LIGO LABORATORY
California Institute of Technology
1200 E. California Blvd.
Pasadena, CA 91125

Statement of Work
Fabrication of Flexure Rods and Cups for Advanced LIGO BSC-ISI

The following documents are incorporated into and made a part this purchase order. Click on the following LIGO Document Control Center (DCC) links to access these documents or go on line to the LIGO Public DCC at https://dcc.ligo.org/ to access the DCC#.

1.0 Terms:

DCC #	*Description*
C080185-v1	Laser Interferometer Gravitational Wave Observatory (LIGO) Commercial Items or Services Contract General Provisions California Institute of Technology "Institute", LIGO Rev 11/12/08
F0810001-v4	Technical Direction Memorandum.

2.0 Quality Control:

DCC #	*Description*
Q0900001-v4	Advanced LIGO Supplier Quality Requirements, dated 2/10/10, describes following contractor/supplier QA/QC actions for this procurement:

☐	3.1 Pre-Award Inspection	☒	3.9 Discrepant Material Storage	☒	4.4 Calibration Program
☒	3.2 Supplier In Process Quality Control	☒	3.10 Quality Records	☐	4.5 Critical Interface
☒	3.3 In Process Inspection	☐	3.11 Drawing and Specification Change Control	☒	4.6 Cleanliness
☒	3.4 Pre-Ship Inspection	☐	3.12 Welding Certification	☒	4.7 Packaging
☒	3.5 Receiving Inspection	☒	3.13 End Item Data Package (including Certifications of Compliance)	☒	4.8 Storage
☒	3.6 Discrepant Material	☐	4.1 Design Verification	☒	4.9 Transport
☒	3.7 Material Review Action	☒	4.2 Raw Material Procurement	☐	4.10 Customs
☒	3.8 Material Review Actions at Contractor	☒	4.3 Traceability of Materials		

For the above list the Supplier shall: 1) Identify the corresponding sections/paragraphs in their existing QA/QC system 2) meet or exceed the design requirements contained in the attached engineering documents for each area called out.

3.0 End Item Data Package:

At the time of delivery of the parts, the Supplier shall also provide the following data, as a minimum:

- Any as-built modifications (with approval of the LIGO Contracting Officer) as mark-ups to the drawings
- Material certifications
- Dimensional & QC inspection reports—this shall include a report showing that parts have been inspected and fall within specified tolerances.
- Heat treatment certification
- Material hardness measurements
- Electroless nickel plating process description
- Certificate or statement of compliance with all contract and drawing process restrictions.

4.0 Included Documents:

The drawings cited below are only partially dimensioned. In addition to the drawings, the contractor will be provided with CAD solid models of the parts (SolidWorks Professional 2009, SP5.0)

DCC #	*Description*
D0901755-v1	Flexure Cup, Stage 0-1
D0901757-v1	Flexure Rod, Stage 0-1
D0901503-v1	Flexure Cup, Stage 1-2
D0901758-v1	Flexure Rod, Stage 1-2
E0900023-v9	Manufacturing Process for Cantilever Spring Blades for Advanced LIGO
E0900364-v1	Metal components intended for use in the AdvLIGO Vacuum System

5.0 Scope:

This RFQ is for the fabrication of four (4) unique parts per drawings included in this package. These parts are made from maraging steel and will be nickel plated in accordance with the included drawings and specifications. These parts will be used in the vacuum system as part of the BSC ISI system for Advanced LIGO.

6.0 Quantity Required:

D0901757-v1	flexure rod stage 0-1	45
D0901758-v1	flexure rod stage 1-2	45
D0901755-v1	flexure cup stage 0-1	180
D0901503-v1	flexure cup stage 1-2	180

7.0 Delivery Requirements:

The deliveries are FOB at these destinations, i.e. the contractor has responsibility for shipping title and control of goods until they are delivered and the transportation has been completed. The contractor selects the carrier and is responsible for the risk of transportation and for filing claims for loss or damage.

Shipping Locations:

These items will be shipped to:

MIT LIGO (MIT)
c/o Myron MacInnis
NW-17
175 Albany St
Cambridge MA 02139

and

LIGO Livingston Observatory (LLO)
Attn: Joe Hanson and Tom Gentry
19100 LIGO Lane
Livingston, LA 70754

and

LIGO Hanford Observatory (LHO)
Attn: Hugh Radkins and Jodi Fauver
127124 North Route 10
Richland, WA 99354

Shipping Containers:
The contractor is responsible for providing shipping containers and transportation which protects these parts from damage from the transportation environment (weather, handling, accidents, etc.). Mating edges of parts should be especially protected from damage during shipping.

8.0 Manufacturing:

8.1 Precedence

The Statement of Work (SOW) sections below regarding processing or fabrication of the parts are meant to convey the scope and nature of the requested work. If there is a conflict between this SOW and the drawing, the drawing has precedence. The parts are to be produced using the CAD models which will be provided to the contractor upon award. If there are discrepancies between the drawings and the CAD model, the model takes precedence.

The order of the manufacturing process sequence is important. The order of the sequence is as listed below.

8.2 Restrictions

- Machine all surfaces to remove oxides and mill finish. Abrasive removal techniques are not acceptable.
- All machining fluids must be fully synthetic, water soluble (not simply water miscible) and free of sulfur, chlorine, and silicone.
- Thoroughly clean part to remove all oil, grease, dirt, and chips with soap and water. Follow with solvent (acetone) wipe.

8.3 Materials

Material: start with maraging 300 (MIL-S-46850D), solution annealed. Intermediate machining and strain relief steps are acceptable.
Sets of three flexure rods, for each of the two types of flexure rods (D0901757 and D0901758), are to be taken from a single block of maraging and labeled as such. Each three successive serial numbers will have been taken from the same piece of maraging, e.g. 001, 002, 003 from one piece; 004, 005, 006 from one piece, etc.
(See section on "Marking" below)
All materials specified by drawings or SOW have been approved for use in the UHV environment in LIGO. No materials may be substituted or added without prior knowledge and testing by LIGO. Cast tooling plate is not permitted.

8.4 Machining

All parts are to be machined. No grinding or lapping with abrasive wheels, cloth or stones is permitted. No sanding of any type. No parts shall be cast or molded. Water soluble (not just water miscible) cutting fluid (lubrication) is to be used for all machining operations. The use of cutting fluids or lubricants, which contain sulfur, chlorine or silicone compounds is prohibited.

For flexure rods (D0901757 and D0901758):
Note: For Parts D0901757 and D0901758 all dimensions apply AFTER heat treatment, section 2.8 of LIGO E0900023-v9. This document describes blade springs; the flexures rods (D0901757 and D0901758) in this SOW will follow the same process.

The flexure rods (D0901757 and D0901758) must be rough cut oversize, followed by the heat treat process described in the next section of this SOW. Final machining is then required to finish dimensions. This two-step machining process is necessary to remove distortions that may occur during the heat treatment. No parts shall be cast or forged.
Material grain direction must be oriented as shown on drawing.

Flexure Cups (D0901755 and D0901503):
For Parts D0901755 and D0901503 all dimensions apply BEFORE heat treatment.

Cleaning and cleanliness references in sections 2.2 and 2.4 of LIGO E090023-v8 refer to the process for maraging steel blade springs. This same process will be used for the flexure rods (D0901757 and D0901758) and flexure cups (D0901755 and D0901503) in this SOW.

8.5 Heat Treatment

See section 2.7 of E0900023-v9.
For flexure rods (D0901757 and D0901758):
After rough machining, heat treat as follows (inert atmosphere or vacuum is required):
-heat to 900degrees F (482 deg C)
-age for 6 hours
-air cool to room temperature.
Resulting hardness is 50-55 Rockwell C.

For flexure cups (D0901755 and D0901503):
After FINAL machining, heat treat as above.

8.6 Post Heat Treatment Machining- Flexure Rods (D0901757 and D0901758) Only

Please refer to section 8.5 above. All drawing dimensions apply post heat treatment.

8.7 Electroless Nickel Plating (Eless NP)

Refer to sections 2.5, 2.6 and 3.0 of LIGO E0900023-v9 for recommended electroless nickel plating procedure. The referenced document is for "springs", "blades" or "blade springs" and the same process will be used for the parts in this SOW.

Specific thickness and heat treatments are called out in E0900023-v9 and for that reason no specific class or grade of electroless nickel plating is defined. Due to outgassing concerns for UHV service, the specific process steps proposed by the plating company must be submitted to LIGO for approval. Once cleaned, the flexure rods must be kept in a clean condition, kept covered in clean stainless steel containers, or wrapped in UHV foil and handled carefully with latex gloves both prior to and after nickel plating. Cleaning should occur just prior to plating.

8.8 Bake to Prevent Hydrogen Embrittlement

Refer to LIGO E0900023-v9, section 2.6 which describes treatment of blade springs. This same process must be followed for the parts in this SOW.
The flexure rods and flexure cups must be baked soon after plating to avoid any problems associated with hydrogen embrittlement.
Handle the flexure rods and flexure cups only with latex gloves and expose them as little as possible to the environment.

Bake the flexure rods and flexure cups within 4 hours of the nickel plating for 12 hours at 150 deg C.

The bake to prevent hydrogen embrittlement must occur in a clean, non-shedding oven with stainless steel surfaces, or in a clean stainless steel box insert within the oven. An oven with re-circulating air is acceptable. Alternatively the contractor may use an oven which is continuously purged with argon gas, or HEPA and carbon filtered air, at a rate of about 10 liters/min through oil-free plumbing lines and valves.

8.9 Additional Bake to Remove Unbound Phosphorous

Refer to LIGO E0900023-v9, section 3. It describes the process used for blade springs and this same process should be used for the parts in this SOW.
Rinse flexure rods and flexure cups in a bath with iso-propanol and agitate (manually or ultrasonically) for 2 minutes prior to performing the bake process. Bake 275 deg C for 24 hours in air.

8.10 Finishing

Any required surface finish is defined in the drawings.
Localized scratches, digs and blemishes should be minimized.

8.11 Marking

Marking location is shown on the drawings.
All parts must be marked with a part number, revision code and serial number at the location indicated on the drawing. Marking is to be accomplished by mechanically scribing, stamping or engraving (no dyes or inks).
If not indicated in the drawing, mechanically scribe, stamp or engrave as follows:

<drawing number> - <revision code>, <type number if applicable>
<unique 3 digit serial number starting at 001 for the first part and incrementing thereafter>

As an example:

D0900026-v1
S/N – 001

The serial number must be a sequential 3-digit number, starting with 001, for each part.

Note: for Flexure Rods (D0901757 and D0901758): Each three successive serial numbers will have been taken from the same piece of maraging, e.g. 001, 002, 003 from one piece; 004, 005, 006 from one piece, etc.