BROOKHAVEN NATIONAL LABORATORY

STATEMENT OF WORK

STRETCHED-WIRE MAGNETIC MEASUREMENT BENCH

APPROVALS

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REVISION CONTROL SHEET

REVISION	DESCRIPTION	DATE	WRITTEN BY	APPROVED BY
A	Initial Release	07/15/2026	F. DePaola	See cover page

STRETCHED-WIRE MAGNET MEASUREMENT BENCH

Section 1: Introduction

The National Synchrotron Light Source II (NSLS-II) facility at Brookhaven National Laboratory (BNL) is planning for an upgrade of its storage ring (792-m in circumference) consisting of approximately 800 electromagnets placed in 30 identical cells. For the upgrade these electromagnets will be replaced by ~ 3000 new magnets comprising mostly of combined-function permanent-magnet based quadrupoles. High precision magnetic measurement systems will be used to measure the magnetic field strength, field homogeneity, magnetic center, and higher field harmonics of each magnet. A stretch wire magnetic measurement bench is being procured as one element of the full magnetic measurement lab.

Section 2: Scope of Work

The Contractor shall provide the facility, equipment, construction of any needed tools and fixtures, personnel, and labor needed to manufacture, inspect, test, and deliver the high-performance stretched-wire magnetic measurement bench specified in this document.

Any nonconforming item(s) shall be clearly identified, isolated, and placed in a secured location by the Contractor. The Contractor shall document the nonconformance and send it to the BNL Technical Representative for review and disposition.

Section 3: System Architecture & Measurement Principle

The measurement system shall utilize the single stretched-wire technique, moving a tensioned conducting wire inside the magnet aperture to measure the change in magnetic flux. The system must meet the following criteria:

- **Wire Loop:** utilize a single stretched wire as a pickup loop, eliminating the requirement for dedicated, magnet-specific measuring coils.
- **Motion Profile:** support precise circular and linear motion profiles to enable harmonic multipole analysis and line-scan field integration.
- **Stability:** feature high stability against environmental vibrations and thermal expansion to ensure long-term mechanical reproducibility.

4. Target Performance Specifications

The system must meet or exceed the following accuracy and reproducibility targets for multipole magnets with apertures larger than 30 mm:

Parameter	Reproducibility	Absolute Accuracy	Conditions / Comments

Magnetic Center Position	±5 µm	±25 µm	Requires precision measurement arm / fiducial reference
Magnetic Roll Angle	±0.05 mRad	±0.1 mRad	With offset calibration applied
Magnetic Integral Strength	0.01%	0.05%	Circular measurement, field integral ≥ 0.03 Tm
Higher Harmonic Content		0.01%	Per higher harmonic multipole term relative to main harmonic

5. Motion Control & Mechanical Specifications

The system shall be equipped with two independent towers, each containing motorized high-precision horizontal and vertical linear stages configured to minimize mechanical crosstalk and vibration transmission.

5.1 Stage Performance Requirements

Stage Axis	Minimum Range	Absolute Accuracy	Reproducibility	Maximum Speed
Horizontal Stage	≥ 250 mm	≤ ±5 µm	≤ 1 µm	≥ 20 mm/s
Vertical Stage	≥ 250 mm	≤ ±5 µm	≤ 1 µm	≥ 20 mm/s

5.2 Bench Capacity & Envelope

- **Base Structure:** Constructed from a high-mass precision-ground granite block (or equivalent highly temperature-stable, vibration-dampening material).
- **Tower Adjustment:** Supported on rails or low-friction guides to facilitate rapid adjustment of the inter-tower distance.
- **Measurement Diameter:** Accommodate a maximum measurement diameter of up to 200 mm.
- **Magnet & Wire Capacity:** Support magnets with physical lengths up to 1600 mm.
- **Weight Capacity:** Capable of supporting magnets weighing up to 4000 kg directly on the main bench structure, and weighing up to 100 kg on the adjustable magnet cradle base.
- **Beam Height:** Accommodation for a maximum magnet beam height of 500 mm (including support structures).

6. Control Electronics & Software Environment

6.1 Instrumentation Requirements

- **Voltage Integration:** A high-precision, low-noise integrating nano-voltmeter optimized for small flux change measurements.
- **Driver Cabinet:** Multi-axis stepper/servo motor controllers fully integrated into a standard 19-inch rack enclosure.
- **Interfaces:** Modern, reliable data interfaces including Ethernet and GPIB (or industry-standard equivalents).

6.2 Functional Requirements

- **Measurement Routines:** Full automated control over the linear motion stages for standard scan routines, including circular scans (multipoles) and point/line scans (dipoles/steerers).
- **Magnetic Measurements:** Built-in capability for automated magnetic centering and roll-angle calculation within multipole fields. From a list of current setpoints, the system shall automatically acquire magnetic measurements at each current value. The software shall automatically generate plots of field integral, magnetic center position, roll angle, and harmonic content as a function of the current.
- **Wire Management:** Standalone technique for wire tension measurement and adjustment, and tension optimization via eigenfrequency tuning.
- **Power Supply Integration:** Provision for automated power supply control (minimum 1 main supply and 4 trim supplies) with automated degaussing cycles through iterative damped current cycling.

7. Deliverables & Standard Package Accessories

At least one week before shipping, the contractor shall provide all documentation to BNL for review and shipping authorization. The documentation shall include all test data on a selected magnet to confirm that all specifications listed in Sections 3-6 have been met.

The supplier shall provide a complete, turnkey system consisting of:

- Precision granite base structure with integrated dual-axis X-Y motion towers.
- Pre-wired 19-inch instrument control cabinet containing all necessary power stages, controllers, and nanovoltmeters.
- A minimum of 50 meters of high-tensile measurement wire (e.g., Titanium/Aluminum/Vanadium alloy or high-performance equivalent).
- An adjustable magnet cradle base offering a minimum of ±10 mm adjustment range in X, Y, and Z axes, with a load capacity of at least 1500 kg.
- Control and analysis software package pre-installed on a modern PC workstation.
- Full interconnecting signal and power cabling, comprehensive operating manuals, and acceptance test procedures.
- High level (layout) CAD models and drawings of the full system.
- Calibration and test data.
- Installation and operating manuals

Section 8: Progress Reporting

The Contractor shall communicate technical and manufacturing progress to the designated BNL Technical Representative every three weeks. Reports shall be delivered via email or conference call, as mutually agreed upon.

Section 9: Quality Assurance Requirements

The Contractor shall provide a comprehensive end-item documentation package serving as objective evidence of complete compliance with the BNL contract requirements. The documentation package shall be fully traceable to the physical items supplied and must include all records specified in Deliverables Section 7.

Section 10: Export Control Disclaimer Statement

This information is controlled by the U.S. Department of Commerce Export Administration Regulations 15 CFR Parts 730-774 as EAR99 Technology.