58.8			
						Radius (mm)		Angle (deg)			
Balance mass (on optics table)	-362.4	-598.9	-67.9	79.5	79.5	700.0		238.8			
N.B.: Balast (Z) mass not indicated		total mass (sans balast), kg		605.4	473.5						

Mass moments (kg-m):	+/- X	+/- Y	Zmin	Zmax
TotalPayload Mass	29	48		
Non-Suspended Payload Mass			-255	-254.6
Optics Table Balance + Payload Mass	0	0	-260	-260.0

Layout 2: BS SUS and 2 POMs for ITMx & ITMy Pos

	Local Coordinate Frame (table center)			Total	Nonsusp	C.G. Position Uncertainty (mm)					
Components (with contingency)	X (mm) TM	Y (mm) TM	Z (mm) NM	MASS (kg)	MASS (kg)	- X	+ X	- Y	+ Y	- Z	+ Z
BS	-150.0	172.3	-570.0	306.9	221.0	0.0	0.0	0.0	0.0	0.0	0.0
POM ITMy	-784.0	-223.0	-1000.0	74.3	51.3	0.0	0.0	0.0	0.0	0.0	0.0
POM ITMx	431.0	263.0	-1000.0	74.3	51.3	0.0	0.0	0.0	0.0	0.0	0.0
						0.0	0.0	0.0	0.0	0.0	0.0
CABLING, misc	-678.2	-363.2	-100.0	22.6	22.6	0.0	0.0	0.0	0.0	0.0	0.0
System contingency (10%)	0.0	0.0	-500.0	47.8	47.8	0.0	0.0	0.0	0.0	0.0	0.0
total payload cg (w/o balance mass)	-166.6	90.6	-646.4	525.9	393.9	-227.4	-227.4	53.5	53.5	-516.3	-516.3
						-227.4		53.5			
						Max (Abs(Xcg))		Max (Abs(Ycg))			
						233.6		166.8			
						Radius (mm)		Angle (deg)			
Balance mass (on optics table)	681.4	-160.2	-149.8	175.5	175.5	700.0		346.8			
N.B.: Balast (Z) mass not indicated		total mass (sans balast), kg		701.4	569.4						

Mass moments (kg-m):	+/- X	+/- Y	Zmin	Zmax
TotalPayload Mass	120	28		
Non-Suspended Payload Mass			-203	-203.4
Optics Table Balance + Payload Mass	0	-8.7311E-11	-230	-229.7

CHAMBER: BSC3

Layout 1: ITMx/CP Combined (nominal layout)

	Local Coordinate Frame (table center)			Total	Nonsusp	C.G. Position Uncertainty (mm)					
Components (with contingency)	X (mm) TM	Y (mm) TM	Z (mm) NM	MASS (kg)	MASS (kg)	- X	+ X	- Y	+ Y	- Z	+ Z
ITMx/CP	67.7	199.4	-570.0	428.0	170.0	0.0	0.0	0.0	0.0	0.0	0.0
						0.0	0.0	0.0	0.0	0.0	0.0
						0.0	0.0	0.0	0.0	0.0	0.0
						0.0	0.0	0.0	0.0	0.0	0.0
CABLING, misc	-678.2	-363.2	-100.0	22.6	22.6	0.0	0.0	0.0	0.0	0.0	0.0
System contingency (10%)	0.0	0.0	-500.0	45.1	45.1	0.0	0.0	0.0	0.0	0.0	0.0
total payload cg (w/o balance mass)	27.5	155.6	-512.0	**495.7**	237.7	27.5	27.5	155.6	155.6	-512.0	-512.0
						27.5		155.6			
						Max (Abs(Xcg))		Max (Abs(Ycg))			
						158.0		80.0			
						Radius (mm)		Angle (deg)			
Balance mass (on optics table)	-121.8	-689.3	-95.5	111.9	111.9	700.0		260.0			
N.B.: Balast (Z) mass not indicated		total mass (sans balast), kg		607.6	349.6						

Mass moments (kg-m):	+/- X	+/- Y	Zmin	Zmax
TotalPayload Mass	**14**	**77**		
Non-Suspended Payload Mass			**-122**	**-121.7**
Optics Table Balance + Payload Mass	-1.03682E-10	0	-132	-132.4

Layout 2: ITM & CP Separate

	Local Coordinate Frame (table center)			Total	Nonsusp	C.G. Position Uncertainty (mm)					
Components (with contingency)	X (mm) TM	Y (mm) TM	Z (mm) NM	MASS (kg)	MASS (kg)	- X	+ X	- Y	+ Y	- Z	+ Z
ITMx	200.0	199.4	-570.0	418.0	170.0	0.0	0.0	0.0	0.0	0.0	0.0
CP	-200.0	199.4	-1000.0	246.2	195.0	0.0	0.0	0.0	0.0	0.0	0.0
						0.0	0.0	0.0	0.0	0.0	0.0
						0.0	0.0	0.0	0.0	0.0	0.0
CABLING, misc	-678.2	-363.2	-100.0	22.6	22.6	0.0	0.0	0.0	0.0	0.0	0.0
System contingency (10%)	0.0	0.0	-500.0	68.7	68.7	0.0	0.0	0.0	0.0	0.0	0.0
total payload cg (w/o balance mass)	25.2	164.4	-719.9	**755.5**	456.3	25.2	25.2	164.4	164.4	-719.9	-719.9
						25.2		164.4			
						Max (Abs(Xcg))		Max (Abs(Ycg))			
						166.3		81.3			
						Radius (mm)		Angle (deg)			
Balance mass (on optics table)	-105.9	-691.9	-153.2	179.5	179.5	700.0		261.3			
N.B.: Balast (Z) mass not indicated		total mass (sans balast), kg		935.1	635.8						

Mass moments (kg-m):	+/- X	+/- Y	Zmin	Zmax
TotalPayload Mass	**19**	**124**		
Non-Suspended Payload Mass			**-329**	**-328.5**
Optics Table Balance + Payload Mass	4.36557E-11	0	-356	-356.0

CHAMBER: BSC9

Layout 1: ETMx and ETMx Telescope (nominal layout)

	Local Coordinate Frame (table center)			Total	Nonsusp	C.G. Position Uncertainty (mm)					
Components (with contingency)	X (mm) TM	Y (mm) TM	Z (mm) NM	MASS (kg)	MASS (kg)	- X	+ X	- Y	+ Y	- Z	+ Z
ETMx	297.0	199.4	-570.0	418.0	170.0	0.0	0.0	0.0	0.0	0.0	0.0
ETMx Telescope	980.0	199.4	-855.0	87.1	49.4	0.0	0.0	0.0	0.0	0.0	0.0
						0.0	0.0	0.0	0.0	0.0	0.0
						0.0	0.0	0.0	0.0	0.0	0.0
CABLING, misc	-678.2	-363.2	-100.0	22.6	22.6	0.0	0.0	0.0	0.0	0.0	0.0
System contingency (10%)	0.0	0.0	-500.0	52.8	52.8	0.0	0.0	0.0	0.0	0.0	0.0
total payload cg (w/o balance mass)	334.5	159.3	-569.2	**580.5**	294.8	334.5	334.5	159.3	159.3	-569.2	-569.2
						334.5		159.3			
						Max (Abs(Xcg))		Max (Abs(Ycg))			
						370.5		25.5			
						Radius (mm)		Angle (deg)			
Balance mass (on optics table)	-631.9	-301.1	-262.2	307.2	307.2	700.0		205.5			
N.B.: Balast (Z) mass not indicated		total mass (sans balast), kg		887.7	602.0						

Mass moments (kg-m):	+/- X	+/- Y	Zmin	Zmax
TotalPayload Mass	**194**	**92**		
Non-Suspended Payload Mass			**-168**	**-167.8**
Optics Table Balance + Payload Mass	0	0	-248	-248.3

CHAMBER: BSC10

Layout 1: ETMy and ETMy Telescope (nominal layout)

	Local Coordinate Frame (table center)			Total	Nonsusp	C.G. Position Uncertainty (mm)					
Components (with contingency)	X (mm) TM	Y (mm) TM	Z (mm) NM	MASS (kg)	MASS (kg)	- X	+ X	- Y	+ Y	- Z	+ Z
ETMy	-200.0	-29.6	-570.0	418.0	170.0	0.0	0.0	0.0	0.0	0.0	0.0
ETMy Telescope	-200.0	686.0	-855.0	87.1	49.4	0.0	0.0	0.0	0.0	0.0	0.0
						0.0	0.0	0.0	0.0	0.0	0.0
						0.0	0.0	0.0	0.0	0.0	0.0
CABLING, misc	-678.2	363.2	-100.0	22.6	22.6	0.0	0.0	0.0	0.0	0.0	0.0
System contingency (10%)	0.0	0.0	-500.0	52.8	52.8	0.0	0.0	0.0	0.0	0.0	0.0
total payload cg (w/o balance mass)	-200.5	95.8	-569.2	580.5	294.8	-200.5	-200.5	95.8	95.8	-569.2	-569.2
						-200.5		95.8			
						Max (Abs(Xcg))		Max (Abs(Ycg))			
						222.2		154.5			
						Radius (mm)		Angle (deg)			
Balance mass (on optics table)	631.6	-301.8	-157.2	184.2	184.2	700.0		334.5			
N.B.: Balast (Z) mass not indicated		total mass (sans balast), kg		764.7	479.0						

Mass moments (kg-m):	+/- X	+/- Y	Zmin	Zmax
TotalPayload Mass	116	56		
Non-Suspended Payload Mass			-168	-167.8
Optics Table Balance + Payload Mass	0	-1.6007E-10	-197	-196.8

CHAMBER: BSC8

Layout 1: ITMy and FMy in common structure (nominal layout)

	Local Coordinate Frame (table center)			Total	Nonsusp	C.G. Position Uncertainty (mm)					
Components (with contingency)	X (mm) TM	Y (mm) TM	Z (mm) NM	MASS (kg)	MASS (kg)	- X	+ X	- Y	+ Y	- Z	+ Z
ITM, FM, CP Combined	200.0	43.0	-570.0	710.5	362.5	0.0	0.0	0.0	0.0	0.0	0.0
						0.0	0.0	0.0	0.0	0.0	0.0
						0.0	0.0	0.0	0.0	0.0	0.0
						0.0	0.0	0.0	0.0	0.0	0.0
CABLING, misc	-678.2	-363.2	-100.0	22.6	22.6	0.0	0.0	0.0	0.0	0.0	0.0
System contingency (10%)	0.0	0.0	-500.0	73.3	73.3	0.0	0.0	0.0	0.0	0.0	0.0
total payload cg (w/o balance mass)	157.2	27.7	-535.6	806.4	458.4	157.2	157.2	27.7	27.7	-535.6	-535.6
						157.2		27.7			
						Max (Abs(Xcg))		Max (Abs(Ycg))			
						159.6		10.0			
						Radius (mm)		Angle (deg)			
Balance mass (on optics table)	-689.4	-121.5	-156.9	183.9	183.9	700.0		190.0			
N.B.: Balast (Z) mass not indicated		total mass (sans balast), kg		990.3	642.3						

Mass moments (kg-m):	+/- X	+/- Y	Zmin	Zmax
TotalPayload Mass	127	22		
Non-Suspended Payload Mass			-246	-245.5
Optics Table Balance + Payload Mass	0	0	-274	-274.4