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|  |  |  |
| --- | --- | --- |
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# Safety

Review [E0900332](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=E0900332&version=) HSTS Assembly and Installation Hazard Analysis.

# Objective and Scope

Subassembly and Final Assembly of the aLIGO HAM Small Triple Suspension, including:

1. General considerations for assembly;
2. Use of the Assembly Fixtures.

# Documents

[E0900332](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=E0900332&version=) HSTS Assembly and Installation Hazard Analysis

[E1100471](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=E1100471&version=) HSTS Assembly and Installation Documentation

[G1100107](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=32930) HSTS Introduction

[T0900435](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=T0900435&version=) HSTS Final Design Document

[E030518](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=E030518&version=) HSTS Assembly Instructions (this document)

[D020700](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D020700&version=) HSTS Assembly

[D040391](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D040391&version=) HSTS Assembly Fixtures

[E0900334](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=E0900334&version=) HSTS Installation Procedure

[T0900467](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=T0900467&version=) HSTS Test Plan

[T0900559](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=T0900559&version=)  HSTS Choice of Blades

[E0900047](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=E0900047&version=) LIGO Contamination Control Plan

[E1000169](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=E1000169&version=) Blade Characterization Spreadsheet

[E960022](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=E960022+&version=) LIGO Vacuum Compatibility, Cleaning Methods and Qualifications Procedures

[E990196](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=E990196+&version=) Magnet/Standoff Assembly Preparation Specification (needs to be updated.)

[T000053](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=T000053&version=) aLIGO, Universal Suspension Subsystem Design Requirements

[T010007](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=T010007&version=) Cavity Optics Suspension Subsystem Design Requirements

[T010103](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=T010103&version=) aLIGO Suspension System Conceptual Design

[T0900559](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=6982) Blade Pairings Spreadsheet

# Documenting the Assembly Process

## Documents

[T1100003](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=T1100003&version=) Building Suspensions Subassemblies in ICS.

## Procedure

### See the above document.

### Data for each Final Assembly will be stored in ICS; using a Process Traveler is optional:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Item** | **Assembly 1**  **Part Name** | **Assembly 1**  **Part Number** | **Serial Number** | **Position** | **Variant** | **Weight** |
| Each Mass | X | X | X | X |  | X |
| Each Blade | X | X | X | X |  |  |
| Each Blade Clamp | X | X | X | X | X |  |
| Each OSEM | X | X | X | X |  |  |
| Each Optic | X | X | X |  |  | X |

*Note regarding Subassembly weights: Each Subassembly must have 3 distinct weights recorded:*

1. *Estimated Weight Calculated by SolidWorks;*
2. *Actual Weight Measured by a lab scale after built to the nominal mass;*
3. *Balanced Weight Totaled after Suspension is balanced (i.e. Actual Weight + Add-On Weights).*

*When Addable weights are used, note their location on the Mass.*

# Vacuum Compatibility

## General Handling

All procedures must be performed in a clean room environment while suited up in:

* Coverall with Hood
* Boot style shoe covers
* LIGO-approved latex gloves
* Glove Liners and Safety Glasses when working with Wire

All Tables surfaces used for Class A components should be wiped down daily with Isopropanol.

Review [E0900047](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=858) Contamination Control Plan for details. All HSTS parts are Class A hardware and once cleaned and baked should not come into contact with anything but Class A or B hardware.

## Cleaning Components

Clean items per [E960022](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=3652) Vacuum Compatibility, Cleaning Methods and Qualification Procedures.

## Inspection

After baking, sample check the cleanliness of blind-tapped and through-tapped holes with a clean swab dampened with alcohol for a minimum of 10% of the holes in case any material has leached out during baking. If any discoloration of the swab is evident, then the part must go through at least one more wash cycle before repeating the bake. After inspection, wrap items per [E960022](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=3652).

# Fasteners

## Silver Plated Stainless Steel

All Silver Plated fasteners are also SSTL, and so are labeled simply “AgPlated”, not “AgPlated SSTL”.

## Screw Applications

|  |  |  |
| --- | --- | --- |
| **Screw Type** | **Screw Description** | **Receiver Application** |
| **AgPlated SSTL** | Silver-Plated Stainless Steel | * Stainless Steel threads |
| **SSTL** | Stainless Steel | * Aluminum Threads * Helicoil Threads |
| **Vented** | SSTL Screw with holes | * Rare Vacuum Compatibility situations |

## Helicoils

Helicoils are specified for:

* Certain SSTL applications to avoid using AgPlated fasteners;
* Certain applications where assembly / disassembly recurs.
* Helicoils are cleaned, baked and installed with clean tools in a Class 100 clean room.

## Torque Values

* Except where noted, Socket Head Cap Screws are to be tightened per the following table, which is based on [T1100066 – Torque Values](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=32881).
* “Generic” applies to Screws that are non-plated, non-vented, and not marked as Holokrome.
* Holokrome Screws are marked as such on the Screw.
* UC (UC Components, Supplier) Screws are AgPlated.
* All Screws are UNC (coarse threaded), except Pitch Adjustment Set Screw.

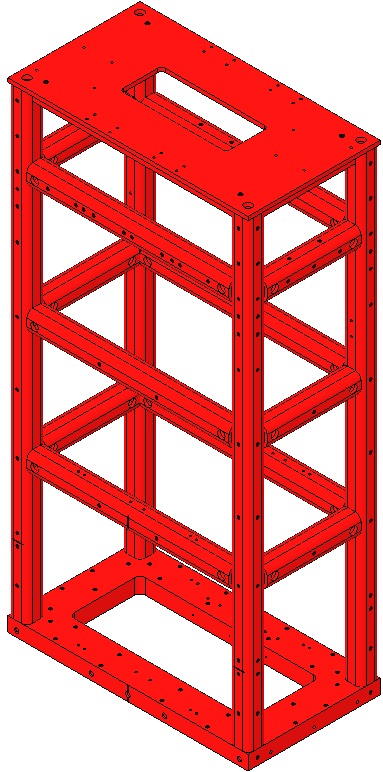
|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Torque (in-lb)** | | | | |
| **Supplier** | **Generic**  (unmarked) | **Holokrome** | **UC** | **UC** | **UC** |
| **Type** | **Unplated** | **Unplated** | **Ag-Plated** | **Ag-Plated, Vented** | **Vented** |
| **Size** |  |  |  |  |  |
| #2-56 | 2.5 | 4 | 4 | 2.9 | 2.9 |
| #4-40 | 5.2 | 6 | 6 | 6.7 | 6.7 |
| #8-32 | 19.8 | 30 | 30 | 25.2 | 25.2 |
| ¼-20 | 75.2 | 100 | 100 | 85.8 | 85.8 |

## Tightening Screw Pairs

To ensure proper alignment of components and to ensure even clamping pressure, it is important to perform the final few turns of the bolts evenly, almost in tandem. That is, after pairs of Screws have first been assembled and snugged up finger tight, when drawing up the Screws to their final Torque value, each Screw should be turned no more than ¼ turn before switching to the opposite screw.

# Overview of Assembly Process

## General sequence:

1. Subassemblies are built first, in any convenient order.
2. Main Assembly is built, mostly from Subassemblies.

Main Assembly sequence:

1. Rotational Adjusters
2. Intermediate Mass
3. Lower Wire
4. Lower Mass
5. Upper Mass + Upper and Intermediate Wires
6. Balancing
7. OSEMS

## Frame of Reference

|  |  |
| --- | --- |
| Using the Right-Hand-Rule when viewed from behind the Weldment, with the origin at the center bottom of the Weldment, the positive X, Y and Z directions are shown at right. | **+Z**  **+X**  **+Y**  Front  Fig 4: Frame of Reference |

# Safety – Handling Suspension Wire

The Wire used for all Suspensions is a hard temper carbon steel, delivered on large spools. When unwound for cleaning, cutting and preparation for clamp-wire-clamp assembly, care must be taken such that the wire’s strong potential energy (making it act like a coiled spring) does not cause injury.

### Safety Glasses, provided in all Clean Room garbing areas, must be worn during all wire work.

### Glove Liners should be worn under the latex clean-room gloves as a protective layer and extra barrier. The [E0900047](https://dcc.ligo.org/DocDB/0000/E0900047/010/E0900047-v10%20Contamination%20Control%20Plan.pdf) Contamination Control Plan, p. 13, provides further information on Glove Liners.

### For easier holding, bend a small section (~3”) of the end of the Wire. The bent section can be hooked around your thumb and held by your index finger. Un-spool the proper length of Wire – including extra for handling – and control the area of the Wire that will be cut. Add a 2nd bend at the newly cut end for easier handling.

### Change your gloves and wipe each Wire at least 3 times each, until nothing further appears on each Wipe, using:

* 1. A Cleaning Wipe with Methanol;
  2. A Cleaning Wipe with Acetone;
  3. A Cleaning Wipe with Isopropanol;

changing Wipes until the wire is completely clean. Clean the Wire while it is coiled; do not stretch the wire until it is taut for cleaning. It can be laid down on a clean surface during this process. Clean one section at a time.

### Transfer the Wire to the Assembly Jig. Use the Jig clamps to hold the Wire in place, and then cut off and discard the bent Wire ends.

# Assembly of Upper Wires

## Documents

[E0900332](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=6079) HSTS Assembly and Installation Hazard Analysis

[D0901854](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=4792) Upper Wire Assembly, HSTS

[E960022](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=3652) Vacuum Compatibility, Cleaning Methods and Qualification Procedures

## Materials

|  |  |  |  |
| --- | --- | --- | --- |
| **Qty** | **Unit** | **Part Number** | **Description** |
| 1 | Each | [D0902108](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=5575) | Upper Wire Jig Assembly, HSTS |
| 4 | Each | [D980184](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=2835) | LOS Clamp, Long |
| 1 | Each | [D020481](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=12431) | Upper Mass C-Clamp, HSTS |
| 1 | Each | [D0901999](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=5178) | Upper Mass Wire Clamp, Inside, Angled, HSTS |
| 1 | Each | [D0901998](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=5177) | Upper Mass Wire Clamp, Outside, Angled, HSTS |
| 1 | Each | [D020198](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=12432) | Upper Blade Wire Clamp, HSTS |
| 1 | Each | [D0901994](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=5173) | Upper Blade Wire Clamp, Outside, Angled, HSTS |
| 2 | Each | N/A | SHCS, #4-40 X 0.375”, Ag-Plated SSTL |
| 4 | Each | N/A | #4 Flat Washer |
| 2 | Each | N/A | SHCS, #4-40 X 0.625”, Ag-Plated SSTL |
| 1 | Spool | N/A | Steel Music Wire, 0.014” Diameter |
| 1 | Each | N/A | Weight Hanger |
| 1 | Set | N/A | Interlocking Test Weights (1kg, 2kg) |
| 1 | Set | N/A | Test Weights (1g – 500g) |
| 1 | Bag | PNHS-99 | Polynit Heatseal Wipes |
| 1 | Bottle | N/A | Methanol |
| 1 | Bottle | N/A | Acetone |
| 1 | Bottle | N/A | Isopropanol |

## Procedure

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 2 Upper Wire Assemblies are required per HSTS. Wire Assemblies should only be assembled as needed (NOT assembled ahead of time and stored for later use). Wear safety glasses and glove liners per [E0900332](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=6079). Ensure that all parts of the Upper Wire Jig Assembly ([D0902108](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=5575)) have been processed to Class B per [E960022](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=3652).Confirm that the Wire Jig is assembled completely and correctly per the drawing.Attach the Jig to an Optical Table using 4X LOS Long Clamps ([D980184](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=2835)). Position the Jig so that the end with the Wire Jig Pin Support ([D0900563](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=1578)) extends beyond the edge of the Optical Table by approximately 3” to allow clearance for the Interlocking Test Weights. | | Class B  Table Edge  Clevis  LOS Clamp  Class A  Fig 5: Upper Wire Jig (to be changed) | | | |
| Assemble the two ends of the Wire Assembly (referred to as the C-Clamp and L-Clamp) before attaching them to the Wire Jig. Do not tighten the SHCS.Each C-Clamp includes:  * 1X [D020481](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=12431) Upper Mass C-Clamp, HSTS * 1X [D0901999](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=5178) Upper Mass Wire Clamp, Inside, Angled, HSTS * 1X [D0901998](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=5177) Upper Mass Wire Clamp, Outside, Angled, HSTS * 2X SHCS, #4-40 X 0.625”, Ag-Plated SSTL * 2X #4 Flat Washers  Each L-Clamp includes:  * 1X [D020198](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=12432) Upper Blade Wire Clamp, HSTS * 1X [D0901994](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=5173) Upper Blade Wire Clamp, Outside, Angled, HSTS * 2X SHCS, #4-40 X 0.375”, Ag-Plated SSTL * 2X #4 Flat Washers | | | | D020481  (2)  D0901999  (2)  D0901998  (2)    D0901994  (2)  D020198  (2)  Fig 6: Clamps | |
| On the Wire Jig, attach one C-Clamp to the outboard side of the Upper Wire Clamp Mount ([D0902110](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=5577)) using:2X SHCS, #8-32 X 0.5”, Ag-Plated SSTLOn the Wire Jig, attach one L-Clamp to the outboard side of the Blade Clamp Mount ([D0902111](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=5578)) using:2X SHCS, #4-40 X 0.5”, Ag-Plated SSTL | | | | D0902110  Screws (2)  (2)    D0902111  (2)  Screws (2)  (2)  Fig 7: Clamp Mounts | |
| Unspool approximately 36” of 0.014” diameter Steel Music Wire. Clean the Steel Music Wire as described in Section 12.4. Cut the Steel Music Wire from the spool using dirty wire cutters.Feed the Steel Music Wire through the Wire Jig and Clamps in the order shown:1) Over the Clevis Pin2) Through the first Wire Start Post ([D1100580](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=10114) and [D1000583](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=10119))3) Through the L-Clamp4) Through the C-Clamp5) Through the second Wire Start PostTighten the SHCS in the second Wire Start Post after feeding approximately 0.5” of Steel Music Wire through the clamp. | | | **5**  **4**  **2**  **1**  **3**  Fig 8: Wire Path | | |
| Using a Weight Hanger, Interlocking Test Weights and a set of small Test Weights, make up a hanging weight with a mass of 4.483 kg. Note that the Weight Hanger and Test Weights are not clean.Tie the end of the Steel Music Wire hanging over the Clevis Pin around the hook on the Weight Hanger. The Steel Music Wire should now be taut, due to the hanging weight.Allow the hanging weight to hang from the Steel Music Wire for at least 5 minutes. Be careful of hands and feet underneath the hanging weight. | | | | | Fig 9: Hanging Weight |
| Measure the length of the wire between inboard sides of the C-Clamp and L-Clamp. The desired length is 294.13 mm.Tighten the SHCS in the clamps in the order shown. The SHCS in clamps 2 (C-Clamp) and 3 (L-Clamp) should be torqued to 6 in-lb. When tightening the SHCS in the C-Clamp and L-Clamp, ensure that the inboard surfaces of the two halves of each clamp are completely parallel.Remove the hanging weight from the wire.Using clean wire cutters, cut the Steel Music Wire in two locations as shown, as close to the outboard sides of the C-Clamp and L-Clamp as possible.Before removing the Wire Assembly from the Wire Jig, record part serial numbers, the measured wire length and the mass of the hanging weight to be included in the ICS assembly load. | | | **3**  **1**  **2**  Cut Wire  Cut Wire  Fig 10: Clamping and Cutting the Wire (backwards) | | |
| Loosen the #8-32 X 0.5” and #4-40 X 0.5” SHCS to remove the Wire Assembly from the Wire Jig. Loosen the SHCS in the Wire Start Posts and discard the leftover Steel Music Wire. The completed Upper Wire Assembly is shown in Figure 11.Create an assembly load in ICS for the Upper Wire Assembly. Use the serial number of [D020481](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=12431) as the serial number of the assembly ([D0901854](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=4792)). | Fig 11: Upper Wire Assembly | | | | |

NOTE: If a wire breaks, the Upper Wire Assembly can be disassembled and certain parts can be reused. Parts that can be reused include [D020481](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=12431), [D0901998](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=5177), [D020198](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=12432) and hardware. These parts can only be used if there is no damage caused to the part (grooves, nicks, etc.) caused by wire clamping.

Parts that CANNOT be reused include [D0901999](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=5178) and [D0901994](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=5173). These parts must be marked as defective in ICS and quarantined from usable production parts.

# Assembly of Intermediate Wires

## Documents

[E0900332](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=6079) HSTS Assembly and Installation Hazard Analysis

[D0901905](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=4969) Intermediate Wire Assembly, HSTS

[E960022](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=3652) Vacuum Compatibility, Cleaning Methods and Qualification Procedures

## Materials

|  |  |  |  |
| --- | --- | --- | --- |
| **Qty** | **Unit** | **Part Number** | **Description** |
| 1 | Each | [D0902526](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=6870) | Intermediate Wire Jig Assembly, HSTS |
| 4 | Each | [D980184](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=2835) | LOS Clamp, Long |
| 1 | Each | [D020132](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=1997) | Lower Blade Wire Clamp, HSTS |
| 1 | Each | [D030044](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=12435) | Lower Blade Wire Clamp Plate, Angled, HSTS |
| 1 | Each | [D0901904](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=4965) | Intermediate Wire Clamp Mount, Lower, HSTS |
| 1 | Each | [D0901903](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=4964) | Intermediate Wire Clamp, Outside, HSTS |
| 2 | Each | N/A | SHCS, #2-56 X 0.375”, Ag-Plated SSTL |
| 2 | Each | N/A | #2 Flat Washer |
| 2 | Each | N/A | SHCS, #4-40 X 0.375”, Ag-Plated SSTL |
| 2 | Each | N/A | #4 Flat Washer |
| 1 | Spool | N/A | Steel Music Wire, 0.0079” Diameter |
| 1 | Each | N/A | Weight Hanger |
| 1 | Each | N/A | Interlocking Test Weight (1kg) |
| 1 | Set | N/A | Test Weights (1g – 500g) |
| 1 | Bag | PNHS-99 | Polynit Heatseal Wipes |
| 1 | Bottle | N/A | Methanol |
| 1 | Bottle | N/A | Acetone |
| 1 | Bottle | N/A | Isopropanol |

## Procedure

Table Edge

Jig

Clevis

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 4 Intermediate Wire Assemblies are required per HSTS. Wire Assemblies should only be assembled as needed (NOT assembled ahead of time and stored for later use). Wear safety glasses and glove liners per [E0900332](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=6079). Ensure that all parts of the Intermediate Wire Jig Assembly ([D0902526](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=6870)) have been processed to Class B per [E960022](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=3652).Confirm that the Wire Jig is assembled completely and correctly per the drawing.Attach the Jig to an Optical Table using 4X LOS Long Clamps ([D980184](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=2835)). Position the Jig so that the end with the Wire Jig Pin Support ([D0900563](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=1578)) extends beyond the edge of the Optical Table by approximately 3” to allow clearance for the Interlocking Test Weights. | | Table Edge  Clevis  Jig  Clamp  Fig 12: Intermediate Wire Jig (to be changed) | | | |
| Assemble the two ends of the Wire Assembly (referred to as the Lower Blade Wire Clamp and the Intermediate Wire Clamp) before attaching them to the Wire Jig. Do not tighten the SHCS.Each Lower Blade Wire Clamp includes:1X [D020132](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=1997) Lower Blade Wire Clamp, HSTS1X [D030044](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=12435) Lower Blade Wire Clamp Plate, Angled, HSTS2X SHCS #2-56 X 0.375”, Ag-Plated SSTL2X #2 Flat WashersEach Intermediate Wire Clamp includes:  * 1X [D0901904](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=4965) Intermediate Wire Clamp Mount, Lower, HSTS * 1X [D0901903](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=4964) Intermediate Wire Clamp, Outside, HSTS * 2X SHCS, #4-40 X 0.375”, Ag-Plated SSTL * 2X #4 Flat Washers | | | | D020132  D030044    D0901904  D0901903  Fig 13: Clamps | |
| On the Wire Jig, attach one Lower Blade Wire Clamp to the outboard side of the Blade Wire Clamp Bracket ([D0902532](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=6877)) using:  * 2X SHCS, #2-56 X 0.375”, Ag-Plated SSTL  On the Wire Jig, attach one Intermediate Wire Clamp to the outboard side of the Mass Wire Clamp Bracket ([D0902533](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=6878)), using:  * 3X SHCS, #4-40 X 0.375”, SSTL | | | L-Clamp  Intermediate Clamp  Fig 14: Clamps Mounted on Wire Jig | | |
| Unspool approximately 24” of 0.0079” diameter Steel Music Wire. Clean the Steel Music Wire as described in Section 12.4. Cut the Steel Music Wire from the spool using dirty wire cutters.Feed the Steel Music Wire through theWire Jig and Clamps in the order shown:1) Over the Clevis Pin2) Through the first Wire Start Post ([D1000628](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=10209) and [D1000583](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=10119))3) Through the Intermediate Wire Clamp4) Through the Lower Blade Wire Clamp5) Through the second Wire Start PostTighten the SHCS in the second Wire Start Post after feeding approximately 0.5” of Steel Music Wire through the clamp. | | | **2**  **5**  **4**  **1**  **3**  Fig 15: Wire Path | | |
| Using a Weight Hanger and a set of Small Test Weights, make up a hanging weight with a mass of 1.460 kg. Note that the Weight Hanger and Test Weights are not clean.Tie the end of the Steel Music Wire hanging over the Clevis Pin around the hook on the Weight Hanger. The Steel Music Wire should now be taut, due to the hanging weight.Allow the hanging weight to hang from the Steel Music Wire for at least 5 minutes. Be careful of hands and feet underneath the hanging weight. | | | | | Fig 16: Hanging Weight |
| Measure the length of the wire between the inboard sides of the Lower Blade Wire Clamp and the Intermediate Wire Clamp. The desired length is 167.02 mm.Tighten the SHCS in the clamps in the order shown. The SHCS in clamp 2 (Lower Blade Wire Clamp) should be torqued to 4 in-lb, while the SHCS in clamp 3 should be torqued to 6 in-lb. When tightening the SHCS, ensure that the inboard surfaces of the two halves of each clamp are completely parallel.Remove the hanging weight from the wire.Using clean wire cutters, cut the Steel Music Wire in two locations as shown, as close to the outboard sides of the clamps as possible. | Cut Wire  **2**  **3**  Cut Wire  **1**  Fig 17: Clamping and Cutting the Wire (backwards) | | | | |
| Before removing the Wire Assembly from the Wire Jig, record part serial numbers, the measured wire length and the mass of the hanging weight to be included in the ICS assembly load.Loosen the #2-56 X 0.375 and #4-40 X 0.375 SHCS holding the clamps to the Wire Jig (NOT the ones holding the clamps together) Loosen the SHCS in the Wire Start Posts and discard the leftover Steel Music Wire. The completed Intermediate Wire Assembly is shown in Figure 18.Create an assembly load in ICS for the Intermediate Wire Assembly. Use the serial number of [D0901904](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=4965) as the serial number of the assembly ([D0901905](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=4969)). | | | | Fig 18: Intermediate Wire Assembly | |
|  | | | |  | |

NOTE: If a wire breaks, the Intermediate Wire Assembly can be disassembled and certain parts can be reused. Parts that can be reused include [D020132](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=1997), [D0901904](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=4965) and hardware. These parts can only be used if there is no damage caused to the part (grooves, nicks, etc.) caused by wire clamping.

Parts that CANNOT be reused include [D030044](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=12435) and [D0901903](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=4964). These parts must be marked as defective in ICS and quarantined from usable production parts.

# Assembly of Lower Wires

## Documents

[E0900332](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=6079) HSTS Assembly and Installation Hazard Analysis

[D0901902](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=4963) Lower Wire Assembly, HSTS

[E960022](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=3652) Vacuum Compatibility, Cleaning Methods and Qualification Procedures

## Materials

|  |  |  |  |
| --- | --- | --- | --- |
| **Qty** | **Unit** | **Part Number** | **Description** |
| 1 | Each | [D0902524](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=6863) | Lower Wire Jig Assembly, HSTS |
| 4 | Each | [D980184](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=2835) | LOS Clamp, Long |
| 2 | Each | [D020202](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=12440) | Lower Wire Clamp Mount, HSTS |
| 4 | Each | [D020203](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=12442) | Lower Wire Clamp, HSTS |
| 2 | Each | [D1200108](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=85580) | Lower Wire Clamp Base, HSTS |
| 2 | Each | [D1200188](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=86671) | Lower Wire Clamp Blank Top, HSTS |
| 4 | Each | N/A | SHCS, #8-32 X 0.625”, Ag-Plated SSTL |
| 4 | Each | N/A | #8 Flat Washer |
| 1 | Spool | N/A | Steel Music Wire, 0.0047” Diameter |
| 2 | Each | N/A | Weight Hanger |
| 2 | Set | N/A | Test Weights (1g – 500g) |
| 1 | Bag | PNHS-99 | Polynit Heatseal Wipes |
| 1 | Bottle | N/A | Methanol |
| 1 | Bottle | N/A | Acetone |
| 1 | Bottle | N/A | Isopropanol |
| 1 | Each | N/A | Vise Grip, 6”, Needle Nose |
| 1 | Each | N/A | Electronic Microscope |

## Procedure

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 2 Lower Wire Assemblies are required per HSTS – one to hang the metal lower mass and one to hang the actual glass optic. Lower Wire Assemblies should only be assembled as needed (NOT assembled ahead of time and stored).Wear safety glasses and glove liners per [E0900332](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=6079).Ensure that all parts of the Lower Wire Jig Assembly ([D0902524](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=6863)) have been processed to Class B per [E960022](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=3652).Confirm that the Wire Jig is assembled completely and correctly per the drawing.Attach the Jig to a corner of an Optical Table such that both ends of the Wire Jig extend beyond the edges of the Optical Table. Use 4X LOS Long Clamps ([D980184](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=2835)) to clamp the Wire Jig to the Optical Table. | | Start & End Posts removed  Start Post removed  Table  Edge  Fig 19: Lower Wire Assembly Jig | | |
| Assemble to the Jig:2 [D1200108](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D1200108&version=) Clamp Base  * 4 (not 6) Socket Head Cap Screws  8/32 x 0.50” SSTL2 Screws are omitted to provide clearance for the Machinist’s Square. Align the Clamp Mounts with the Jig Blocks using the Machinist’s Square, and Torque to 20 in-lb. | | | Base with 2 Screws  Machinist’s  Square    Block    Fig 20: Clamps with 2 Screws each | |
| **Assemble the 1st Wire** Cut 2 48” pieces of .0047” Wire from the spool.Clean the Wire per Section 12.4Lay the 1st Wire down on the far-side Wire Grooves of the 2 Clamp Bases.Feed the LH end of the Wire through the LH Start Clamp, leaving about ½” of Wire beyond the Clamp.Drape the RH end of the Wire over the RH Clevis.Lay out the wire in a straight line from the Start Clamp, across the Clamp Bases and over the Clevis.Tighten the 2 Start Clamp Screws to 30 in-lb. | LH Start Clamp  Fig 21: Installing 1st Wire | | | |
| Create a small loop in the free end of the Wire and tie a Square Knot to secure the Loop.Slide the Hang Weight hook through the Wire Loop and allow the Weight to pull the Wire taught.Ensure the Wire lies smooth and straight from the Start Clamp, across the 2 Wire Grooves in the Clamp Bases, and across the Clevis.Leave the Weight on the Wire for at least 5 minutes. | | | Fig 22: Hang Weight | |
| **Assemble the 2nd Wire** Lay the 2nd Wire down on the near-side Wire Grooves of the 2 Clamp Bases.Drape the LH end of the Wire over the LH Clevis.Ensure the Wire is lying in a straight line across the Clamp Bases and over the Clevis.Lay the 2 [D1200188](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D1200188&version=) Clamp Tops on top of the Wires and Clamp Bases.Assemble through the RH Clamp Base and Clamp Top:  * 2 Socket Head Cap Screws   8/32 x .625” AgPlated   * 2 Flat Washers   Inspect the Clamps from the side, to verify the Wires are fully seated in the Grooves of each bottom Clamp.  Align the Clamp Top with the Clamp Base using the Machinist’s Square.  Torque to 30 in-lb. | Fig 23: Installing the 2nd Wire | | | |
| Ensure the Wire is lying in a smooth, straight line across the other Clamp Base and across the LH Clevis.Leave the Weight on the Wire for at least 5 minutes.Assemble through the LH Clamp Base and Clamp Top:  * 2 Socket Head Cap Screws   8-32 x .625” AgPlated   * 2 Flat Washers   Inspect the Clamps from the side, to verify the Wires are fully seated in the Grooves of each bottom Clamp.  Align the Clamp Top with the Clamp Base using the Machinist’s Square.  Torque to 30 in-lb. | | | | |
| Remove the Hang Weights from the Wires.Cut the Wires just outboard of the 2 Lower Wire Clamps, making three cuts total.To avoid puncture injury, fold over the 4 cut ends of Wire on the final Assembly.Remove the Assembly from the Fixture:  * Loosen the 2 inboard Screws * Loosen the 4 outboard Screws | Loosen inboard Screw first  Cut  Cut  Fig 24: Measuring and cutting, first Wire | | | |
| Finished lower wire, Clamp-Wire-Clamp assembly: 2 Wires, 2 Clamps. | | | | Fig 25: Lower Wire Assembly complete |

# Assembly of Top Blade Guards

## Documents

[D0901934](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=5032) Top Blade Guard Assembly, HSTS

## Materials

|  |  |  |  |
| --- | --- | --- | --- |
| **Qty** | **Unit** | **Part Number** | **Description** |
| 2 | Each | [D0901936](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=5034) | Blade Guard Riser, HSTS |
| 1 | Each | [D0901935](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=5033) | Blade Guard Crossbeam, HSTS |
| 4 | Each | N/A | SHCS, #8-32 X 0.625”, SSTL |
| 2 | Each | 1185-4EN375 | Helicoil, ¼-20 X 0.375”, Nitronic 60 |
| 2 | Each | [D0900999](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=2469) | SHCS, ¼-20 x 2”, Fully Threaded, Rounded End, SSTL |
| 2 | Each | N/A | Hex Nut, ¼-20, Ag-Plated SSTL |

## Procedure

|  |  |
| --- | --- |
| 2 Top Blade Guard Assemblies are required per HSTS.Insert 2 Helicoils into the Blade Guard Crossbeam ([D0901935](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=2469)). Before removing the tangs, thread an SHCS into each Helicoil to be sure that the Helicoil is threaded correctly.Attach 2 Blade Guard Risers ([D0901936](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0901936&version=)) to the Blade Guard Crossbeam ([D0901935](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0901935&version=)) using 4 SHCS, #8-32 X 0.625”. Torque the SHCS to 30 in-lb.Thread 1 Ag-Plated Hex Nut onto each of 2 Rounded End SHCS, ¼-20 X 2” ([D0900999](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=2469)). Thread the 2 Rounded End SHCS into the Blade Guard Crossbeam with the rounded ends facing down, as shown in Figure 26. | Crossbeam  ¼-20 x 2.00  Riser  8-32 x .625 SSTL  Fig 26: Top Blade Guard Assembly |

# Assembling Upper Blade Rotational Adjusters

## Documents

[D1000045](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=8304) HSTS Rotational Adjuster Assembly

[E1000169](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=E1000169&version=) Blade Characterization Spreadsheet

[T0900559](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=6982) Blade Pairings Spreadsheet

## Materials

|  |  |  |  |
| --- | --- | --- | --- |
| **Qty** | **U** | **ID** | **Description** |
| 2 | Ea | [D020660](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D020660&version=) | **Blade Pulldown Device** |
| 2 | Ea | [D0901815](https://dcc.ligo.org/cgi-bin/private/DocDB/ProcessDocumentAdd) | Upper Clamp Inside |
| 2 | Ea | [D0901813](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D070341&version=) | Upper Clamp Outside |
| 4 | Ea | NA | 2 Socket Head Cap Screw 4-40 x 0.375” AgPlated |
| 2 | Ea | NA | Flat Washer #4 Vented, SSTL |
| 2 | Ea | NA | Socket Head Cap Screw 4-40 x 0.25” AgPlated |
| 1 | Ea | NA | 4.483 kg in weight |
| 2 | Ft | NA | Music Wire .024” dia. min. |
| 1 | Ea | [D020677](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D020677&version=) | **Library of Clamps** |
| 2 | Ea | [D1000045](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=8304) | **HSTS Rotational Adjuster Assembly** |
| 1 | Ea | [D030448](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D030448&version=) | Base Plate |
| 1 | Ea | [D030447](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D030447&version=) | Rotating Plate |
| 2 | Ea | [D1001812](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D1001812&version=) | HSTS Upper Blades |
| 1 | Ea | [DXXXXXX](https://dcc.ligo.org/cgi-bin/private/DocDB/Search?.submit=+Title+&titlesearch=HSTS+Upper+Blade+Clamp&titlesearchmode=allsub) | Upper Blade Clamp, Upper Side, 0-3.5**°** |
| 1 | Ea | [DXXXXXX](https://dcc.ligo.org/cgi-bin/private/DocDB/Search?.submit=+Title+&titlesearch=HSTS+Upper+Blade+Clamp&titlesearchmode=allsub) | Upper Blade Clamp, Lower Side, 0-3.5**°** |
| 1 | Ea | [DXXXXXX](https://dcc.ligo.org/cgi-bin/private/DocDB/Search?.submit=+Title+&titlesearch=HSTS+Upper+Blade+Clamp+Shim&titlesearchmode=allsub) | Upper Blade Clamp, Lower Shim |
| 1 | Ea | [D030449](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D030449&version=) | Push Plate |
| 1 | Ea | [D030450](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D030450&version=) | Pull Plate |
| 2 | Ea | NA | Flat Washer, ¼” SSTL |
| 3 | Ea | NA | Socket Head Cap Screw, ¼-20 x .375”, SSTL |
| 2 | Ea | NA | Socket Head Cap Screw, 8-32 x 1.00”, SSTL |
| 2 | Ea | NA | Socket Head Cap Screw, 8-32 x 0.75”, AgPlated |
| 1 | Ea | NA | Socket Head Cap Screw, 8-32 x 1.00”, AgPlated |
| 1 | Ea | NA | Socket Head Cap Screw, 8-32 x 1.00” Round Tip AgPlated |
| 3 | Ea | [D1100785](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D1100785&version=)-472 | Flat Washer, ¼” x .472 OD, N-60 |
| 1 | Ea | [D1100785](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D1100785&version=)-359 | Flat Washer, .20 x .359 OD, N-60 |
| 2 | Ea | NA | Socket Head Cap Screw, ¼-20 x 1.375”, AgPlated |
| 1 | Ea | [D1002440](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=20931) | **HSTS Upper Blade Bake Fixture** |

## Procedure

Use Safety Glasses and Glove Liners per [E0900332](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=6079).

|  |  |  |
| --- | --- | --- |
| Prepare 2 [D020660](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D020660+&version=) Blade Pulldown Devices per Materials List above. | | Fig 27: Blade Pulldown Device |
| Select pairs of [D1001812](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D1001812&version=) Blades and Blade Clamps per the [T0900559](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=6982) Blade Pairings Spreadsheet.Correlate each Blade to a location within the Suspension:  * The Blade with the higher tip goes to the +X, -Y corner (meaning that the blade with the higher tip is installed in the Rotational Adjuster that is mounted on the +X, -Y corner). * The Blade with the lower tip goes to the -X, +Y corner (meaning that the blade with the lower tip is installed in the Rotational Adjuster that is mounted on the –X, +Y corner). * Blade launch angle is set by Blade Clamps. These range from 0-3.5 deg. in .5 deg. increments. * Select Clamps from the [D020677](https://dcc.ligo.org/cgi-bin/private/DocDB/Search?.submit=+Title+&titlesearch=HSTS+Library+of+clamps&titlesearchmode=allsub) HSTS Library of Clamps * Select Clamps according to Blade Characterization data for stiffness and expected load. * Select Blades in pairs according to Blade Characterization data. * Record the Blade serial numbers and Blade clamp angles and orientations within ICS. | | | |
| Fig 28: Clamps Control Launch Angle | Fig 29: HSTS Library of Clamps | | |

|  |  |
| --- | --- |
| Mount the [D1002440](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=20931) Baking Fixture to an Optics Table, aligning the Crossbar side with the Table edge to allow clearance for the Blade Pulldown Device.Remove a [D1002443](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D1002443&version=) Crossbar from the Baking Fixture.Assemble to the Baking Fixture:  * 2 [D030447](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D030447&version=) Rotating Plates   Beveled-side-down   * 4 Socket Head Cap Screws   ¼-20 x 0.375” SSTL   * 4 [D1100785](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D1100785&version=)-472 Flat Washers   Tighten the Screws firmly | Table Edge  Fig 30: Base Plates in Baking Fixture |
| Assemble to each Rotating Plate:  * 1 [DXXXXXX](https://dcc.ligo.org/cgi-bin/private/DocDB/Search?.submit=+Title+&titlesearch=HSTS+Upper+Blade+Clamp+Shim&titlesearchmode=allsub) Shim, Upper Blade Clamp   Each Weldment is packaged with 2 Rotational Adjuster Shim’s, each marked with the Weldment Serial Number   * 1 [DXXXXXX](https://dcc.ligo.org/cgi-bin/private/DocDB/Search?.submit=+Title+&titlesearch=HSTS+Upper+Blade+Clamp&titlesearchmode=allsub) Lower Clamp * 1 [D1001812](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D1001812&version=) Upper Blade * 1 [DXXXXXX](https://dcc.ligo.org/cgi-bin/private/DocDB/Search?.submit=+Title+&titlesearch=HSTS+Upper+Blade+Clamp&titlesearchmode=allsub) Upper Clamp * 2 Socket Head Cap Screws   ¼-20 x 1.375” SSTL   * Flat Washer ¼” SSTL   Hand-tighten the 2 Screws | Machinist’s  Square  Fig 31: Shim, Clamps, Blade, Screws, Washers |

|  |
| --- |
| Attach a Pulldown Device from each Upper Blade Tip to flatten the Blades.Assemble to the Bake Fixture:  * 1 [D1002443](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D1002443&version=) Bake Fixture Crossbar * 2 Socket Head Cap Screws 8-32 x 0.625” SSTL * 2 Flat Washers #8 SSTL   Tighten the Screws firmly   * 2 Socket Head Cap Screws ¼-20 x 1.0 Full-Thread, Round-Tip SSTL  Turn down the Round-Tip Screws until the weighted Blade tip is level with the Blade root. Be careful not to damage the nickel plating on the blade Leaving the Wire Clamp attached to the Blade, remove the rest of the Blade Pulldown Device.Using the Machinist’s Square, square the Blade, Clamps, and Shim to each other and to the Rotating Plate.Tighten the ¼-20 Screws that clamp the Blade, to 100 in-lb.Re-attach the Blade Pulldown Device to the Wire Clamp.Turn back the Rounded-End Screws and remove the [D1002443](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D1002443&version=) Crossbar again.Slowly lift and then disconnect the Blade Pulldown Device, allowing each Blade to curve fully upward.Disassemble the Rotational Adjuster(s) from the Upper Blade Baking Fixture. |

|  |  |
| --- | --- |
| Assemble to a [D030448](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D030448&version=) Base Plate:A just-assembled Rotational Adjuster3 Socket Head Cap Screw¼-20 x 0.375” SSTL3 [D1100785](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D1100785&version=)-472 N-60 Flat WashersHand-tighten only[D030450](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D030450&version=) Pull Plate2 Socket Head Cap Screw8-32 x 0.75” AgPlatedTorque to 30 in-lb | Rotating Plate  Pull Plate  8-32 x 0.75  ¼-20 x 0.375” (3)  Flat Washer ¼” (3)  Base Plate  Fig 32: Base Plate and Pull Plate added |
| Assemble to the Base Plate:  * [D030449](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D030449&version=) Push Plate * 2 Socket Head Cap Screws  8-32 x 1.00” SSTLTorque to 20 in-lbAssemble through the Push Plate, into the Pull Plate:  * 1 Socket Head Cap Screw  8-32 x 1.00” AgPlated  * 1 [D1100785](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D1100785&version=)-359 N-60 Flat Washer * 1 Socket Head Cap Screw  8-32 x 1.00” Round Tip AgPlated | 8-32 x 1” SSTL  8-32 x 1” AgPlated  8-32 x 1” AgPlated Round Tip  Fig 33: Adding Push Plate |

# Assembling Barrel Earthquake Stops

**2 Assemblies for Intermediate Mass / Upper Side**

## Documents

[D0902203](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902203&version=) Barrel Earthquake Stop Assembly / Intermediate Wire

## Materials

|  |  |  |  |
| --- | --- | --- | --- |
| **Qty** | **U** | **ID** | **Description** |
| 4 | Ea | [D0902009](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902009&version=) | Barrel EQ Stop Base |
| 4 | Ea | [D0902008](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=5192) | Barrel EQ Stop Top |
| 8 | Ea | NA | Socket Head Cap Screw 4-40 x 0.375” SSTL |
| 2 | Ea | [D0901925](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0901925&version=) | Barrel EQ Stop Crossbar, Intermediate Wire |
| 8 | Ea | NA | Socket Head Cap Screw ¼-20 x 0.875” SSTL |
| 8 | Ea | NA | Flat Washer, ¼” SSTL |
| 4 | Ea | NA | Socket Head Cap Screw ¼-20 x 2.25” SSTL Round Tip |
| 4 | Ea | NA | Hex Nut ¼-20 AgPlated |

## Procedure

|  |  |
| --- | --- |
| Repeat these steps to build 2 Assemblies.Used above the Intermediate Mass.Assemble:  * 2 [D0902009](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902009&version=) Barrel EQ Stop Base * 2 [D0902008](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=5192) Barrel EQ Stop Top * 2 Socket Head Cap Screws  4-40 x 0.375” SSTLTorque to 5 in-lbEnsure the Vent Holes of each D0902008 are facing outboard.Ensure the Bases and Tops are aligned with a Precision Square.Assemble 1 [D0901925](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0901925&version=) Barrel EQ Stop Crossbar to the previous assemblies, using:  * Socket Head Cap Screw  ¼-20 0.875” SSTL  * Flat Washer ¼” SSTL  Assemble Bolts loosely.Assemble to the Crossbar:  * 2 Socket Head Cap Screw  ¼-20 2.25” SSTL Rounded Tip  * 2 Hex Nuts ¼-20 AgPlated  Note the orientation of the bolts relative to the Crossbar. | Bolt  Orientation  Precision  Square    D0902009  ¼-20 x 2.25”  ¼-20 x .875” Loose  4-40 x 0.375”  D0902008  Hex Nut  D0901925  Vent Holes facing **outboard**.  D0902008  Fig 34: Build 2 Assemblies |

**2 Assemblies for Intermediate Mass / Lower Side**

**4 Assemblies for Lower Mass**

## Documents

[D0902201](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902201&version=) HSTS Barrel EQ Stop Assembly, Lower Wire

## Materials

|  |  |  |  |
| --- | --- | --- | --- |
| **Qty** | **U** | **ID** | **Description** |
| 12 | Ea | [D0902009](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902009&version=) | Barrel EQ Stop Base |
| 12 | Ea | [D0902008](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=5192) | Barrel EQ Stop Top |
| 24 | Ea | NA | Socket Head Cap Screw 4-40 x 0.375” SSTL |
| 6 | Ea | [D0902202](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902202&version=) | Barrel EQ Stop Crossbar |
| 24 | Ea | NA | Socket Head Cap Screw ¼-20 x 0.875” SSTL |
| 24 | Ea | NA | Flat Washer, ¼” SSTL |
| 12 | Ea | NA | Socket Head Cap Screw ¼-20 x 2.25” Round-Tip SSTL |
| 8 | Ea | [D0900932](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0900932&version=) | EQ Stop for Glass |
| 12 | Ea | NA | Hex Nut ¼-20 AgPlated |
| 1 | Ea | NA | Machinist’s Square |

## Procedure

6 Assemblies; 2 beneath Intermediate Mass; 4 for Bottom Mass or Optic. For Optic, use EQ Stops for Glass; for Intermediate and Bottom Mass, use ¼-20 x 2.25” SHCS Round Tip.

|  |  |
| --- | --- |
| Assemble:  * 2 [D0902009](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902009&version=) Barrel EQ Stop Bases * 2 [D0902008](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=5192) Barrel EQ Stop Tops * 2 Socket Head Cap Screws  4-40 x 0.375” SSTLTorque to 5 in-lbEnsure the vent holes of the D0902008 are facing outboard relative to the D0902009.Ensure the Bases and Tops are aligned with a Machinist’s Square.Assemble 1 [D0902202](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902202&version=) Barrel EQ Stop Crossbar, Lower Wire, to the previous assemblies, using:  * Socket Head Cap Screw  ¼-20 x 0.875” SSTL  * Flat Washer ¼” SSTL  Assemble Bolts loosely.Assemble to the Crossbar:  * 2 Socket Head Cap Screw  ¼-20 x 2.25” SSTL Round Tip  * Hex Nuts ¼-20 AgPlated  Note the orientation of the bolts relative to the Crossbar. | Machinist’s  Square    Hex Nut  Bolt  Orientation  ¼-20 x .875” Loose  D0902008  Vent Holes facing **outboard**.  D0902009  4-40 x 0.375”  ¼-20 x 2.25”  D0902202  Fig 35: Build 6 Assemblies |

# Assembling Face EQ Stops

**2 Assemblies for Intermediate Mass**

## Documents

[D0902413](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902413&version=) Face EQ Stop Assembly, Intermediate Mass

## Materials

|  |  |  |  |
| --- | --- | --- | --- |
| **Qty** | **U** | **ID** | **Description** |
| 2 | Ea | [D0902204](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902204&version=) | HSTS Face EQ Stop Bracket, Intermediate Mass |
| 2 | Ea | [D0901923](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0901923&version=) | HSTS Face EQ Stop Base |
| 4 | Ea | NA | Socket Head Cap Screw 8-32 x 0.625” SSTL |
| 4 | Ea | NA | Socket Head Cap Screw ¼-20 x 2.25” SSTL Round Tip |
| 4 | Ea | NA | Hex Nut ¼-20 AgPlated |
| 4 | Ea | 1185-4EN375 | Helicoil ¼-20 x 0.375” |

## Procedure

|  |  |
| --- | --- |
| Repeat steps to build 2 Assemblies: Assemble:  * 1 [D0901923](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0901923&version=) Base * 1 [D0902204](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902204&version=) Bracket * 2 Socket Head Cap Screws  8-32 x 0.625” SSTLTorque to 20 in-lb  * 2 Socket Head Cap Screws   ¼-20 x 2.25” SSTL Round-Tip   * 2 Hex Nuts ¼-20 AgPlated | Hex Nut  ¼-20 x 2.25”  D0901923  D0902204  8-32 x 0.625”  Fig 36: 2 Assemblies |

**2 Assemblies for Lower Mass**

## Documents

[D0902205](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902205&version=) Face EQ Stop Assembly, Bottom Mass

## Materials

|  |  |  |  |
| --- | --- | --- | --- |
| **Qty** | **U** | **ID** | **Description** |
| 2 | Ea | [D0901922](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0901922&version=) | HSTS Face EQ Stop Bracket, Lower Mass |
| 2 | Ea | [D0901923](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0901923&version=) | HSTS Face EQ Stop Base |
| 4 | Ea | NA | Socket Head Cap Screw 8-32 x 0.625” SSTL |
| 4 | Ea | NA | Socket Head Cap Screw ¼-20 x 2.25” Round-Tip SSTL (for Mass) |
| 4 | Ea | [D0900932](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0900932&version=) | EQ Stop for Glass, 2” (for Optic) |
| 4 | Ea | NA | Hex Nut ¼-20 AgPlated |
| 4 | Ea | 1185-4EN375 | Helicoil ¼-20 x 0.375” |

## Procedure

|  |  |
| --- | --- |
| Create 2 Assemblies, each with:  * 1 [D0901923](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0901923&version=) Base * 1 [D0901922](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0901922&version=) Bracket * 2 Socket Head Cap Screws   8-32 x 0.625” SSTL  Torque to 20 in-lb  **For Mass:**   * 2 Socket Head Cap Screws   ¼-20 x 2.25” Round-Tip SSTL   * 2 Hex Nuts ¼-20 AgPlated   **For Optic:**   * 2 [D0900932](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0900932&version=) EQ Stop for Glass * 2 Hex Nuts ¼-20 AgPlated | D0901923  8-32 x 0.625”  Jam Nut  D0900932  D0901922  Fig 37: 2 Assemblies |

# Assembling AOSEM Alignment Assemblies

These assemblies are identical, with 3 exceptions:

* Intermediate Mass assemblies have a shorter Alignment Bracket;
* LH / RH versions (Alignment Bracket is reversed);
* 3 heights of Alignment Bracket Mounts, depending on PN.

Brackets are shown with A OSEMs in place, but A OSEMs are actually installed later on.

|  |  |  |  |
| --- | --- | --- | --- |
| [**D0901924**](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0901924&version=) **(4)**  A OSEM Alignment Assy  Intermediate Mass  Used in all 4 locations at the Intermediate Mass. |  | Small Mount    LH  Configuration  Shorter Bracket | RH  Configuration |
| [**D0902207**](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902207&version=) **(2)**  Upper A OSEM Alignment Assy  Lower Mass  Used in the top 2 positions at the Lower Mass. |  | Medium Mount    LH  Configuration | RH Configuration |
| [**D0902208**](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902208&version=) **(2)**  Lower A OSEM Alignment Assy  Lower Mass  Used in the lower 2 positions at the Lower Mass. |  | Large Mount    LH  Configuration | RH  Configuration |

## Materials

|  |  |  |  |
| --- | --- | --- | --- |
| **D0901924** | | | |
| **Qty** | **U** | **ID** | **Description** |
| 1 | Ea | [D0902206](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902206&version=) | A OSEM Alignment Bracket Mount, Intermediate Mass |
| 1 | Ea | [D0902414](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902414&version=) | A OSEM Alignment Bracket, Intermediate Mass |
| 1 | Ea | [D0901065](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0901065&version=) | A OSEM Assembly |
| 1 | Ea | [D0901548](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0901548&version=) | A OSEM Adjustment Collar |
| 2 | Ea | [D1000660](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D1000660&version=) | Adjustment Nut |
| 2 | Ea | [D1000659](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D1000659&version=) | Adjustment Shaft |
| 1 | Ea | NA | Socket Head Cap Screw ¼-20 x 2.25” Round-Tip SSTL |
| 1 | Ea | 1185-4EN250 | Helicoil ¼-20 x 0.25” |
| 2 | Ea | 1185-2EN246 | Helicoil 8-32 x 0.246” |
| 2 | Ea | NA | Socket Head Cap Screw 8-32 x 0.625” |
| 2 | Ea | NA | Flat Washer #8 SSTL |
| 1 | Ea | NA | Socket Head Cap Screw 2-56 x 0.375” |
| 1 | Ea | NA | Hex Nut ¼-20 AgPlated |
| **D0902207** | | | |
| **Qty** | **U** | **ID** | **Description** |
| 1 | Ea | [D0902417](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902417&version=) | A OSEM Alignment Bracket |
| 1 | Ea | [D0902416](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902416&version=) | A OSEM Alignment Bracket Mount, Intermediate Mass |
| 1 | Ea | [D0901065](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0901065&version=) | A OSEM Assembly |
| 1 | Ea | [D0901548](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0901548&version=) | A OSEM Adjustment Collar |
| 2 | Ea | [D1000660](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D1000660&version=) | Adjustment Nut |
| 2 | Ea | [D1000659](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D1000659&version=) | Adjustment Shaft |
| 1 | Ea | NA | Socket Head Cap Screw ¼-20 x 2.25” Round-Tip SSTL (for Mass) |
| 1 | Ea | [D0900932](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0900932&version=) | EQ Stop for Glass 2” (for Optic) |
| 1 | Ea | 1185-4EN250 | Helicoil ¼-20 x 0.25” |
| 2 | Ea | 1185-2EN246 | Helicoil 8-32 x 0.246” |
| 2 | Ea | NA | Socket Head Cap Screw 8-32 x 0.625” |
| 2 | Ea | NA | Flat Washer #8 SSTL |
| 1 | Ea | NA | Socket Head Cap Screw 2-56 x 0.375” |
| 1 | Ea | NA | Hex Nut ¼-20 AgPlated |
| **D0902208** | | | |
| **Qty** | **U** | **ID** | **Description** |
| 1 | Ea | [D0902417](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902417&version=) | A OSEM Alignment Bracket |
| 1 | Ea | [D0902415](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902415&version=) | A OSEM Alignment Bracket Mount, Intermediate Mass |
| 1 | Ea | [D0901065](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0901065&version=) | A OSEM Assembly |
| 1 | Ea | [D0901548](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0901548&version=) | A OSEM Adjustment Collar |
| 2 | Ea | [D1000660](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D1000660&version=) | Adjustment Nut |
| 2 | Ea | [D1000659](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D1000659&version=) | Adjustment Shaft |
| 1 | Ea | NA | Socket Head Cap Screw ¼-20 x 2.25” Round-Tip SSTL (for Mass) |
| 1 | Ea | [D0900932](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0900932&version=) | EQ Stop for Glass 2” (for Optic) |
| 1 | Ea | 1185-4EN250 | Helicoil ¼-20 x 0.25” |
| 2 | Ea | 1185-2EN246 | Helicoil 8-32 x 0.246” |
| 2 | Ea | NA | Socket Head Cap Screw 8-32 x 0.500” |
| 2 | Ea | NA | Flat Washer #8 SSTL |
| 1 | Ea | NA | Socket Head Cap Screw 2-56 x 0.375” SSTL |
| 1 | Ea | NA | Hex Nut ¼-20 AgPlated |

## Procedure

Assembly procedure is nearly identical for all 3 units, but varies by the part number and orientation of the Alignment Bracket, and Mount.

|  |  |
| --- | --- |
| Assemble [D1000659](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D1000659&version=) Adjustment Shafts to an Alignment Bracket, ensuring you have the correct Alignment Bracket and ensuring the correct orientation of the Shafts to the Bracket to enable the LH/RH configuration.Assemble to the [D0901548](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0901548&version=) Adjustment Collar:  * 1 Socket Head Cap Screw   2-56 x 0.375” SSTL Do not tighten ScrewAssemble the Adjustment Collar to the [D1000659](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D1000659&version=) Adjustment Shafts using [D1000660](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D1000660&version=) Adjustment Nuts The Adjustment Nut threads MUST be tapped; as is, the Nuts are tight and will seize  Be extremely careful to not strip the Heads of the Nuts Assemble the correct Bracket Mount to the Alignment Bracket using:  * Correct Socket Head Cap Screw 8-32 * Flat Washer #8  Assemble EQ Stop to Alignment Bracket with Hex Nuts | EQ Stop  8-32 Screw  Adjustment Collar  Adjustment Shaft  Bracket Mount  Adjustment Nut  2-56 Screw  Alignment Bracket  Fig 38: Assembly without A OSEM |

# Overall Assembly

The following document sections encompass installation into the main [D020023](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D020023+&version=) Weldment of:

* All aforementioned Subassemblies;
* Other individual components.

*Each Subassembly must be weighed and documented in ICS, correlated to a specific overall assembly.*

## Subassemblies

|  |  |  |  |
| --- | --- | --- | --- |
| **Qty** | **U** | **ID** | **Description** |
| 2 | Ea | [D1000045](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D1000045&version=) | Rotational Adjuster |
| 2 | Ea | [D0901934](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0901934&version=) | Upper Blade Guard |
| 1 | Ea | [D020534](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D020534&version=) | Upper Mass |
| 2 | Ea | [D0901854](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0901854&version=) | Upper Wire |
| 2 | Ea | [D0901905](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0901905&version=) | Intermediate Wire |
| 2 | Ea | [D0901902](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0901902&version=) | Lower Wire |
| 1 | Ea | [D0901873](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0901873&version=) | Intermediate Mass |
| 1 | Ea | [D0901791](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0901791&version=) | Metal Lower Mass MC |
| 1 | Ea | [D0902333](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902333&version=) | Metal Lower Mass PR/RS |
| 2 | Ea | [D0902201](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902201&version=) | Earthquake Barrel Stop, Lower Wire |
| 1 | Ea | [D0902413](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902413&version=) | Face EQ Stop, Intermediate Mass |
| 1 | Ea | [D0902205](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902205&version=) | Face EQ Stop, Test Mass |
| 6 | Ea | [D060218](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D060218+&version=) | BOSEM |
| 4 | Ea | [D0901924](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0901924&version=) | Upper AOSEM Alignment, Intermediate Mass |
| 2 | Ea | [D0902207](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902207&version=) | Upper AOSEM Alignment, Test Mass |
| 2 | Ea | [D0902208](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902208&version=) | Lower AOSEM Alignment, Test Mass |

## Individual Components

|  |  |  |  |
| --- | --- | --- | --- |
| **Qty** | **U** | **ID** | **Description** |
| 8 | Ea | [D980184](https://dcc.ligo.org/DocDB/0002/D980184/002/D980184-v2.PDF) | LOS Clamps |
| 8 | Ea | NA | Socket Head Cap Screw ¼-20 x 1.5” AgPlated |
| 4 | Ea | [D020346](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D020346+&version=) | Tablecloth Bracket |
| 1 | Ea | [D020239](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=13242) | Tablecloth |

# Preparing the Weldment

## Procedure

|  |  |  |
| --- | --- | --- |
| Verify usability of ALL tapped holes.Install at the base of the Weldment:  * 6 1185-2EN492 Helicoils   8-32 x 3.0D  Install these BEFORE securing the Weldment to the Optical Table! Install in the top plate of the Weldment:  * 4 1185-4EN250   Helicoils  ¼-20 x 1.0D Identify the Front vs Rear of the Weldment by examining the hole patterns on the top surfaces of the bottom crossmembers. | Helicoils  Helicoils  **Fig 39: Front of Weldment Fig 40: Rear of Weldment** | |
| Secure the Weldment to an Optics Table with  * 8 [D980184](https://dcc.ligo.org/DocDB/0002/D980184/002/D980184-v2.PDF) LOS Clamps, 2 per corner * 8 ¼-20 x 1.5” Screws AgPlated | | Fig 41: Clamping Weldment to Optics Table |

# Installing the Rotational Adjusters

## Documents

[D020023](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D020023&version=) HSTS Weldment Assembly

## Materials

|  |  |  |  |
| --- | --- | --- | --- |
| **Qty** | **U** | **ID** | **Description** |
| 2 | Ea | [D020660](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D020660&version=) | **Blade Pulldown Device** |
| 2 | Ea | [D0901815](https://dcc.ligo.org/cgi-bin/private/DocDB/ProcessDocumentAdd) | Upper Clamp Inside |
| 2 | Ea | [D0901813](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D070341&version=) | Upper Clamp Outside |
| 4 | Ea | NA | 2 Socket Head Cap Screw 4-40 x 0.375” AgPlated |
| 4 | Ea | NA | Flat Washer #4 Vented, SSTL |
| 4 | Ea | NA | Socket Head Cap Screw 4-40 x 0.25” AgPlated |
| 1 | Kg | NA | 4.483 kg in weight |
| 2 | Ft | NA | Music Wire .024” dia. min. |
| 2 | Ea | [D1102119](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D1102119&version=) | **Blade Pulldown Support** Class B cleaned |
| 2 | Ea | [D1000045](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D1000045&version=) | **Upper Blade Rotational Adjustment Assemblies** |
| 2 | Ea | [D0901934](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0901934&version=) | **Blade Guard Assembly** |
| 24 | Ea | NA | Socket Head Cap Screw 8-32 x .625” AgPlated SSTL |
| 24 | Ea | NA | Washer, Flat #8 SSTL |
| 1 | Roll | NA | UHV Foil |

## Process

|  |  |
| --- | --- |
| Wear Safety Glasses and Glove Liners per E1000043. Prepare 2 [D020660](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D020660+&version=) Blade Pulldown Devices per Materials List. | Fig 42: Blade Pulldown Device |

|  |  |
| --- | --- |
| Attach 2 [D0901934](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0901934&version=) Upper Blade Guard Assemblies to the Weldment using:16 Socket Head Cap Screws8-32 x 0.625” AgPlated SSTL16 Washers, Flat #8 SSTL Torque to 30 in-lb | Fig 43: Base Plates and Blade Guards |
| Remove the 2 [D0901935](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0901935&version=) Blade Guard BarsAttach the Rotational Adjusters to the Weldment with:8 Socket Head Cap Screws8-32 x 0.625” AgPlated SSTL8 Washers, Flat #8 SSTL Torque to 20 in-lb.  Blades are shown flat but are actually curved upward at this point.  Record the serial number and location of both Upper Blades in ICS in the RA assembly load. | Fig 44: Crossbars removed |
| Ensure the 2 [D1102119](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D1102119&version=) Blade Pulldown Supports are Class B clean.Attach the Blade Pulldown Supports to the center of the Weldment cross member shown, Clevis extending outboard.Cover each end of the Weldment Structure and surrounding Optical Table areas with UHV Aluminum Foil, to protect them from the dirty Pulldown Device. 2 workers required: 1st person holds the Pulldown Weight.2nd person passes Wire Clamp of the Pulldown Device through the Weldment side opening, up toward the Upper Blade Tip, then attaches the Clamp to the Blade tip with:  * 2 Socket Head Cap Screws   4-40 x .375” AgPlated SSTL 1st person gently drapes the wire over the Clevis, and slowly releases the Weight.Repeat Steps 11-13 for the second Pulldown Device. | Fig 45: Blade Pulldown Support    Blade Pulldown Supports  Fig 46: Location of Blade Pulldown Support |
| Re-Assemble the 2 [D0901935](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0901935&version=) Blade Guard Bars to the Risers, using the original:  * 4 Socket Head Cap Screws  8-32 x .625” SSTL Torque to 20 in-lb  Ensure the Bars are oriented with the EQ Stop Screws directly over the Blades.  The EQ Stop Screws should be adjusted so the Blades are flat. Once adjusted, the Screws should be secured with the Hex Nuts. Carefully remove the 2 Blade Pulldown Devices.Remove the 2 Blade Pulldown Supports. | Fig 47: Bar orientation    Fig 48: EQ Stops turned to flatten Blades |

# Installing Barrel EQ Stops

## Materials

|  |  |  |  |
| --- | --- | --- | --- |
| **Qty** | **U** | **ID** | **Description** |
| 2 | Ea | [D0902203](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902203&version=) | Barrel EQ Stop, Intermediate Wire |
| 6 | Ea | [D0902201](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902201&version=) | Barrel EQ Stop, Lower Wire |
| 32 | Ea | NA | Socket Head Cap Screw 8-32 x 0.5” AgPlated |
| 32 | Ea | NA | Flat Washer #8 |
| 1 | Ea | NA | Machinist’s Square |

## Procedure

|  |  |
| --- | --- |
| Assemble to the Weldment:  * 2 [D0902203](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902203&version=) Assemblies above the Intermediate Mass   Raise Crossbars  Retract Stop Screws   * 2 [D0902201](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902201&version=) Assemblies beneath the Intermediate Mass   Lower Crossbars  Extend Stop Screws to support the Mass   * 2 [D0902201](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902201&version=) Assemblies above Bottom Mass / Optic   Crossbars at midpoint  Stop Screws at midpoint   * 2 [D0902201](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902201&version=) Assemblies beneath Bottom Mass / Optic   Raise Crossbars  Extend Stop Screws   * 32 Socket Head Cap Screw   8-32 x 0.675” AgPlated   * 32 Flat Washer #8  Torque to 30 in-lb | D0902201 Lower Crossbars, Screws support Mass  D0902201 Screws Halfway, Crossbars Halfway  D0902201 Raise Crossbars, Extend Screws  D0902203 Raise Crossbars, Retract Screws  Fig 49: Weldment / Front View |

# Assembling the Intermediate Mass (M2)

## Documents

[D0901873](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=4835) HSTS Intermediate Mass Assembly

## Materials

|  |  |  |  |
| --- | --- | --- | --- |
| **Qty** | **U** | **ID** | **Description** |
| 1 | Ea | D0901792 | **HSTS Intermediate Mass** |
| 2 | Ea | NA | Socket Head Cap Screw ¼-20 x .875” Vented |
| 2 | Ea | Several | Add-On Masses |
| 2 | Ea | D020202 | Lower Wire Clamp, Inside |
| 4 | Ea | D020203 | Lower Wire Clamp, Outside |
| 6 | Ea | NA | Socket Head Cap Screw, 8-32 x .5” SSTL |
| 4 | Ea | NA | Socket Head Cap Screw, 8-32 x .625” AgPlated |
| 10 | Ea | NA | Flat Washer #8 SSTL |
| 4 | Ea | D0901904 | Intermediate Wire Clamp Mount |
| 4 | Ea | D0901903 | Intermediate Wire Clamp, Lower |
| 8 | Ea | NA | Socket Head Cap Screw 4-40 x .375” AgPlated |
| 12 | Ea | NA | Socket Head Cap Screw 4-40 x .375” SSTL |
| 20 | Ea | NA | Flat Washer #4 SSTL |

## Procedure

|  |  |
| --- | --- |
| Weigh the following items, selecting Add-On Weights to arrive at 2963.30 total:  * Intermediate Mass * Lower Wire Clamps per list above * Intermediate Wire Clamps per list above * Add-On Masses for the Intermediate Mass   D1100894 2g  D1100863 5g  D1100855 10g  D030078 20g  D020351 50g  D020350 100g | Fig 50: Add-On Weights and Wire Clamps |
| Assemble the Add-On Masses to the Intermediate Mass.*The grooves on the Add-On Masses must face inboard* | Fig 51: Intermediate Mass with Add-On Masses |

# Assembling the Lower Mass (M3)

## Documents

[D0901791](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=4623) HSTS Metal Lower Mass Assembly (MC)

## Materials

|  |  |  |  |
| --- | --- | --- | --- |
| **Qty** | **U** | **ID** | **Description** |
| 1 | Ea | [D0902658](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902658&version=) | Optic Holder |
| 4 | Ea | [D980184](https://dcc.ligo.org/DocDB/0002/D980184/002/D980184-v2.PDF) | LOS Clamps |
| 4 | Ea | NA | Socket Head Cap Screw ¼-20 x 1.5” AgPlated |
| 1 | Ea | D020234 | **HSTS Metal Lower Mass** |
| 2 | Ea | Y1-1037-0 | Laser Mirror |
| 8 | Ea | NA | Socket Head Cap Screw 4-40 x .375” SSTL |
| 8 | Ea | NA | Flat Washer #4 SSTL |
| 8 | Ea | NA | Flat Washer #8 SSTL |
| 2 | Ea | [D0901790](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0901790&version=) | Primary Metal Breakoff Prism |
| 4 | Ea | NA | Socket Head Cap Screw 8-32 x .375” SSTL |
| 4 | Ea | NA | Flat Washer #8 SSTL |
| 2 | Ea | [D0901278](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0901278&version=) | Secondary Metal Breakoff Prism |

## Procedure

|  |  |
| --- | --- |
| Mount the [D0902658](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902658&version=) Optic Holder to an Optic Table using 4 [D980184](https://dcc.ligo.org/DocDB/0002/D980184/002/D980184-v2.PDF) Clamps and 4 Socket Head Cap Screws, ¼-20 x 1.5” AgPlated.Place the [D0901792](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D070338&version=) Intermediate Mass into the [D0902658](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902658&version=) Optic Holder. | Fig 52: Optic Holder and Bottom Mass |
| Assemble to the Lower Mass:  * 2 Y1-1037-0 Laser Mirrors * 8 Socket Head Cap Screws   4-40 x 0. 375” SSTL   * 4 Flat Washers #4 SSTL * 4 Flat Washers #8 SSTL   Torque to 5 in-lb  Mirror Arrow must face outwards.   * 2 [D0901790](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0901790&version=) Prism Breakoffs * 4 Socket Head Cap Screws   8-32 x 0.375 SSTL   * 4 Flat Washers #8 SSTL   Torque to 20 in-lb |  |
| With the assembly process complete, weigh the Bottom Mass Assembly, including the [D0901278](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0901278&version=) Secondary Metal Prism Breakoffs; the combined weight should be 2888.695g. Record this value in ICS. The Lower Mass is not designed to be weight-adjusted; weight is added to or subtracted from the Intermediate Mass. So adjusting Lower Mass weight is actually adjusting the combined weight of the Intermediate and Lower Masses, a total of 2963.30g + 2888.69g = 5851.99g. | |

# Installing Intermediate and Lower Masses and Face EQ Stops

## Materials

|  |  |  |  |
| --- | --- | --- | --- |
| **Qty** | **U** | **ID** | **Description** |
| 1 | Ea | [D0901873](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=4835) | Intermediate Mass Assembly |
| 1 | Ea | [D0901791](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=4623) | Lower Mass Assembly |

## Procedure

|  |  |  |
| --- | --- | --- |
| Place a [0901873](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=4835) Intermediate Mass Assembly on top of the 4 Barrel EQ Stop Screws at the Intermediate Mass level.  * Magnets on the Mass face the rear of the Weldment. * Top/Bottom of the Mass is identified per the Screw hole pattern in the side of the Mass.  Level the Mass (flat sides vertical) by adjusting the 4 EQ Stop Screws such that the lower four corners of the Mass are equidistant from the Optic Table surface. | | |
| **Fig 53: Intermediate Mass on Stops** | **Mass**  **Right-Side Up** | **Mass**  **Upside Down** |
| Fig 54: Right-Hand View of Mass | |

|  |  |  |
| --- | --- | --- |
| Assemble 2 [D0902413](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902413&version=) Face EQ Stops to the Weldment in front of the Mass, using:  * 4 Socket Head Cap Screws   8-32 UHC x .75” AgPlated   * 4 Flat Washers #8 SSTL  Torque to 30 in-lb | Fig 55: Face EQ Stops | |
| Assemble both ends of the [D0901902](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0901902&version=) Lower Wire Assembly to the Intermediate Mass with:  * 6 Socket Head Cap Screws  8-32 x 0.5” SSTL  * 6 Flat Washers #8 SSTL  Torque to 20 in-lbsUse the Machinist’s Square to square the Wire Clamps with the front side of the Mass.   Machinist’s  Square | | Fig 56: Lower Wire Assembly / Side View |
| Place a [D0901791](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0901791&version=) Lower Mass within the twin wires of the [D0901902](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=4963) Lower Wire Assembly, but resting on the lower Stop Screws. Ensure:  * The 2 Crossbeams are raised fully; * The 4 Stop Screws are extended fully. * Each wire is seated in a Prism notch.  Retract the 4 Stop Screws until the Lower Wires are almost taught. *Retract the Screws equally, turning each no more than 1 revolution at a time.*Level the Mass by adjusting the 4 Stop Screws such that both ends of each Prism are equidistant from the Optic Table surface. | | Crossbars Raised  Prism  Screws Extended  Fig 57: Lower Mass installed |
| Seat the 2 Lower Wires within the tiny grooves in the 2 Prisms. Adjust the 2 Wire loops such that they are equally spaced beneath the Mass.Retract the 4 Stop Screws to lower the Mass until it is fully supported by the Lower Wires. Adjust the Screws equally, turning each Screw no more than 1 revolution at a time. Level the Lower Mass: Raise the Mass evenly on the 4 Stop Screws until the wire is slack but does not leave the Prism Grooves.Reposition the 2 Wires to achieve leveling. If leveling is not possible, then the Lower Wire Assembly is defective and must be replaced (the 2 wires likely are of different lengths). | | |
| Install 2 [D0902205](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902205&version=) Face EQ Stops in front of the Lower Mass, using:  * 4 Socket Head Cap Screws   ¼-20 UHC x 0.375” SSTL   * 4 Flat Washers ¼” SSTL  Torque to 75 in-lbBack off the lower Stop Screws (4) so that the Mass hangs free and the Lower Wires (2) are therefore taught. | | Wires Taught  Fig 58: Lower Mass and Face EQ Stops |

# Assembling Magnets – Upper Mass

## Materials – Upper Mass Magnets

|  |  |  |  |
| --- | --- | --- | --- |
| **Qty** | **U** | **ID** | **Description** |
| 9 | Ea | [D1100573](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D1100573&version=) | BOSEM Flat Magnet Flag |
| 9 | Ea | [D1100574](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D1100574&version=) | BOSEM Flat Magnet Flag Disk |
| 9 | Ea | 94518A108 | Screw, Countersunk |
| 9 | Ea | D394197N35UHP | Sintered NdFeB Magnet, Ni Plated, 10mm x 5mm |
| 18 | Ea | [D1001534](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D1001534&version=) | BOSEM Magnetic Plug |
| 3 | Ea | [D0902494](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902494&version=) | BOSEM Magnet Holder, Short |
| 6 | Ea | [D0902423](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902423&version=) | BOSEM Magnet Holder, Long |

## Assembly Procedure – Upper Mass Magnets

|  |  |
| --- | --- |
| Assemble 3 [D0902492](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902492&version=) BOSEM Magnet / Flag Assemblies, Short, each with (shown left-to-right, at right):[D1100573](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D1100573&version=) BOSEM Flat Magnet Flag[D1100574](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D1100574&version=) BOSEM Flat Magnet Flag Disk94518A108 Screw, CountersunkMagnet DCNI 00626/N Sintered NdFeB Ni-Plated10 mm x 5 mm[D1001534](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D1001534&version=) BOSEM Magnetic Plug*See Plug Insertion procedure, below*[D0902494](https://dcc.ligo.org/cgi-bin/private/DocDB/ProcessDocumentAdd) BOSEM Magnet Holder, ShortHandle with care; thin sidewalls are easily damaged. | Plug  Magnet  Screw  Disk  Flag  Short Magnet Holder  Fig 59: Short Magnet Assembly |
| Assemble 6 [D0902418](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902418&version=) BOSEM Magnet / Flag Assemblies, Long, each with (shown left-to-right, at right):[D1100573](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D1100573&version=) BOSEM Flat Magnet Flag[D1100574](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D1100574&version=) BOSEM Flat Magnet Flag Disk94518A108 Screw, CountersunkMagnet DCNI 00626/N Sintered NdFeB Ni-Plated10 mm x 5 mm[D1001534](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D1001534&version=) BOSEM Magnetic Plug*See Plug Insertion procedure, below*[D0902423](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902423&version=) Magnet Holder, LongHandle with care; thin sidewalls are easily damaged. | Screw  Magnet  Plug  Long Magnet Holder  Disk  Flag  Fig 60: Long Magnet Assembly |

## Procedure – Plug Insertion

|  |  |
| --- | --- |
| **Procedure for assembling** [**D1001534**](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D1001534&version=) **Plug to Magnet Holder:**Heat Air Bake Oven to 70**°**C;Attach Magnet Holders to Heating Fixture with:  * Socket Head Cap Screw   8-32 x 0.3125” SSTL  Screws must be Class A or B clean Place Heating Fixture in Oven for 10 min. minimum;Remove Heating Fixture from Oven and inspect Magnet Holders for out-of-round condition, using tapered end of the Disk Insertion Tool to address any out-of-round conditions.Place Disk on a Magnet Holder, Place non-tapered end of Disk Insertion Tool on Disk, and tap Insertion Tool until Disk is fully seated within Holder.Return Heating Fixture to Oven for another 5 minutes, minimum.Remove Heating Fixture from Oven, and repeat Step 5, above.Remove Magnet Holders from Heating Fixture. | Fig 61: Heating Fixture with Holders    Fig 62: Insertion Tool in position  Note: Tapered end of Tool is up  Note: Seated Disks on left 2 Holders |

# Assembling the Upper Mass (M1)

## Documents

[D020534](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D020534&version=) HSTS Upper Mass Assembly

[E0900023](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=E0900023&version=) Maraging Steel Blade Specification

[E1000169](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=E1000169&version=) Blade Characterization Spreadsheet

[T0900559](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=6982) Blade Pairings Spreadsheet

## Materials

|  |  |  |  |
| --- | --- | --- | --- |
| **Qty** | **U** | **ID** | **Description** |
| 1 | Ea | [D040259](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D040259&version=) | **HSTS Jig, Upper Mass and Coil Holder** |
| 1 | Ea | [D020534](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D020534&version=) | **HSTS Upper Mass Assembly** |
| 1 | Ea | [D020134](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D020134&version=) | HSTS Upper Mass Main Section |
| 4 | Ea | [D080761](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D080761+&version=) | HSTS Lower Blades |
| 2 | Ea | [0902030](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902030&version=) | HSTS Blade Guards, Upper Mass |
| 4 | Ea | NA | Socket Head Cap Screws 4-40 x .5” SSTL |
| 4 | Ea | NA | Socket Set Screw 4-40 x .625 SSTL |
| 4 | Ea | [D020482](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D020482&version=) | Screw Drive Body |
| 8 | Ea | NA | Socket Head Cap Screw 8-32 x .625 SSTL |
| 4 | Ea | NA | Socket Head Cap Screw 8-32 x .75” Fully-Threaded SSTL |
| 7 | Ea | [D0902493](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902493&version=) | Base Plate, Long |
| 2 | Ea | [D020199](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D020199+&version=) | Base Plate, Short |
| 4 | Ea | NA | Socket Head Cap Screw 4-40 x .625” Vented AgPlated |
| 2 | Ea | NA | Socket Head Cap Screw 4-40 x .625” AgPlated |
| 4 | Ea | NA | Socket Head Cap Screw 4-40 x .625” SSTL |
| 7 | Ea | NA | Socket Head Cap Screw 8-32 x .3125” SSTL 2 |
| 2 | Ea | NA | Socket Head Cap Screw 8-32 x .5” SSTL |
| 4 | Ea | [D0902492](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902492&version=) | BOSEM Magnet Holder, Short |
| 6 | Ea | [D0902418](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902418&version=) | BOSEM Magnet Holder, Long 4 |
| 4 | Ea | [D020211](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D020211+&version=) | Magnet Holder Brace |
| 8 | Ea | NA | Socket Head Cap Screw 4-40 x 1.25” AgPlated |
| 18 | Ea | NA | Flat Washer #4 |
| 8 | Ea | NA | Socket Head Cap Screw 2-56 x 0.25” AgPlated |
| 8 | Ea | NA | Flat Washer #2 SSTL |
| 1 | Ea | [D020136](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D020136&version=) | HSTS Upper Mass T-Section |
| 1 | Ea | [D020137](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D020137&version=) | HSTS Pitch Insert for T-Section |
| 1 | Ea | NA | Socket Set Screw ½”-20 x 2.00” AgPlated |
| 1 | Ea | [D020676](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D020676&version=) | HSTS Roll Insert for T-Section |
| 4 | Ea | NA | Socket Set Screw 8-32 x .25” AgPlated SSTL |
| 2 | Ea | NA | Socket Head Cap Screw ¼-20 x .375 AgPlated SSTL |
| 10 | Ea | NA | Flat Washers #8 |
| 1 | Ea | [D020677](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=2655) | **HSTS/OMC Library of Clamps** |
| 4 | Ea | [D0XXXXX](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=2655) | HSTS Lower Blade Clamp, Upper Side |
| 4 | Ea | [D0XXXXX](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=2655) | HSTS Lower Blade Clamp, Lower Side |
| 1 | Ea | [D020239](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=13242) | **HSTS Coil Holder** |
| 2 | Ea | NA | Socket Head Cap Screw ¼-20 x 1.125” AgPlated |
| 2 | Ea | NA | Hex Nut ¼-20 SSTL |
| 12 | Ea | NA | Socket Head Cap Screw 8-32 x 1.00” Round Tip, AgPlated |
| 12 | Ea | NA | Hex Nut 8-32 SSTL |
| 2 | Ea | [D020660](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D020660&version=) | **Blade Pulldown Device** |
| 2 | Ea | [D020132](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D020132&version=) | Lower Blade Wire Clamp |
| 2 | Ea | [D0901855](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0901855&version=) | Intermediate Wire Upper Clamp, Outside |
| 8 | Ea | NA | Socket Head Cap Screw 2-56 x 0.25” AgPlated |
| 4 | Ea | NA | Flat Washer #2 Vented SSTL |
| 1 | Kg | NA | 1.4595 kg in weight |
| 2 | Ft | NA | Music Wire .024” dia. |
| 1 | Ea | NA | Machinist’s Square |

## Procedure – Main Section & T Section

|  |  |
| --- | --- |
| Assemble to the T-Section [D020136](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D020136&version=):  * Roll Insert [D020676](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D020676&version=) * Pitch Insert [D020137](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D020137&version=) * 4 Socket Set Screws   8-32 x .25” AgPlated  Torque to 30 in-lb | Screws (2)  Roll Insert  Pitch Insert  Screws (2)  Fig 63: Upper Mass T-Section |
| Attach the [D040259](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D040259&version=) Upper Mass Jig to an Optics Table with a ¼-20 Ag-Plated Bolt.Thread the T-Section onto the ¼-20 stud at the top of the Jig.The Jig will not be shown for the remainder of the assembly steps, but is necessary to secure the Upper Mass during the assembly process. | Fig 64: Upper Mass Jig and T-Section |
| Assemble the [D020134](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D020134&version=) Upper Mass Main Section to the T-Section using:2 Socket Head Cap Screws¼-20 x .375” AgPlatedTorque to 100 in-lb | Upper Mass  Main Section  T-Section  Screws (2)  Fig 65: Main Section assembled to T-Section |

## Procedure – Lower Blades & Screw Drives

|  |  |
| --- | --- |
| Wear Safety Glasses and Glove Liners per E1000043.  Blades are shown flattened but are curved upward until weighted. Prepare 2 [D020660](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D020660+&version=) Blade Pulldown Devices per Materials List.Per the data in [T0900559](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=6982) Blade Pairings, retrieve:A matched set of 4 [D080761](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=226) Lower Blades.4 sets of Blade Clamps from the [D020677](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=2655) Library of Clamps, each with an Angle corresponding to a specific Blade.Identify the Blades for installation in the Upper Mass as follows:  * Blade with highest tip in +X, +Y corner * Blade with next to highest tip in –X, +Y corner * Blade with next to lowest tip in +X, -Y corner * Blade with lowest tip in –X, -Y corner | Fig 66: Blade Pulldown Device |

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| Assemble Blade Assemblies with:  * 2 Socket Head Cap Screws  8-32 x 1” AgPlated  * 2 #8 Flat Washers SSTL * 1 [D0XXXXX](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=2655) Blade Clamp, Lower * 1 [D080761](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D080761+&version=) Lower Blade * 1 [D0XXXXX](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=2655) Blade Clamp, Upper | 8/32 x 1” AgPlated  Blade Clamp Lower Side  Blade Clamp Upper Side  Fig 67: Lower Blade Assemblies | |
| The Upper Mass remains on the Upper Mass Jig, as shown in Step 2.Attach each Blade assembly to the Main Section in the location specified in the [T0900559](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=6982) Blade Pairings file; snug the Screws tight.Square Blades and Clamps with the Main Section using the Machinist’s Square. Ensure the Blade tips won’t touch the oval cutout walls.Attach the Blade Pulldown Device to the tip of each Blade. The Blade tips will pass through the cutouts until the Blades are essentially flat.Torque the Blade Clamp Screws to 30 in-lb AFTER the Blades are flattened. | | Blade tips must not touch cutouts as they pass through  Machinist’s  Square  Fig 68: Attaching the Blades to the Main Section | |
| When using Blade Clamp pairs other than 0**°** ensure the orientation of Upper Clamp to Lower Clamp is such that the bolt holes are concentric (visibly, the Clamp sidewalls must be parallel). | | Measure      Non-Concentric  Concentric    Fig 69: Profile Matching & Blade Clamp Alignment | |
| Assemble a [0902030](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902030&version=) Blade Guard to the Main Section with:2 Socket Head Cap Screw4-40 x .5” SSTLTorque to 5 in-lbAssemble to the Blade Guard:2 Socket Set Screws4-40 x .625” SSTL *Diagram shows SHC Screws; ½” Set Screws are being used as a temporary deviation as of 2/12.* *Turn the Screws down as far as possible.*Disconnect the Pulldown Devices from the Blade tips. | | 4-40 x .625”  4-40 x .5”  Blade Guard  Fig 70: Adding Blade Guards | |
| Repeat steps 7–14 to assemble the 2nd pair of Lower Blades and Blade Guards. | | | |
| Assemble to Pitch Insert:1 Socket Set Screw½”-20 x 2.00” AgPlatedAssemble 4 [D020482](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D020482&version=) Screw Drive bodies to Main Section with:8 Socket Head Cap Screws8-32 x .625” SSTL8 Flat Washers #8Torque to 20 in-lbUse a Machinist’s Square to ensure Screw Drive bodies are square with the Upper Mass Main Section.Assemble to Screw Drive System bodies:4 SHCS 8-32 x .75”Fully-Threaded SSTL | | | Socket Set Screw  8-32 x .625”  8-32 x .75”  Screw Drive (4)  Fig 71: Adding Screw Drives  Machinist’s  Square |

## Procedure – Magnets

The Magnet Holders and Wires that follow, are vulnerable to damage and therefore must ONLY be added JUST PRIOR to the Upper Mass being assembled (with the Coil Holder) to the Weldment. The Magnet/Flag Assemblies are left off until all Masses and Wires are installed and suspended.

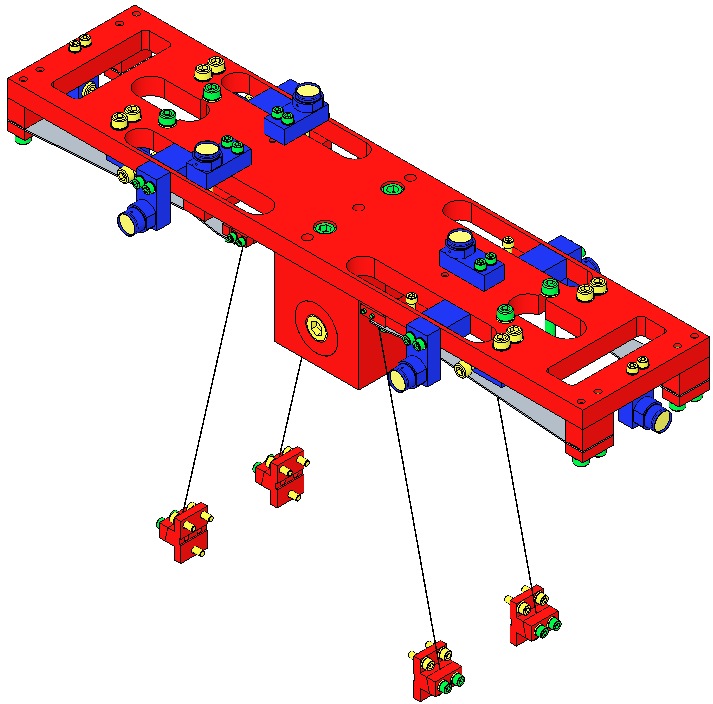
|  |  |  |
| --- | --- | --- |
| The Upper Mass continues to be mounted on the Upper Mass Jig, as shown in Section 24.3 Step 2.Assemble:2 [D0902492](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902492&version=) Magnet Holder, Short2 [D0902493](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902493&version=) Base Plates, Long2 SHCS 8-32 x .3125” SSTLs to 20 in-lbAssemble these to the top of the Main Section with:4 SHCS 4-40 x .625” Vented AgPlated4 Flat Washers #4Torque to 7 in-lb | | Base Long  Magnet Holder  Short  8-32 x .3125  Remove Flag for ease of assembly  Fig 72: 2 Short Assemblies attached to Main Section |
| Assemble:1 [D0902492](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902492&version=) Magnet Holder Short1 [D0902493](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902493&version=) Base Long1 SHCS 8-32 x .3125” SSTLTorque to 20 in-lbRemove Magnet Flag for ease of assembly.Assemble the Base to the top of the Main Section with:2 SHCS 4-40 x .625” AgPlated2 Flat Washer #4Torque to 6 in-lb | | Base Long  Remove Flag for ease of assembly  Magnet  Holder  Short  8-32 x .3125  Fig 73: 1 Short Assembly attached to Main Section |
| Assemble:4 [D0902418](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902418&version=) Magnet Holder, Long4 [D0902493](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902493&version=) Base Plate, Long4 SHCS 8-32 x .3125” SSTLTorque to 20 in-lbRemove Magnet Flag for ease of assembly. | Base Long  Magnet Holder Long  Remove Flag for ease of assembly  Fig 74: 5 Long Assemblies | |

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| Assemble these 4 Assemblies to the sides of the Main Section with:  * 4 [D020211](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D020211+&version=) Magnet Holder Brace * 8 SHCS 4-40 x 1.25” AgPlated * 8 Flat Washer #4  Torque to 30 in-lb | Magnet Holder Brace  Fig 75: 4-7 of 9 Magnet Assemblies |
| Assemble:  * 2 [D020199](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D020199+&version=) Base Plate Short * 2 [D0902418](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=6301) Magnet Holder Long * 2 SHCS 8-32 x .5” SSTL  Torque to 20 in-lbRemove the Flag portion of the M/F Assembly when attaching the | Remove Flag for ease of assembly  Magnet Holder Long  Base Short  8-32 x .5”  Fig 76: 2 Short Assemblies |
| Assemble one of these Assemblies to eachend of the Main Section using:  * 4 SHCS 4-40 x .625” SSTL * 4 Flat Washer #4  Torque the -Y assembly to 5 in-lbHand-tighten +Y Assembly; it will be dis-assembled and re-assembled during assembly to the Weldment. | Fig 77: LH end of Main Section; 8 of 9 Magnet Assys    **Fig 78: RH end of Main Section; 9 of 9 Magnet Assys** |

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| Weigh the following items to arrive at the Upper Mass total weight of 3115 gm., and record with the Upper Mass Serial Number in ICS: 1 Upper Mass assembly just completed, including the 9 Magnet Flags  2 Lower Clamps (with bolts) from the Upper Wire Assembly:   * 2 [D020481](https://dcc.ligo.org/DocDB/0012/D020481/001/D020481-v1_AdvLIGO_SUS_HSTS_Uppermass%20C%20Clamp.PDF) Upper Mass C-Clamp * 2 [D0901999](https://dcc.ligo.org/DocDB/0005/D0901999/001/D0901999-v1_AdvLIGO_SUS_HSTS_Upper%20Mass%20Wire%20Clamp%2C%20Inside%2C%20Angled.PDF) Upper Mass Wire Clamp, Inside * 2 [D0901998](https://dcc.ligo.org/DocDB/0005/D0901998/001/D0901998-v1_AdvLIGO_SUS_HSTS_Upper%20Wire%20Clamp%2C%20Outside%2C%20Angled.PDF) Upper Mass Wire Clamp, Outside * 4 Socket Head Cap Screws   2-56 x .375” AgPlated SSTL   * 4 Flat Washers, #2 SSTL * 4 Socket Head Cap Screws   8-32 x 1.00” AgPlated SSTL   * 4 Flat Washer, #8, [D1100785](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D1100785&version=)-281   4 Upper Clamps (with bolts) from the Lower Wire Assembly:   * 4 [D020132](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D020132&version=) Lower Blade Wire Clamp * 4 [D030044](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D030044&version=) Lower Blade Wire Clamp Plate, angled * 8 Socket Head Cap Screws   2-56 x .375” AgPlated SSTL   * 8 Washers, Flat, #2 * 8 Socket Head Cap Screws   2-56 x 0.25” AgPlated SSTL   * 8 Washers, Flat #2, SSTL   Hand-tighten the Screws. | Fig 79: Upper Mass subassembly    2-56 x .375”  (2)  D0901999  (2)  8-32 x 1.00”  (2)  D020481  (2)  D0901998  (2)  Fig 80: Lower Clamp from Upper Wire Assy    2-56 x .25”  2-56 x .375”  D030044  D020132  Fig 81: Upper Clamp from Lower Wire Assy |

## Procedure – Lower Wires

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| The Upper Mass continues to be mounted on the Upper Mass Jig, as shown in Section 24.3 Step 2.Assemble the L-Clamps of the 4 [D0901905](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0901905&version=) Lower Wire Assemblies to the tips of the 4 Lower Blades, using:  * 8 Socket Head Cap Screws   2-56 x 0.25” AgPlated   * 8 Flat Washers #2, SSTL  Hand-tighten the Screws. Note that the Clamp mounts *above* the Blade and the Screw assembles from *beneath* the Blade.  Note the orientation of each Clamp is the same relative to each Blade tip.  If any Wire becomes kinked during assembly, replace with another Wire Assembly. | Fig 82: Top View of Clamps    Fig 83: Lower Wire Assemblies added |



**Fig 84: Upper Mass (Magnet Flags removed) with Lower Wires**

## Procedure – Coil Holder

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| The Upper Mass continues to be mounted on the Upper Mass Jig, as shown in Section 24.3 Step 2.Remove the previously hand-tightened Magnet Holder at the +Y side of the Upper Mass, to allow assembly clearance for the Coil Holder.Place the [D020239](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D020535&version=) Coil Holder over the Upper Mass and secure with:  * 2 Socket Head Cap Screws  ¼-20 x 1.125” AgPlated  * 2 Hex Nuts ¼-20 SSTL | Hex Nut  ¼-20  Magnet  Holder  removed  Fig 85: Assembling Upper Mass to Coil Holder |
| Using the 2 ¼-20 Screws, draw the Upper Mass fully upwards into the Coil Holder, to optimize later assembly steps.Re-attach the end Magnet Holder.Torque to 30 in-lbAssemble into the Coil Holder:  * 12 Socket Head Cap Screws   8-32 x 1.00” Round Tip, AgPlated   * 12 Hex Nuts 8-32 SSTL   *Diagram will be updated to show Hex Nuts.* *Adjust the Screws to protrude 10 mm inside the Coil Holder.* | Ensure Upper Mass is fully raised into the Coil Holder  Magnet  Holder  re-attached  Fig 86: 12 Screws added |

# Installing the Upper Mass and Coil Holder

## Materials

|  |  |  |  |
| --- | --- | --- | --- |
| **Qty** | **U** | **ID** | **Description** |
| 1 | Ea | [D040259](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D040259&version=) | **Upper Mass Jig** |
| 1 | Ea | [D020239](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=13242) | **HSTS Coil Holder** |
| 4 | Ea | [D020346](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D020346+&version=) | HSTS Coil Holder Bracket |
| 16 | Ea | NA | Socket Head Cap Screw 8-32 x .375” AgPlated |
| 16 | Ea | NA | Flat Washer #8 SSTL |
| 12 | Ea | [D030025](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D030025&version=) | Socket Head Cap Screw, 8-32 x 1.00”, Round Tip, AgPlated |
| 1 | Ea | [D020534](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=7031) | **HSTS Upper Mass Assembly** |
| 4 | Ea | [D020482](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D020482&version=) | HSTS Screw Drive System |
| 9 | Ea | [D0902418](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902418&version=) | Magnet/Flag Assembly Long |
| 7 | Ea | [D0902493](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902493&version=) | Magnet/Flag Assembly Base |
| 2 | Ea | [D020199](file:///C:\Derek%20Shared\HAM%20Small%20Triple%20Suspension\D020199) | Magnet/Flag Assembly Base Short |
| 4 | Ea | [D020211](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D020211&version=) | HSTS Magnet Holder Brace |
| 8 | Ea | NA | Socket Head Cap Screw 4-40 x 1.25” AgPlated |
| 4 | Ea | NA | Socket Head Cap Screw 4-40 x .625” Vented AgPlated |
| 6 | Ea | NA | Socket Head Cap Screw 4-40 x .625” AgPlated |
| 18 | Ea | NA | Flat Washer #4 |
| 4 | Ea | NA | Socket Head Cap Screw 4-40 x 0.375” AgPlated SSTL |
| 1 | Ea | NA | Allen Head Wrench #4 T-Handle |

### *It is important that the Upper Wires NOT be assembled to the Upper Mass / Coil Holder until it is ready to be installed in the Weldment.*

## Procedure – Assembling Upper Mass & Coil Holder to Weldment

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| Coil Holder brackets are made to match each Weldment. Assemble loosely to one end of the Weldment (LH end of Weldment shown):  * 2 [D020346](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D020346+&version=) Coil Holder Brackets * 4 Socket Head Cap Screws   8-32 x .375” AgPlated SSTL   * 4 Flat Washers #8 SSTL  Attach Bracket to the Weldment through the horizontal Screw Slots. | Coil Holder Slots  Weldment Slots  **Fig 87: 1st pair of Coil Holder Brackets** |
| Assemble loosely to the 2 Brackets:  * The [D020239](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=13242) Coil Holder * 4 Socket Head Cap Screws   8-32 x .375” AgPlated SSTL  (2 shown)   * 4 Flat Washers #8 SSTL  Although each Coil Holder Bracket has 3 Screw slots for the Coil Holder, only 2 Screw slots are usable due to clearance issues with the Weldment.Assemble loosely to the other end of the Weldment:  * 2 [D020346](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D020346+&version=) Coil Holder Brackets * 4 Socket Head Cap Screws   8-32 x .375” AgPlated SSTL   * 4 Flat Washers #8 SSTL  Assemble loosely to the 2 Brackets:  * The [D020239](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=13242) Coil Holder * 4 Socket Head Cap Screws   8-32 x .375” AgPlated SSTL   * 4 Flat Washers #8 SSTL  Align Coil Holder to Weldment and with the 4 Coil Holder Brackets:  * **Horizontally**: Visually centered * **Vertically**: Low in the Bracket Slots  Torque all 8 Screws that connect the Brackets to the Weldment to 30 in-lb. Leave the 8 Screws that connect the Brackets to the Coil Holder loose. | **Fig 88: Assemble Coil Holder to 2 Brackets**    **Fig 89: Unusable Screw locations**      Fig 90: 2nd pair of Coil Holder Brackets |

## Procedure – Assembling Intermediate Wires to Intermediate Mass

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| Extend the Intermediate Mass lower Barrel EQ Stop screws (4) as far as possible. These will raise both the Intermediate and Lower Masses.*While extending these screws, observe the 8 screws within the 4 upper Barrel EQ Stops, and retract those screws if it appears either Mass will come in contact with any of them.* | Lower  Mass  Intermediate Mass  Fig 91: Raising the Masses |
| Ensure the Coil Holder is fully raised within the Coil Holder Brackets. The Screws may be left loose at this point.Using the 2 center ¼-20 Screws, lower the Upper Mass fully, within the Coil Holder (shown transparent here). | Fig 92: Coil Holder lowered |
| Assemble the 4 Intermediate Clamps of the [D0901905](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0901905&version=) Intermediate Wire Assemblies to the Intermediate Mass with:  * 12 Socket Head Cap Screws   4-40 x 0.375” SSTL   * Flat Washer #4 SSTL   Torque to 5 in-lb | Fig 93: Intermediate Mass and Face EQ Stops |
| Raise the Coil Holder fully within the Coil Holder Brackets and then tighten the Screws.Using the 2 center ¼-20 Screws, raise the Upper Mass fully, within the Coil Holder (shown transparent here). | Fig 94: Coil Holder raised |

## Procedure – Assembling Upper Wires to Upper Mass

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| --- | --- |
| *To improve clarity, the diagrams for this procedure do not show the Weldment.*Grasp the L-Clamp end of each [D0901854](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0901854&version=) Upper Wire Assembly and feed the Assemblies upwards through the oval openings in the Upper Mass and Coil Holder.*If any Wire becomes kinked during assembly, replace with another Wire Assembly.* | Fig 95: Upper Wires fed through Upper Mass |
| Assemble the C-Clamps of the Upper Wire Assemblies to the Upper Mass, using:  * 4 Socket Head Cap Screws 8-32 x 1.00” AgPlated SSTL   Use Screws that have only ½” of shaft threaded; fully-threaded Screws will not fit in the slots.   * 4 Washers Flat, #8, SSTL  Torque to 30 in-lb | C-Clamp Screws  Fig 96: Attaching Upper Wires to Upper Mass |
| Use the 4 Screws from the Screw Drive Systems to center the C-Clamps on the oval openings. | Screw Drive Screws  **Fig 97: Centering the C-Clamps with the Screw Drives** |

## Procedure – Assembling Upper Wires to Upper Blades

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| Fasten the 2 L-Clamps of the Upper Wire Assemblies to the Upper Blades using:  * 4 Socket Head Cap Screws   4-40 x .375” AgPlated SSTL  When assembling the Screws, use a T-Handle Allen Wrench, approaching the Screws from below. Hand-tighten only; do not use a Torque Wrench.  The L-Clamps are mounted ON TOP OF each Upper Blade.  Note the orientation of the L-Clamps, relative to each Blade.  If any Wire becomes kinked during assembly, replace with another Wire Assembly. | Use T-Wrench from below Blade  Clamps ON TOP of Blades  Fig 98: Upper Wire L-Clamps    Fig 99: Orientation of Clamps |

# Suspending the Masses

## Procedure

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| Lower the Coil Holder halfway within the Coil Holder Brackets and then tighten the 8 Screws.Using the 2 center ¼-20 Screws, lower the Upper Mass halfway within the Coil Holder (shown transparent here). | | Fig 100: Coil Holder & Upper Mass lowered |
| Retract the 4 screws of the Intermediate Mass lower Barrel EQ Stops until the Intermediate Wires are taught (until the Intermediate and Lower Masses are supported by the Upper Mass, and not the EQ Stops). *The EQ screws should barely contact the Mass.* | | Fig 101: Lower Screws retracted |
| Adjust all 24 EQ Stop Screws so they contact the 2 Masses, but with no pressure.Turn these Screws ¾ turn counterclockwise to leave a 1 mm gap at the 2 Masses:Adjust Lower Mass Screws first:  * 8 Barrel EQ Stop Screws * 4 Face EQ Stop Screws  Adjust Intermediate Mass last:  * 8 Barrel EQ Stop Screws * 4 Face EQ Stop Screws  Tighten each Hex Nut at all 24 of the above Screws, to ensure each Screw is locked in the 1 mm gap position. | | Adjust  Lower Mass Screws first  Adjust  Int. Mass Screws second  Fig 102: Adjusting Screws to 1 mm gaps |
| Separate the Upper Mass from the Coil Holder by completely removing the 2 ¼-20 Screws and Hex Nuts (the Upper Mass is then supported by the Upper Blades).Adjust the 12 8-32 round-tipped Coil Holder Screws so that they contact the Upper Mass, but with no pressure.Turn the 8-32 Screws counterclockwise 1 ¼ turns, to leave a 1 mm gap with the Upper Mass. | Fig 103: Suspending the Upper Mass | |
| Adjust the 4 Lower Blade Guard Screws so they contact the Blades, but with no pressure.*2 Magnet Holder Assemblies will need to be removed to access 2 of the Screws.*Turn the 4 Screws counterclockwise 1 ½ turns each, to leave a 1 mm gap at the Lower Blades.Replace the 2 Magnet Holders when finished. | Fig 104: Top View / Adjusting Blade Guard Screws    Fig 105: Side View / Adjusting Blade Guard Screws | |
| Turn the 4 Upper Blade Guard Screws down until they contact the Upper Blades, but apply no pressure.Turn Screws counterclockwise ¾ turn, to leave a 1 mm gap with the Blades.Tighten each Hex Nut to ensure each Screw is locked in the new position. | Fig 106: Suspending the Upper Blades | |

# Creep Bake

All Blades (2 Upper, 4 Lower) are exposed to 120**°**C @ 168 hr., accelerating the microscopic yielding of the Blade material, to reduce mechanical noise of the Suspension when in operation.

## Documents

[T1100289](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=T1100289&version=) Notes on Creep/Creak Bakes for Blades

[E0900023](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=E0900023&version=) Process for Manufacturing Cantilever Spring Blades

## Materials

|  |  |  |  |
| --- | --- | --- | --- |
| **Qty** | **U** | **ID** | **Description** |
| 1 | Ea | [D1002440](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=20931) | **Upper Blade Baking Fixture** |
| 2 | Ea | [D020660](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D020660&version=) | **Blade Pulldown Device** |
| 2 | Ea | [D0901815](https://dcc.ligo.org/cgi-bin/private/DocDB/ProcessDocumentAdd) | Upper Clamp Inside |
| 2 | Ea | [D0901813](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D070341&version=) | Upper Clamp Outside |
| 4 | Ea | NA | 2 Socket Head Cap Screw 4-40 x 0.375” AgPlated |
| 4 | Ea | NA | Flat Washer #4 Vented SSTL |
| 4 | Ea | NA | Socket Head Cap Screw 4-40 x 0.25” AgPlated |
| 1 | Kg | NA | 4.483 kg in weight |
| 2 | Ft | NA | Music Wire .024” dia. min. |

## Procedure

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| Wear Safety Glasses and Glove Liners per E1000043. Prepare 2 [D020660](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D020660+&version=) Blade Pulldown Devices per Materials List. | Fig 107: Blade Pulldown Device |
| Lock down the 2 Upper Blades by extending the 4 EQ Stop Screws until they just contact the Blades.Disconnect the 2 Upper Clamps from the Upper Blade tips. Handle the Wire Assemblies carefully to ensure they are not kinked. | | Wire Clamps  Fig 108: EQ Stop Screws contact Blades |

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| Ensure the 2 [D1102119](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D1102119&version=) Blade Pulldown Supports are Class B clean.Attach the Blade Pulldown Supports to the center of the Weldment cross member shown, Clevis extending outboard.Cover each end of the Weldment Structure and surrounding Optical Table areas with UHV Aluminum Foil, to protect them from the dirty Pulldown Device. 2 workers required: 1st person holds the Pulldown Weight.2nd person passes Wire Clamp of the Pulldown Device through the Weldment side opening, up toward the Upper Blade Tip, then attaches the Clamp to the Blade tip with:  * 2 Socket Head Cap Screws   4-40 x .375” AgPlated SSTL 1st person gently drapes the wire over the Clevis, and slowly releases the Weight.Repeat Steps 7-9 for the second Pulldown Device. | | Fig 109: Blade Pulldown Support    Blade Pulldown Supports  Fig 110: Location of Blade Pulldown Support |
| Remove the 2 [D0901935](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0901935&version=) Blade Guard Bars.Slowly lift the Pulldown Devices and then disconnect the Wire Clamps from the Blade tips. The Blades will be left curving upward.Remove the Rotational Adjusters from the Weldment, down to the Rotating Plate (leaving the Base Plate attached to the Weldment). Record the serial number and location of both Upper Blades in ICS in the RA assembly load. | | Fig 111: Rotational Adjusters removed |
| Ensure the [D1002440](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=20931) Baking Fixture is Class B clean.Mount the Baking Fixture to an Optics Table, aligning the Crossbar side with the Table edge to allow clearance for the Blade Pulldown Device.Remove a [D1002443](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D1002443&version=) Crossbar from the Baking Fixture. | Table Edge  Fig 112: Base Plates in Baking Fixture | |
| Assemble to the Baking Fixture the 2 Rotational Adjuster assemblies using the same Screws from the Suspension:  * 4 Socket Head Cap Screws   ¼-20 x 0.375” SSTL   * 4 [D1100785](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D1100785&version=)-472 Flat Washers   Tighten the Screws firmly  The Blades are shown here as flat, but are actually curved upward at this point. | Machinist’s  Square  Fig 113: Shim, Clamps, Blade, Screws, Washers | |

|  |  |
| --- | --- |
| Attach a Pulldown Device to each Upper Blade Tip to flatten the Blades.Re-assemble the Crossbar to the Bake Fixture:  * 1 [D1002443](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D1002443&version=) Bake Fixture Crossbar * 2 Socket Head Cap Screws 8-32 x 0.625” SSTL * 2 Flat Washers #8 SSTL   Tighten the Screws firmly   * 2 Socket Head Cap Screws ¼-20 x 1.0 Full-Thread, Round-Tip SSTL  Turn down the Round-Tip Screws until the weighted Blade tip is level with the Blade root. Be careful not to damage the nickel plating on the blade Remove the Blade Pulldown Devices. The Rotational Adjusters and Baking Fixture are now ready for the Creep Bake. | |
| Fully retract the 8 Screws in the 4 Upper Barrel EQ Stops. | | Fig 114: 8 Screws in Upper Barrel EQ Stops | |
| Fully raise the Coil Holder within it’s 4 corner Brackets (The Screws will be at the top of their Bracket slots). | | Fig 115: Coil Holder Raised in Brackets | |
| Using the two ¼-20 Screws, fully raise the Upper Mass within the Coil Holder.*The Upper Wires will go slack at this point.* | | Fig 116: Upper Mass raised within Coil Holder | |
| Fully retract the 4 Adjustment Screws within the 4 Screw Drives. | | **Fig 117: Top View – 4 Screws Retracted**    Fig 118: Side View – 4 Screws retracted | |
| Disconnect the Upper Wire Assemblies:  * Remove the 4 C-Clamp Screws at the Upper Mass | | Fig 119: Top View – 4 C-Clamp Screws | |
| Remove the Upper Wire Assemblies completely by grasping the L-Clamps and lowering the Assemblies down through the openings in the Coil Holder and Upper Mass.Record in ICS, which Wire Assembly correlates to which Upper Blade.Handle the Wire Assemblies with great care and store them in a protected container until the Creep Bake process is complete. | | Fig 120: Upper Wires fed downward      Fig 121: 2 Upper Wire Assemblies removed | |

|  |  |
| --- | --- |
| Fully extend the 8 Screws within the lower 4 Barrel EQ Stops. | Fig 122: 8 Screws extended |
| Remove the 4 Screws that attach the pair of Magnet Holders on top of the Upper Mass.Remove the 2 Magnet Holders. | Fig 123: 4 Screws to remove |
| Extend the 4 Blade Guard Screws until they just touch the Lower Blades. | Fig 124: Top View - 4 Blade Guard Screws    Fig 125: Side View – 4 Screws extended |
| Using the 2 ¼-20 Screws, lower the Upper Mass within the Coil Holder.*The Intermediate Wires will go slack at this point.* | Fig 126: Upper Mass lowered within Coil Holder |
| Disconnect the Intermediate Wires from the Intermediate Mass by removing the 12 Screws from the 4 Lower Clamps of the Intermediate Wire Assemblies. | Fig 127: Lower Clamps of Intermediate Wires |
| Remove the Upper Face EQ Stop from in front of the Intermediate Mass. | Fig 128: Upper Face EQ Stop |
| Remove the 8 Screws attaching the L-Clamps of the Intermediate Wire Assemblies to the 4 Lower Blades.Remove the 4 Intermediate Wire Assemblies.Record in ICS, which Wire Assembly correlates to which Lower Blade.*Handle the Wire Assemblies with great care and store them in a protected container until the Creep Bake process is complete.* | Fig 129: Bottom View – L-Clamp Screws          Fig 130: Intermediate Wire Assemblies |
| Remove the 8 Screws from the 4 Coil Holder Brackets.Remove the Coil Holder / Upper Mass Assembly from either short side opening in the Weldment. | Fig 131: Coil Holder Screws |
| From one of the two Magnet Holders assembled to the ends of the Upper Mass, remove 1 Magnet Holder from it’s Base. This will provide clearance for separation of the Upper Mass from the Coil Holder.Remove the 2 ¼-20 Screws from the Coil Holder.Separate the Upper Mass Assembly from the Coil Holder.Re-attach the Magnet Holder to its Base. | Fig 132: Upper Mass and Coil Holder seperated |
| Remove all 9 Magnet Holder / Base Assemblies from the Upper Mass. This includes the 4 Braces for the Magnet Assemblies attached to the sides of the Upper Mass.Remove all 4 Screw Drives from the Upper Mass.Remove the T-Section from the Upper Mass Main Section. | Fig 133: Disassembled Upper Mass |
| *The remaining Assembly, ready for Creep Bake, consists only of:**1 Main Section;**4 clamped Lower Blades;**2 Blade Guards with 4 Screws each.* | Fig 134: Assembly Ready for Creep Bake |
| Follow the process outlined in [E0900023](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=E0900023&version=) for baking all 6 Blades for 120**°**C @ 168 hr.  * 2 Upper Blades (2 Rotational Adjusters); * 4 Lower Blades (clamped in 1 Main Section);  Re-assemble and install in the Weldment:  * The Upper Blades in their Rotational Adjusters, per the section, “Installing the Rotational Adjusters”; * The Upper Mass per the sections, “Assembling the Upper Mass” and “Installing the Upper Mass and Coil Holder”. | |

# Bonding Magnet Assemblies to Intermediate Mass

## Documents

[M0900034](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=M0900034&version=) Use of Magnets in Suspensions

[E990196](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=E990196&version=) HSTS HLTS Magnet/Standoff Assembly Preparation

[E960022](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=E960022&version=) Vacuum Compatibility, Cleaning Methods and Qualification Procedures

## Materials

|  |  |  |  |
| --- | --- | --- | --- |
| **Qty** | **U** | **ID** | **Description** |
| 1 | Ea | [D1100356](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D1100356&version=) | **Triple Optic Base Assembly** |
| 4 | Ea | [D980184](https://dcc.ligo.org/DocDB/0002/D980184/002/D980184-v2.PDF) | LOS Clamps |
| 4 | Ea | NA | Socket Head Cap Screw ¼-20 x 1.5” AgPlated |
| 1 | Ea | [D0901873](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0901873&version=) | **HSTS Intermediate Mass Assembly** |
| 2 | Ea | [D020661](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D020661&version=) | North magnet/dumbbell assembly, Intermediate Mass |
| 2 | Ea | [D020661](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D020661&version=) | South magnet/dumbbell assembly, Intermediate Mass |
| 1 | Ea | [D1002606](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=21904) | **Intermediate Mass Ring Fixture Assembly** |
| 1 | Ea | TBD | Gun Applicator, MasterBond |
| 1 | Ea | EP30-2 | Epoxy, Double Barrel Cartridge with Mix Tube, MasterBond |
| 1 | Ea | NA | Machinist Square, approx. 6” in length |
| 1 | Ea | NA | Depth Gage; either Vernier Calipers or Spring-Type Needle Gage |
| 1 | Ea | NA | Tweezers |
| 1 | Btl | NA | Isopropanol |
| X | Ea | NA | Lint Free Wipes |
| X | Ea | TBD | Sewing Needle |
| X | Ea | TBD | Razor Blade |
| X | Roll | NA | UHV Aluminum Foil |
| 1 | Ea | NA | Heat Lamp, 120w Bulb |

## Procedure

|  |  |
| --- | --- |
| Mount the [D1100356](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D1100356&version=) Base Assembly to an Optics Table with the 4 [D980184](https://dcc.ligo.org/DocDB/0002/D980184/002/D980184-v2.PDF) LOS Clamps and ¼-20 x 1.5” AgPlated Screws.Place the [D0901873](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0901873&version=) Intermediate Mass Assembly on the Base Plate.Place the [D1002606](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=21904) Intermediate Mass Ring Fixture Assembly on top of the Intermediate Mass. For clarity, the Base Plate is not shown after this point. | Fig 135: Ring Fixture, Mass, Base Plate |
| **Align the Ring Fixture and Mass**Center the Ring Fixture on the Mass by obtaining equidistant readings between opposing parallel sides of the Fixture and Mass, using a Depth Gage. The Ring Fixture Screw tips must barely contact and not “clamp” the Mass. Note the locations of the 4 Magnet Plungers. | Magnet Plunger   Fig 136: Ring Fixture Aligned with Mass |
| Prepare 2 “N” and 2 “S” [D020661](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D020661&version=) Magnet/Standoff assemblies per the [E990196](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=E990196&version=) Preparation procedure. | Fig 137: D020661 Magnet/Standoff Assembly |
| **Load Plungers**Remove the 4 Magnet Plungers from the Fixture and wipe the counterbore end of each plunger with Isopropanol and a Wipe.Using the Tweezers, load 4 Magnet/Standoff assemblies into the 4 Plungers, 2 North Magnets and 2 South Magnets. The Magnet end of each assembly rests within the Plunger counterbore.The Magnet/Standoffs are held to the Plungers magnetically. | Counterbore  Assembly held to Plunger Magnetically  Fig 138: Plungers Empty and Loaded |
| Determine the correct Magnet Polarity Layout by identifying the in-use top of the Mass. The Wire Assembly Clamp Hole patterns on the sides of the Mass identify the top of the Mass. | |
| Top of Mass | **N**  **S**  **N**  **S**  Top of Mass |
| **Fig 139: Top of Mass identified by Hole Pattern** | **Fig 140: Magnet Polarity Layout** |
| **Bond Magnets to Mass/Optic**Load the EP30-2 Cartridge with Mix Tube attached, into the Gun Applicator.Pull the trigger on the Gun Applicator 1 full stroke, to purge the Mix Tube of under-mixed adhesive.Dispense a “quarter-sized” pool of Adhesive onto a small piece of clean UHV aluminum foil.Pick up a Plunger loaded with a Magnet/Standoff assembly and hold it vertically, with the Magnet/Standoff end facing up. Clean the Standoff with Isopropanol and a Wipe.Dip the end of a Sewing Needle in the pool of Epoxy and withdraw it, leaving a tiny drop on the Needle tip. Apply approximately ½ mm of Epoxy to the center of the Standoff end.Load the Plunger, Magnet/Standoff down, into the appropriate Bushing in the Ring Fixture. Slide the Plunger down within the Bushing until the Standoff contacts the Mass/Optic. Press down on the Plunger lightly with one finger for about 2 seconds, then release.Repeat steps 13-15 to load all 4 Plungers into the Placement Fixture.Allow the Epoxy to cure within the Fixture at room temperature for 24 hours.Carefully remove the 4 Plungers from their Bushings, and remove the Fixture from the Mass/Optic.Center the Heat Lamp over the Fixture and adjust the height such that the Fixture surface is receiving 60°C, then allow the adhesive to cure for 4hr. The assembly process is complete. | |

# Bonding Magnet Assemblies to Lower Masses

## Documents

[M0900034](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=M0900034&version=) Use of Magnets in Suspensions

[E990196](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=E990196&version=) HSTS HLTS Magnet/Standoff Assembly Preparation

[D020234](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D020234&version=) HSTS Metal Lower Mass, 0.5 Degree Wedge

[D0902332](https://dcc.ligo.org/cgi-bin/private/DocDB/ProcessDocumentAdd) HSTS Metal Lower Mass, 1.0 Degree Wedge

[E0900342](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=E0900342&version=) HSTS Optic Orientations

[E960022](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=E960022&version=) Vacuum Compatibility, Cleaning Methods and Qualification Procedures

## Materials

|  |  |  |  |
| --- | --- | --- | --- |
| **Qty** | **U** | **ID** | **Description** |
| 1 | Ea | [D1100356](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D1100356&version=) | **Triple Optic Base Assembly** |
| 4 | Ea | [D980184](https://dcc.ligo.org/DocDB/0002/D980184/002/D980184-v2.PDF) | LOS Clamps |
| 4 | Ea | NA | Socket Head Cap Screw ¼-20 x 1.5” AgPlated |
| 1 | Ea | [D020427](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D020427&version=) | **HSTS Magnet Gluing Ring Fixture, Lower Mass** |
| 1 | Ea | [D0901791](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0901791&version=) | HSTS Lower Mass Assembly |
| 1 | Ea | Various | Optic, HSTS |
| 4 | Ea | [D0902432](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902432&version=) | Magnet/Standoff Assemblies, 2 N and 2 S configurations |
| 1 | Ea | NA | Machinist Square, approx. 6” in length |
| 1 | Ea | NA | Depth Gage; either Vernier Calipers or Spring-Type Needle Gage |
| 1 | Ea | EP30-2 | Epoxy, Double Barrel Cartridge with Mix Tube, MasterBond |
| 1 | Ea | TBD | Gun Applicator, MasterBond |
| 1 | Ea | NA | Generic Compass mounted on non-magnetic isolation post |
| 1 | Ea | NA | Tweezers |
| 1 | Btl | NA | Isopropanol |
| X | Ea | NA | Lint Free Wipes |
| X | Ea | TBD | Sewing Needle |
| X | Ea | TBD | Razor Blade |
| X | Ea | NA | UHV Aluminum Foil |
| 1 | Ea | NA | Heat Lamp, 120w Bulb |

## Procedure

Notes:

The D020427 Fixture is being modified as of 3/12. Major modifications include:

* + The Fixture as shown will be inverted, and a Base for the Mass/Optic has been added.
  + The Stop Screw design will change.
  + The Magnet placement bushings will change.
* Glass Optics and Metal Masses will not be Air Baked.
* Glue Magnets before gluing Prisms (primary and secondary).

### Ensure the Main Section of the Mass has been cleaned and baked before attaching the Magnet/Dumbbell assemblies.

* Thoroughly Class B clean all parts of the Magnet Gluing Ring Fixture.
* Magnet/Standoff Assemblies are produced per [E990196](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=E990196&version=) HSTS HLTS Magnet/Standoff Assembly Preparation.

|  |  |  |
| --- | --- | --- |
| Prepare 2 “N” and 2 “S” [D0902432](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902432&version=) Magnet/Standoff assemblies per [E990196](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=E990196&version=) Preparation procedure. | | **Fig 141: D0902432 Assembly** |
| Mount the [D1100356](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D1100356&version=) Base Assembly to an Optics Table with the 4 [D980184](https://dcc.ligo.org/DocDB/0002/D980184/002/D980184-v2.PDF) LOS Clamps and ¼-20 x 1.5” AgPlated Screws.Place the Mass/Optic Assembly on the Base Plate with arrows pointing down.Place the[D020427](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D020427&version=) Magnet Gluing Fixture Assembly on top of the Mass/Optic. Note the Scribe Lines on both the Fixture and the Mass / Optic. For clarity, the Base Plate is not shown after this point. | Scribe Lines  Arrow    Fig 142: Magnet Gluing Ring Fixture | |
| Center the Mass / Optic within the Fixture by using the 4 Stop Screws. Use a Depth Gage to obtain equidistant readings at opposing pairs of Mass / Optic Scribe Lines, between the Fixture and Mass / Optic perimeters. The Screw tips must barely contact and not “clamp” the Mass/Optic. | Stop Screw  Equal measurements  Fig 143: Top View of Centering | |
| For a Metal Mass, rotate the Gluing Fixture while aligning the Mass and Fixture Scribe Lines with a Machinist’s Square. Align at 2 Line positions 90**°** apart.For an Optic, sight across (through) the glass through 2 opposing Scribe Lines, then rotate the Gluing Fixture to align the Optic and Fixture scribe lines with a Machinist’s Square. | Machinist’s  Square  Scribe Lines Aligned  **Fig 144: Centering the Mass / Optic in the Fixture** | |

|  |  |  |
| --- | --- | --- |
| **Load Plungers**Remove the 4 Magnet Plungers from the Fixture and wipe the counterbore end of each plunger with Isopropanol and a Wipe.Using the Tweezers, load 4 Magnet/Standoff assemblies into the 4 Plungers, 2 North Magnets and 2 South Magnets. The Magnet end of each assembly rests within the Plunger counterbore.The Magnet/Standoffs are held to the Plungers magnetically. | | Counterbore  Assembly held to Plunger Magnetically  Fig 145: Plungers Empty and Loaded |
| Determine the correct Magnet Polarity Layout by identifying the in-use top of the Mass/Optic. The prisms on the sides of the Mass and the arrow on the Optic and the identify the top of the Mass. | | |
| Magnet  Fig 146: HSTS Lower Mass Assembly | Magnet  Fig 147: HSTS Optic Assembly | | |

|  |  |
| --- | --- |
| **Bond Magnets to Mass/Optic**Load the EP30-2 Cartridge with Mix Tube attached, into the Gun Applicator.Pull the trigger on the Gun Applicator 1 full stroke, to purge the Mix Tube of under-mixed adhesive.Dispense a “quarter-sized” pool of Adhesive onto a small piece of clean UHV aluminum foil.Pick up a Plunger loaded with a Magnet/Standoff assembly and hold it vertically, with the Magnet/Standoff end facing up. Clean the Standoff with Isopropanol and a Wipe.Dip the end of a Sewing Needle in the pool of Epoxy and withdraw it, leaving a tiny drop on the Needle tip. Apply approximately ½ mm of Epoxy to the center of the Standoff end.Load the Plunger, Magnet/Standoff down, into the appropriate Bushing in the Ring Fixture. Slide the Plunger down within the Bushing until the Standoff contacts the Mass/Optic. Press down on the Plunger lightly with one finger for about 2 seconds, then release.Repeat steps 11-13 to load all 4 Plungers into the Placement Fixture.Allow the Epoxy to cure within the Fixture at room temperature for 24 hours.Carefully remove the 4 Plungers from their Bushings, and remove the Fixture from the Mass/Optic.Center the Heat Lamp over the Fixture and adjust the height such that the Fixture surface is receiving 60°C, then allow the adhesive to cure for 4hr. The assembly process is complete. | Top of Mass    **N**  **S**  **N**  **S**  **Fig 148: Magnet Polarity Layout** |

# Installing AOSEM Brackets

## Materials

|  |  |  |  |
| --- | --- | --- | --- |
| **Qty** | **U** | **ID** | **Description** |
| 4 | Ea | [D0901924](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0901924&version=) | A OSEM Alignment Assemblies |
| 2 | Ea | [D0902207](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902207&version=) | A OSEM Alignment Assemblies |
| 2 | Ea | [D0902208](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902208&version=) | A OSEM Alignment Assemblies |
| 16 | Ea | NA | Socket Head Cap Screws 8-32 x 0.5 AgPlated |
| 16 | Ea | NA | Flat Washer #8 SSTL |

## Procedure

|  |  |
| --- | --- |
| A OSEMS are assembled in LH and RH configurations per section 16. Note the configuration at each location within the Weldment.The A OSEM Assemblies are attached using:  * 16 Socket Head Cap Screws   8-32 x 0.5” AgPlated   * 16 Flat Washers #8 SSTL   Torque to 30 in-lb Assemble 4 [**D0901924**](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0901924&version=)A OSEM Alignment Assemblies into the Intermediate Mass section of the Weldment.Assemble 2 [**D0902207**](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902207&version=)A OSEM Alignment Assemblies into the upper half of the Lower Mass section of the Weldment.Assemble 2 [**D0902208**](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902208&version=)A OSEM Alignment Assemblies into the lower half of the Lower Mass section of the Weldment. | D0901924 RH  D0902208 RH  D0902207 RH  D0901924 LH  D0901924 RH  D0902207 LH  D0902208 LH  D0901924 LH  **Fig 149: Rear view of Weldment** |

# Installing AOSEMs and BOSEMs

## Documents

[D060218](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D060218&version=) BOSEM Assembly

[D0901065](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0901065&version=) AOSEM Assembly

## Materials

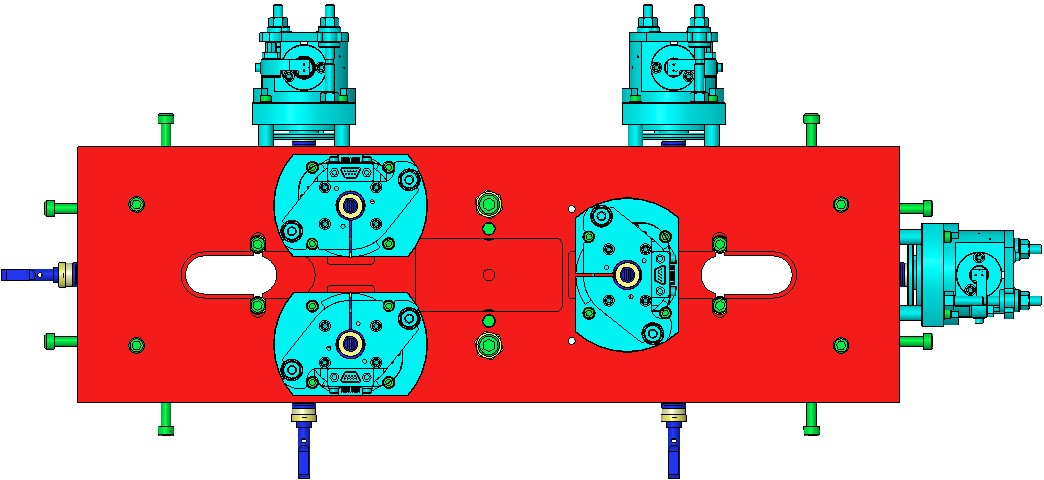
|  |  |  |  |
| --- | --- | --- | --- |
| **Qty** | **U** | **ID** | **Description** |
| 8 | Ea | [D0901065](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=2607) | **AOSEM Assembly** |
| 6 | Ea | [D060218](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=4018) | **BOSEM Assembly** |
| 24 | Ea | NA | Socket Head Cap Screw 4-40 x 1.0 AgPlated |
| 24 | Ea | NA | Flat Washer #4 SSTL |

## Procedure

### Review the test data that comes with the BOSEMs & the AOSEMs.

|  |  |
| --- | --- |
| Position each BOSEM such that it is centered around its magnet. Assemble each to the Coil Holder with:  * 4 Socket Head Cap Screw   4-40 x 1.0” AgPlated   * 4 Flat Washers #4 SSTL   Torque to 6 in-lb  Each HSTS assembly must contain 1 fully-characterized  BOSEM, mounted at the T2 position (the –Y location). | 4-40 x 1”  Characterized  BOSEM  Fig 150: B OSEMS mounted on Coil Holder |

### Using the electronics test stand, read the open light voltage for each B OSEM, and position the BOSEM longitudinally to 50% open light voltage.



**S**

**S**

**N**

**S**

**N**

**S**

**+X**

**+Y**

+ / - indicates

magnet polarity

Fig 151: Top View of Upper Mass and BOSEMS

|  |  |
| --- | --- |
| Place 4 AOSEMs in the Brackets behind the Intermediate Mass. Place another 4 A OSEMs in the Brackets behind the Lower Mass or Optic. Position each A OSEM such that it is centered around its magnet. | Fig 152: A OSEMs installed in Brackets |

# 

# Balancing of the Suspended Masses

*The alignment tolerance for the Metal Build is much greater than that for the Optic Build. This procedure references the Optic requirements.*

|  |  |
| --- | --- |
|  |  |

|  |  |
| --- | --- |
|  | Fig 159: Yaw Adjustment with Push/Pull Screws |

## Documents

[T1200209](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=91218) Balancing of HSTS Suspensions

[E0900342](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=6200) ALIGO IO HSTS and HLTS Optic Orientations

[T010076-v1](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=8667&version=1) Optical Layout for Advanced LIGO, beam height requirement, Table 2, page 26 of v1

[M1100192](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=67040) RODA: Accuracy of Height of Mirrors in HSTS and HLTS. Accuracy of the height of the mirrors for HSTS & HLTS is +/- 1mm. This RODA supersedes just the vertical positioning static alignment requirements in the Cavity Optics Suspensions, Table 1, page 9

[T010007](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=127) Core Optics Suspension Subsystem Design Requirements, Table 1, page 9

## Materials

|  |  |  |  |
| --- | --- | --- | --- |
| **Qty** | **Unit** | **Part Number** | **Description** |
| TBD | TBD | TBD | TBD |

## Desired Results of Balancing

The goal of balancing is to produce a suspension with the following key attributes:

1. All suspension stages are balanced and free of pitch and roll
2. Blade tips are set to the correct d-value of 2mm. In practice, setting the d-values to between 2 and 3mm has yielded very good results in testing.
3. Blade tips are within .5mm of each other
4. The height of the lower optic is within +/-1mm of its correct height of 215mm.

Additionally, for the sake of uniformity between suspensions, it is desirable to keep the mass of the system as close to nominal as possible. This is not, however, a strict requirement.

## Adjustments Available for Balancing

There are several different ways in which the various masses are able to be adjusted:

Rotational Adjusters (Upper Blades)

* + Push-Pull Plates

These screw-driven plates adjust the yaw of the upper mass by adjusting where the tip of the blade falls.

* + Upper Blade Clamps

This adjusts the height of the upper blade tips. Each 0.5 degree increment amounts to nominally 2mm of tip height adjustment.

Upper Mass

* + Screwdrives

These adjust the attachment position of the upper wires to the upper mass. Sliding the clamp left and right will alter the pitch of the mass (and will also very slightly alter the yaw).

* + Sliding Mass

This sliding mass will adjust the roll of the upper mass.

* + Adjustment Screw

A large silver plated screw in the upper mass is the fine adjustment for pitch.

* + Addable Masses

Adjusts the height of the upper mass while leaving the relative heights below it unchanged. Useful for final optic height adjustments.

* + Lower Blade Clamps

Adjusts the height of each blade tip. One blade clamp swap of 0.5 degrees is nominally 1mm of independent height adjustment. It is important to note that this is not the case when it is installed in the structure because the load is shared between all the springs. This is discussed in more detail below.

Intermediate Mass

* + Addable Masses

The addition and removal of addable masses does two things. Firstly, it can lower and raise the intermediate mass (thereby adjusting the blade tip height relative to the upper mass) and it can adjust pitch of the intermediate mass if addable masses are removed from either the front or the back. It has been determined that each side of the intermediate mass works relatively independent from the other. So, in order to correct pitch, mass need only be removed or added to one side at a rate of roughly 1 gram for .1mm adjustment.

Lower Mass

* + Lower Wire

The lower mass can be adjusted in the lower wire (i.e. where the prism contacts the wire) to compensate for roll. There is no way to compensate for pitch differences between the lower and intermediate masses.

## Theory of Balancing

The theory behind the balancing of this suspension is in some ways unintuitive. Because of the way each stage plays off the ones below and above it, it is important to understand how one adjustment can affect the other parts of the system.

## Upper Blades

When it is necessary to make a clamp swap to the upper blades, the added height of one of the blade tips will affect the height of everything below it. A clamp swap of 0.5 degrees will change the blade height by 2mm. Because there are two blades and only one of them is being switched, the net effect on the center of mass of the lower levels is that they will rise by 1mm. This effect adds linearly. Therefore, the total change of the height of the lower levels is given by the total clamp angle difference multiplied by 2mm. For example, if both clamps are switched upward by 0.5 degrees, the net change would be (0.5+0.5)\*2mm = 2mm rise in the center of mass of the intermediate mass.

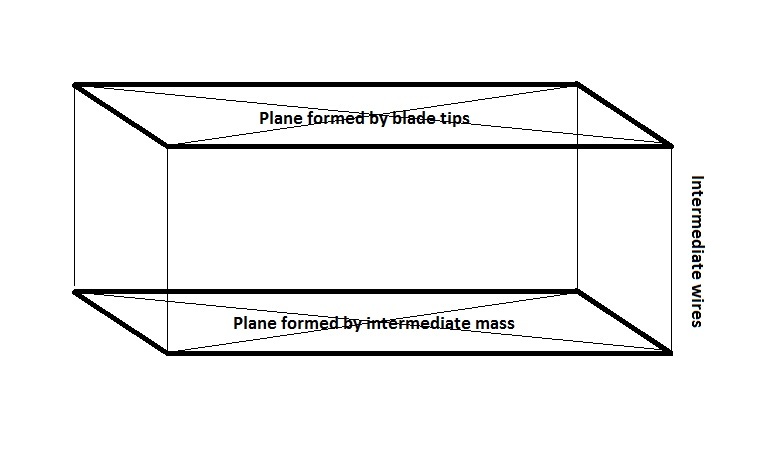
## Upper Mass

The upper mass seems to have strange effects on things such as d-values when it is not level. It is very important to make sure the upper mass is as level as possible before taking any measurements. In practice, .25mm corner-to-corner height difference has been shown to be sufficient. Failure to do so will result in sometimes large errors for critical parts of the balancing process.

## Lower Blades

The blade tips are rigidly attached to the intermediate mass by the intermediate wires. Before beginning the balancing method, it should be ensured that the clamps are pushed to their highest position on the intermediate mass. This will cause the clamps to be square with respect to the intermediate mass. There are other ways of doing this, but this has been found to be an effective method. Failure to mount the clamps properly will result in meaningless data.

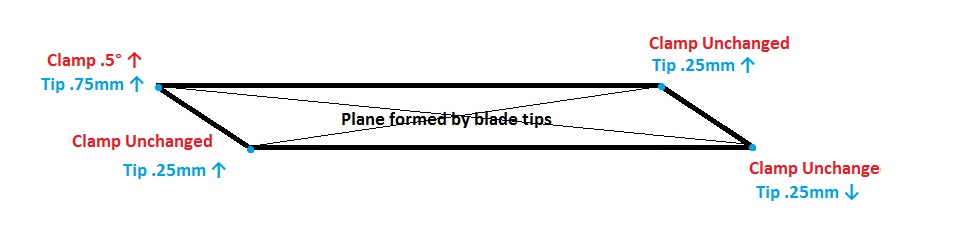
Once this is done, the blade tips should all be equal distance from the intermediate mass. This is guaranteed by the assumption that the intermediate wires are all the same length. Using this assumption, we can see that if the clamp holes in the intermediate mass are drilled straight, then the blade tips must also be parallel.



As the figure above shows, the blade tips must have two criteria: Firstly, they must form a plane. Because we know that the intermediate mass has its holes drilled properly and the wires are the same length, the 4 blade tips must also be planar. It is not possible for 3 blade tips to be equal with one blade tip either too high or too low. If this condition occurs, there is an error with the wire length and it must be replaced. Secondly, in addition to the blade tips being in plane with each other, the plane it forms must be parallel to the plane formed by the intermediate mass. Therefore, the pitch and roll of the blade tip “plane” must be the same as the pitch and roll of the intermediate mass.

This has serious implications for balancing. It is very important to understand that correction of one blade tip while leaving the others alone is not possible. When adjusting only one of the blade clamps on the lower blades, you will ultimately have an effect on the other 3 lower blades. The best idea is to attempt to correct pitch and roll independently, as these are very easy to control by switching two clamps at a time.

A one-clamp swap will, in theory, have the following effect on the blade tips: The adjusted blade will move by 1.5mm/degree, the two adjacent blade tips will move by 0.5mm/degree, and the opposite blade tip will move by -.5mm/degree as illustrated below.

These effects can be superpositioned. Therefore, switching two clamps on one side will cancel out the effects on the opposite side. This is why it is very important to switch two clamps at a time.

The overall effect of a clamp swap on the stages below it is roughly 0.5mm/degree of net clamp swap. Therefore, if two clamps are switched by 0.5 degrees upward, the net clamp change is 1 degree and will move the center of mass of the intermediate and lower masses upward by .5mm. Similarly (and intuitively) if 4 clamps are each switched by 0.5 degrees upward, the net effect will be a change of 1mm upward in the lower and intermediate masses.

## Intermediate Mass

The intermediate mass is adjustable with the one set of weights on either side of the mass. Addition and removal of these masses will affect the pitch of the blade tips, intermediate mass, and lower mass because all three are rigidly attached with wires. The rate of pitch adjustment is roughly .1mm/gram per side. This means that if 10 grams are removed from the +X side, the +X blade tips will move by 1mm, the +X side of the intermediate mass will move by 1mm, and the +X side of the lower mass will move by 1mm. The -X side, however, will remain relatively unchanged, thus isolating pitch adjustment. Note that the upper mass will need to be re-balanced after any mass is changed on the intermediate mass.

The rate of the center of mass rising is roughly equal to .05mm/gram of weight added or removed. So, if 10 grams are removed, it is expected that the center of mass of the intermediate mass will rise by .5mm.

## Lower Mass

The lower mass is of course rigidly attached to the intermediate mass and cannot be adjusted in pitch. It is, however, infinitely adjustable in roll. It is a good idea to correct a bit of roll from the lower mass before attempting to take measurements. Within +/- 1mm between the tops of the horizontal holes has been found to be adequate. Subsequent roll reduction of the lower mass showed little to no effect on the upper stages. Final balancing will require that all of the roll be removed [INSERT REQUIREMENT] before testing.

## Steps in the Balancing Process

Once the suspension has been assembled and is hanging freely, the following steps should be performed to balance the suspension.

## Ensure All Hardware is Present

The first step is to ensure all hardware is present on the upper mass. Double check with ICS that the correct addable masses are present on the top and bottom of the mass. Also check that the magnet and flag assemblies have been installed and that the upper wires are roughly centered (these will be adjusted in a later step). Unlock all stages, starting with the bottom.

## Adjust Upper Mass Yaw

The yaw needs to be adjusted next. In theory it should have no effect on the pitch and roll of the upper mass, but keeping the mass correctly centered in the tablecloth has additional benefits such as keeping the mass away from rubbing on the earthquake stops and tablecloth. This adjustment can be made by loosening the 3 x 1/4-20 bolts on the upper blade rotational adjusters and using the push pull plates to move the blade tips. The position of the upper mass can be determined by looking through the +Y and -Y OSEM holes. At this stage, a visual alignment is sufficient.

## Balance the Upper Mass

Before anything else, the upper mass must be as level as possible. In practice, it has been found that the upper mass needs to be level to within .25mm corner-to-corner. Failure to do so will result in incorrect d1-values.

The first step to balancing the mass is to place a bubble level on top of the upper mass (on the actual upper mass itself, not atop the addable masses). Then adjust the screw drives to correct for pitch. Once pitch is correct, use the slider to adjust the roll of the mass. If it is found that the slider is all the way or nearly all the way out, an upper clamp must be switched.

If it is necessary to switch an upper clamp, the height of the lower mass should first be measured (the nominal height of the top of the optic is 215mm). Any clamp swap at the upper level will have a 1mm effect on the lower mass. So, if the lower mass is too high, switch to a lower upper clamp and vice versa. Once the swap has been performed, begin the balancing process again.

## Take Measurements of the Whole System

The next step is to measure the heights of all critical points in the system. The purpose of this is to determine the following:

1. Upper blade tip heights
2. Upper mass pitch and roll
3. Lower blade tip heights (and therefore d1-values, pitch, and roll)
4. Intermediate mass pitch and roll
5. Lower mass pitch and roll

In order to achieve this, the following points must be measured:

1. Upper blade wire breakoffs – Measure where the wire enters the upper clamp of the upper wire assembly.
2. Upper mass through the OSEM holes – Measure the top side of the upper mass through the (+X+Y), (+X-Y), (-X+Y), and (-X-Y) OSEM holes. These 4 measurements give pitch and roll.
3. Lower blade wire breakoffs – Measure the upper clamp of the intermediate wire assembly where the wire enters the clamp. This is used to calculate d-values
4. Top of the intermediate mass holes – Measure the tops of the (+X+Y), (+X-Y), (-X+Y), and (-X-Y) holes in the intermediate mass. These will give the pitch and roll of the intermediate mass.
5. Top of the lower mass – This will give you the height of the lower mass (which should be 215mm)
6. Top of the lower mass holes – Measure the tops of the (+X+Y) and (+X-Y) (or (-X+Y) and (-X-Y)) holes to determine the roll of the lower mass.

Enter all of the values into a spreadsheet as they are measured from the top of the table. This will make the next steps easier.

## Determine What Changes Must Be Made

This is probably the most difficult part of the process because each stage depends on each other. Recall our objectives in this procedure: We want to have a suspension with the lower mass at 215mm (+/-1mm), d1-values between 2 and 3, and as little pitch and roll of each stage as possible.

## Determine the Wire Lengths

First, before any adjustment can be made, it must be determined whether or not the blade tips are coplanar with the intermediate mass. That is to say, the pitch and roll of the blade tips must be identical (or nearly identical) to that of the intermediate mass. This should be readily observable by looking at the spreadsheet you created in 5.4. If there appears to be a wire that is too short or too long with respect to the other three, it must be switched. If there seems to be no correlation between the blade tip plane and the intermediate mass plane, they should all be re-pulled and replaced.

A simple way to check that the blade tips are planer is to use the following equation:

Height(+X+Y) + Height(-X-Y) = Height(+X-Y) + Height(-X+Y)

Next, look at the pitch difference between the lower and intermediate mass. They should be very close, if not identical. If there is a difference between the two, check with the wire comb that the wire is properly in the prism grooves and is the correct width all the way around the metal mass. After this, re-balance and re-shoot the system. If the problem persists, try flipping the wire around so that the clamp that was on the +Y side is now situated on the -Y side. Readjust the wire, re-balance the upper mass, and re-shoot. If it is still incorrect, you will need to replace the lower wire. A correct lower wire will show no pitch difference between the two masses. Because the lower wires are so precious (due to a shortage of wire), it may be necessary to live with wires that are incorrect. Since the wire is to be replaced when the actual optic is inserted, we can get away with less than .5 mm or so of pitch difference, but know that this means a more time-consuming adjustment period after the optic goes in (the adjustment will need to be made with intermediate addable masses) and less accurate testing. Additionally, if there is a pitch difference, you should be trying to correct the pitch in the lower mass, not the intermediate mass and upper blades. The pitch of the lower mass is far more critical than the the d1-value difference in the lower blades, so if there is a problem with the wire, make sure you are not trying to correct both, as it is a Sisyphean task.

After any wires are replaced, the suspension must be re-balanced and re-shot. Return to the top of Section 5. Proceed to 5.7 ONLY when the wires are as correct as possible.

## Adjusting the Lower Blades

Once the wire lengths are correct, the most isolated item to adjust is first the lower blade clamps. The d1-values only depend upon the clamp angle and the mass of the intermediate mass. For consistency between suspensions, it is preferable to adjust the clamps before adjusting mass (which will slightly alter the frequency of the blades).

Look at the spreadsheet and determine the pitch and roll of the blade tips. If there is more than 1mm of pitch in the blade tips or more than 0.75mm of roll, a blade clamp swap will be necessary. It is almost always preferable to adjust either pitch or roll (but not both) with a clamp single swap. This is because the manufacturing inconsistencies in the clamps can actually cause an effect in both roll and pitch, even when only trying to correct one. You may find, for example, that switching clamps to only fix pitch will also fix your roll issue (conversely, it can exacerbate your problem).

The amount of pitch and roll adjustment is theoretically 1mm per 0.5 degrees of adjustment. If there needs to be 1.5mm of adjustment, for example, it is preferable to only move your clamps by the smaller increment (that is to say, round down). It has been found in practice that the blade tips move sometimes more than the clamp swap would predict them to.

Let's look at an example (Center of Mass = 20mm below top of upper mass):

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | +X+Y | +X-Y | -X+Y | -X-Y |
| Top of Upper Mass | 549.25 | 549.25 | 549.25 | 549.25 |
| Blade Tips | 527 | 527 | 525.5 | 525.5 |
| d1-Values | 2.25 | 2.25 | 3.75 | 3.75 |
| Current Clamp Angle | .5 | 1 | 0.5 | 1 |
| Recommended New Clamp Angle | .5 | 1 | 1 | 1.5 |
| Expected New d1-Values | 2.25 | 2.25 | 2.75 | 2.75 |

In this simple example, we only dealt with a correction in pitch. Obviously, these fictitious numbers will not be so nice in a real-world setting. This is just to illustrate the method in which clamp swaps should be performed: They should be 2 or 4 clamps at a time, by the same amount, between adjacent blades.

After each clamp swap, it will be necessary to re-balance and re-shoot the entire system. If you are careful and thorough in your approach, you will eventually dial in the pitch and roll of the system. It is vital, therefore, that clamp angles and serial numbers be recorded with each swap, in case you need to return to a previous configuration. It is also a very good idea to keep the wires on the same blade tips. This will eliminate any error associated with different wire lengths (though in theory we correct this in the previous step).

## Adjusting the Intermediate Mass

By this point, roll and pitch of the blade tips should be roughly correct and the d1-values should be between 2 and 3. Unfortunately, there is no roll correction available for the intermediate mass, so we are limited to adjusting pitch with weights. Take another look at your d1-values. Weight should be added to the side for blade tips that need to be brought down and weight should be removed from sides that are too low at a rate of around 10grams/mm. If everything was done properly in the previous step, very little weight will need to be removed from the mass. After adjustments of the weights, you will need to re-level the upper mass and re-shoot the blade tips. Do this until all pitch has been eliminated from all 3 levels of the suspension (or, if you know that your lower wire is wrong, do this until the lower mass shows no pitch).

## Adjusting the Height of the Lower Mass

The lower mass height adjustment should be the absolute last thing you do because it can be adjusted in two ways without affecting other critical parts of the system. The upper blade clamps can be swapped and mass can be added/removed from the upper mass. If the lower mass needs to move by more than 2mm, it is preferable to attempt to switch clamps on the upper mass. This can be a trying experience, so getting it correct will take patience. Hopefully, because we have up until this point not adjusted weights too much, the lower mass will be in roughly the correct place. If it is more than 2mm high or low, the upper clamps should be switched up or down by .5 degrees (the rate of movement is, in theory, 2mm per half degree). In practice, the blade clamps used at LLO are wildly inconsistent. We have found 0.5 degree clamps that are actually more than 1.0 degrees. Care should be taken to inspect the clamps for obvious defects such as this (holding the two profiles up to one another has proven useful more than once). If you see inconsistent movement when switching clamps, it is likely that either the one that was replaced was bad or the one that replaced it is bad. Trial and error here is the only advice I can give. Fortunately, upper clamp swaps do not require the removal of the upper mass and can be done reasonably quickly. It is especially important that serial numbers of clamps be recorded for this process as well, so that incorrect clamps can be identified and removed from circulation.

After the upper mass is level and the optic is within 2mm of where it should be, weights should be added and removed from the upper mass. The easiest way I have found to do this is to remove the weights from the top of the upper mass and have a partner set the optical level to 215mm (the nominal height of the top of the lower mass). Place the crosshairs over the lower mass and re-add the weights to the upper mass until the top of the lower mass just touches the crosshairs. After a final weight has been determined, the weight should nearly evenly split between the top and bottom of the mass. This keeps the center of mass roughly the same which keeps your d1-values from changing too much.

## Final Steps

At this stage, you should have a well-balanced suspension. Now, everything must be balanced, shot, and recorded. Finally, when all looks good, the suspension can be pulled apart and placed into a creep bake. The spreadsheet containing your shootings, angles, and weights should be placed into an aLOG.

# Replacing the Lower Mass with the Optic

## Documents

## Materials

|  |  |  |  |
| --- | --- | --- | --- |
| **Qty** | **Unit** | **Part Number** | **Description** |
| TBD | TBD | TBD | TBD |

## Procedure

|  |  |
| --- | --- |
| *The* [*D0901791*](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0901791&version=) *Metal Test Mass assembly has bolted-on* [*D0901790*](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0901791&version=) *Primary Prisms similar to the bonded-on* [*D0810033*](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0810033&version=) *Primary Prisms for the Optic.*  *The* [*D0901278*](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0901278&version=) *Secondary Prisms are the same for each.* | Primary Prism  Secondary Prism  Fig 160: Metal Test Mass |
| Weigh the Test Mass and Optic, including:  * 4 Magnet Assemblies * 2 Primary Prisms * 2 Secondary Prisms * 2 Mirrors * 8 Screws * 8 Washers   *The weights must be within a few hundred grams of each other. Compensation can be made at the Upper or Intermediate Masses.* Document the data in ICS. | Fig 161: Test Mass Assembly |
| Bond the sapphire prisms to the optic using epoxy TBD and the bonding fixture, [D0902543](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0902543&version=). |  |

### Bond magnet/standoff assemblies to the optic, per the procedure detailed in Section 6.3.

### Move the bottom EQ stops up onto the metal test mass. Remove the front stops and brackets. Move the stops up even further to provide slack in the wire. Remove and set aside the secondary prisms. Carefully remove the metal test mass, while leaving intact the wires.

### Replace all of the test mass EQ stops with silica tipped ones: Earthquake Stop For Glass (Glass Tip), Simplified, 2 Inch, [D0900932](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0900932&version=).

### Carefully, move the optic in place of the metal test mass, onto the bottom EQ stops. Make sure the wires are securely positioned in the v-grooves of the sapphire prisms. Replace the front stops and brackets. Back down on the bottom EQ stops, until the optic is just suspended. Re-insert the secondary prisms, until there is no slack in the wire between the primary prism and the place where the wire meets the optic.

### Realign the BOSEMs & AOSEMs. Check for damping with the electronics test stand.

### Torque all bracket screws to 20 in-lb. Check torque on all blade clamp screws at 30 in-lb.

|  |  |
| --- | --- |
| IMG_1378  Fig 162: Prototype Small Triple Suspension | IMG_1610  Fig 163: Prototype Small Triple Suspension with Control System |