

## Advanced LIGO UK share – technical specification and parameter list.

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See revision history at end.

June 2005, version 03, following further discussions DCC/JHR. Action items have highlights

Last update 9 June 2005

Check WP number given for each line.

Key for "source": SRD = T010007-02 Cavity optics DRD

Uni = T000053 Universal SUS DR

Gen = E010613 Generic requirements for subsystems

ICD = E030647 and sub-documents; interface control document set.

??? = currently unclear (to Justin)

Int = Internal to SUS

Requirement number, WP affected, subject	Current values	Source (see above)	other notes	Verif (see below)	Action	Dead-line
<b>Performance requirements</b>						
P1. (all) Noise performance etc	See table 2	SRD	Derived from science spec.	A	None	
P2. (all) Assumed SEI performance	2*10e-13 m/rt Hz at 10Hz in both all three directions	ICD SUS- SEI	E990303-03-D. Needed to decide how good the SUS transfer functions must be to meet the science spec. See also table 2.	A	None	
P3. (3,4) The lower frequency cutoff	Vertical modes 12 Hz or lower, observation possible down to 10 Hz	???	See T020034 (esp section 6) and T010103. This will be fed into the design by Norna as part of her work.	A	None	

P4. (all) Technical noise	1/10 of thermal noise for each contribution. Contributions include wire rubbing at clamps, sensor noise in OSEMs, electronic noise from local and global control, thermal noise from blade internal resonances and silicate bonds.	SRD	It is not clear how the design can be tested for this requirement. See also ALUKGLA0005.	R, A	None	
P5. (3,5) ETM/ITM test mass material	Silica with sapphire fallback	???	Is there a RODA on this?	R	None	
P6. (3) Separate CP	CP is part of ITM SUS	???	RODA M040005-00	R	None	
P7. (3) Material of masses	All metal except test mass, test reaction mass, penultimate mass	Int	T010103?	R	None	
P8. (3,5) Wedge angles on COC masses	Will vary from mass to mass and location to location. Range will be +/- (TBD~10) mRad.	ICD SUS- COC	T010076. (DCC to revise this document and transfer numbers to ICD)	I	DCC	End June 2005
P8a Wedge angles on ETM reaction mass	Yes - to match those on the ETM. Wedge on ETM will be small.	Int				
P9. pitch angles on COC masses	Will vary from mass to mass and location to location. Range will be +/- (TBD~10) mRad.	ICD SUS- COC	T010076. (DCC to revise this document and transfer numbers to ICD)		DCC	End June 2005
<b>Design requirements</b>						
D1.1. (all) Mass limits	ITM = 418kg ETM=418 kg ITM+FM=710.5kg BS=306.9kg	ICD SUS- SEI	E040136-00. Note we must not just stay BELOW these: any significant variation must be agreed. T040137 also refers. CEIT to comment on current mass for C Ptype structure. DCC for put into ICD	A, T	CEIT  ICD	15 June 2005  8 June 2005
D1.2. (3,4) OSEM mass	TBD	ICD UK-	Also affects HAM SUS if they use the same design.	A,T	RJSG	End 2005

		US				
D2.1 (3) C of G and moment of inertia requirements	Overall: Should reflect numbers given in table at back of E040136.	ICD SUS- SEI	E040136-00  Needs mass of OSEMS as input.	A, T	None	
D2.2 (3) C of G on suspended masses	For each suspended mass: must agree with modelling work.	Int	T010103-04 & T040214. Need to ensure Norna approves final values. Needs mass of global OSEMs as input.	A,T	None	
D3. (3) Structure frequencies - the 150Hz issue	TBD	ICD SUS- SEI	Latest in T050005. DCC to complete heroic modelling task.	A	DCC	mid June 2005
D4 . (3) Envelope	TBD	ICD SUS- SYS	Not in Dennis's optics paper T010076-01-D +DCC to update E040136 to include envelopes (note the ITM that includes an FM will not be done for Jun deadline)	R	DCC	8 June 2005
D5. (3) Reaction chain masses	It is likely these will be made the same as the corresponding main chain masses but they do not have to be. The exceptions are the CP which is not the same as the ITM TM and the PUR which is not the same as the ITM PU.	Int	If they are not the same then the analysis given in T010103 would have to be redone. This is being done for the CP chain, in T040038.	R	None	
D6. (3) Wire clamp mass	Mass should be minimised but up to 100g seems OK for the top stage blades.	Int	Txxxx (Justin blade FEA calcs). Revisit, possibly using DCC's analysis in T050078	R, A	RJSG	End Jul 2005
D7. (3) Stress limits in blades	Tentative - use 55% of yield.	Int	2 Virgo papers referred to in Txxxxx (Justin) T010103-02 has 951 MPa in the top blades. Txxxx (blade ctte) Blade committee to confirm. RJSG to	A	RJSG	End June 2005

			convene + fill in missing doc numbers above			
D7.1 Stress limits in clamps	Currently use 55% of yield but bake under load before use.	Int	Blade committee to confirm. RJSG to convene	R, A	RJSG	End June 2005
D8. (3) Stress limits in wires	Still under discussion - currently bake under load before use.	Int	Blade committee to confirm. RJSG to convene	R, A	RJSG	End June 2005
D9.1 (3) Blade internal modes	Must not contribute noise in violation of P4 above. Requires damping at UIM for current ETM/ITM design	Int	Norna's note ALUKGLA0010a. See also calculation of effects in T040061 (Justin FEA) and more recent note from Norna T050046-01.	A	None	
D9.2 blade damping	Make provision for blade dampers on all blades on noise prototype	Int	Discussion still ongoing - unlikely to be required for blades above the UIM. Decision on blade damping to be made once CP tests are done.	R	NAR	End 2005
D10. (3) Wire violin mode damping	Provide mounting points for violin mode dampers in the fibre/ribbons.	ICD SUS- ISC	T020034 section 6. Will require E2E modelling to resolve.	R	SYS forum	April 2006
D11. (3) Blade matching	No sharp requirements identified in asymmetry calculations. Use +/- 1.5% max difference in a pair, target +/- 0.5%.	Int	See also A4 and presentations at March 2005 LSC, and Txxxx note of Norna and Mark B.	R, A, T	None	
D13. (3) OSEM mounting rigidity	No specific requirements				None	
D14. (3,4) OSEM electrostatic buildup	Coil housing (OSEM head) to be metal.	ICD SUS- ISC	See T000119.	A, T	None	
D15. Vacuum requirements						
D15.1 (3,4,5)	Materials allowed and	Uni or	E960050 (materials),	R	DCC	mid

	prohibited	Gen	(needs updating)			June 2005
D15.2 (3,4,5)	Processes allowed and prohibited	Uni or Gen	E960022 (procedures). See also email from DCC of 17 Feb 2005 which references M990034-C and L990205-00. The email is in addendum 3 to M050167.	R	None	
D15.3 cleaning and baking of OSEMs	Agreed processes	Uni or Gen	Given in E030084-02. SMA to cite in OSEM documents. JHR to add to Uni	R	JHR SMA	8 June 2005 OSEM DRR July 2005
D15.4 Welding	Processes	Gen	E970063-01 sections 1 to 5.2	R	JHR	8 June 2005
D16.1 (3,4,5) Thread types	Use "imperial" thread sizes. Use silver-plated screws and oversize tapped holes in all in-vacuum parts. Use nitronic inserts as an option.	Uni or Gen	E030350 T040111	R	None	
D16.2 (all) drawing dimensions	Use mm dimensions or inch with mm dual dimensions	Uni or Gen	Agreement at Grey areas meeting LSC March 2005. Drawing requirements document E030350-A	R		
D17. (3,5) ETM + ITM test masses - mass and dimensions	Fused Silica baseline: 340mm diameter by 200 mm thick Sapphire fall back: 314mm diameter by 130mm thick	ICD SUS- COC	M040283. See T040214 for mass. Get RODA M05028-02 signed; Put in ICD	R	DCC	8 Jun 2005
D18. (3,5) Beamsplitter - mass and dimensions	Silica, 37cm by 6cm, 95mm flat	ICD SUS- COC	Concept only. T010103 T040027 needs updating. RODA needed Confirmed in email from Garilynn via Janeen 3 jun 2005	R	Garilyn n Billingsl ey	

D19 (3,5) Folding mirror - mass and dimensions	Same as BS	ICD SUS- COC	RODA M040006.	R	None	
D20. (3,5) Compensator plate size + mass	TBD		Phil Willems is working on this. DCC to check status.	R	DCC	mid June 2005
D21. (3,4,5) Clearance for light paths	There are none other than the main beam	ICD SUS- SYS		R	None	
D22. (3,4,5) Earthquake survival	Lateral 0.4 or 0.5g.	Gen + Uni	Email DCC 26 April 2005. Needs firming up with two sets of figures (survival and continued operation)	R, A?	DCC	8 June 2005
D22.2 transport shock loads	TBD	Uni	Especially during loading and unloading. Likely to be in "caged" condition. Put in Uni.	R, A	JHR	8 June
D23. (3,5) Wire or fibre breakage	Must be able to withstand wire or fibre breakage	Uni	Needs stating if not already there	R	JHR	8 June 2005
D24. (4) EMC - generation	Provisions in E020350-08 and E040288-00	Gen + Uni	Should be in Bham ICD + T000053 para 2.5.2 E960036-A	A	SMA	8 June 2005
D25. (4) EMC - ability to withstand	Provisions in E020350-08 and E040288-00	Gen + Uni	Should be in Bham ICD	A	SMA	8 June 2005
D26. (4) OSEM force capability	As G010086-00	ICD SUS- ISC	G010086-00 discusses. See also T050005.	A, (T?)	None	
D27. (4) OSEM detector noise performance	3E-10 m/root(Hz) at 1-10 Hz.	ICD SUS- SYS	OSEM review outcome document? RJSG to verify source document	A	RJSG	End Jun 2005
D28. (3,4) OSEM active range	0.7mm peak-peak target.	ICD OSEM -SUS	Noted in E040373-01	R	None	
D29. (3,4) OSEM	TBD	int	Needs better understanding of	R	RJSG	End

dead-reckoning alignment			issues (by RJSG)			Aug 2005
D30 (3) Accuracy of gap between TM and test reaction mass	Gap size accurate to +/- 0.5mm, parallel to +/- 0.25 mm. (Could be, for example, 5mm at top and 4.5 at bottom or 5.5 at left and 5 at right.)	Int?	To allow ES actuation to work properly. KAS email of 6 Jun 2005 refers.	R		
D31 Anti-glint coating	TBD	Gen or Uni	DCC to chase Mike Smith	R	DCC	mid jun 2005
D32 Flexibility	Design must be reasonably easy to modify to take alternate test mass material	ICD SUS-SYS	T050005-01	R	None	
D33 fibre ends	Drum ended for wires supporting top mass and UI mass.	Gen or Uni	T050005-01 Active area of work	R	Part of current design work	
D34 electrostatic actuator force capability	Currently building a dual-range drive which allows up to xxxV (high range) and xxV 9low range)	ICD SUS-ISC	Completely unknown and unknowable until E2E studies done.	A	DCC-KAS and SYS forum	End 2005?
D34.1 ESD drive satellite box constraints	Power output, size, fans allowed or not	???	DCC to pronounce?	R	DCC	Mid Jun 2005
D35 axis system	X - along the laser path Z - upwards vertical Y - transverse	Uni	See Mike's note T040072. See T010076 for translation to others systems.	R	None	
D37 Static/anti-static requirements on earthquake stops	TBD	int	RJSG to keep watching brief. Some experiments in progress. Note also email from DCC of 17 Feb 2005 re Flourel in E970130-A. The email is in addendum 3 to M050167. Requirements given in E040457 (Janeen - email 3 jun 2005)	R	RJSG	End 2005

D38 how much ECD, on which axes	TBD	ICD SUS- ISC	KAS has made an interim suggestion (email 11 may 2005). Needs KAS to finish the document and then get approval from M Barton of the inferred control system requirements.	A, R	KAS, M Barton	End Jun 2005
D39 Sensors on OSEMS	Noise prototype has sensors on all OSEMs. Subsequent suspensions have no sensors on global control OSEMs.	ICD SUS- ISC	Email exchanges April 3 & 4 2005, and subsequent SYS meeting. Needs documenting. RODA needed (DCC)	R	DCC	8 Jun 2005
Leave a row blank to insert above						
<b>Adjustment and alignment requirements</b>						
A1. (3,4) Adjustments - how much do we need to allow for alignment after installation	Yaw a few mRad range (TBC) Pitch a few m Rad range (TBC)	ICD SUS- AOS	See draft in M050167 addendum 1.	A, R		
A2. (3,4) with what resolution do we need to be able to make the alignment in A1?	10 micro Radians.	ICD SUS- AOS	Derived from G010086 page 10	A, R		
A3. (3,4) OSEM range required by AdLIGO after provision has been used up in internal alignment	+/- 0.25 mRAD	ICD SUS- AOS	G010086 page 9.	A, R		
A4	Accuracy of spring constants, masses etc must Keep "d" distance correct to +/- 0.5mm.	Int	Need to ensure that the predicted performance is OK with the given d deviations.	A, R	None	



A5. (4) Location of test mass (to interact with beam)	Xxxx mm below SEI table	ICD SUS- SYS	DCC to include centre height of optic in ICD document.	R	DCC	8 jun 2005
A6	Attachment of targets	ICD SUS- AOS	RODA - DCC to complete and issue	R	DCC	End jun 2005
<b>Assembly requirements</b>						
S1.	Removed					
S2 (3) Optics protection during assembly	Optic surfaces to be covered at all times except when access to optical surfaces is required.	ICD SUS- COC	RODA refers. Design will be joint between SUS and COC. Part of assembly tooling.	R		
<b>Operations requirements</b>						
Operations requirements	Need to follow the requirements under many headings	Uni	Universal SUS requirements doc T000053-01-D RJSG to detail these specifically DCC/JHR - key ones missing?	R	RJSG  DCC/J HR	End Jun 2005  8 Jun 2005
O1. (3,4,5) MTBF	Put numbers in here	Uni?	Email Wed 02/07/2003 23:07 (Coyne). Update to Uni	A	JHR	8 June 2005
O2. (3,4,5) Repair capabilities - fibre, ribbon	Target 1: must be possible to replace any fibre or ribbon in the vacuum tank	Uni?	May need revision as the design progresses.	R	None	
O3. (3,4,5) Repair capabilities - wire,	Target 2: must be possible to replace any wire in the vacuum tank	Uni?	May need revision as the design progresses.	R	None	
O4. (3,4,5) Repair capabilities - OSEM	Target 3: must be possible to replace any OSEM in the vacuum tank	Uni?	May need revision as the design progresses.	R	None	
O5 OSEM conditioning	TBD	???	Bham to specify OSEM testing and conditioning regimes	A, T, R	Bham	OSEM DRR
O6. (3,4) OSEM	Must not deleteriously affect	int	Mark Barton email	A, T	ALUK	OSEM

eddy current damping	detector performance		Needs developing. <b>ALUK need to come a conclusion.</b>			DRR July 2005
<b>Interface requirements</b>						
IF 1 (all)	Removed		Removed			
IF 2 (3,4)	WP3 to WP4		See xxxxxx			
IF 3. (3,5)	WP3 to WP5		See xxxxxx			
IF 4. (4,5)	WP4 to WP5		None identified			
IF 5.1 Baffles attachment	TBD - assumed easily added later	ICD SUS- AOS	<b>TMH to discuss with Phil Willems (heater) and Mike Smith (baffles)</b>	R	TMH	End Jul 2005
IF 5.2 Baffles mass	Baffles = negligible mass	ICD SUS- AOS	<b>DCC to confirm design assumptions 15.1 to 15.4</b> (and see T050005)	R	DCC	15 jun 2005
IF 5.3 Ring heater attachment	TBD - assumed easily added later	ICD SUS- AOS	<b>TMH to discuss with Phil Willems (heater) and Mike Smith (baffles)</b>	R	TMH	End Jul 2005
IF 5.4 ring heater mass	Ring heater = 1 kg	ICD SUS- AOS	<b>DCC to confirm design assumptions 15.1 to 15.4</b>	A (effect)	DCC	15 jun 2005
IF 6 interface to SEI table	3/8 UNF holes on 1" pitch.	ICD SUS- SEI	<b>RODA required.</b> Note dog clamps for SUS are in SUS scope.	R	DCC	8 jun 2005

Verification:

R: Review of design data

A: analysis

T: test

I: inspection

List of applicable documents now at web page:

[http://eng-external.rl.ac.uk/advligo/papers-public/DRD\\_webpage.html](http://eng-external.rl.ac.uk/advligo/papers-public/DRD_webpage.html)

Justin to check for inclusion:

Earthquake requirements See email from Dennis

Table 1

Basic numerical performance requirements of suspension systems within ALUK scope. Source for most numbers is LIGO-T010007-01 Cavity Optics Suspensions Subsystem DRD, Willems et al, Oct 2001 which also contains extensive explanatory text. Tables 1, 2, 4, and 5 of that reference apply.

		ETM, ITM		BS		FM		CP
		at $f_{crit}$ (1)	Falling as $1/f^n$ , where n is	at $f_{crit}$	at 100Hz	at $f_{crit}$	at 100Hz	ALL TBD
Longitudinal	TM internal (2)	$5E-20 m / \sqrt{Hz}$	$\sim 1$	$2E-17 m / \sqrt{Hz}$ for all sources combined	$6E-19 m / \sqrt{Hz}$ for all sources combined	$2E-17 m / \sqrt{Hz}$ for all sources combined	$6E-19 m / \sqrt{Hz}$ for all sources combined	
	Pendulum	$1E-19 m / \sqrt{Hz}$	$\sim 2$					
	Technical	1/10 of thermal above $f_{cutoff}$ (3)						
	Seismic noise	$1E-19 m / \sqrt{Hz}$	$>4$					
	Derived SUS isolation (4)	$5E-7$						$5E-5$
V Transverse	Thermal	$1E-16 m / \sqrt{Hz}$	$\sim 2$	$2.2E-15 m / \sqrt{Hz}$ for all sources combined	$6.7E-17 m / \sqrt{Hz}$ for all sources combined	TBD	TBD	
	Technical	1/10 of thermal above $f_{cutoff}$						
	Seismic noise	$3.3E-17 m / \sqrt{Hz}$	$>4$					
	Derived SUS isolation(4)	$1.7E-4(5)$						$5.5E-3$
H transverse	Thermal	$1E-17 m / \sqrt{Hz}$	$\sim 2$	$2E-14 m / \sqrt{Hz}$ for all sources combined	$\sim 2E-15 m / \sqrt{Hz}$ for all sources combined	$2E-14 m / \sqrt{Hz}$ for all sources combined	$6E-16 m / \sqrt{Hz}$ for all sources combined	
	Technical	1/10 of thermal above $f_{cutoff}$						
	Seismic noise	$3.3E-17 m / \sqrt{Hz}$	$>4$					
	Derived SUS isolation(4)	$1.7E-4$		$5E-2$		$5E-2$		
Pitch		$5E-18 rad / \sqrt{Hz}$	$\sim 1$	$2.9E-15 rad / \sqrt{Hz}$	$8.6E-17 rad / \sqrt{Hz}$	$4E-15$	$1.2E-16$	
Yaw		$5E-18 rad / \sqrt{Hz}$	$\sim 1$	$1.3E-15 rad / \sqrt{Hz}$	$4E-17 rad / \sqrt{Hz}$	$1.3E-15$	$4E-17$	

See notes on next page

Notes

1. Current value for  $f_{\text{crit}}$  is yyyy Hz
2. Not part of UK scope
3. Current value for  $f_{\text{cutoff}}$  is xxx Hz
4. Values for SUS share of ETM/ITM isolation assume SEI delivers  $2\text{E-}13 \text{ m} / \sqrt{\text{Hz}}$  at  $f_{\text{crit}}$ . SUS share of isolation for BS assumes same SEI performance and that seismic noise is half the total noise.
5. This requirement is NOT fully met by the design in T010103-02



Revision history

12 October 2003 added requirements numbers, verification method, affected group

Nov 18 2004 Minor updates following email from Norna.

Dec 4 2004 updates following US trip. Removed document list (now on separate web page) version 1.

May26 2005 updated in part following March 2005 LSC and the "Grey areas" exercise M050167. Version 02. Added columns for action items etc.