LIGO Laboratory / LIGO Scientific Collaboration

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ALIGO NP-type: Preparations and hazard analysis for test hangs at LASTI in July/August 2009

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Introduction

In the period of the 6th of July until the 7th of August work will be ongoing at LASTI to execute two tests in which an aluminium dummy test mass is suspended from another dummy test mass by four silica fibres, welded to silica 'ears' that are bonded to silica disc inserts. These slot into the aluminium mass using aluminium disc insert plates.

These tests are performed to practice and refine procedures for the fully monolithic suspension that is scheduled to be fabricated at LASTI in September 2009.

The three main steps will consist of a preparation of the laboratory in the first week, pulling of fibres; setting up welding equipment in the second week and making the first suspension in the third week. Finally, in a fourth and slightly separated week, there will be a second test hang.

This preparation document contains a list of relevant documents, a schedule of the activities, a detailed description, a required items check list, and some words on the risk assessment.

1 Reference documents

Will be added asap.

Design documentation fibre pulling machine	
D050…	
D050…	
D060…	
D060…	
Design documentation the lower structure assembly	
D070…	
D070…	
D070…	
D070….	
Design documentation on lower structure assembly tooling	
D080359	Turntable pallet assembly
Documentation on welding set-up	
T0900064	Alignment of laser articulated arm for welding suspensions
Back ground documents	
T070138-00-K	Ribbon/Fibre Length Budget
	User manual dimensional characterisation machine
	User manual bounce tester
	User manual fibre pulling machine

2 Goals

Goals of the visit are to:

1) Prepare pulling machine
2) Pull and test fibres for 2 test suspensions and possibly for the monolithic suspension
3) Prepare the welding set-up and masses
4) Weld fibres into a first suspension and suspend the test mass on the penultimate mass
5) Weld fibres into a second suspension and suspend the test mass on the penultimate mass
6) Possibly move one of the suspensions to test transport and integrity of the fibres

3 Prospected time schedule

The time schedule shown in table 3.1 is intended as a rough guide on the activities that will take place leading to the final goal of performing 2 test suspensions.

Table 3.1 Draft time schedule

	Tuesday 07-07-2009		Wednesday 08-07-2009		Thursday 09-07-2009		Friday 10-07-2009	
Check pulling machine								
Prepare stock in fuse ends								
Pull fibres								
Strength test a few fibres to test actual strength is high enough								
Pull more fibres								
Profile fibres								
Bounce test fibres								
Proof test fibres								

	Monday 13-07-2009		Tuesday 14-07-2009		Wednesday 15-07-2009		Thursday 16-07-2009		Friday 17-07-2009	
Check articulated arm										
Practice bench top welds										
Set-up structure with masses										
Check lever arm clamp										
Fit checks of fibre holder and baffles										
Remove ears from PM										

	Monday	Tuesday	Wednesday	Thursday

	20-07-2009		21-07-2009		22-07-2009		23-07-2009	
Fit in fibre holder and baffles								
Weld in fibres								
De-stress fibres								
Suspend the test mass								

	Monday 03-08-2009		Tuesday 04-08-2009		Wednesday 05-08-2009		Thursday 06-08-2009		Friday 07-08-2009	
Fit in fibre holder and baffles										
Weld in fibres										
De-stress fibres										
Suspend the test mass										
Transport tests of the suspension										

4 Safety equipment

- 8x Safety glasses
- 8x laser safety glasses that are marked for 10600 nm and have an optical density of 6 or higher
- Gloves (disposable)
- 1x ULPA filtered vacuum cleaner
- 1x glass/sharp container
- 1x ergo arm
- 2x respirator masks with P2 filters fit checked for the personnel using it
- 10x sandblasted aluminium baffles
- 1x Lexan bodyshield
- 3x Lexan welding screens

5 Check fibre pulling machine and fibre pulling and testing

Safety glasses and gloves are worn at all times.

The laser is operated only by trained laser operator.

5.1 Check fibre pulling machine

The fibre pulling machine is checked according to the standard operating procedure.

The checks include:

- A check of the laser cooling system (it is working well and there are no coolant leaks)
- **Safety check of the laser, laser cooling, and interlocking**
- Laser power with (water cooled) power meter
- Check laser alignment with red guide laser
- Align mirrors for fibre pulling
- Pull test fibres and strength test those to confirm average strength is high enough.

Figure 1 Fibre pulling machine at LASTI

5.2 Pull fibres

- A piece of 94 mm Suprasil 2A ∅ 3 mm stock is cut using a diamond scribe (for 628mm fibre – check lengths!!).
- Clean the stock by wiping with and optical cloth soaked with acetone or chloroform, followed by a wipe with methanol.
- Prepare Araldite 2012 epoxy adhesive
- Glue into fuse ends on either end (label the upper fuse end with a number). Ensure no adhesive lands on the stock.
- Cure adhesive for 24 hours at room temperature
- For the test hangs 8 fibres are needed plus 4-8 fibres spare. (For the monolithic another 4 fibres are needed plus 4 spare) This means we need at least 48 fuse ends.
- Clean the prepared stock by wiping with an optical cloth with some methanol **(Personnel should wear gloves while doing this)**
- Install prepared stock into pulling machine by first fixing the upper fuse end into the upper stage and then fixing the lower fuse into the lower stage
- Reclean stock when installed in pulling clamps
- **Turn on ULPA filtered vacuum cleaner**
- **All personnel put on safety goggles that are marked for 10600 nm and have an optical density of 6 or higher**
- Start pulling programme. The pulling process consists of a slow laser polish (20-40 minutes) and the actual fibre pulling (5 minutes).

- Leave the pulled fibre for 2 minutes to let the stock and fuse ends cool down.
- Attach angle brackets to the clamping blocks of the fuse ends to form a cartridge.
- Release the lower and upper clamps by sliding out the complete cartridge. Remove top/bottom attachments ready for installation into dimensional characterisation machine.
- BE CAREFUL NOT TO TOUCH THE FIBRE AT ANY TIME

Timing: 30-50 minutes per fibre

For the 2 test hangs we will need 8 good fibres, and 4-8 more as spares. This means we will need 16 man hours to pull enough fibres for these two hangs.

(For the monolithic we will need 4 fibres, and 2-4 more as spares. This means we will need 8 man hours to pull enough fibres for this production.)

Length of the fibres: 628mm stock end to stock end with current ear position

5.3 Characterise fibres

The characterisation of fibres consists of 3 procedures: measurement of the fibre dimensions along its length, the proof load test and a vertical bounce frequency measurement. The order of these tests is set by ease of handling.

If the fibre is thought to have been touched at any time it will have to be discarded into the special glass disposal box.

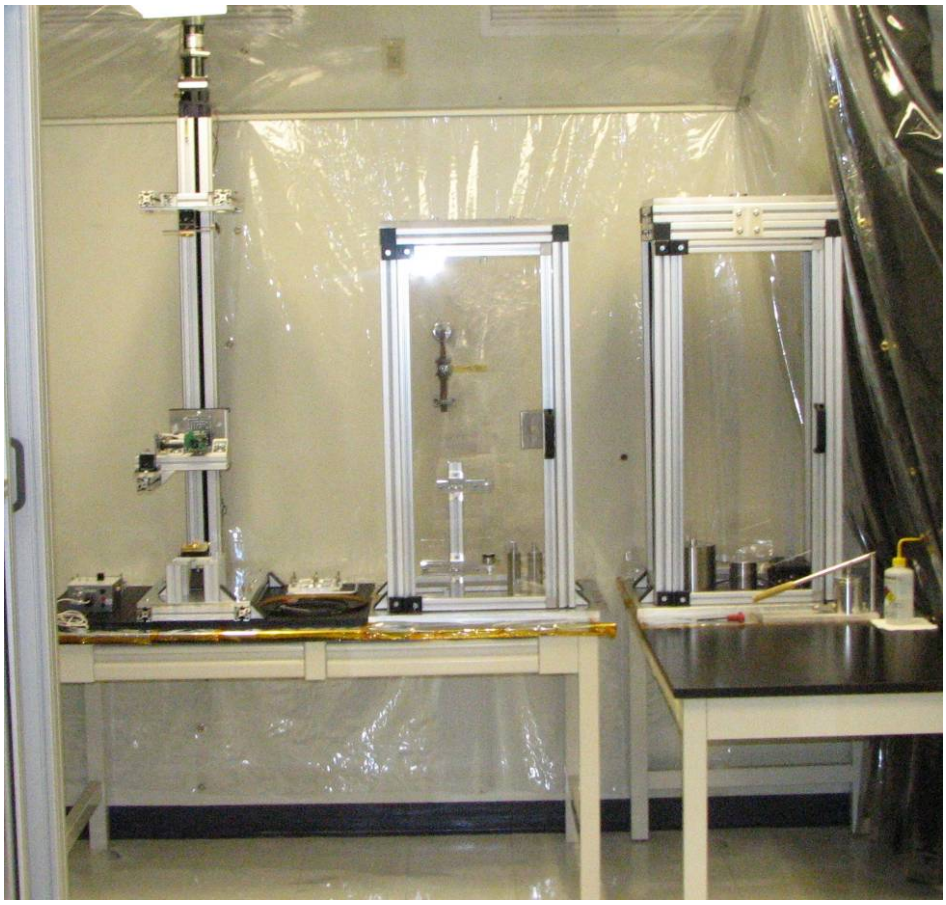

Figure 2 From left to right: profile measuring machine, bounce tester and proof tester

5.3.1 Dimensional Characterisation machine

This paragraph contains a rough sequence of procedures in the use of the dimension characterisation machine.

- Install the fibre into the profile measuring machine using the cartridge. The cartridge is installed onto the circular boss on the base of the profiler, and the upper boss is advanced downwards to engage the top of the cartridge
- Align the fibre.
- Run the profiling programme and save the data with the fibre number.
- Check the diameter of the central part of the fibre (should be 400 μm) and the bending ends of the fibre (should be 800 μm) Test hang out by 10%, still meets all the requirements
- Remove the fibre cartridge – process is reverse of installation

Timing: Resolution dependent – upto 40-60 minutes

INTERMEDIATE STAGE – remove fused fibre from cartridge

5.3.2 Proof load test

- Ensure that the top attachment of the 12.5 kg test mass is well below and the lowest point of the fibre by lowering the hydraulic jack to prevent hitting the fibre against the test mass. Also ensure the mass is well centred with respect to the fibre.
- The fused fibre is carefully suspended in the proof tester cabinet, by lining the upper fuse end up with the C-attachment and fixing with the pin through the central hole.
- Raise the jack to allow for installing the lower fuse end into the C-attachment on the test mass and fix the lower fuse end with the pin through the central hole.
- Close the proof tester door.
- Lower the jack slowly until the mass is suspended freely on the fibre.
- Leave the mass suspended for 1 or 2 minutes. (It is highly likely that the fibre will break immediately upon loading if it is not strong enough. Therefore only a very short period is needed to subject the fibre to the test load if strong enough)
- **If the fibre breaks, carefully remove larger pieces of fibre and discard them into the glass container. Use the ULPA filtered vacuum cleaner to remove any small parts of silica.**
- If the fibre does not break (this should be the case for 99% of the silica fibres), raise the jack to unload the fibre and release the lower pin. Hold the fuse end at the top and remove the pin carefully. Remove the fibre carefully from the proof tester set-up.

Timing: 15 minutes per fibre

5.3.3 Vertical bounce frequency measurement

- Install the fibre into the bounce test machine.
- Excite the mass with a coil magnet drive. (1.104 kg)
- Note the bounce frequency with the fibre number.
- If the bounce frequency is within specification, remove the fibre from the bounce tester
- If the bounce frequency deviates from the specification, remove the fibre from the bounce tester and discard the fibre carefully into the glass disposal box. Fuse ends are recycled.

Timing: 15 minutes per fibre

5.4 Store fibres

- The fibres are stored in a custom modified fridge.
- The humidity inside the fridge will be monitored and logged.
- A desiccant changing schedule will be put on the fridge

6 Set-up lower structure and lower structure assembly tooling

6.1 Lower structure assembly tooling

- Install the turntable and elevation table (this might involve heavy lifting for personnel)
- Install test hang inner structure and outer structure (this might involve heavy lifting for personnel)
- (Drill holes into the inside of the outer structure) (Brett)
- Install the lower lever arm clamp or jack
- Install the aluminium dummy masses into the structure **(the dummy mass is 40 kg. This involves heavy lifting for personnel, safety pre-caution, lift the mass with 2 people)**. Set distance to required.
- Install the top lever arm clamps for overload
- The disc insert plates with bonded ears are carefully fixed onto the sides of the dummy masses using Allen keys (1/4 20")
- Fix a spirit level onto the front of the dummy penultimate mass and clock it by adjusting the entire structure
- Fix the spirit level onto the front of the dummy test mass and levelling it by adjusting the support bars and clock the mass by rotating it.

7 Weld fibres and suspend

7.1 Welding set-up

7.1.1 Weld scaffolding

- (Install spacers for welding)
- Install weld hub and scaffolding (one single assembly) on one side of the mass. **The scaffolding is equipped with sandblasted aluminium sheet in appropriate locations that acts as a beam dump for reflected CO_2 light.**
- Install the welding mirrors by clipping onto the weld hubs

7.1.2 Prepare the fibre

- Carefully take a fibre from the fridge. Note the fibre number.
- Place the fibre into the fibre cutting tool. The cutter is set to exactly the length between the two weld horns before bringing the fibre in. The fibre is placed symmetrically into the cutter
- The fibre is clamped into place by screwing an aluminium block on top of the fibre
- Scribe the fibre outside the holder blocks of the fibre around the fibre using a diamond scribe.

- Carefully break away the fibre ends by pulling them away from the clamp with a slight downward motion. Check the end of the fibres and file flat if necessary. Store fuse ends with fibre ends in recycling box.
- Advance the tweezers (in x-direction) over the 3 mm part of the fibre. The tweezers are at a 45 degree angle with respect to the axis of the fibre.
- Clamp tweezers using M3 wingnut when the 3mm stock is seated in the tweezer grooves.
- Remove the clamping blocks.
- Retract tweezers (in x-direction).
- Carefully lift the fibre holder with fibre out of the fibre cutting tool and move to the weld structure. **The fibre holder is also equipped with integrated sandblasted aluminium shields to block known reflected CO_2 radiation from the angled ear horns.**

7.1.3 Fibre installation

- Install the fibre holder onto the outer structure tooling by sliding carefully onto the appropriate bolts on installation brackets. Care must be exercised to bring the holder in vertically and not touch either ear,
- Advance tweezers in the x-direction to bring the fibre toward the mass and ears. Use appropriate adjustments of y, z to butt ends of fibres against ear weld horns
- **Install the Lexan body shield onto the outer structure tooling**
- Install the welding shelves onto the outer structure tooling
- Install the birdcage onto the top welding shelf.
- Connect the articulated arm to the 'birdcage'.
- Use the red pointer beam to align the beam on the weld horn of the ear - just off the joint between it and the fibre.
- **Switch of the lights and investigate that all stray beams are caught with the sandblasted aluminium baffles.**
- **Switch lights back on**
- **Install Lexan shielding around the structure**

7.2 Weld fibres

- **All personnel put on safety goggles that are marked for 10600 nm and have an optical density of 6 or higher**
- **The welder stands behind the body shield and can adjust the z-stages of the fibre holder and control the galvanometer using the arrow keys on a computer keyboard.**
- **All other personnel stand behind the large Lexan shielding.**
- The welder switches on the CO_2 laser to commence welding. Welding is performed by heating the joint up to melting point on the front of the fibre/ear interface. More detail in LIGO-T0900xx

- The process of installing the birdcage and articulated arm is then repeated for the bottom part of the fibre and the bottom part of the fibre is welded in the same fashion.
- The fibre installation and welding procedure is repeated for the remaining 3 fibres
- Remove fibre holder (it is no longer required).

7.3 Straighten welds

- Using the lever arm clamp or jack, the test mass is lowered until the fibres are straightened with only very slight tension. The straightening is observed visually. The motion down is expected to be around 0.5 mm, but can vary.
- Each top weld is heated consecutively with laser with the same scaffolding set-up as during welding. The silica is heated enough to soften.
- Using the lever arm clamp the test mass is then lowered again until the fibres are straightened and under very slight tension. Again the motion down is expected to be around 0.5 mm.
- Each lower weld is then heated consecutively in the same fashion as was done for the top welds.
- The stock region is also laser polished.

7.4 Suspend the test mass

- **Set-up the welding screen. All personnel except the person suspending the mass stand behind it.**
- **Person suspending the mass is wearing protective goggles and gloves**
- If not already supporting the mass, the jack is raised to just lift the mass from its stops.
- Stops are retracted approximately 7 mm
- The jack is lowered
- When suspended, stops are advanced to distance of 1mm from the mass.

8 Remove ‘old’ ears from penultimate mass

- The penultimate mass is set-up on it’s V-block using the ergo arm, with one of the flat sides with ears up
- The flat is covered with a protective aluminium sheet (covered with Teflon at the bottom)
- Cover prism with aluminium cover
- The rest of the mass is covered with a house of aluminium foil, sealed with Kapton tape
- **Personnel put on respirator masks with P2 dust filter and goggles**
- **Turn on the ULPA filtered vacuum cleaner and hold close**
- Use Dremel with diamond cutting disc to remove ear
- Wipe excess dust with an optical cloth soaked in methanol

- Remove protective sheets
- Repeat this procedure for the other side
- Turn the mass 90 degrees and rinse the area with copious amounts of DI water and rinse lightly with methanol, blow dry with dry nitrogen.

9 List of required items

Required items list		**status**	**24-Jun-09**
Fibre pulling machine	MIT	Yes	Fully installed
Dovetail clamps	MIT	Yes	
Angle locking bars	MIT	Yes	4 angle brackets present at MIT, length 29" = 736.6 mm, check length for monolithic
Fuse ends	MIT	Yes	60 still need drilled 3 mm, 23 pre-drilled for 3 mm stock
3 mm stock	MIT	Yes	18 m of 3mm type 2A suprasil stock - checked by Gregg Harry on 28th May 2009
Fibre cutting and holding tool	Glasgow	Yes	check that there enough machined tweezer tips with it, ship to MIT
Fuse set-up jig - Jig for gluing fuse ends onto stock	Glasgow	No	No, adapt existing ribbon jigs, shipped back from MIT, for monolithic
Tool to aid removing fibre from cartridge	Glasgow	No	Needs made, can be very basic
Proof tester	MIT	Yes	change attachments on jack handle with angle bracket + fill jack (how?)
Bounce frequency tester	MIT	Yes	checked on 24th June, borrow spectrum analysis
Profile measuring machine	MIT	Yes	checked on 24th June
Fridge	MIT	No	make same as stuff available in Glasgow (basic hanger)
Humidity sensor	MIT	Yes	Is present according to Alastair, check with MIT
Disc insert plates with bonded ears	Glasgow	No	Waiting for the delivery of ears
Masses	MIT	Yes	Need wiped with methanol
Spare ears for welding tests	Glasgow	No	Take with us to MIT
Lower structure for tests	MIT	Yes	
Lower structure assembly tooling	MIT	Yes	The tooling will need some extra holes for the . Brett can help with that
Turntable and elevation table	MIT	Yes	Checked and preliminary install, needs feet. Stabilising bolts done
Lever arm clamp for test chains	MIT	Yes	Crap
Jack	Glasgow	No	In production next week, jacks have also not arrived yet
Welding shelves	Glasgow	No	Ship to MIT
Brackets for shelves	MIT	Yes	Checked on 24th June
Brackets for fibre holder onto structure	Glasgow	No	Colin is making them, Ship to MIT
Articulated arm	Glasgow	No	High speed shipping to MIT
Baffle plates	Glasgow	No	Need made by Colin
Weld hubs and scaffolding	Glasgow	No	Possibly make out of cutter
Prism shield for welding	Glasgow	No	Needs made for monolithic
Weld mirrors	Glasgow	No	With CRK, lead time 2 week
Mirror spring clips	Glasgow	No	Need made by Colin
Long USB cable/extra keyboard/mouse	MIT	No	Discussed with Brett
Table	MIT	Yes	Discussed with Brett
Lenses for articulated arm	MIT	Yes	2 at MIT, check with Giles
Thorlabs equipment for attaching baffles	Glasgow	Yes	Ship to MIT

to scaffolding etc.			
Diamond scribes	Glasgow	No	order a number of diamond scribes and bring/ship over to MIT
Tools for pulling machine (Alan keys,other?)	MIT	Yes	Checked on 24th June
Glass disposal box	MIT	Yes	Checked on 24th June
ULPA filtered vacuum cleaner	MIT	Yes	Checked on 24th June
Spirit level	Glasgow	Yes	order multiple, bring over to MIT
Quick set epoxy	MIT	Yes	
methanol 99.9 % pure	MIT	Yes	
Acetone	MIT	Yes	
Alcohol	MIT	Yes	
Araldite 2012 adhesive + mixing tubes	MIT	Yes	Checked on 24th June
optical wipes	MIT	Yes	
UHV aluminum foil	MIT	Yes	
Kapton tape	MIT	Yes	
Overshoes	MIT	Yes	
Cleanroom suits	MIT	Yes	
Gloves (small, medium, large)	MIT	Yes	
Safety glasses and goggles	MIT	Yes	Checked on 24th June
Penultimate masses	MIT	Yes	
Aluminium sheet to protect masses from Dremel	Glasgow	No	Needs made
Prism shield	Glasgow	No	Needs made from aluminium sheeting
Dremel and sawing discs	Glasgow	No	Take to Boston, order discs
Combination filter respirator	Glasgow	Yes	Ship to MIT
Ergo-arm	MIT	No	Will be shipped to Boston by GariLynn Billingsley
Documentation	Glasgow	Yes	finish documentation and plan, bring it over to MIT

10 Hazard analysis

ITEM #	Hazard	Cause	Effect	Un-mitigated severity	Un-mitigated probability level	Un-mitigated Risk Index	Comment	Mitigation	Mitigated severity	Mitigated probability level	Mitigated risk index
1	Exposure of flammable elements, skin or eyes to light from a 10 μm laser	Insufficient baffling, personnel are using the laser without closing Lexan shielding, or is not wearing the correct safety goggles	Injury to personnel, damage to property	Marginal	Frequent	2A	Laser is used intermittently but often. Laser is a high power (130 W) 10 μm laser	Use of baffles, use of an interlocked enclosure in an interlocked room; personnel checks for stray beams by turning off lights and using a red pointer beam to search for them prior to welding, IR 10.6 μm filtered laser goggles with an optical density of 6 or higher	Minor	Remote	4D
2	Tipping of lower suspension or installation tooling	Personnel leaning on tooling or suspension weight shifting	Injury to personnel, damage to equipment	Critical	Occasional	2C	Lower suspension weighs ~530 lbs	Fixing the lower structure to the turn table and fixing the turn table after every rotation	Marginal	Improbable	3E
3	Strain from lifting heavy mass	Lifting without support	Injury to personnel, damage to equipment	Marginal	Occasional	3C	Masses are 40 kg each	2 people should lift together or the ergo arm should be used	Minore	Improbable	4E
4	Fracture of a fibre	Spontaneous or due to personnel or tools touching a fibre	Injury to personnel	Marginal	Occasional	3C		All personnel wear clear goggles at all times in the laboratory where the suspension is. Also the set-up is shielded at all times when suspended with Lexan screens	Minor	Occasional	4C
5	Production of silica vapour and dust	As part of the pulling and welding silica fibres	Long term illness of personnel	Critical	Marginal	2C	Exposure of the lungs to silica vapour can occasionally lead to silicosis: lung cancer caused by silica vapour	Using an ULPA filtered vacuum cleaner very close to the welding area	Minor	Improbable	4E
6	Production of silica vapour and dust	As part of the effort to remove ‘old’ ears from the penultimate mass	Long term illness of personnel	Critical	Marginal	2C	Exposure of the lungs to silica vapour can occasionally lead	Using a ULPA filtered vacuum cleaner very close to the cutting area,	Minor	Improbable	4E

							to silicosis: lung cancer caused by silica vapour	Using P2 filtered face masks, fit checked, goggles and gloves.			

Hazard severity	Category	Definition
Catastrophic	1	Death or permanent total disability, system loss, major property damage or severe environmental damage
Critical	2	Severe injury, severe occupational illness, major system or environmental damage
Marginal	3	Minor injury, lost workday accident, minor occupational illness, or minor system or environmental damage
Minor or negligible	4	Less then minor injury, first aid or minor supportive medical treatment type of occupational illness, or less than minor system or environmental damage

Probability	Level	Individual item
Frequent	A	Likely to occur frequently or continuously experienced
Probable	B	Will occur several times in the life of an item
Occasional	C	Likely to occur some time in the life of an item
Remote	D	Unlikely but possible to occur in the life of an item
Improbable	E	So unlikely, it can be assumed occurrence may not be experienced