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|  |  |  |
| --- | --- | --- |
| Fig 1: HSTS | Fig 2: Front | Fig 3: Rear |

# Safety

Read and understand the HSTS Assembly and Installation Hazard Analysis ([E0900332](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=6079)). For specific safety information on wire handling, see Section 21.

# Objective and Scope

The objection of this document is to outline and describe the steps necessary for the assembly of the HSTS. The following tasks are within the scope of this document:

* Assembly of subassemblies (Masses, Wires, Earthquake Stops, etc.), including the use of jigs and fixtures shown in [D040391](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=6872) (HSTS Overall Assembly and Assembly Fixtures)
* Installation of subassemblies into the suspension structure
* Balancing of the suspension
* Gluing magnets on the metal masses and optic
* Installation and alignment of OSEMs
* Creep baking of the maraging steel blades
* Installation of the optic into the suspension
* Transportation of the suspension using a storage container

The following tasks are outside the scope of this document:

* Testing and commissioning of the suspension – see Ideal Order/Contents of aLIGO Triple Suspension Testing/Commissioning ([G1200070](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=86697))
* Gluing primary and secondary prisms to the optic – see Prism Gluing for Input Optics ([E1200211](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=87340))
* Installation of the suspension into the chamber – see the HSTS Installation Document ([E0900334](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=6081))

## Assembly Sequence

The steps required for the assembly of the HSTS are listed below. Some of the steps can be done in parallel with one another, while other steps can be rearranged to accommodate whatever tools, parts, or hardware are available.

1. Prepare Structural Weldment Assembly ([D020023](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=6926))
2. Assemble subassemblies, in any order:
   1. Top Blade Guard Assemblies (2X [D0901934](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=5032))
   2. Face Earthquake Stop Assemblies (2X [D0902413](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=6289) and 2X [D0902205](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=5784))
   3. Barrel Earthquake Stop Assemblies (2X [D0902203](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=5782) and 6X [D0902201](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=5780))
   4. AOSEM Alignment Assemblies (4X [D0901924](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=4998) and 2X [D0902207](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=5786) and 2X [D0902208](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=5787))
   5. Rotational Adjusters (2X [D1000045](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=8304))
   6. Upper Mass Assembly (1X [D020534](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=7031))
   7. Intermediate Mass Assembly (1X [D0901873](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=4835))
   8. Metal Lower Mass Assembly (1X [D0901791](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=4623) or [D0902333](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=6060) or [D1200886](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=92718))
3. Attach Top Blade Guard Assemblies to Structural Weldment
4. Attach Rotational Adjusters on Structural Weldment and flatten Upper Blades
5. Attach Barrel Earthquake Stop Assemblies on Structural Weldment
6. Install Intermediate and Metal Lower Mass Assemblies
7. Attach Face Earthquake Stop Assemblies
8. Assemble Intermediate Wire Assemblies (4X [D0901905](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=4969)) and attach to Upper Mass Assembly
9. Assemble Upper Wire Assemblies (2X [D0901854](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=4792)) and attach to Upper Mass Assembly
10. Place Coil Holder/Tablecloth ([D020239](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=13242)) over Upper Mass Assembly and lock the two together
11. Attach Upper Mass/Coil Holder Assembly ([D020535](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=6912)) to Structural Weldment
12. Connect Upper Wire Assemblies to Upper Blades
13. Connect Intermediate Wire Assemblies to Intermediate Mass Assembly
14. Assemble Lower Wire Assembly ([D0901902](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=4963))
15. Attach Lower Wire Assembly to Intermediate Mass Assembly
16. Suspend all masses
17. Initial balancing
18. Remove all Masses and Rotational Adjusters
19. In parallel:
    1. Creep baking of Upper Blades (in Rotational Adjusters) and Lower Blades (in Upper Mass Assembly)
    2. Magnet gluing for Intermediate Mass and Metal Lower Mass Assemblies
20. Reinstall Rotational Adjusters, Wires and Masses
21. Rebalancing
22. Install AOSEM Alignment Brackets
23. Install BOSEMs on Coil Holder/Tablecloth
24. Metal-Build Testing (Phase 1) (not covered in this document – see [G1200070](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=86697))
25. Transport HSTS to chamberside using a storage container
26. Metal-Build Testing, Continued (Phase 2a) (not covered in this document – see [G1200070](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=86697))
27. Replace Metal Lower Mass with Glass Optic
28. Rebalancing
29. Glass-Build Testing (Phase 2b) (not covered in this document – see [G1200070](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=86697))
30. Install HSTS into chamber (not covered in this document – see [E0900334](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=6081))
31. In-Chamber Testing (Phase 3) (not covered in this document – see [G1200070](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=86697))

# Contamination Control

## Related Documents

[E0900047](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=858) LIGO Contamination Control Plan

[E960022](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=3652) LIGO Clean and Bake Methods and Procedures

## General Practices

All assembly procedures must be performed in a Class 100 clean room environment while wearing:

* Hood
* Face Mask
* Coverall
* Overshoe Boots
* LIGO-approved UHV Gloves
* Safety Glasses (when working around wires, blades under load, and/or chemicals)
* Glove Liners (when pulling Wire Assemblies)

All work surfaces used for Class A or B components should be wiped down at the beginning of each work day, first with Acetone, then with Isopropanol. 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. Review the LIGO Contamination Control Plan ([E0900047](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=858)) for details.

## Clean and Bake of Components

All parts and hardware must be cleaned and bake to Class A or B as described in [E960022](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=3652). Any part that comes into contact with anything other than an equivalent to a Class A or B part must be recleaned and rebaked.

# Hardware and Fasteners

## Applications of Screw Types

The table below lists the most common types of screws used in the assembly of the HLTS, along with their applications. These types and applications apply to socket head cap screws (SHCS), flat head cap screws (FHCS), and set screws.

Table 1: Common Types of Screws

|  |  |  |
| --- | --- | --- |
| **Screw Type** | **Description** | **Applications** |
| Stainless Steel (SSTL) | Most common type of screw | * Threaded holes in aluminum parts * Helicoils, in any material |
| Stainless Steel, Vented | Stainless steel screw with a hole drilled through the shank of the screw | * Threaded holes in aluminum parts where the trapped volume in the hole must be vented * Helicoils, in any material, where the trapped volume in the hole must be vented |
| Silver-Plated (Ag-Plated) Stainless Steel | Stainless steel screw plated with a thin layer of silver | * Threaded holes ONLY in stainless steel parts |
| Silver-Plated Stainless Steel, Vented | Stainless steel screw plated with a thin layer of silver with a hole drilled through the shank of the screw | * Threaded holes ONLY in stainless steel parts where the trapped volume in the hole must be vented |

## Silver-Plated Stainless Steel Screws

As listed in the table above, all Silver-Plated screws are made of stainless steel SSTL, so they may be labeled simply as “Ag-Plated”, not “Ag-Plated SSTL” in this document.

## Torque Values

All Socket Head Cap Screws (SHCS) are required to be tightened to the proper torque value using a torque wrench. The proper torque values (unless otherwise specified in this document) come from [T1100066](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=32881) on the DCC and are listed in the table below. In future sections, the given torque values will be rounded to the nearest in-lb.

Torque values for Flat Head Cap Screws (FHCS) will be given in sections where the screws are used. In general, set screws are tightened by hand, not with a torque wrench.

Table 2: Torque Values for SHCS

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

In this table, all values are for coarse-threaded (UNC) SHCS, as shown by the listed thread pitch. Torque values for fine-threaded (UNF) or specially-threaded (UNS) SHCS will be given in sections where they are used. The Supplier of a SHCS can be determined in this manner: all Ag-Plated SHCS and vented SHCS are supplied by UC Components; Holo-Krome SHCS are indicated by an “H-K” marking on the head; all other SHCS should be considered to be generic, unless UC Components is positively known to be the supplier.

## Tightening Screw Patterns

To ensure proper alignment of components and to ensure even clamping pressure, it is important to tighten the final few threads of screws in a pattern evenly. That is, after all screws have been tightened initially by hand, each screw should be turned no more than ¼ turn (either by hand or with a torque wrench) before continuing to the next screw. Continue to tighten each screw ¼ turn in sequence until all screws are properly torqued.

## Helicoils

Helicoils (also known as threaded inserts) are used in threaded holes in aluminum or SSTL parts for a number of reasons:

* Additional strength
* Additional durability (for example, where a screw is frequently tightened and loosened for adjustment or repeated assembly/disassembly)
* To avoid the use of Ag-Plated hardware in a SSTL part
* To lock a screw in place (screw-lock helicoils only)

All helicoils used in this assembly are to be made of Nitronic 60. As with any other type of hardware, helicoils are cleaned and baked to Class A and installed using clean tools in a Class 100 clean room. After installation but before removing the tang, all helicoils should be checked by inserting a SHCS of sufficient length.

## Washers

The majority of washers used in assembly are flat washers made from stainless steel. In specific locations where parts slide against one another, Nitronic 60 flat washers ([D1100785](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=60032), various types) may be used; these locations will be called out in the assembly procedure.

# 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)

[D040391](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=6872) HSTS Overall Assembly and Assembly Fixtures

[D020700](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=6873) HSTS Overall Assembly

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

[G1200070](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=86697) Ideal Order/Contents of aLIGO Triple SUS Testing/Commissioning

[T0900559](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=6982) HLTS/HSTS/OMCS Blade Groupings

[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

[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

# Documenting the Assembly Process

## Related Documents

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

[T0900559](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=6982) HLTS/HSTS/OMCS Blade Groupings

[E1200343](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=89855) OSEM Chart

[E1200145](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=86722) HLTS/HSTS Optic Assemblies with Assembly Numbers

## Inventory Control System (ICS)

For Advanced LIGO, all information on parts and assemblies will be recorded in the [Inventory Control System (ICS)](https://ics-redux.ligo-la.caltech.edu/JIRA/secure/Dashboard.jspa). Information may also be stored in other documents, but it must be included in ICS as well.

As assembly progresses, each (sub)assembly should have an assembly record created in ICS and each part included in that assembly should be added to the corresponding assembly record. In general, this means that parts will be identified by serial number and assemblies will be identified by the serial number of a central part (as outlined in [T1100003](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=T1100003&version=)). Some parts are too small or too numerous to have serial numbers; these parts have been added to ICS in bulk. If the bulk quantities of a particular part have been divided into groups that match the number of parts in an assembly, then that part should be added to the assembly record.

In addition to part and serial numbers, there is important data that should be included in certain assembly records. This data should be included as a comment, but can be supported by images or other attachments. Data that should be recorded is listed in the table below.

Table 3: Data to be Recorded in Assembly Records

|  |  |
| --- | --- |
| **Assembly Record** | **Data to be Recorded** |
| HSTS Overall Assembly ([D020700](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=6873)) | * Overall weight information (including a list of parts that were included when the suspension was weighed) |
| Rotational Adjusters ([D1000045](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=8304)) | * Rotational Adjuster position in Overall Assembly * Blade serial number * Blade clamp angle and orientation (blade tip up or down) * Shim height |
| Upper Wire Assemblies ([D0901854](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=4792)) | * Amount of mass used to pull Wire Assembly |
| Upper Mass Assembly ([D020534](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=7031)) | * Blade serial numbers * Blade positions * Blade clamp angles and orientations (blade tip up or down) * Pre-creep bake mass value and additional mass configuration * Metal-build mass value and additional mass configuration * Final mass value and additional mass configuration |
| Intermediate Wire Assemblies ([D0901905](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=4969)) | * Amount of mass used to pull Wire Assembly |
| Intermediate Mass Assembly ([D0901873](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=4835)) | * Pre-creep bake mass value and additional mass configuration * Metal-build mass value and additional mass configuration * Final mass value and additional mass configuration |
| Lower Wire Assembly ([D0901902](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=4963)) | * Amount of mass used to pull Wire Assembly |
| Metal Lower Mass Assembly ([D0901791](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=4623) or [D0902333](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=6060)) | * Pre-creep bake mass value and additional mass configuration * Metal-build mass value and additional mass configuration |
| Coil Holder Assembly ([D020535](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=6912)) | * BOSEM serial numbers and positions |
| AOSEM Bracket Assemblies ([D0901924](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=4998), [D0902207](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=5786), and [D0902208](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=5787)) | * AOSEM serial number * AOSEM and bracket position |
| Optic Assembly (see [E1200145](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=86722)) | * Mass value of glass only * Total mass value (including magnets and prisms) |

## Process Travelers

Process travelers may be used to temporarily record information about part and serial numbers and other relevant data. Any final information recorded in a process traveler must be transferred to the corresponding assembly record in ICS.

## aLogs

The Advanced LIGO logbooks (or aLogs) are used at the [Livingston](https://alog.ligo-la.caltech.edu/aLOG/) and [Hanford](https://alog.ligo-wa.caltech.edu/aLOG/) Observatories to keep a daily record of activity on the site. Progress reports during assembly should be posted regularly, along with information important to the assembly process and any other relevant data. Any final data must be transferred to the corresponding assembly record in ICS.

## Other Documents

A number of other documents on the DCC and elsewhere are used to record data for certain important suspension parts. These documents are listed below:

* HLTS/HSTS/OMCS Blade Groupings ([T0900559](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=6982)) – This document lists suggested groupings of Upper and Lower Blades, along with blade clamp angles and orientations; final information on actual blade positions and blade clamp angles and orientations should be added to this document.
* OSEM Chart ([E1200343](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=89855)) – This document lists information on BOSEMs and AOSEMs, including open-light counts and other data; the BOSEMs and AOSEMs are arranged by suspension and then position within the suspension. Final information on OSEM positions and other data should be added to this document.
* [Nebula](https://nebula.ligo.caltech.edu/optics/) – This webpage, maintained by the Core Optics group, lists all COC and IO optics along with relevant information, such as mass values.

# Preparing the Structural Weldment

## Related Documents

[D020700](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=6873) HSTS Overall Assembly

[D020023](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=6926) Structural Weldment Assembly, HSTS

## Materials

|  |  |  |  |
| --- | --- | --- | --- |
| **Qty** | **Unit** | **Part Number** | **Description** |
| 1 | Each | [D020023](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=6926) | Structural Weldment Assembly, HSTS |
| 6 | Each | 1185-2EN492 | Helicoil, #8-32 X 0.492” Long, Nitronic 60 |
| 4 | Each | 1185-4EN250 | Helicoil, ¼-20 X 0.25” Long, Nitronic 60 |
| 4 | Each | [D980184](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=2835) | LOS Clamp, Long |
| 4 | Each | N/A | SHCS, ¼-20 X 1.5” Long, Ag-Plated SSTL |
| 4 | Each | N/A | Flat Washer, ¼”, SSTL |
| 1 | Each | N/A | Helicoil Go/No Go Gage, #8-32 |
| 1 | Each | N/A | Tap, #8-32 Helicoil |
| 1 | Each | N/A | Helicoil Insertion Tool, #8-32 |
| 1 | Each | N/A | Helicoil Tang Removal Tool |
| 1 | Each | N/A | Helicoil Go/No Go Gage, ¼-20 |
| 1 | Each | N/A | Tap, ¼-20 Helicoil |
| 1 | Each | N/A | Helicoil Insertion Tool, ¼-20 |
| 1 | Each | N/A | Tap, #8-32 +0.005” Oversize |
| 1 | Each | N/A | Tap, ¼-20 +0.005” Oversize |
| 1 | Bag | PNHS-99 | Polynit Heatseal Wipes |
| 1 | Bottle | N/A | Methanol |

## 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. | Fig 4: Frame of Reference  Front |

## Procedure

|  |  |
| --- | --- |
| Verify usability of every tapped hole in the Structural Weldment, including holes for Helicoils.Use a properly-sized Ag-Plated SSTL SHCS of sufficient length to check every tapped hole. If the silver plating is stripped from the SHCS, replace it before continuing to other holes.Use a properly-sized Helicoil Go/No Go Gage to check every Helicoil hole (4X ¼-20 Helicoil and 6X #8-32 Helicoil). Wipe the Gage down using Methanol after checking each hole.If any holes need to be retapped, use a clean tap of the proper size and type (tapped hole or Helicoil hole). After tapping, clean the hole and the tap thoroughly using Methanol and recheck the hole.Insert 6X Helicoils, #8-32 X 0.492” Long, into the base plate of the Structural Weldment, 3X on each of the short sides. Before removing the tangs, thread a SSTL SHCS into each Helicoil to be sure that the Helicoil is threaded correctly.Insert 4X Helicoils, ¼-20 X 0.25” Long, into the top plate of the Structural Weldment. Before removing the tangs, thread a SSTL SHCS into each Helicoil to be sure that the Helicoil is threaded correctly.Secure the Structural Weldment to an Optical Table using at least 4X Long LOS Clamps ([D980184](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=2835)), 4X ¼-20 X 1.5” Long Ag-Plated SSTL SHCS and 4X ¼” Flat Washers. Orient the Structural Weldment so that there is easy access to the back (-y) side, which is the side with 8X #8-32 tapped holes in the top side of the base plate. Do not cover any of the #8-32 tapped holes. | Figure 1: HSTS Structural Weldment |

# Assembling the Top Blade Guards

## Related Document

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

## Materials

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

## Procedure

|  |  |
| --- | --- |
| Insert 2X Helicoils, ¼-20 X 0.375” Long, into the Blade Guard Crossbeam ([D0901935](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=2469)). Before removing the tangs, thread a SSTL SHCS into each Helicoil to be sure that the Helicoil is threaded correctly.Attach 2X 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 4X #8-32 X 0.625” Long SSTL SHCS. Torque the SHCS to 30 in-lb using a torque wrench.Thread 1X ¼-20 Hex Nut, Ag-Plated SSTL onto each of 2X ¼-20 X 2” Long, Fully Threaded, Rounded End, SSTL SHCS ([D0900999](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=2469)). Thread the 2X Rounded End SHCS into the Blade Guard Crossbeam with the rounded ends facing down, as shown in the figure at right.Create an assembly record in ICS and record the serial numbers of the Blade Guard Crossbeam and Blade Guard Risers.Repeat Steps 1 through 4; each HSTS Overall Assembly has 2X Top Blade Guard Assemblies. | Crossbeam  ¼-20 x 2.00  Riser  8-32 x .625 SSTL  Figure 2: Top Blade Guard Assembly |

# Assembling the Face Earthquake Stops

## Related Documents

[D0902413](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=6289) Face Earthquake Stop Assembly, Intermediate Mass

[D0902205](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=5784) Face Earthquake Stop Assembly, Lower Mass

## Materials

|  |  |  |  |
| --- | --- | --- | --- |
| **Qty** | **Unit** | **Part Number** | **Description** |
| 4 | Each | [D0901923](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=4997) | Face Earthquake Stop Base |
| 2 | Each | [D0902204](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=5783) | Face Earthquake Stop Bracket, Intermediate Mass |
| 2 | Each | [D0901922](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=4996) | Face Earthquake Stop Bracket, Lower Mass |
| 4 | Each | 1185-4EN375 | Helicoil, ¼-20 X 0.375” Long, Nitronic 60 |
| 4 | Each | N/A | SHCS, #8-32 X 0.625” Long, SSTL |
| 4 | Each | N/A | Hex Nut, ¼-20, Ag-Plated SSTL |
| 4 | Each | [D0900999](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=2469) | SHCS, ¼-20 X 2” Long, Fully Threaded, Rounded End, SSTL |

## Procedure

|  |  |
| --- | --- |
| Insert 2X Helicoils, ¼-20 X 0.375” Long, into the Face Earthquake Stop Bracket, Intermediate Mass ([D0902204](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=5783)). Before removing the tangs, thread a SSTL SHCS into each Helicoil to be sure that the Helicoil is threaded correctly.Attach 1X Face Earthquake Stop Base ([D0901923](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=4997)) to the Face Earthquake Stop Bracket using 2X #8-32 X 0.625” Long SSTL SHCS. Torque the SHCS to 30 in-lb using a torque wrench.Thread 1X ¼-20 Hex Nut, Ag-Plated SSTL onto each of 2X ¼-20 X 2” Long, Fully Threaded, Rounded End, SSTL SHCS ([D0900999](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=2469)). Thread the 2X Rounded End SHCS into the Face Earthquake Stop Bracket with the rounded ends facing away from the slot in the Face Earthquake Stop Base, as shown in the figure at right.Create an assembly record in ICS and record the serial numbers of the Face Earthquake Stop Base and Bracket.Repeat Steps 1 through 4 once more; each HSTS Overall Assembly has 2X Intermediate Mass Face Earthquake Stop Assemblies.Repeat Steps 1 through 4 twice more, substituting the Face Earthquake Stop Bracket, Lower Mass ([D0901922](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=4996)) for the Face Earthquake Stop Bracket, Intermediate Mass; each HSTS Overall Assembly has 2X Lower Mass Face Earthquake Stop Assemblies. | Hex Nut  ¼-20 x 2.25”  D0901923  D0902204  8-32 x 0.625”  Fig 5: 2 Assemblies |

# Assembling the Barrel Earthquake Stops

## Related Documents

[D0902203](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=5782) Barrel Earthquake Stop Assembly, Intermediate Wire

[D0902201](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=5780) Barrel Earthquake Stop Assembly, Lower Wire

## Materials

|  |  |  |  |
| --- | --- | --- | --- |
| **Qty** | **Unit** | **Part Number** | **Description** |
| 16 | Each | [D0902008](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=5192) | Barrel Earthquake Stop Bracket |
| 16 | Each | [D0902009](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=5193) | Barrel Earthquake Stop Base |
| 2 | Each | [D0901925](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=4999) | Barrel Earthquake Stop Crossbar, Intermediate Wire |
| 6 | Each | [D0902202](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=5781) | Barrel Earthquake Stop Crossbar, Lower Wire |
| 32 | Each | N/A | SHCS, #4-40 X 0.375” Long, SSTL |
| 16 | Each | 1185-4EN500 | Helicoil, ¼-20 X 0.5” Long, Nitronic 60 |
| 32 | Each | N/A | SHCS, ¼-20 X 0.875” Long, SSTL |
| 32 | Each | N/A | Flat Washer, ¼”, SSTL |
| 16 | Each | N/A | Hex Nut, ¼-20, Ag-Plated SSTL |
| 16 | Each | [D030022](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=2350) | SHCS, ¼-20 X 2.25” Long, Fully Threaded, Rounded End, SSTL |
| 1 | Each | N/A | Machinist Square |

## Procedure

|  |  |
| --- | --- |
| Attach 1X Barrel Earthquake Stop Base ([D0902009](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=5193)) to 1X Barrel Earthquake Stop Bracket ([D0902008](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=5192)) using 2X #4-40 X 0.375” Long SSTL SHCS, so that the vent holes in the Barrel Earthquake Stop Bracket face the slots in the Barrel Earthquake Stop Base. Use a Machinist Square to keep the two parts aligned. Torque the SHCS to 6 in-lb using a torque wrench.Repeat Step 1 once more.Insert 2X Helicoils, ¼-20 X 0.5” Long, into the Intermediate Wire Barrel Earthquake Stop Crossbar ([D0901925](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=4999)). Before removing the tangs, thread a SSTL SHCS into each Helicoil to be sure that the Helicoil is threaded correctly.Attach 2X Barrel Earthquake Stop Brackets ([D0902008](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=5192)) to either end of the Intermediate Wire Barrel Earthquake Stop Crossbar ([D0901925](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=4999)) using 4X ¼-20 X 0.875” Long SSTL SHCS and 4X ¼” Flat Washers. Hand-tighten the SHCS; do NOT torque them at this time.Thread 1X ¼-20 Hex Nut, Ag-Plated SSTL onto each of 2X ¼-20 X 2.25” Long, Fully Threaded, Rounded End, SSTL SHCS ([D030022](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=2350)). Thread the 2X Rounded End SHCS into the Barrel Earthquake Stop Crossbar so that the rounded ends face away from the Barrel Earthquake Stop Base.Create an assembly record in ICS and record the serial numbers of the Barrel Earthquake Stop Brackets, Barrel Earthquake Stop Bases and Barrel Earthquake Stop Crossbars.Repeat Steps 1 through 6 once more; each HSTS Overall Assembly has 2X Intermediate Wire Barrel Earthquake Stop Assemblies.Repeat Steps 1 through 6, but substitute the Lower Wire Barrel Earthquake Stop Crossbar ([D0902202](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=5781)) for the Intermediate Wire Barrel Earthquake Stop Crossbar ([D0901925](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=4999)). Assemble a total of 6X Lower Wire Barrel Earthquake Stop Assemblies. | 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 6: Build 2 Assemblies |

# Assembling the AOSEM Alignment Assemblies

## Related Documents

[D090](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=4998)1924 AOSEM Alignment Assembly, Intermediate Mass

[D0902207](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=5786) Upper AOSEM Alignment Assembly, Lower Mass

[D0902208](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=5787) Lower AOSEM Alignment Assembly, Lower Mass

## Materials

|  |  |  |  |
| --- | --- | --- | --- |
| **Qty** | **Unit** | **Part Number** | **Description** |
| 4 | Each | [D0902414](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=6290) | AOSEM Alignment Bracket, Intermediate Mass |
| 8 | Each | [D0901548](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=4182) | AOSEM Adjustment Collar |
| 16 | Each | [D1000659](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=10290) | AOSEM Adjuster Shaft |
| 16 | Each | [D1000660](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=10291) | Adjustment Nut, AOSEM Alignment Assembly |
| 4 | Each | [D0902206](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=5785) | AOSEM Alignment Bracket Mount, Intermediate Mass |
| 16 | Each | 1185-2EN246 | Helicoil, #8-32 X 0.246” Long, Nitronic 60 |
| 8 | Each | 1185-4EN250 | Helicoil, ¼-20 X 0.25” Long, Nitronic 60 |
| 1 | Each | N/A | Helicoil Insertion Tool, #8-32 |
| 1 | Each | N/A | Helicoil Tang Removal Tool |
| 1 | Each | N/A | Helicoil Insertion Tool, ¼-20 |
| 8 | Each | N/A | SHCS, #2-56 X 0.375” Long, SSTL |
| 16 | Each | N/A | SHCS, #8-32 X 0.625” Long, SSTL |
| 16 | Each | N/A | Flat Washer, ¼”, SSTL |
| 8 | Each | Stop | Stop |
| 8 | Each | N/A | Hex Nut, ¼-20, Ag-Plated SSTL |
| 4 | Each | [D0902417](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=6293) | AOSEM Alignment Bracket, Lower Mass |
| 2 | Each | [D0902416](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=6292) | Upper AOSEM Alignment Bracket Mount, Lower Mass |
| 2 | Each | [D0902415](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=6291) | Lower AOSEM Alignment Bracket Mount, Lower Mass |

## Procedure – Intermediate Mass

Placeholder

## Procedure – Lower Mass, Upper

Placeholder

## Procedure – Lower Mass, Lower

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 AOSEMs in place, but AOSEMs are actually installed later on.

|  |  |  |  |
| --- | --- | --- | --- |
| [**D0901924**](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0901924&version=) **(4)**  AOSEM 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 AOSEM 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 AOSEM Alignment Assy  Lower Mass  Used in the lower 2 positions at the Lower Mass. |  | Large Mount    LH  Configuration | RH  Configuration |

## 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 7: Assembly without AOSEM |

# Assembling the Rotational Adjusters

## Related Documents

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

[E1000169](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=11850) HAM Suspension Blade Characterization Spreadsheet

[T0900559](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=6982) HLTS/HSTS/OMCS Blade Groupings

[D020677](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=2655) HSTS/OMCS Library of Clamps

## Materials

|  |  |  |  |
| --- | --- | --- | --- |
| **Qty** | **Unit** | **Part Number** | **Description** |
| 2 | Each | [D030447](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=1994) | Rotating Plate, Rotational Adjuster |
| 2 | Each | [D020679](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=2015), [D020680](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=2002), [D1100844](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=60611), or [D1102145](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=75477) | Upper Blade Clamp, Lower Side, Shim, 1mm  Upper Blade Clamp, Lower Side, Shim, 2mm  Upper Blade Clamp, Lower Side, Shim, 4.77mm  Upper Blade Clamp, Lower Side, Shim, Custom |
| 2 | Each | Various | Upper Blade Clamp, Lower Side, 0.0 Degree through 3.5 Degree |
| 2 | Each | [D1001812](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=13576) | Upper Blade |
| 2 | Each | Various | Upper Blade Clamp, Upper Side, 0.0 Degree through 3.5 Degree |
| 4 | Each | N/A | SHCS, ¼-20 X 1.375” Long, Ag-Plated SSTL |
| 4 | Each | N/A | Flat Washer, ¼”, SSTL |
| 2 | Each | [D1002440](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=20931) | Upper Blade Baking Fixture, HSTS/OMC |
| 1 | Each | [D020660](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=16026) | Blade Pulldown Device, HAM Suspensions |
| 1 | Set | N/A | Interlocking Test Weights (1kg, 2kg) |
| 1 | Set | N/A | Test Weights (1g – 500g) |
| 2 | Each | N/A | Machinist Square |
| 2 | Each | [D030448](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=2579) | Base Plate, Rotational Adjuster |
| 6 | Each | N/A | SHCS, ¼-20 X 0.375” Long, SSTL |
| 6 | Each | [D1100785-472](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=60032) | Flat Washer, ¼” X 0.472” Outer Diameter, Nitronic 60 |
| 2 | Each | D030450 | Pull Plate, Rotational Adjuster |
| 4 | Each | N/A | SHCS, #8-32 X 0.75” Long, Ag-Plated SSTL |
| 2 | Each | D030449 | Push Plate, Rotational Adjuster |
| 4 | Each | N/A | SHCS, #8-32 X 1” Long, SSTL |
| 2 | Each | N/A | SHCS, #8-32 X 1” Long, Ag-Plated, SSTL |
| 2 | Each | [D1100785-359](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=60032) | Flat Washer, 0.20” X 0.359” Outer Diameter, Nitronic 60 |
| 2 | Each | [D030025](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=2352) | SHCS, #8-32 X 1” Long, Fully Threaded, Rounded End, SSTL |

## 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 8: 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 9: Clamps Control Launch Angle | Fig 10: 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 11: 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 12: 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 13: 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 14: Adding Push Plate |

# Assembling the Upper Mass (M1)

## Related Documents

[D020534](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=7031) Upper Mass Assembly, HSTS

[E1000169](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=11850) HAM Suspension Blade Characterization Spreadsheet

[T0900559](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=6982) HLTS/HSTS/OMCS Blade Groupings

[D020677](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=2655) HSTS/OMCS Library of Clamps

## Materials

| **Qty** | **Unit** | **Part Number** | **Description** |
| --- | --- | --- | --- |
| 1 | Each | [D020134](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=12728) | Main Section, Upper Mass |
| 4 | Each | 1185-04EN336 | Helicoil, #4-40 X 0.336” Long, Nitronic 60 |
| 1 | Each | N/A | Helicoil Insertion Tool, #4-40 |
| 1 | Each | N/A | Helicoil Tang Removal Tool |
| 1 | Each | [D020136](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=12726) | T-Section, Upper Mass |
| 1 | Each | [D040259](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=16483) | Tablecloth and Upper Mass Jig |
| 1 | Each | 1185-4EN250 | Helicoil, ¼-20 X 0.25” Long, Nitronic 60 |
| 1 | Each | N/A | Helicoil Insertion Tool, ¼-20 |
| 2 | Each | N/A | SHCS, ¼-20 X 0.375” Long, Ag-Plated SSTL |
| 1 | Each | [D020137](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=12725) | Pitch Insert, T-Section, Upper Mass |
| 1 | Each | N/A | Screw, Socket Set, ½-20 X 2” Long, Ag-Plated SSTL |
| 4 | Each | N/A | Screw, Socket Set, #8-32 X 0.25” Long, Ag-Plated SSTL |
| 1 | Each | [D020676](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=12706) | Roll Insert, T-Section, Upper Mass |
| 4 | Each | Various | Lower Blade Clamp, Lower Side, 0.0 Degree through 3.5 Degree |
| 4 | Each | [D080761](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=226) | Upper Blade |
| 4 | Each | Various | Lower Blade Clamp, Upper Side, 0.0 Degree through 3.5 Degree |
| 8 | Each | N/A | SHCS, #8-32 X 1” Long, Ag-Plated SSTL |
| 16 | Each | N/A | Flat Washer, #8, SSTL |
| 2 | Each | [D020660](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=16026) | Blade Pulldown Device, HAM Suspensions |
| 2 | Set | N/A | Interlocking Test Weights (1kg, 2kg) |
| 2 | Set | N/A | Test Weights (1g – 500g) |
| 2 | Each | N/A | Machinist Square |
| 2 | Each | [D0902030](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=5259) | Blade Guard, Upper Mass |
| 4 | Each | 1185-04EN168 | Helicoil, #4-40 X 0.168” Long, Nitronic 60 |
| 4 | Each | N/A | SHCS, #4-40 X 0.5” Long, SSTL |
| 4 | Each | [D0900980](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=2450) | SHCS, #4-40 X 0.375” Long, Fully Threaded, Rounded End, SSTL |
| 4 | Each | [D020482](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=2613) | Screwdrive System, Upper Mass |
| 8 | Each | N/A | SHCS, #8-32 X 0.625” Long, SSTL |
| 4 | Each | N/A | SHCS, #8-32 X 0.75” Long, Fully Threaded, SSTL |
| 3 | Each | [D0902494](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=6780) | Magnet Holder (Short), Upper Mass |
| 6 | Each | [D0902423](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=6301) | Magnet Holder (Long), Upper Mass |
| 9 | Each | [D1001534](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=12610) | Magnetic Plug, BOSEM |
| 1 | Each | ? | Plate to Press Disks |
| 9 | Each | D1100573 | Flag, BOSEM |
| 9 | Each | D1100574 | Flat Flag Disk, BOSEM |
| 9 | Each | N/A | Flat Head Cap Screw, #4-40 X 0.1875” Long, SSTL |
| 9 | Each | D394197N35UHP | Sintered NdFeB Magnet, Ni-Plated, 10mm X 5mm |
| 2 | Each | [D020199](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=12705) | Magnet/Flag Base (Short), Upper Mass |
| 9 | Each | N/A | SHCS, #8-32 X 0.3125” Long, SSTL |
| 4 | Each | N/A | SHCS, #4-40 X 0.625” Long, SSTL |
| 18 | Each | N/A | Flat Washer, #4, SSTL |
| 7 | Each | [D0902493](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=6779) | Magnet/Flag Assembly Base Plate, Upper Mass |
| 4 | Each | [D020211](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=12701) | Magnet Holder Brace |
| 8 | Each | N/A | SHCS, #4-40 X 1.25” Long, Ag-Plated SSTL |
| 2 | Each | N/A | SHCS, #4-40 X 0.625” Long, Ag-Plated SSTL |
| 4 | Each | N/A | SHCS, #4-40 X 0.625” Long, Vented, Ag-Plated SSTL |

## Procedure – Main Section, T-Section, and Blades

|  |  |
| --- | --- |
| 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 15: 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 16: 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 17: 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 18: Blade Pulldown Device |

|  |  |  |
| --- | --- | --- |
| 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 19: 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 20: 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 21: Profile Matching & Blade Clamp Alignment | |
| Assemble a [D0902030](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:2X SHCS, #4-40 X 0.375” Long, Fully Threaded, Rounded End, SSTL ([D0900980](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=2450)) *Diagram shows SHC Screws* *Turn the Screws down as far as possible.*Disconnect the Pulldown Devices from the Blade tips. | | #4-40 X 0.375, Rounded End  #4-40 x 0.5”  Blade Guard  Fig 22: 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 23: 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.

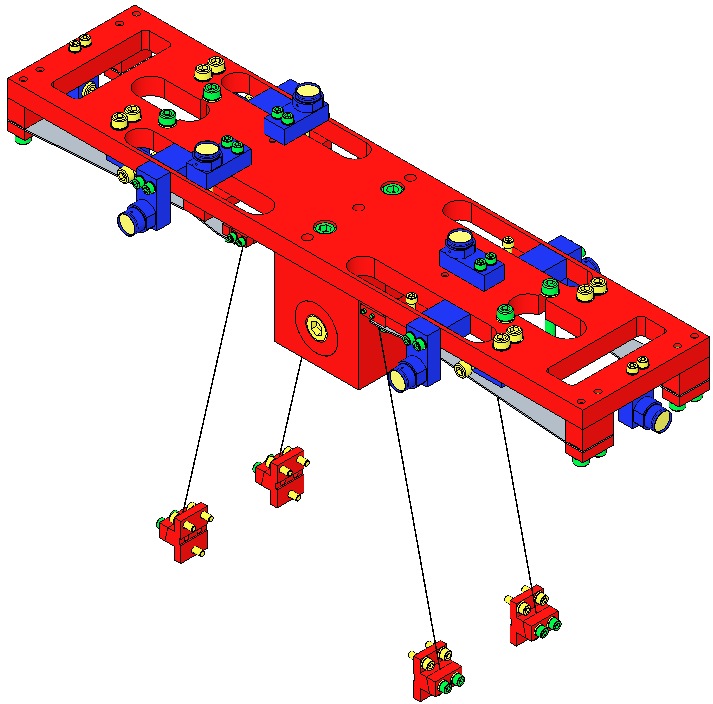
|  |  |  |
| --- | --- | --- |
| The Upper Mass continues to be mounted on the Upper Mass Jig, as shown in Section 24.3 Step 2.Assemble:2X [D0902494](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=6778) Magnet Holder (Short)2X [D0902493](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=6779) Magnet/Flag Assembly Base Plate2X SHCS, #8-32 X 0.3125” LongTorque to 20 in-lb.Assemble the Base Plates to the upper side of the Main Section in the T2 and T3 positions with:4X SHCS, # 4-40 X 0.625” Long, Ag-Plated, Vented4X #4 Flat WashersUse a Machinist’s Square to keep the Base Plates square to the Main Section. Torque to 7 in-lb. | | Base Long  Magnet Holder  Short  8-32 x .3125  Remove Flag for ease of assembly  Fig 24: 2 Short Assemblies attached to Main Section |
| Assemble:1X [D0902494](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=6778) Magnet Holder (Short)1X [D0902493](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=6779) Magnet/Flag Assembly Base Plate1X SHCS, #8-32 X 0.3125” LongTorque to 20 in-lb.Assemble the Base to the upper side of the Main Section in the T1 position with:2X SHCS, # 4-40 X 0.625” Long, Ag-Plated, Vented2X #4 Flat WashersUse a Machinist’s Square to keep the Base Plates square to the Main Section. Torque to 7 in-lb. | | Base Long  Remove Flag for ease of assembly  Magnet  Holder  Short  8-32 x .3125  Fig 25: 1 Short Assembly attached to Main Section |
| Assemble:4X [D0902423](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=6778) Magnet Holder (Long)4X [D0902493](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=6779) Magnet/Flag Assembly Base Plate4X SHCS, #8-32 X 0.3125” LongTorque to 20 in-lb. | Base Long  Magnet Holder Long  Remove Flag for ease of assembly  Fig 26: 4 Long Assemblies | |

|  |  |
| --- | --- |
| Attach the 4X Base Plates to the long sides of the Main Section using:  * 4X [D020211](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=12701) Magnet Holder Brace * 8X SHCS, #4-40 X 1.25” Long, Ag-Plated * 8X #4 Flat Washers  Use a Machinist’s Square to keep the Base Plates square to the Main Section. Torque to 6 in-lb. | Magnet Holder Brace  Fig 27: 4-7 of 9 Magnet Assemblies |
| Assemble:  * 2X [D020199](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=12705) Magnet/Flag Assembly Base Plate (Short)  2X [D0902423](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=6778) Magnet Holder (Long)  * 2X SHCS, #8-32 X 0.3125” Long  Torque to 20 in-lb. | Remove Flag for ease of assembly  Magnet Holder Long  Base Short  8-32 x .5”  Fig 28: 2 Short Assemblies |
| Attach one Base Plate to the lower side of each shortside of the Main Section using:  * 4X SHCS, #4-40 X 0.625” Long * 4X #4 Flat Washers  Use a Machinist’s Square to keep the Base Plates square to the Main Section. Torque to 5 in-lb.One of these Base Plates will need to be removed to allow the Coil Holder to fit over the Upper Mass, and then reattached. The Base Plate that should be removed is the one that will NOT be covered by the Side BOSEM (+/-y direction depends on the particular suspension), since it is difficult to keep the Base Plate square to the Main Section after the Coil Holder is placed over the Upper Mass. | Fig 29: LH end of Main Section; 8 of 9 Magnet Assys    **Fig 30: RH end of Main Section; 9 of 9 Magnet Assys** |

|  |  |
| --- | --- |
| 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 31: Upper Mass subassembly    2-56 x .375”  (2)  D0901999  (2)  8-32 x 1.00”  (2)  D020481  (2)  D0901998  (2)  Fig 32: Lower Clamp from Upper Wire Assy    2-56 x .25”  2-56 x .375”  D030044  D020132  Fig 33: Upper Clamp from Lower Wire Assy |

## Procedure – Lower Wires

|  |  |
| --- | --- |
| 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 34: Top View of Clamps    Fig 35: Lower Wire Assemblies added |



**Fig 36: 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 37: 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 38: 12 Screws added |

# Assembling Magnets – Upper Mass

## Materials – Upper Mass Magnets

|  |  |  |  |
| --- | --- | --- | --- |
| **Qty** | **U** | **ID** | **Description** |

## 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 39: 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 40: Long Magnet Assembly |

## Procedure – Plug Insertion

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| --- | --- |
| **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 41: Heating Fixture with Holders    Fig 42: Insertion Tool in position  Note: Tapered end of Tool is up  Note: Seated Disks on left 2 Holders |

# Assembling the Intermediate Mass (M2)

## Related Document

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

## Materials

|  |  |  |  |
| --- | --- | --- | --- |
| **Qty** | **Unit** | **Part Number** | **Description** |
| 1 | Each | [D0901792](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=4624) | Intermediate Mass |
| 2 | Each | [D020350](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=1988) | Add-On Mass, 100g |
| 2 | Each | N/A | SHCS, ¼-20 X 0.875” Long, Vented, SSTL |
|  |  |  |  |
|  |  |  |  |
| 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 43: 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 44: Intermediate Mass with Add-On Masses |

# Assembling the Lower Mass (M3)

## Related Documents

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

[D0902333](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=6060) Metal Lower Mass Assembly (PR/SR), HSTS

## Materials

|  |  |  |  |
| --- | --- | --- | --- |
| **Qty** | **Unit** | **Part Number** | **Description** |
| 1 | Each | [D020234](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=8546&version=1) or [D0902332](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=6058&version=1) | Metal Lower Mass (MC) or Metal Lower Mass (PR/SR) |
| 2 | Each | [D0901790](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=4622) | Primary Metal Breakoff Prism |
| 4 | Each | N/A | SHCS, #8-32 X 0.375 Long, SSTL |
| 12 | Each | N/A | Flat Washer, #8, SSTL |
| 2 | Each | [D1100197](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=33001) | Spacer, Bottom Mass |
|  |  |  |  |
| 8 | Each | N/A | SHCS, #4-40 X 0.375” Long, SSTL |
| 8 | Each | N/A | Flat Washer, #4, SSTL |
| 2 | Each | 033-0280 (OptoSigma) | Metallized Mirror, Round |
|  |  |  |  |
| 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 |

## 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 45: 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. | |

# Attaching the Top Blade Guards

# Installing the Rotational Adjusters

# 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 46: Weldment / Front View |

## Related 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 47: 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 48: 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 49: 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 50: Blade Pulldown Support    Blade Pulldown Supports  Fig 51: 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 52: Bar orientation    Fig 53: EQ Stops turned to flatten Blades |

# 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 54: Intermediate Mass on Stops** | **Mass**  **Right-Side Up** | **Mass**  **Upside Down** |
| Fig 55: 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 56: 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 57: 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 58: 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 59: Lower Mass and Face EQ Stops |

# Safe Handling of Suspension Wire

The wire used in all stages of the HSTS is a hard temper carbon steel, delivered and stored on large spools. When unspooled for cleaning, cutting, and preparation for assembly, safety precautions must be followed so that the large amount of potential energy stored in the coiled wire and sharp wire ends do not cause injury.

## Personal Protective Equipment

The following items of personal protection equipment must be work when working with wire:

* Safety Glasses (available in all clean room garbing areas) must be worn at all times when working with wire or near Wire Assemblies under load
* Glove Liners (also available in all clean room garbing areas) must be worn under UHV Gloves at all times when working with wire to avoid puncture injuries by providing an additional layer of protection

## Cleaning Suspension Wire

Follow the steps listed below to cut a section of wire from a spool and clean it for use in producing a Wire Assembly. Two people are needed to cut and clean a section of wire.

* + 1. After removing the spool from its bag, remove the protective layer of paper and set it aside so that it can be replaced after cutting the wire.
    2. Unspool a short length of wire and bend the wire over approximately 3” from the end. This helps to make the wire easier to hold and to avoid puncture injury.
    3. Unspool the proper length of wire needed for the Wire Assembly, including extra for handling.
    4. (Person 1) Hold on to the wire near the free end and the section to be cut so that the loose ends do not spring out of control away from the spool.
    5. (Person 2) Cut the wire using dirty wire cutters.
    6. (Person 2) Bend the cut end of the wire over approximately 3” from the end.
    7. (Person 1) Hold on to both ends of the wire, keeping it from touching the floor.
    8. (Person 2) Change gloves.
    9. (Person 2) Spray a clean wipe with Methanol. Take one end of the wire from Person 1 and wipe the entire wire starting from that end. When finished, take the other end from Person 1.
    10. (Person 1) Change gloves.
    11. (Person 1) Spray a clean wipe with Acetone. Take one end of the wire from Person 2 and wipe the entire wire starting from that end. When finished, take the other end from Person 2.
    12. (Person 2) Change gloves.
    13. (Person 2) Spray a clean wipe with Isopropanol. Take one end of the wire from Person 1 and wipe the entire wire starting from that end. When finished, take the other end from Person 1.
    14. Repeat Steps 8-13, alternating holding the wire between Person 1 and Person 2, until nothing is left on the wipe after cleaning.
    15. The wire is now considered to be clean and should only be handled with clean gloves. Transfer the wire to the Assembly Jig. Use the Wire Clamps on the Assembly Jig to hold the wire in place.
    16. After using the wire spool, tape the free end of the wire to the spool with the small piece of tape on the spool. Replace the protective layer of paper and place the spool back into its bag.

# Assembling the Intermediate Wires

## Related 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 60: 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 61: 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 62: 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 63: 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 64: 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 65: 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 66: 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.

# Assembling the Upper Wires

## Related 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 67: 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 68: 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 69: 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 70: 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 71: 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 72: 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 73: 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.

# 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

|  |  |
| --- | --- |
| 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 74: 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 75: Assemble Coil Holder to 2 Brackets**    **Fig 76: Unusable Screw locations**      Fig 77: 2nd pair of Coil Holder Brackets |

## Procedure – Assembling Intermediate Wires to Intermediate Mass

|  |  |
| --- | --- |
| 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 78: 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 79: 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 80: 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 81: Coil Holder raised |

## Procedure – Assembling Upper Wires to Upper Mass

|  |  |
| --- | --- |
| *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 82: 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 83: 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 84: Centering the C-Clamps with the Screw Drives** |

## Procedure – Assembling Upper Wires to Upper Blades

|  |  |
| --- | --- |
| 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 85: Upper Wire L-Clamps    Fig 86: Orientation of Clamps |

# Assembling the Lower Wire

## Related 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 | [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” Long, Ag-Plated SSTL |
| 4 | Each | N/A | #8 Flat Washer |
| 1 | Spool | N/A | Steel Music Wire, 0.0047” Diameter |
| 2 | Set | N/A | Test Weights (1g – 500g) |
| 2 | Each | N/A | Ameristat Bag |
| 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 |
| A/R | N/A | N/A | Shims |
| 1 | Each | N/A | Machinist’s Square |

## 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 as 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. | | Table  Edge  Fig 87: Lower Wire Assembly Jig | | |
| Assemble to the Jig:2X [D020202](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=12440) Wire Clamp Mount2X [D1200188](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=86671) Wire Clamp Blank Top4X SHCS, #8-32 X 0.50” Long2X SHCS are omitted to provide clearance for the Machinist’s Square. Align the Clamp Bases with the Wire Clamp Blocks using the Machinist’s Square, and torque to 20 in-lb. | | | Base with 2X SHCS  Machinist’s  Square    Block    Fig 88: Clamps with 2X SHCS each | |
| **Place the First Wire** Cut 1 piece of 0.0047” Diameter Steel Music Wire, 48” long, from the spool.Clean the Wire per Section 12.4.Feed one end of the wire through a Wire Start Clamp, leaving about ½” of wire beyond the Wire Start Clamp.Feed the other end of the wire through the corresponding Wire Start Clamp so that the wire is parallel to the long edge of the Wire Jig Base Plate. Drape the end of the wire over the Clevis Pin.Torque the 2X SHCS in the Wire Start Clamp away from the Clevis Pin to 6 in-lb.Using the Test Weights, place 720 grams into an Ameristat bag. Confirm the mass using a digital scale. Cut a small slot in the bag for the wire to pass through. | Fig 89: Placing First Wire (some Wire Start Clamps missing) | | | |
| Tie the free end of the wire around the Ameristat bag.Ensure that the wire lies smooth and straight from the Wire Start Clamp, across the 2 Wire Clamp Bases and over the Clevis Pin. The edge of the wire should touch the edges of the 2X Wire Jig Combs ([D12009089](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=92753)) as shown in Figure 22.Keep the bag with the Test Weights hanging on the wire. | | | Wires against Wire Jig Comb  D1200909  Fig 90: Hang Weight | |
| **Place the Second Wire** Repeat Steps 5-13 for the second wire. Note that the arrangement of the Wire Start Clamps and the Clevis Pin is reversed from the first wire segment. **Clamp the Wires** On top of the two wires:2X [D1200188](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=86671) Wire Clamp Blank Top4X SHCS, #8-32 X 0.625” Long, Ag-Plated  * 4X #8 Flat Washers   Keep the Wire Clamp Blank Tops aligned with the Wire Clamp Mount using a Machinist’s Square. Keep the inside faces of each pair of Wire Clamp Blank Tops aligned using Shims.  Torque the SHCS to 30 in-lb. | Fig 91: Installing the 2nd Wire | | | |
| Keep the bags with the Test Weights hanging on the wires for at least 5 minutes after torqueing the Wire Clamps. | | | | |
| Torque the 2X SHCS in each of the 2 Wire Start Clamps near the Clevis Pins to 6 in-lb.Cut the wires just outboard of the 2 Lower Wire Clamps, making four cuts total. Make the cuts as close as possible to the Wire Clamps.Remove the Lower Wire Assembly from the Lower Wire Jig. Loosen the 2X inboard SHCS first, then loosen the 2X outboard SHCS. Only SSTL SHCS should be loosened; do NOT loosen any Ag-Plated SSTL SHCS. Carefully remove the 2X Wire Jig Combs. | Loosen inboard Screw first  Cut  Cut  Fig 92: Measuring and cutting, first Wire | | | |
| Carefully store the completed Lower Wire Assembly.Replace the 2X Wire Jig Combs and 4X SHCS that were removed in Step 19.Loosen the Ag-Plated SSTL SHCS in each of the Wire Start Clamps. Remove the Ameristat bags with the Test Weights from the leftover wire. Dispose of the 4 sections of leftover wire. | | | | Fig 93: Completed Lower Wire Assembly |

# Suspending the Masses

## Procedure

|  |  |  |
| --- | --- | --- |
| 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 94: 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 95: 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 96: 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 SHCS counterclockwise 1 ¼ turns, to leave a 1 mm gap with the Upper Mass. | Fig 97: 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 3 turns each, to leave a 2mm gap at the Lower Blades.Replace the 2 Magnet Holders when finished. | Fig 98: Top View / Adjusting Blade Guard Screws    Fig 99: 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 100: Suspending the Upper Blades | |

# 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.*

|  |  |
| --- | --- |
|  |  |
|  | (Intermediate Mass with addable weights  drawing in progress 1/2012)    Fig 101: Intermediate Mass with Add-on Masses |
|  | Fig 102: HSTS Library of Clamps |
|  | Screw Drive  C-Clamp  Fig 103: Adjusting Upper Wire Clamps to address Pitch |
|  | **IMG_1612**  **Fig 104: Using Laser & Target to adjust Pitch** |
|  | Pitch Mass  Fig 105: Adjusting the Pitch Mass |

## Related 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.

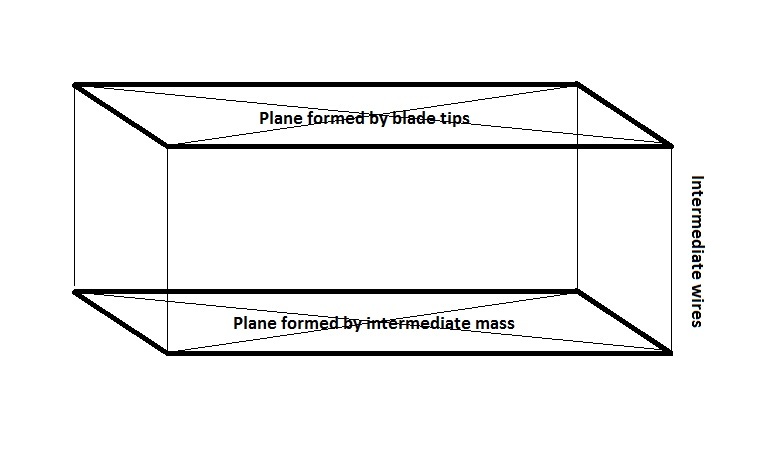
## Upper Mass

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.

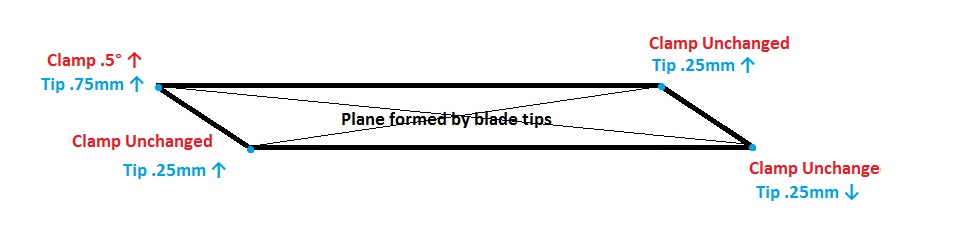
Once this is done, the blade tips should all be equal distance from the intermediate mass. This is guaranteed by the assumption that the intermediate wires are all the same length. Using this assumption, we can see that if the clamp holes in the intermediate mass are drilled straight, then the blade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

# Removing the Suspended Components

# Creep Baking the Upper and Lower Blades

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.

## Related 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

|  |  |
| --- | --- |
| 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 106: 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 107: EQ Stop Screws contact Blades |

|  |  |  |
| --- | --- | --- |
| 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 108: Blade Pulldown Support    Blade Pulldown Supports  Fig 109: 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 110: 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 111: 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 112: 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 113: 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 114: 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 115: Upper Mass raised within Coil Holder | |
| Fully retract the 4 Adjustment Screws within the 4 Screw Drives. | | **Fig 116: Top View – 4 Screws Retracted**    Fig 117: Side View – 4 Screws retracted | |
| Disconnect the Upper Wire Assemblies:  * Remove the 4 C-Clamp Screws at the Upper Mass | | Fig 118: 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 119: Upper Wires fed downward      Fig 120: 2 Upper Wire Assemblies removed | |

|  |  |
| --- | --- |
| Fully extend the 8 Screws within the lower 4 Barrel EQ Stops. | Fig 121: 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 122: 4 Screws to remove |
| Extend the 4 Blade Guard Screws until they just touch the Lower Blades. | Fig 123: Top View - 4 Blade Guard Screws    Fig 124: 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 125: 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 126: Lower Clamps of Intermediate Wires |
| Remove the Upper Face EQ Stop from in front of the Intermediate Mass. | Fig 127: 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 128: Bottom View – L-Clamp Screws          Fig 129: 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 130: 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 131: 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 132: 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 133: 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

## Related 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 | Bake Oven with Thermocouple |
| 1 | Ea | NA | Heat Lamp, 120W Bulb (for magnet repair) |

## 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 134: 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 135: 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=) Intermediate Mass Magnet/Standoff assemblies as per the [E990196](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=E990196&version=) Preparation procedure. Use nickel-plated magnets for all Intermediate Mass Assemblies. | Fig 136: 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 137: 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 138: Top of Mass identified by Hole Pattern** | **Fig 139: 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 12 to 16 hours.Carefully remove the 4 Plungers from their Bushings, and remove the Fixture from the Mass/Optic.Place the Intermediate Mass in a Bake Oven with a thermocouple. Cure the Epoxy at 34**°**C for 3 to 4 hours, ramping the temperature up at the beginning and down at the end by no more than 1.5**°**C per minute. Use the oven thermocouple to monitor the temperature.The assembly process is complete. | |

# Bonding Magnet Assemblies to Lower Masses

## Related 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 | Bake Oven with Thermocouple |
| 1 | Ea | NA | Heat Lamp, 120w Bulb (for magnet repair) |

## Procedure

Notes:

* Glue Magnets after 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=) Lower Mass Magnet/Standoff assemblies as per [E990196](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=E990196&version=) Preparation procedure. For metal dummy masses, use unplated magnets; for glass optics, use nickel-plated magnets. | | **Fig 140: 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 141: 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 142: 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 143: 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 144: 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 145: HSTS Lower Mass Assembly | Magnet  Fig 146: 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 12 to 16 hours.Carefully remove the 4 Plungers from their Bushings, and remove the Fixture from the Mass/Optic.Place the Mass/Optic in a Bake Oven with a thermocouple. Cure the Epoxy at 34**°**C for 3 to 4 hours, ramping the temperature up at the beginning and down at the end by no more than 1.5**°**C per minute. Use the oven thermocouple to monitor the temperature.The assembly process is complete. | Top of Mass    **N**  **S**  **N**  **S**  **Fig 147: Magnet Polarity Layout** |

# Reinstalling the Suspended Components

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

## Procedure

|  |  |
| --- | --- |
| AOSEMS are assembled in LH and RH configurations per section **Error! Reference source not found.**. Note the configuration at each location within the Weldment.The AOSEM 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=)AOSEM 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=)AOSEM 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=)AOSEM 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 148: Rear view of Weldment** |

# Installing AOSEMs and BOSEMs

## Related 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

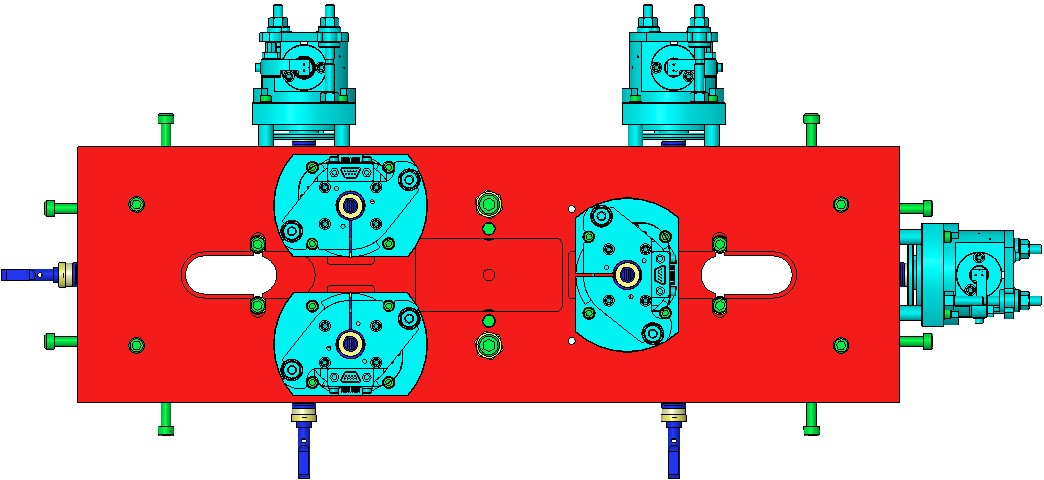
|  |  |  |  |
| --- | --- | --- | --- |
| **Qty** | **U** | **ID** | **Description** |
| 8 | Ea | [D0901065](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=2607) | **AOSEM Assembly** |
| 6 | Ea | [D060218](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=4018) | **BOSEM Assembly** |
| 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 149: BOSEMS mounted on Coil Holder |

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



N/S indicates polarity of the outward-facing side of the magnet

**S**

**S**

**N**

**S**

**N**

**S**

**+X**

**+Y**

Fig 150: Top View of Upper Mass and BOSEMS

|  |  |
| --- | --- |
| Place 4 AOSEMs in the Brackets behind the Intermediate Mass. Place another 4 AOSEMs in the Brackets behind the Lower Mass or Optic. Position each AOSEM such that it is centered around its magnet. | Fig 151: AOSEMs installed in Brackets |

# Metal-Build Testing

# Storage and Transport

# Replacing the Lower Mass with the Optic

## Related 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 152: 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 153: 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 the wires intact.

### 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=). Cover all glass tips with PFA slide covers (part number TBD).

### 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 and the secondary prisms. Replace the front stops and brackets. Back down on the bottom EQ stops, until the optic is just suspended.

### 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.

### Adjust all earthquake stops on the Intermediate and Lower Masses to have a gap of approximately 0.75 mm (between ½ and ¾ of a turn for ¼-20 earthquake stop screws).

### Measure the distance from the face of the optic to the base plate of the Structural Weldment.

|  |  |
| --- | --- |
| IMG_1378  Fig 154: Prototype Small Triple Suspension | IMG_1610  Fig 155: Prototype Small Triple Suspension with Control System |

# Glass-Build Testing and Installation into Chamber

Placeholder