

Compliance matrix for Quad suspension noise prototype design.

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This note gathers the performance requirements and key interface requirements and documents compliance to them, with cross-reference to other relevant documents.

Revision 01 March 2006 following RRR review – see [M060041](#).

Revision 02 June 2006 following steady work on loose ends.

Revision 03 March 2008 in preparation for Quad Fabrication readiness review

Revision 04 April 2008 in preparation for Quad Fabrication Readiness Review (Machined parts and Blades)

Introduction

This compliance matrix was originally put together for PDR #3 in Summer 2006. It was compiled to address all the requirements from the various requirements documents. Most of these were marked as “comply” and the few that were not had explanations attached.

In this update (04) the status information has been re-checked, and the document colour coded to reflect structural and suspension requirements, this has been done to facilitate quick review of just the structures or suspensions as the review has been split. The colour coding scheme is as follows:

Grey: Unchanged since last review (PDR#3)

Light Blue: Relevant to structures but unchanged since PDR #3

Blue: Relevant to Structure review, and changed since the last review

Light Pink: Relevant changes have been made to Machining since PDR#3 but matrix is unchanged

Dark Pink: Relevant changes have been made to Machining since PDR#3 and matrix has changed

Part 1 – complete listing of requirements in Design Requirements Documents.

Document section	Parameter	requirement	Status	Notes
<u>T010007-03</u> Cavity Optics suspension subsystem DRD, 7 Jun 2005, Barton et al.				
3.3	Technical noise	No source must contribute to the gravity wave signal more than 10% of the "fundamental" requirements in T010075-00	Comply	See 3.7, 4.2 and 6.7.2 below.
3.5.1	Alignment	Longitudinal: +/- 3mm Transverse/vertical: +/- 1mm Pitch/yaw: +/- 0.1 mRad	Comply Comply Comply	See assembly procedure document T060040-06-K , latest version. Problems were encountered with perminant DC pitches, this has been solved and is being tested at LASTI
3.5.1	Actuator range	Must provide a range of +/- 1mRad Updated by document cited at right.	Comply	See T050271-00 (Fritschel, "Considerations regarding magnet strengths ...") for the detail. T060001-00 (Strain) showed how we will meet the requirements.
3.5.2	Earthquake stops or assembly jigs	Facilitate assembly	Comply	See assembly procedure T060040-04-K
	Earthquake stops or assembly jigs	Immobilize optic	Comply	See end of assembly procedure T060040-04-K
	Earthquake stops	Protect suspended parts during earthquake	Comply	See fuller description in T060139-00-K .
	Earthquake stops	Protect suspended parts when wire/ribbon breaks	Comply	

3.6	Structure resonances	No mode below 100Hz	Do not comply	1 st mode is ~54Hz, This has been given preliminary approval. See also below in E050159-00 item 1.1.4.3
3.7	Reaction chain and actuator noise	Noise of the actuators	Comply	The design will meet the requirements as set out in T060067-00 .
		Control noise	Comply	As above.
		Coupling of reaction chain noise via non-zero rate of change of force with distance	Comply	T060043 shows that we meet this requirement.
		Fluctuating forces from scanning TCS if used	N/A	Scanning TCS not currently planned
3.8	Mass budget	Must agree with E040136-00 (Seismic Isolation System (SEI) Payload Mass Properties) or revisions	Comply	See mass breakdown in T060141-00-K Note that the Folding mirrors are not considered at this review. Agreed with DCC at RRR.
3.9	Interfaces			See detailed breakdown below
		Note that the requirements below should be split between SEI and SUS - so the SUS should be given an isolation requirement, not a noise requirement.		
4.2	Noise performance	Test mass internal mode longitudinal thermal noise	N/A	Not covered at this review.
		Suspension longitudinal thermal noise	Comply	Covered in T010103-05 (summed with vert thermal)
		Longitudinal and vertical seismic sqrt term	Comply	Covered in T010103-05 (presented separately, but when

				summed satisfy requirements).
		Pitch noise	Comply	Not covered in T010103. A document is pending on pitch, yaw and transverse thermal and seismic noise.
		Yaw noise	Comply	Not covered in T010103. See above.
		Vertical thermal	Comply	Covered in T010103-05 (link above) (summed with long. Thermal)
		Transverse thermal and seismic	Comply	Not covered in T010103. See above.
		Longitudinal, vertical and transverse technical noise	Comply	See T060099-00-K (insert link) which describes the effects for various technical noise sources.
		Roll noise	N/A	We are no longer planning to use sapphire.

[E010613-01-D](#) Generic requirements & Standards for Detector subsystems, 9 June 2005, Coyne et al

4	Documentation	Documents on DCC, drawings approved in accordance with E030350-A-D	Comply	See also further commentary in M050438-01.
6.2, 6.3	Part numbers and serial numbers	LIGO drawing number marked on all parts	Comply	All detail drawings require marking of LIGO part number as in E030350-A-D
6.4	Co-ordinate system	As per T980044	Comply	See also T040072-01-R which is specific to the quad.
6.5.1	Structural safety	Metals other than maraging steel 1.25 on	Comply	See stress calculations in top

	factor	yield, 1.4 on ultimate		stage PDS T050233-00-K , structure FEA document T060135-00-K , wire clamp PDS T060042-00-K .
6.5.2	Structural safety factor	Maraging steel FS + 1.8	Comply	See blade PDS T060047 .
6.5.3	Structural safety factor	Bonds FS of 2.0	Comply	Magnets are used for holding flags. Ear bonds are using FS of 3 minimum.
6.5.4	Glass & ceramics	FS 3.0	Comply	Ears and their bonds covered in PDR#2 and updates . FS well above 3 expected for laser-pulled ribbons.
6.5.4.1.1	Proof testing	Proof test all bonds and brittle structures. We note that the ribbon proof test requires to be done in an inert environment. The current procedure does not address this.	Will comply	Covered in ribbon, ear and welding review PDR#2. See updates for latest data.
6.5.4.1.2	Ribbon environment	Ribbons to be kept moisture free	Comply	See under T000053-03 section 2.8.6.2 below.
6.7.1	Cleaning	To LIGO specs	Comply	All components of final production will be cleaned by LIGO. These parts will be handled and treated in accordance with the LIGO specifications during manufacture. Welding

				technique is described in the RFQ.
6.7.2	Creep acceleration	Requirement here updated by blade committee document T040108-03 . See also requirements in T000053-05 section 2.6.1 below.	Comply	Detailed in assembly procedure T060040-04-K, now gives 1 week at 120C (per T040108-03) rather than at 100C to 200C(per E010613) or at 110C per T000053 2.6.1 table 1.
6.8.1	Welding of metals	Various requirements specified	Comply	See T000053-03 section 2.8.3.4.2 below, and RFQ for weldments for exact detail.
6.8.2	Welding fused silica	TBD	Comply	Requirements further developed and reviewed in at PDR#2. See updates .
6.8.3	Dip brazing	No dip brazing	Comply	
6.9	Finishes	Tooling protected against corrosion. In-vacuum components not to be anodized.	Comply	See T000053-03 section 2.8.3.1 below.
6.10	Threaded fasteners		Comply	See detail under T000053-03 section 2.8.3.3 below. All fastener holes are tapped either 0.005" oversize or have Nitronic helicoils, this allows the use of regular SS bolts throughout. Helicoils are used in locations of high load or multiple removals.
6.11, 6.12	Drawing and CAD standards	See E030350	Comply	

6.16.1	Vacuum parts preparation	See E960022-00-D	Comply	See under T000053-03 section 4.1 below.
6.16.2, 6.16.3	Packaging, marking	Appropriate to the parts, decent wooden crates, properly marked	Comply	Relevant standards will be used
		Parts for in-vacuum use must use the right kind of wrapping	Comply	Note that such wrapping is not required BEFORE vacuum-quality cleaning.
7	Electrical standards			Covered at previous review PDR #1. See update documents on Birmingham website .
7.4	Cabling	See E960177-00. (Must also meet vacuum requirements)	Comply	Relevant for wiring over the SUS between actuators and interface with SEI. See PDR#1 update document T050112-01 on Birmingham website .
8	Vacuum compatibility	See E960022 (below) and E960050 (also below)	Comply	
9	Acoustic requirements		N/A	Only applies to electronics drive units; covered by previous review PDR#1. ESD drives will be water cooled, see T050110-01 on Birmingham website .
10	Earthquake requirements	Limits given for maintaining operation (10.3), no damage (10.2) and maintaining structural integrity (10.1)	Comply	See section 2.6.1.2 of T000053-03 below which gives a static equivalent interpretation.
11	QA	Requirements for inspections, analysis, demonstration, similarity and test.	Comply	See section 3.4 of T000053-03 below

12	Reliability		Comply	See T000053-03 section 2.4 below
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T000053-04, Universal Suspensions subsystem DRD, Dec 2005, Dennis Coyne

2.1	Fit	Must fit in the chamber without interfering with neighbouring components. See details in D050266-00	Comply	Almost fits with envelope supplied by SYS only very localised violations at the bottom of the sleeve. An updated drawing will be provided.
2.2	Interfaces external to LIGO		N/A	
2.3	Interfaces internally	E030647 and extant RODAs	Comply	See also below for interfaces
2.4	Reliability	Failure rate 5 years per interferometer.		OSEMs have been covered by a separate review. There are no structural parts subject to fatigue, and creep in the highly-stressed parts (wires and blades) has been extensively studied; See T040108-03 (blade process spec). See comments on OSEM life in T060142-00-K .
2.5	Maintenance and repair - general			See also E040329-03 (Failure and repair) and T060116-00-K (FEMA) and T060040-04-K (assembly proc with repair)

				scenarios)
2.5.1	Maintenance and repair - in-air	Less than 1 day	N/A	Electronics covered by separate review
2.5.2	Maintenance and repair - in - vacuum	Minimise the need for cartridge de-installation where possible	Comply	
2.5.2.1.1	Fibres/ribbons	Suspension partially or fully removed from vacuum. Time to repair not to exceed two days	Comply	Covered in earlier review see updates and also latest assembly procedure T060040-04-K
2.5.2.1.2	Wires	Time to replace less than two days including cleanup	Comply	See T060040-04-K (assembly procedure)
2.5.2.1.3	Optic ears	Fifty days including bonding; two days with pre-bonded parts	N/A	Covered in earlier review see updates
2.5.2.1.4	OSEM	Replacement possible in situ, time not to exceed two days.	Comply	See T060040-04-K (assembly procedure) and T060116-00-K (FEMA)
2.5.2.1.5	Magnets	Replacement of optic plus magnet not to exceed 14 days. Replacement of screw-in magnet not to exceed two days	Comply	This has been superseded by the innovation of “magnetic bonding” for the flags. See T060122-00-K
2.5.2.1.6	Mechanical adjustments	Realignment goal 4 hours in situ	Comply	As far as we are aware this can be done; it depends on the extent of the alignment required and the metrology available.
2.6	Environment	Suspension assembled at observatory from easily shipped parts	Comply	The assembly process has been designed with this in mind and

				we will supply assembly tooling.
2.6.1	Temperature and humidity	Storage of various items, only the first line applies in this review.	Comply	The only items which might subject to degradation are the maraging steel blades and the steel wires, which might rust.
		Creep bake.	Comply	For the creep bake see E010613-01-D section 6.7.2 above.
		In vacuum bake. Note additional request by email from Dennis Coyne May 9 th 2006 requesting highest temperature possible. The target under discussion in preceding emails was 125C.	Comply	No temperature-sensitive parts in this review except wiring and magnets, but this new requirement was not reviewed as part of the electronics review PDR#1. See T050111-01 page 26.
		Assembly	Comply	No special requirements.
		Assembly with fused silica	Comply	
		Transport of parts - no special requirements	Comply	
		Transport of assembly (no fused silica parts) extra care and air-ride van	Comply	Movement stops are provided see T060139-00-K
		Transport and handling (final assembly including mirrors) within facility	Comply	Not part of this review, although the suspension is designed so that it can be installed using special tooling and the crane.
		Operation in-vacuum 23 +/- 2C	Comply	But note that most parts of the

				suspension will reach higher temperatures see T060115-01-K re thermal effects.
		Operation external to vacuum 23 +/- 2C	Comply	No special requirements during assembly.
2.6.1.2	Seismic	Severe: 0.4g sideways and 1.1g vertically must cause no major damage	Comply	See T060118-00-K Which has a section on earthquake survival calculations. See FEMA document T060116-00-K
		Moderate: 0.11g sideways and 1.03g vertical must cause no failures	Comply	Ditto
		Minor ground motion - not defined	N/A	
2.6.1.3	Magnetic fields	See ICD E050159-00 . Suspension must fulfil design requirements with given fields and gradients.	Comply	See T050271-00 (revised force requirements) and T060001-00 (proposed response) Ref stress relieve bake
2.6.2	Magnetic damping	Requirement not defined - there must be no eddy-current damping effects that violate the "technical noise" requirement.	Comply	See T060099-01-K (technical noise sources) section 2.10.
2.6.3	Electrostatics	(for objects near the optics) Requirement not defined	Comply	Earthquake stops will use silica tips
2.6.4.1	EMI compatibility	Various requirements	N/A	Covered in electronics review; key documents updated are T050111-01 (OSEMs); T050112-01 (electronics); T050110-01 (ESD) on Birmingham website .

2.6.4.2	Acoustic	Various requirements	N/A	Covered in electronics review; ESD drives will now use water cooling see T050110-01 on Birmingham website .
2.6.4.3	Mechanical vibration	Natural vibration amplitude not increased by more than 1dB with 1 m.	Comply	SUS not coupled directly to vacuum tanks.
2.7	Transportability	Transportable by commercial carriers; lifting provisions over 100 lbs; handling frames to be provided by SUS	Comply	The most delicate parts currently envisaged to ship are the PM and RM (Test mass not part of this review) and assembled top and UI masses. None of these are above 100 lbs unless multiple systems are assembled together.
2.8.1, 2.8.2	Electronics, electrics		N/A	Covered in electronics review.
2.8.3	Materials and processes			
2.8.3.1	Finishes	Tooling protected against corrosion. In-vacuum components not to be anodized. Sliding surfaces to be avoided where possible, must only use approved lubricants.	Comply	No in-vacuum components have any surface treatment. Tooling will use non-corroding materials or mild steel parts which are surface treated eg by cadmium plating.
2.8.3.2	Fasteners	All imperial (E030350-A-D is cited) In vacuum fasteners to be treated as specified in accordance with E030350 to	Comply	Specified on detail drawings

		prevent galling (oversize taps; silver plating; nitronic inserts) (note that the requirement has in fact been removed from E030350 and is now duplicated here and in E010613-01 generic requirements, section 6.10)		
2.8.3.3	Materials for vacuum service	Must come from E960050-B or be tested	Comply	The material of the flexi-circuit is still under test. See T060137-00-K
2.8.3.4.1	Cleaning	Cleaning must be done to E960022-B	Comply	In-vacuum parts will be supplied laboratory clean to Caltech where they will be cleaned baked packed and shipped to LASTI. Tooling will be cleaned in accordance with E960022-B, class B (Appendix A3) with the possible exception of scissors-jack for jacking sus assembly.
2.8.3.4.2	Welding	Various requirements specified. See also recent experience from SAS HAM as set out in email from Dennis Coyne of 23 May 2006	Comply	See draft welding specification T060113-00-K and Weldment RFQ
2.8.4	Component naming	Use the standard LIGO naming convention	Comply	
2.8.5	Interchangeability	Only two or three OSEM designs	Comply	Currently only two are envisaged, the "LIGO-1" and

				"Birmingham" designs. However, the Birmingham design will come in two flavours, with and without sensors.
		Magnet/Standoff/flag common to all suspensions	Comply	
		Electronics designs similar	N/A	Covered in separate review
		Dog clamps single design	Variant	The dog-clamps for the quad suspensions will need to be much stiffer than those for the HAMs - see T050098 (Dennis at March 2005 LSC)
2.8.6	Safety	Hazard Analysis required per M950046-F section 3.3.2.	Comply	First draft at T060131-00-K The hazards include stored energy in blades, injury from lifting, injury from dropping, lasers during welding.
2.8.6.1	Personnel safety	lasers (for welding). SOP compliant with M0401112-07 (LLO), M020131-01 (LHO) and TBD (LASTI)	Will comply	An SOP will be produced for the ribbon pulling/welding machine. Glasgow have just delivered a similar system to Virgo for EGO, which complies with Glasgow University and EGO rules.
		heavy items,	Comply	

		spring energy release	Comply	
		high voltage	N/A	High voltage was considered in a previous review.
2.8.6.2	Machine safety	Provide mass stops	Comply	
		Design FS	Comply	See under E010613-01-D section 6.5 above
		Proof testing on all magnet bonds, ear bonds, ribbon welds	Comply	Ears and ribbons covered in previous review. See also under E010613-01-D section 6.5 above
		Ribbons to be kept moisture free	Comply	Suitable storage will be provided. See assembly procedure T060040-04-K
		Coil over-current	N/A	Covered in previous review. See T050111-01 (OSEMs); T050112-01 (electronics) on Birmingham website .
2.8.7	Human Engineering	Several factors listed for consideration in assembly procedures	Comply	
2.8.8	Assembly and maintenance	Assembly possible in class 100 clean area	Comply	
		Alignment tooling provided	Comply	
		Installation	N/A	Not part of this review, but installation of controls prototype shows that it is feasible and we are working closely with LIGO on installation tooling.

		Repair/replacement procedure and tooling	Comply	See also section 2.5.2 above.
		Assembly procedures tested by “third parties”	Will comply as far as LIGO observatory staff can be made available.	Procedure has been developed between several groups, needs to be tested on the noise prototype.
		“Cartridge” installation method	Comply	
2.9.1	Specifications	ICDs	Comply	Reviewed in June 2005, UK comments in M050438-01
		OSEM and ESD	N/A	Covered by electronics review
		Welded structure process spec	Comply	See draft welding specification T060113-00-K . and Weldment RFQ.
		Suspension UHV cleaning and FTIR sampling spec	Comply	It is hoped that the weldment vendor will take on some of the cleaning duties, the spec they will be provided with is still subject to discussion
2.9.2	Design documents	Conceptual design T010103 and T010007 DRD to be kept up to date	Comply	Revised and reviewed in June 2005
		Installation and commissioning plans		Not covered by this review.
2.9.3	Engineering drawings	To E030350	Comply	See comment in M050438-01 on the details of the UK compliance.
2.9.4	Procedures	OSEM assembly	N/A	Earlier review

		Suspension assembly	Comply	T060040-04-K assembly procedure
		Fiber/Ribbon welding	N/A	Earlier review
		Ear bonding	N/A	Earlier review
		Initial installation and setup	pending	Not UK deliverable but UK should have input.
		Normal operation		Instructions required?
		Normal and/or preventative maintenance	Comply	None envisaged
		Troubleshooting guide	Pending	Recognise need. Has been developed during noise prototype assembly and installation. Will be improved during 1 st article assembly.
2.9.5	Manuals	<p>Requirements modified in forthcoming release of T000053, to include</p> <p>The following manuals shall be provided:</p> <ul style="list-style-type: none"> • OSEM Manual • OSEM Drive/Readout Electronics Manual • Electro-Static Drive Electronics Manual • Suspension Controller and System Manual 	Pending	The manuals will be provided.

		Each of these manuals shall include guidance on operational use, maintenance, repair, and troubleshooting, as appropriate.		
2.9.6	Numbering	Documents use DCC	Comply	
2.9.7	Travellers	Requirements not yet complete	Pending	Will be developed during noise prototype assembly/cleaning/installation
2.10	Test plans and procedures		N/A	Requirement not relevant to this review
2.11	Logistics	Spares etc	Comply	Numbers of spares have been agreed with SYS, embodied in UK Scope document M030162-A released by DCN E050036-00
3.2	Reliability testing	OSEMS	N/A	Covered by electronics review
		Ear bonds and ribbon welds	N/A	Covered by ear etc review
3.3	Configuration management	Must follow LIGO detector implementation plan	Intend to comply	Need to see the plan. We assume much of this will be covered by our compliance with E030350-A-D (Drawing standards)
3.4	Quality conformance	Requirements for inspections, analysis, demonstration, similarity and test.	Comply	Design at RAL is within a ISO 9001 QA system. LIGO QA procedure are followed for example in drawing approvals and by reviews.

4.1	Vacuum parts preparation	See E960022-00-D	Comply	All in-vacuum parts will be cleaned in US. Parts will be supplied to them to general lab clean standard. And will be machined with appropriate processes to enable cleaning. Structures may be supplied clean and RGA tested
4.2, 4.3	Packaging, marking	Appropriate to the parts, decent wooden crates, properly marked	Comply	Relevant standards will be used

Part 2 Key interface requirements

It would not be productive to list here all of the items in the several interface documents to which SUS-UK is party. There follows a listing of those requirements which the design team feel to be particularly relevant.

Document section	Parameter	Requirement	Status	Notes
E050160-01 ICD SUS/UK - SUS/US Coyne et al. Draft four from Birmingham website, Sept 2005				
UPDATED VERSION NOW LINKED HERE E050160-01				
Figure 1 and Figure 2	Diagrams showing scope of provision	Embodied in diagrams. This is mostly not relevant for this review except for the "pigtailed"	Comply	
Table 1 etc.	Table of OSEM connections	The pigtailed must conform to the relevant tables at both ends.	Comply	
E050169-01 ICD SUS/UK - AOS Coyne et al, June 21, 2005.				
1.1.1.1.1	Compensator	Comp Plate is mounted to the end of the	Comply	Note that the requirement is for

	plate	reaction chain of the ITM.		the N-Ptype to be reconfigurable between ETM and ITM.
1.1.1.1.2	Ring heater and radiation shield attachments	Heater and shield, mass up to 1.5kg each.	Comply	Has an adverse affect on natural frequency of structure. Note: Baffles no longer interface to structure
1.1.1.1.2 & 1.1.1.1.4		Must be able to mount heater and shield, with suitable view factor,	Comply	Being tested
1.1.1.2	Ring heater power	Expected to exploit unused wire in the D25 connectors	Unsure	Need to check if the D25 connectors are suitably rated.
1.1.1.3	TCS parasitic heating	TBD limit on heat into structure from TCS		See recent analysis in T060115-01-K
1.1.3.1.2	Obscuration by earthquake stops	Must not protrude more than 10mm from edge of optic	Comply	Note limit is assumed to be from edge of chamfer to maximise contact area. (Agreed with Coyne Dec 2005)
1.1.6.1.1	Alignment marks	Required per diagrams in ICD.	Comply	Shown on detail drawings.
Not yet included	Requirement to allow for SPI	Location of SPI not yet formalised	Intent is to comply	No provision in present design to allow for SPI

E050168-00 ICD SUS/UK - COC Coyne et al, June 14, 2005.

Table 1	Optics sizes	Definitive sizes of optics	Comply	
1.1.1.4	Electrostatic coating	In discussion	Compliance anticipated	Need to agree who provides these.
1.1.1.6	Covers and Ergo arm	Covers will be provided for optics when not in use, in particular during assembly	Comply	Use of the covers and ergo arm is allowed for in the assembly

		of SUS. The “Ergo arm” provided by COC will be used for handling the optics		procedure.
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E050159-00 ICD SUS/UK - SEI Coyne et al, June 14, 2005.

Figure 1 and Figure 2	Interface between pigtails and SEI	Required to conform to diagram	Compliance anticipated	Alternate diagram proposed – see above under Figure 1 & 2 of E050161-01
1.1.1.2	Envelope	Drawing supplied by SYS		
1.1.4.3	Frequencies	> 200 Hz (upper), >100 Hz (lower), > 100 Hz (both) See also T010007-03 item 3.6. Beware duplicates modes.	NOT COMPLIANT but effects are understood to be acceptable	Requirements are discussed in T050005-01 , and further interpreted in T050014-00 . FEA of structures is in T060135-00-K . Feedback from LASTI and Brian Lantz indicate 1 st mode of 77hz as tested to be acceptable.
1.1.6.1	SEI static range	Limits given for movements that can be achieved by SEI to move the whole SUS into alignment.	Comply	See alignment document T050103-00-K

[E050176-00](#) ICD SUS/UK - ISC, Coyne, June 2005

1.1.2.1	Global control actuator requirements	All superseded by more recent documents T060067 “AdL Quad Suspension UK Coil Driver Design Requirements” and T050271-00 “Considerations regarding magnet strengths for the Advanced LIGO test mass quadruple suspensions” (Not sure about the ESD requirements)	Comply	Key documents updated are T050111-01 (OSEMs); T050112-01 (electronics); T050110-01 (ESD) on Birmingham website .
1.1.2.2	Violin modes	Above 400 Hz and quality factor above	Comply	See T010103-05 for violin modes

		10^{10}		and T050267-00 for further discussion. Mechanical provision exists and Nick Lockerby agrees there is adequate provision (verbal)
Not yet included	Gap between Test mass and reaction mass	We will set the gap to 5mm +/- 0.25mm. If necessary this will involve mounted the RM at a small angle. And we note the requirement that we do not align the RM with the interferometer. See also email from KAS 26 May 2006	Comply	Assembly procedure T060040-04-K . Additional provision has been added to allow looking at the side of the optics with microscopes to help this.

Part 3 relevant RODAs and other areas

Relevant RODAs

See http://www.ligo.caltech.edu/~coyne/AL/project_management/RODA/RODA_status.htm

M040005-01.pdf		CP location, dimensions and mass baselined	Comply	Noise prototype and final design are subtly different but both comply.
M040088-01.pdf		OSEM counts etc	Pending	Needs updating to reflect decision to use LIGO 1 OSEMs on PU mass
M040099-00.pdf		ETM/ITM quad pendulum structure length not to exceed 2005mm	Comply	Current envelope D050266 has 1960 with which we comply.
M050397-00.pdf		Core Optic sizes, including TMs, BS, FM and RM		Covered in PDR #2
M050418-01.pdf		Separation of chains in quad suspensions	Comply	

M060043-00 (still in signature cycle)		Will not fit sensors on UIM and PM except for the noise prototype.	Will comply	Does not affect Noise Ptype.
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Other areas not covered above

	Wedge angles and pitch angles	Should be in ICD SUS/COC? See email from Dennis Coyne of 02 May 2006	Intend compliance	RODA M050397-00.pdf has "WEDGES: The wedge angles are given in Table 3 of the optical layout T010076-01 . However, Mike Smith has noted that the separation distance assumed in the analysis for pick-off beams was inadequate. The result is a larger wedge angle for the ITMs. Wedges are therefore not yet finally defined in this document."
	Design flexibility - reconfigurable	T050005-01 - but did this ever get into any of the DRDs or ICDs?	Comply	See review overview document T060142-00-K .
	Blade matching	We should ensure that mismatching of the blades does not upset the suspension performance or controllability	Comply	The design seems to be quite tolerant of larger errors than we envisage. See cross-coupling paper T040143-00-R

Are these all "derived requirements"?

	Blade internal modes		OK	See T010103-05
	Accuracy of setting of d	d = 0.5 to 2mm for each stage. Silica stage length correct to +/- TBD	Comply	Ref conversation with Norna. See cross-coupling paper

	distance and pendulum lengths	d distances on any set of four stage must be matched within a 1mm band. Pitch of masses needs to be controlled to allow alignment of OSEMs etc.		T040143-00-R Target Ds changed but we still comply
	Violin mode damping	Must provide mounting points for sensors and allow 50g per sensor.	Comply	