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Statement of Work:

Pilot Test: Vacuum Bake and Hydrocarbon Residual Gas Assay

LIGO-C1105429-v3

1.0 Scope

The Advanced LIGO program (aLIGO, the Buyer) requires high vacuum mechanical and electronic components to be free of hydrocarbon and particulate contaminants, in order to maintain optic cleanliness. Nominal part preparation comprises chemical precision cleaning followed by high-vacuum bake at between 100 and 250C, depending upon material. A post-bake residual gas analysis (RGA) of the cooled bake chamber and contents, using a quadruple mass spectrometer, provides quality assurance to confirm that no volatile contaminants remain. Due to time and equipment limitations, the Buyer has elected to outsource a significant fraction of its production scale high-vacuum bakout and RGA work.

This **Pilot Test** is intended to demonstrate vendor capability for **high vacuum bake** of fabricated high-vacuum components, coupled with **post-bake residual gas analysis** hydrocarbon assay. Precision-cleaned sample fabrications will be provided to the vendor for vacuum bake at elevated temperature. This will be followed directly (without air-release) by ambient-temperature residual gas assay of the bake vessel and its contents.

On successful completion of this Pilot Test, the Buyer will invite the awardee(s) to propose provision of production vacuum bakeout services, through subsequent fixed price, batch, or time and material contracts which will be negotiated separately. Subject to vendor capacity, fabricator schedules, and other factors, LIGO expects in this later phase to require approximately two to four batch cycles per week over a sustained duration of approximately 18 months.

2.0 Document Access

Certain supplemental documents and specifications are incorporated into and made part this Statement of Work. Click on highlighted document links, or enter the provided document numbers in the LIGO Public Document Control Center (DCC) at https://dcc.ligo.org/ , in order to obtain these documents.

3.0 Commercial Terms and Applicable LIGO Specifications

3.1 Applicable Documents

The following documents are invoked by this Statement of Work and define additional requirements integral to its scope:

- LIGO-C080185 LIGO Commercial Items or Services Contract General Provisions

- LIGO-E0900047 LIGO Contamination Control Plan (only sections applicable to ISO Class 5 Cleanroom protocols; Class A Vacuum Components; Particulate and Hydrocarbon contamination control; packing and shipment)
- LIGO-E080177 RGA Test Qualification for Vacuum Bake Loads

The following documents are provided strictly as technical reference material:

- LIGO-E960050 LIGO Vacuum Compatible Materials List
- LIGO-E960022 LIGO Vacuum Compatibility, Cleaning Methods and Qualification Procedures

3.2 Subcontracts

LIGO expects this work to be executed by direct employees of the Seller, at a facility owned or fully controlled by the Seller. No subcontracts are permitted without specific Buyer approval.

3.3 Quality System

The Seller should include a copy of their current ISO 9001, AS9100, or TS16949 certification in their submittal. Suppliers lacking current certification should submit a copy of their Quality Manual.

3.4 Buyer access

The Seller grants the Buyer non-escort access privileges to inspect all areas of the Seller facility where this work is being performed, during nominal business hours.

3.5 Contract Basis

The basic scope defined in Section 5.2 below, comprising **commissioning and qualification** of the oven system and **three complete bake and RGA evaluation cycles**, will be executed on a **firm fixed-price** basis.

Vendor labor, material markup, overhead, administrative, and profit rates are requested to allow pricing of optional future scope extension(s), at the Buyer's discretion, on a reimbursable **time and material** basis. Such extension(s) may be warranted, for example, to accommodate additional test cycles, or to explore unforeseen process variability.

4.0 Parts/Assemblies to be processed

The following examples represent different "large" LIGO component classes, for the purposes of determining vendor capability. Numerous smaller parts and assemblies will also be candidates. While capacity for baking the largest listed LIGO components is highly desirable, it is not necessarily required; vendors should clarify all present facility and equipment constraints with their submittals. Where applicable, any *future* potential for increased capacity (e.g., to accommodate the largest LIGO parts) should be indicated.

Final sample component selection will be based on vendor capacity and on production availability at the time of performance. Candidate sample components will be either Type 6061 or 2024 aluminum alloy, or Type 304 or 316 stainless steel, and may comprise welded subassemblies. Fabrication and weld details (if any) will conform to ASME best practices for high-vacuum service. Sample components will be provided to the vendor in precision-cleaned condition, as specified in LIGO-E0900047 (Sec. 3.1).

item	*Drawing ref*	*Dimensions (in.)*	*Material*
Optical Table, Down-Facing, BSC ISI	D0901516-v2	84 x 84 x 3	6061-T6
Base Plate, Stage 1, aLIGO BSC-ISI	D0902279-v2	79 x 74 x 2	6061-T6
BSC-ISI Stage 0 Monolithic Half Bottom	D0900894-v2	95 x 87 x 6	6061-T6
Structural Weldment, HLTS	D070442-v6	29 x 19 x 12	304L SS
SUS, Quad ETM/ITM, Upper Structure Weldment	D060492-v2	29 x 28 x 24	304L SS

Table 1: Some candidate aLIGO components for tests of vacuum bake processing capability

5.0 Requirements

5.1 Seller Equipment

- The Seller will commission and demonstrate at her/his facility a Vacuum Bake Oven (VBO) suitable for processing aLIGO sample component(s).
- The equipment design, specifications, and compatible Operating Procedure will be submitted by the Seller for aLIGO approval.
- This Procedure is expected to be comparable in both scope and principal process parameters to procedures given in LIGO-E960022 (Sec. 3.1), specifically those sections applicable to vacuum bake of aluminum alloy and stainless steel fabrications. Note that different process temperatures and soak times may be specified for these two material classes.
- The Vacuum Bake Oven shall have “Back to Atmosphere” re-pressurization systems which control gas velocities and avoid re-contaminating cleaned parts after bakeout.
- Stainless steel sintered metal muffler headers should be used to control high velocity jetting during re-pressurization.
- High purity dry nitrogen shall be used as the re-pressurization gas.
- All vacuum chamber seals, including loading access door(s), must be dry and un-lubricated.
- The Bake Oven vacuum pumping system and auxiliary/instrumentation support pumping systems must be 100% lubricant-free. Cryopumps, dry or magnetic bearing turbo pumps, and dry mechanical roughing and backing pumps are acceptable.
- A hydrocarbon-free and particulate-controlled ambient environment, and corresponding “cleanroom” work protocols, will be established for loading and unloading the VBO, staging parts for loading, and packaging and sealing processed parts for transport.

- Environmental particulate controls and practices shall conform to ISO Standard 14644 Class 5, as adapted for aLIGO under LIGO-E0900047 (Sec. 3.1), in all areas where exposed parts will be handled, stored or processed[1].
- Vacuum Bake Ovens shall be pre-cleaned to eliminate residual hydrocarbon and particulate contamination from any prior use.
- The Bake Oven process area shall be located away from any other "dirty processes" (welding, grinding, solvent cleaning, etc.) in the Vendor's facility.
- If needed, the Bake Oven shall be purged with hydrocarbon free/ Class 5 particulate free air during periods of loading and unloading.

5.2 Process

- The Seller will perform a minimum of **three full bake cycles** with this equipment. Each cycle will comprise:
  - Loading of components (if any)
  - Sealing of chamber and leak test as required
  - Pump down to specified high vacuum
  - Controlled thermal ramp to bake temperature
  - Verification of temperature uniformity and vacuum integrity
  - Soak at regulated temperature
  - Controlled cooldown to ambient temperature
  - Calibrated mass-spectrometer analysis of residual gas (RGA)
  - Controlled backfill with dry, clean gas to ambient pressure
  - Opening, unloading and packaging of contents (if any) for shipment

- The three (minimum) demonstration cycles will comprise:
  - An initial empty "background" with no LIGO-supplied payload
  - A sample degassing bake with LIGO-supplied sample components, and
  - A final empty "background" bake to verify repeatability.
- The Bake Oven pumping system shall be capable of maintaining total pressure below 1e-4 torr throughout each cycle, including peak payload degassing at elevated temperature.
- Final process pressure on return to ambient temperature must be adequate to support residual gas analysis as specified below.
- Each cycle's sample RGA, the background of the mass spectrometer system itself, and its calibration must conform to LIGO specification LIGO-E080177 (Sec. 3.1).

[1] Substitutions for listed *Cleanroom Materials/Supplies* and *Cleanroom Garb* (clothing) in LIGO-E0900047 (Sec. 3.1) are **not** allowed unless approved by LIGO. Alternatively, LIGO can supply approved *Cleanroom Materials/Supplies* and *Cleanroom Garb* (clothing) at cost.

- Additional process cycles may be required if outgas rates or residual hydrocarbon signatures exceeding documented limits are detected. Time and material rates for such additional cycles should be provided the Seller's submittal. Foreseeable facility or schedule constraints deemed likely to affect potential test extension should also be provided.
- On completion of testing, all furnished sample components will be handled and repackaged according to specifications for handling "Class "A" Vacuum Components" given in LIGO-E960022 (Sec. 3.1), then crated appropriately and returned to the Buyer.

5.3 Resources furnished by Buyer

- The Buyer will provide representative sample metal components for vacuum processing in the Seller's facility.
- If required, the Buyer will lend to the Seller a mass-spectrometer Residual Gas Analyzer instrument, along with corresponding readout electronics and calibration apparatus, and will train the Seller in its operation at the Seller facility or other mutually agreed location.
- Interface flange(s), portable pumping systems, isolation valve(s), power and cooling as may be required to operate this furnished instrumentation at the Seller's facility, will be furnished by the Seller according to Buyer specifications.
- All Buyer-furnished equipment and materials will remain property of the Buyer, and will be returned to the Buyer upon completion or termination of the subject contract.

5.4 End item data

The Seller will furnish a report documenting the pilot test, comprising, at a minimum:

- Commissioning data for the VBO, including
    - Physical arrangement, schematics and PID diagrams (as applicable)
    - Heating and cooling rate measurements and calculations
    - Temperature uniformity of the vessel and interior points (if applicable)
    - Ramp overshoot and peak temperature excursions during soak at set point
    - Pumpdown pressure curves (including process volume, roughing and forelines, and multiple gauge types, as applicable)
    - Measured and/or calculated pumping fluences for typical operating (bake) and measuring (RGA) pressure regimes and volume/valve configurations
    - Make, model and principal specifications of major purchased components
- Diagrams and digital photographs of the apparatus and the test environment
- Documentation of environmental cleanliness, as outlined in LIGO-E0900047 (Sec. 3.1). This may include, for example, calibrated airborne particle counts in the vicinity of the oven, in staging or packing areas, and in the chamber backfill gas flow stream.
- Residual gas spectra corresponding to the Process cycles outlined above. All data required for interpretation of spectra in terms of sample flux will be provided. These data will include, for example, scans with calibrated leaks on and off, time accumulation tests, pump fluence calibrations, area and volume calculations, etc.
- Other information deemed pertinent to further LIGO applications and/or escalation toward a production process.
- Data will be provided in digital form wherever feasible, using non-proprietary or industry standard formats.
- Data will remain property of the Buyer, except insofar as limited by any qualifying non-disclosure agreement executed between the parties.

6.0 Sample schedule

A formal performance schedule will be negotiated at time of award. The following *sample* schedule, consistent with LIGO delivery requirements, is provided for reference:

Task	***Date (weeks A.R.O)***
Submit VBO configuration & draft operating procedure	4
Complete commissioning of VBO and RGA system	6
Process cycle 1 complete	8
Receive sample components	8
Process cycle 2 complete	9
Process cycle 3 complete	10
Submit test report & ship back furnished materials	12

Table 2: Sample performance schedule

7.0 Proposal Information

We request that proposers address the following information with their submittals:

- Firm fixed-price offer for the basic Pilot Test scope defined in Section 5.2
- Pilot Test performance schedule (including time to mobilize, clean and prepare VBO, instruments and facilities)
- All-in Time and Material markups and rates for each staff category expected to participate
- VBO technical information, including:
    - payload envelope dimensions for each chamber
    - pumping system type(s), configuration(s), speed(s), and ultimate pressure(s)
    - backfill system type, configuration, source and filtration
    - heating system and process controls
    - evacuation piping and instrumentation
    - access door seal type
    - sample operating procedure
    - standard (or typical prior) QA and cleanliness assessment methods and results
- RGA operation and interpretation experience
- ISO Class 5 cleanroom experience, including any applicable existing facilities
- Description of any similar vacuum bakeout work performed in the past