Specifications for a Wideband Underwater Acoustic Target

1. **Introduction.** The Naval Research Laboratory is seeking to acquire the hardware necessary to complete the development of a controlled and calibrated underwater target simulator capable of operating over a very broad frequency range. This device shall be capable of operating either as a simulated target (i.e., echo repeater) or as a broadband, coherent source. It is intended to support a variety of investigations relevant to active Navy sonar performance in littoral, reverberation-limited environments. The baseline system must include all components and equipment necessary to configure a system that is safely transportable, deployable, and retrievable by end-users. It will be deployed from oceanographic research vessels such as those operated by the University-National Oceanographic Laboratory System (UNOLS), the North Atlantic Treaty Organization, and the U. S. Navy.

   The contractor shall furnish a system that includes a tow body, housing source and receiver components and engineering sensors, electromechanical tow and deck cables, power systems (to provide electrical power to sources, hydrophones, and engineering sensors), and a handling system consisting of a winch and slip rings.

2. **Background.** The Naval Research Laboratory (NRL) has developed a computer system and software that has been used to implement an echo repeater capability for at-sea active acoustics measurements. Input to the NRL system consists of the analog voltage from one or more hydrophones. NRL's software performs signal detection following analog-to-digital conversion of the hydrophone voltage(s). Once an incoming signal is detected and stored, the user has the option to transmit the captured signal, a time-reversed copy of the captured signal, one or more pre-built waveforms different from the captured signal, or a combination of captured and pre-built waveforms. Signals to be transmitted are output by the NRL system as an analog voltage (nominally in the range of 0 to 1 V RMS), which is fed to a power amplifier driving a transducer. The purpose of this procurement is to acquire the source and receiver components that, when integrated with Laboratory's existing computer system, will form a complete wideband target simulator.

3. **General Requirements**. The contractor shall provide a tow body that houses the following system components: (1) one or more source projectors, (2) a short receiver array for acquiring signals, (3) a desensitized hydrophone for monitoring source transmission levels, and (4) engineering sensors to monitor the depth and orientation of the tow body.
   a. **Construction:** The unit must be ruggedized for operation in the harsh marine environment and must be deployable, operable, and retrievable in conditions up to and including sea state 3.
   b. **Physical size:**
      i. **Deployment:** The size of the in-water unit must be such that it is possible to deploy it from the stern A-frame of class II/III UNOLS vessels. A typical A-frame on such a vessel has a vertical clearance of 17 feet above the deck, a horizontal clearance of 11 feet between legs, and extends at least 4 feet beyond the edge of the fantail when fully extended aft. If a block attached to

the A-frame is required for deployment of the device, the size of the block, which depends on the minimum bending diameter of the tow cable, must also be taken into account.

ii. **Shipping:** The sizes of all components of the system must be such that they can be shipped without special permits on a standard flatbed trailer.

c. **Weak link:** If the breaking strength of the armored tow cable (see paragraph 8) exceeds 30,000 pounds, there must be a weak link between the tow cable and the tow body, and this weak link must break when a tension of 30,000 pounds is exerted on it. The specification is designed to guarantee that the unit shall comply with the Code of Federal Regulations 46 CFR 189.35.9.

d. **Operational depth:** The unit must meet all specifications and the sources must function without cavitation when deployed in the ocean between depths of 20 and 200 meters. Preference will been given to units that can function and meet all specifications at depths to 300 meters; however, the offeror is not required to propose a system meeting the 300-meter depth requirement if doing so would add excessively to the cost of the system.

e. **Towability:** During any given deployment, the target/source will be operated in either a "stationary" mode (i.e., drifting, moored, or station keeping) or in a "towed" mode. While it is preferable to be able to switch between modes (stationary vs towed) without bringing the unit on deck, the contractor may provide separate tow cable (mechanical) attachment points for stationary and towed operations and require an on-deck reconfiguration when switching modes if doing so ensures stable operation in both modes. However, no such reconfiguration shall be required if the purpose of the tow is merely to transit from one station to another without transmitting enroute.

i. **Stationary mode:** If a separate mechanical attachment point is provided for stationary operations, it must still be possible to safely tow the target/source from station to station at speeds up to 4 knots with the tow cable attached to this point and without damaging the unit. That is, it must be possible to operate the target/source in stationary mode at a series of stations and transit between them without bringing the unit on deck and reconfiguring it and without causing any damage to the unit.

ii. **Towed mode:**

1. **Tow speed:** At any operational depth, the unit must be fully functional and meet all specifications when towed at speeds from 0 to 4 knots.
2. **Vertical tilt:** When there are source transmissions while the unit is under tow, vertical tilt of the tow body is potentially an issue if any source is not omni-directional in the vertical. The vertical tilt must not be so great that the system fails to comply with the ***horizontal*** directionality specification in paragraph 4.d. For the minimum vertical 6-dB down beamwidth of 90 degrees, a vertical tilt of no more than 25 degrees is acceptable. If no source has a vertical 6-dB down beamwidth of less than 120 degrees, a vertical tilt of no more than 30 degrees is acceptable. If no source has a vertical 6-dB down

beamwidth of less than 150 degrees, a vertical tilt of no more than 35 degrees is acceptable.

3. **Provision for additional weight:** If additional tensioning weight is required to meet the vertical tilt requirement when under tow, there must be a provision for adding the required additional weight to the tow body itself, and it must be possible to easily add the required weight to the tow body -- or remove it from the tow body -- with the tow body on deck during operations.
4. **Depth stability:** When towed in a straight line at a constant speed up to 4 kts in sea state 0, the depth of the tow body shall change by no more than two meters.

f. **Weight:** In order to (1) keep tension on the weak link (or cable) to an acceptable level, and (2) remain well within the lifting capability of the typical stern A-frame, the combined weight in air of the tow body (fully instrumented) **and** any additional weight needed for stable towing must not exceed 3000 pounds.

g. **Additional attachment points:** In addition to one or more points for mechanically attaching the tow cable to the tow body, a minimum of two additional attachment points shall be provided to be used for securing the device on deck and for affixing tag lines during deployment and recovery of the system.

h. **Operating temperature and humidity:** All in-water components, together with tow cable, must function and meet all specifications in temperatures of 3 to 30 degrees Celsius. All laboratory components (e.g., amplifiers, filters, power supplies) must function and meet specifications in temperatures of 0 to 40 degrees Celsius and relative humidity up to 90 per cent.

i. **Storage temperature:** All system components must function and meet all specifications after being stored for an indefinite period of time in temperatures of 0 to 50 degrees Celsius.

j. **Warranty:** The system shall be warranted against defects in materials and workmanship for one year from date of delivery. The contractor shall repair or replace at no charge any part that proves to be defective during the warranty period. This warranty does not apply if the item has been damaged by accident or misuse.

4. **Source Requirements**. Ideally, the simulated target would include a single, omni-directional source; however, the target must operate over a very wide range of frequency spanning 200 Hz to 5000 Hz. It is unlikely that the required source level throughout such a wide range of frequency can be achieved cost effectively with a single omni-directional transducer. Therefore, in order to meet the frequency and source level requirements, it is acceptable to propose (1) multiple sources to cover the frequency band of operation, and (2) sources with vertical directivity to achieve the required source level in the horizontal plane.

Note: In the following specifications, the use of "source" denotes one or more identical projectors operating within a particular frequency band. [Thus, different "sources" have different resonance frequencies.] Each source may consist of more than one "projector".

[Thus, projectors comprising a source have the same characteristics (resonance frequency, source level, directivity, etc.).]

- **a. Source level:** The peak source level of the unit must be a minimum of 188 decibels re 1 micropascal at 1 meter for frequencies from 200 Hz to 5000 Hz.
- **b. Operating frequency range**: The source(s) must be operable over the interval from 200 Hz to 5000 Hz. Multiple sources, each operating in its own band, may be proposed to meet this requirement, and each source may consist of more than 1 projector element. In order to limit both the physical size and the complexity of the system, however, the 200-5000 Hz interval may be partitioned into at most three bands.
- **c. Frequency bands:** If the offeror proposes to meet the frequency-range and source-level requirements by using multiple sources operating in distinct bands that partition the interval from 200 to 5000 Hz, the offeror may choose the cross-over frequencies between bands subject to the following constraints:
  - **i.** There must be no more than 3 bands spanning the range from 200 to 5000 Hz.
  - **ii.** The interval from 380 Hz to 420 Hz must lie entirely within a single band.
  - **iii.** The interval from 900 Hz to 1100 Hz must lie entirely within a single band.
  - **iv.** The interval from 2000 Hz to 5000 Hz must lie entirely within a single band.
- **d. Horizontal directionality:** The projection system must be omni-directional in the horizontal plane for all frequencies from 200 to 5000 Hz. More precisely, for any frequency from 200 to 5000 Hz, the difference between the maximum and minimum values of the system's horizontal transmit voltage response function must be 2 decibels or less. If multiple sources are proposed, each source must satisfy this requirement within its band of operation.
- **e. Vertical directionality:** For all frequencies from 200 Hz to 5000 Hz, the projection system's vertical transmit voltage response function must have a 6-dB beamwidth of 90 degrees or greater with the maximum response occurring at horizontal. If multiple sources are proposed, each source must satisfy this requirement throughout its band of operation.
- **f. Signals and duty cycle:** The projection system must be capable of transmitting coded waveforms (such as continuous wave and frequency-modulated signals) having pulse lengths as short as 10 milliseconds and as long as 20 seconds. The duty cycle must be at least 10% when operating at full power.
- **g. Mechanical requirements:** For the purposes of testing and repair, each projector must be mounted within the tow body in such a way that it can be removed and/or replaced by end-users in the field. The contractor must provide as part of the system any special tools required to remove, install, or maintain projectors in the field.
- **h. Electrical connections:** Electrical attachment to the tow cable must be made using waterproof connectors that have strain-relief caps. These strain-relief caps must withstand a force of at least 50 pounds without disconnecting or compromising the electrical integrity of the attachment.
- **i. Power amplifier requirements:** The system must include one or more power amplifiers meeting the following specifications:

i. If multiple sources are proposed, there must be a separate power amplifier provided for each source. The driving signal from the NRL computer system shall be input at a single BNC connector. [The voltage of the supplied signal will be in the range of 0 to 1 volt RMS.]

ii. The maximum total harmonic distortion of each amplifier must not exceed 3%.

iii. The RMS noise of each amplifier must be at least 60 dB below the maximum output.

iv. Each amplifier must be ruggedized for operations at sea.

v. Each amplifier must have protection such that no combination of passive loads, input signals, or switch settings can cause the amplifier to fail.

vi. Each amplifier must include a switch that will allow the end-user to manually inhibit/enable that individual amplifier.

vii. Each amplifier must include the capability to inhibit/enable it with a TTL signal.

viii. Each amplifier must include both voltage and current monitors accessible via BNC connectors on the front panel.

j. Filters: A single driving voltage, in the range of 0 to 1 volt RMS, will be supplied by the NRL computer system. If multiple sources are proposed, the offeror must provide appropriate filters to ensure that individual sources are not driven by energy that is out of band.

5. Receiver Requirements. A short, vertical array of hydrophones must be included for acoustic signal acquisition. The array (as opposed to a single hydrophone) is intended to provide vertical directivity to enhance the system's ability to detect mid-frequency signals arriving at angles near horizontal. [It is understood that such an array, designed for mid frequencies, will not provide enhanced signal-to-noise at frequencies in the low end of the frequency range.]

a. Number of elements: The array shall consist of 4 identical hydrophones.

b. Element spacing: The center-to-center inter-element spacing shall be constant, between 0.15 meters (5.9 inches) and 0.25 meters (9.8 inches), and as close to 0.15 meters as practicable.

c. Location: The receiver array shall be located as close as practicable to the source. If multiple sources are proposed, it should be placed as close as practicable to the 5000 Hz source. The receiver array must be acoustically isolated from the tow body to reduce the effects of mechanically induced noise.

d. Operational depth: The array shall function and meet all specifications when deployed to any depth less than or equal to 300 meters.

e. Inter-element crosstalk: The signal crosstalk between any pair of hydrophones or engineering sensor channels shall be no greater than -60 decibels.

f. Hydrophones: Either voltage-mode or current-mode hydrophones may be proposed; however, in order to minimize the number of conductors required in the tow and deck cables, current-mode hydrophones are preferred. If current-mode hydrophones are proposed, current-to-voltage conversion shall take place in the top-

side receiver electronics enclosure (see paragraph 5.g below). If voltage-mode hydrophones are proposed: (1) the hydrophones must have differential output, (2) separate power leads to each hydrophone must be provided, and (3) the signal leads of each hydrophone must be shielded. Regardless of type, each hydrophone must meet the following requirements:

i. **Attachment:** The hydrophones shall be mounted in such a way that they are readily removable for repair or replacement. Electrical attachment to the array shall be made using waterproof electrical connectors that have strain relief caps. These strain relief caps shall withstand a force of 50 pounds without disconnecting or compromising its electrical integrity.

ii. **Sensitivity:** The nominal sensitivity of the hydrophone sensors shall be at least -180 decibels re 1 volt per micropascal.

iii. **Passband flatness:** Each hydrophone shall have a constant sensitivity to within ± 1 dB from 200 Hz to 5000 Hz. If the offeror proposes a system capable of operating at frequencies above 5000 Hz, then each hydrophone must also have a constant sensitivity to within ± 2 dB from 5000 Hz to the system's maximum operating frequency.

iv. **Uniformity:** The array shall be comprised of four identical hydrophones whose sensitivities vary by no more than 3 dB at all frequencies from 200 Hz to 5000 Hz. If the offeror proposes a system capable of operating at frequencies above 5000 Hz, then the hydrophone sensitivities must vary by no more than 5 dB from 5000 Hz to the system's maximum operating frequency.

v. **Self-noise:** The electrical self-noise of the assembled hydrophone/preamplifier/interface electronics, when operated in the system's highest gain setting, shall be sufficiently low that this self-noise, measured at the receiver system's output, shall not exceed 45 dB re 1 $\mu Pa^2/Hz$ throughout the frequency range from 200 to 500 Hz, and 25 dB re 1 $\mu Pa^2/Hz$ throughout the frequency range from 500 Hz to the system's maximum operating frequency (5000 Hz or greater).

g. **Receiver interface:** Top-side receiver electronics shall be housed in a rack-mountable enclosure that meets the following requirements:

i. **Power supply:** A DC power supply shall be included to provide power to the hydrophones.

ii. **Amplification:** It shall be possible to amplify the voltage signals of the hydrophones from 0 to 60 dB (or more) in steps of 10 dB (or finer). The same gain shall be applied to each of the four individual hydrophone channels and shall be controlled by a switch (or switches) located on the enclosure's front panel.

iii. **Selectable high-pass filtering:** High-pass filters shall be provided to filter low frequency components in the hydrophone voltage signals. The filtering shall be user-selectable (on/off) and controlled by a switch located on the front panel. The filter shall have a corner frequency of 185 Hz and a slope of 12 dB per octave. The same filtering shall be applied to all four individual hydrophone channels.

iv. **Output connectors:** The individual hydrophone voltage signals shall be accessible via BNC connectors mounted on the front panel of the enclosure.

v. **Test signal input:** A test signal input shall be provided for each hydrophone channel to allow proper system calibration. The externally provided test signal must be injected prior to any amplification or filtering stages in the receiver interface.

6. **Monitor Hydrophone Requirements.** A desensitized hydrophone must be included to monitor source transmissions. [Note: The monitor hydrophone is intended to provide a representation of the transmitted signal having the same frequency components and phase information, but it is not expected to provide a precise measure of SPL.] The monitor hydrophone must meet the following requirements:

   a. **Operational depth:** The monitor hydrophone shall function and meet all specifications when deployed to any depth less than or equal to 300 meters.

   b. **Hydrophone type:** Either a voltage-mode or current-mode hydrophone may be proposed; however, in order to minimize the number of conductors required in the tow and deck cables, a current-mode hydrophone is preferred. If a current-mode hydrophone is proposed, current-to-voltage conversion shall take place in the top-side receiver electronics enclosure (see paragraph 5.g above). If a voltage-mode hydrophone is proposed: (1) the hydrophone must have differential output, (2) separate power leads to it must be provided, and (3) the signal leads must be shielded.

   c. **Attachment:** The monitor hydrophone shall be mounted in such a way that it is readily removable for repair or replacement. Electrical attachment to the array shall be made using waterproof electrical connectors that have strain relief caps. These strain relief caps shall withstand a force of 50 pounds without disconnecting or compromising its electrical integrity.

   d. **Sensitivity:** The sensitivity must be such that its output does not overload during source transmissions at full power.

   e. **Passband flatness:** The monitor hydrophone shall have a constant sensitivity to within ± 1 dB from 200 Hz to 5000 Hz. If the offeror proposes a system capable of operating at frequencies above 5000 Hz, then the monitor hydrophone must also have constant sensitivity to within ± 2 dB from 5000 Hz to the system's maximum operating frequency.

   f. **Self-noise:** The electrical self-noise of the assembled hydrophone/preamplifier/interface electronics, when operated in the system's highest gain setting, shall be sufficiently low that this self-noise, measured at the receiver system's output, shall not exceed 45 dB re 1 $\mu Pa^2/Hz$ throughout the frequency range from 200 to 500 Hz and 25 dB re 1 $\mu Pa^2/Hz$ throughout the frequency range from 500 Hz to the system's maximum operating frequency (5000 Hz or greater).

   g. **Crosstalk:** The error produced in the monitor hydrophone output due to crosstalk from the projector power lines (and other sources) shall be no greater than 0.01 dB re 1 micropascal at full projector output.

h. **Monitor hydrophone interface:** Top-side electronics shall be housed in a rack-mountable enclosure. The same enclosure that houses the receiver array electronics may be used for this purpose.
   i. **Power supply:** A DC power supply shall be included to provide power to the monitor hydrophone. The same power supply that powers the receiver array hydrophones may be used for this purpose.
   ii. **Amplification:** It shall be possible to amplify the voltage signal of the monitor hydrophone from 0 to 60 dB (or more) in steps of 10 dB (or finer). The gain shall be controlled by a switch (or switches) located on the enclosure's front panel. Gain selection for the monitor hydrophone shall be independent of the gain selection for the receiver array elements.
   iii. **Selectable high-pass filtering:** A high-pass filter shall be provided to filter low frequency components in the monitor hydrophone voltage signal. The filtering shall be user-selectable (on/off) and controlled by a switch located on the front panel. The filter shall have a corner frequency of 185 Hz and a slope of 12 dB per octave. The selection of this filtering shall be independent of the selection of filtering applied to the receiver array elements.
   iv. **Output connectors:** The monitor hydrophone voltage signal shall be accessible via a BNC connector mounted on the front panel of the enclosure.
   v. **Test signal input:** A test signal input shall be provided for the monitor hydrophone channel to allow proper system calibration. The externally provided test signal must be injected prior to any amplification or filtering stages in the monitor hydrophone interface.

7. **Engineering Sensor Requirements.** An engineering sensor module must be provided for attachment to the tow body. The engineering module must have a single watertight connector providing both signal and power connections. A connector end-cap of appropriate pressure rating must be provided to allow the target simulator to be deployed to its maximum operational depth with or without the engineering sensor module attached.
   a. **Required sensors:** The engineering sensor module must include the following five sensors: a depth sensor, a two-axis tilt sensor pair, a heading sensor, and a temperature sensor. All sensor-specific factors needed to convert voltages to engineering units must be provided in the documentation. (See 13.a.) Required sensor accuracies are:
      i. **Depth sensor:** The depth sensor must be accurate to within 0.1 meters over the full operating depth of the unit.
      ii. **Tilt sensor pair:** The minimum measurement accuracy of the two-axis tilt sensor must be ± 0.5 degrees at any tilt angle up to ± 45 degrees.
      iii. **Heading sensor:** The heading sensor must measure heading to an accuracy of ± 2 degrees when tilted at angles up to ± 45 degrees.
      iv. **Temperature sensor:** The temperature sensor must measure temperature with a resolution of 0.01 degrees Celsius and with an accuracy of 0.1 degree Celsius and a time constant of less than 10 seconds.

- **b. Attachment:** The engineering sensor module shall be mounted in such a way that it is readily removable for repair or replacement. Electrical attachment to the tow cable shall be made using waterproof electrical connectors that have strain relief caps. These strain relief caps shall withstand a force of 50 pounds without disconnecting or compromising its electrical integrity.
- **c. Engineering sensor interface:** A rack-mountable enclosure shall be provided to make engineering sensor outputs accessible. It must meet the following requirements:
  - **i. Power supply:** One or more DC power supplies shall be provided to power all of the engineering sensors.
  - **ii. Output connectors:** The individual sensor voltage signals shall be accessible via BNC connectors mounted on the front panel of the enclosure.

8. <u>Tow and Deck Cable Requirements</u>.

- **a. Tow cable:** The electromechanical tow cable provides power and signal lines to the source(s), hydrophones, and engineering sensors in addition to mechanically supporting the tow body and any weight attached to it. It must meet the following requirements:
  - **i. Length:** The tow cable must be at least 275 meters in length.
  - **ii. Construction:** The tow cable must be marine grade, water blocked, double-armored, steel cable.
  - **iii. Strength:** The minimum working strength of the tow cable must exceed the dynamic tension that results from towing the fully instrumented tow body, full length of cable, and any additional required tensioning weight at the system's maximum operating depth at a speed of 4 knots. The breaking strength of the cable must exceed that tension by a factor of at least 5.
  - **iv. Mechanical terminations:** Separate electrical and mechanical terminations must be used to provide strain relief for the electrical connectors and to enable the electrical connectors to be connected and disconnected while maintaining a working strength tension on the assembled mechanical terminations.
  - **v. Fairing:** The tow cable must be faired along its entire length with a haired fairing. The minimum length of the fairing strands must be 4 times the cable diameter. The linear density of the fairing must conform to customary industry practice for effective reduction of flow-induced strum.
  - **vi. Spare conductors:** In addition to providing a sufficient number of conductors for the required number of sources, hydrophones, and engineering sensors, the cable shall also provide 2 spare pairs of conductors capable of powering source elements. The cable shall also provide spare conductors for 2 hydrophones. (The actual number of conductors will depend on the type of hydrophone used.)
- **b. Deck cable:** A deck leader shall be provided to connect electrically between the winch and the laboratory electronics. It must meet the following requirements:
  - **i. Length:** The deck leader shall be 50 meters in length.

ii. **Electrical terminations:** The deck leader shall be electrically terminated at both ends to provide easy and convenient connections at the winch and to laboratory systems.

iii. **Spare conductors:** In addition to providing a sufficient number of conductors for the required number of sources, hydrophones, and engineering sensors, the deck cable shall also provide 2 spare pairs of conductors capable of powering source elements. The deck cable shall also provide spare conductors for 2 hydrophones. (The actual number of conductors will depend on the type of hydrophone used.)

iv. **Construction:** The deck leader must be watertight and oil-resistant for use in a harsh ship-deck environment. The projector power lines (and spares) and the hydrophone and engineering sensor conductors (and spares) may be encased in two separate cables.

9. **Handling System Requirements.** A winch for deploying/recovering the system must be provided. The winch must be ruggedized for shipboard use in harsh marine operating environments. The base of the winch must conform with the standard UNOLS (NATO) 2' x 2' bolt-down pattern (1" diameter bolts) so that the winch can be bolted to the deck of UNOLS vessels. The winch must also meet the following requirements:
   a. **Drum core diameter:** The diameter of the winch drum must be no smaller than the minimum bending diameter of the tow cable.
   b. **Drum capacity:** The drum must be capable of holding 375 meters of tow cable.
   c. **Line pull:** The winch must be capable of providing a line pull of at least 5000 pounds when fully loaded.
   d. **Line speed:** The winch must be capable of operating at variable pay-in/pay-out speeds from 0 to 0.5 meter per second.
   e. **Level wind:** The winch must include a level wind attachment. The level wind must be capable of handling the faired cable without damaging the fairing.
   f. **Brake:** The winch must have a brake that prevents the drum from rotating under full load whenever the winch is powered off or in the event that power fails during use.
   g. **Slip rings:** The winch must be outfitted with electrical slip rings so that it is not necessary to connect or disconnect the deck and tow cables prior to running the winch to deploy, recover, or change the operating depth of the system. A sufficient number of appropriately rated (voltage and amperage) conductors must be provided so that all components (source(s), hydrophones, and engineering sensors) are fully operational when the tow and deck cables are connected through the slip rings. Also, additional conductors must be provided so that the spare hydrophone conductors in the tow and deck cables can be electrically connected through the slip rings.

10. **Calibrations and Acceptance Testing.**
   a. **Calibrations:** All sources and hydrophones must be calibrated to ensure that the system meets all acoustic specifications. Calibrations must be conducted at a facility such as NUWC's Seneca Lake Test Facility, the USRD Leesburg Facility, or an

equivalent facility that is capable of producing calibration measurements that are traceable to USRD standards.

i. **Source calibration:** All source measurements shall be made with all in-water system components (i.e., projectors, hydrophones, and engineering sensor module) mounted in the tow body and all amplifiers powered. The system's amplifiers -- not amplifiers provided by the facility -- must be used for all source measurements. The following measurements must be included:

1. **Sound pressure level (SPL) versus frequency** for frequencies spanning the operating range of the system (minimum 200 Hz to 5000 Hz). Frequency shall be sampled at intervals of 25 Hz or less throughout the range from 200 Hz to 1000 Hz and at intervals of 100 Hz or less throughout the range from 1000 Hz to the upper limit of the system's operating range (5000 Hz or greater). If the offeror proposes to meet the frequency-range and source-level requirements by using multiple sources, then the SPL must also be measured at the cross-over frequencies between bands. The SPL vs frequency must be measured once at "full power", where full power is defined to be the power that yields an SPL of 188 decibels re 1 micropascal at 1 meter or greater for all operating frequencies (from 200 Hz to 5000 Hz or greater), and once at "one-quarter power", where one-quarter power is defined to be 25 per cent of full power.
2. **Phase angle versus frequency** for frequencies spanning the operating range of the system (minimum 200 to 5000 Hz). Frequency shall be sampled at intervals of 25 Hz or less throughout the range from 200 Hz to 1000 Hz and at intervals of 100 Hz or less throughout the range from 1000 Hz to the upper limit of the system's operating range (5000 Hz or greater). If the offeror proposes to meet the frequency-range and source-level requirements by using multiple sources, then the phase angle must be measured at the cross-over frequencies between bands. The phase angle vs frequency must be measured at both full power and one-quarter power.
3. **Horizontal directivity patterns** at selected frequencies. These measurements shall be made for horizontal angles in the range from 0 degrees to 360 degrees, sampled at intervals of three degrees or finer. A set of no more than 10 frequencies will be selected by the Contracting Officer's Representative within 90 days after contract award. These measurements shall be made with a nominal source level of 188 dB re 1 micropascal at 1 meter.
4. **Vertical directivity patterns** at selected frequencies. These measurements shall be made for vertical angles in the range from 0 degrees to 360 degrees in the vertical plane parallel to the direction of tow and sampled at intervals of three degrees or finer. Measurements shall be made at the same set of frequencies as in subparagraph

10.a.i.3 above. These measurements shall be made with a nominal source level of 188 dB re 1 micropascal at 1 meter.

ii. **Hydrophone calibrations:** All hydrophone measurements shall be made with all in-water system components (i.e., projectors, hydrophones, and engineering sensor module) mounted in the tow body.

1. **Voltage and phase sensitivity** (referred to 1 micropascal) of each hydrophone (i.e., the monitor hydrophone and all four hydrophones comprising the receiver array) shall be measured to an accuracy of 1 decibel over the operational frequency range of the system (i.e., from 200 Hz to at least 5000 Hz) at intervals of 1/3 octave or less.
2. **Horizontal directivity** of each hydrophone shall be measured at selected frequencies. This measurement shall be made for horizontal angles in the range from 0 degrees to 360 degrees, sampled at intervals of one degree. A set of (no more than 10) frequencies will be selected by the Contracting Officer's Representative within 90 days after contract award.
3. **Vertical directivity** of each hydrophone shall be measured at selected frequencies. This measurement shall be made for vertical angles in the range from 0 degrees to 360 degrees, sampled at intervals of one degree. Measurements shall be made at the same set of frequencies as in subparagraph 10.a.ii.2 above.

iii. **Report of calibration results:** The contractor shall provide a report on the results of the system calibration. This report shall include results of all measurements specified in subparagraphs 10.a.i and 10.a.ii above in graphical and/or tabular form. Delivery of this report must take place within 30 days of the completion of the acoustic calibrations. The report shall be delivered in electronic format -- either Adobe Acrobat (.PDF) or Microsoft Word (.DOC). If the calibration facility makes available to the contractor calibration data in computer files (e.g., spreadsheet workbooks, ASCII files), copies of these computer files -- in the format provided by the calibration facility -- shall be delivered to the Government along with the written report.

b. Pressure test: The system must be pressure tested. The pressure test may be conducted at a pressure test facility, or at the same facility where the system is calibrated (if the facility has the capability to lower the in-water components to the required depth), or contemporaneously with the tow test specified in paragraph 10.c below. If the pressure test is conducted at the calibration facility, it shall be conducted prior to the calibrations. Similarly, if the pressure test is conducted as part of a field test including the tow test, it shall be conducted prior to the tow test.

The depth (or equivalent pressure) for this test shall be the system's maximum operating depth or the greatest depth allowed by the length of the tow cable, whichever is shallower. The system shall be deployed to the test depth and shall remain suspended at this depth for at least 2 hours with the source pinging intermittently -- nominally, at one-minute intervals. At a minimum, all amplifier

voltage and current monitors and the monitor hydrophone voltage must be recorded during this test. The Contracting Officer's Representative will approve the waveforms to be transmitted, source levels, and the transmission schedule.

c. Tow test: The successful completion of a short tow test of the system is required prior to its acceptance by the Government. The objective of the field test is to determine the system's hydrodynamic performance when under tow as observed from the deck of the tow vessel and as measured by engineering sensors. [Note: It is not necessary to demonstrate that the sources meet all acoustic requirements as part of this test since that determination is the purpose of the source calibration. It is necessary, however, to demonstrate that all components of the system, including the sources, function normally throughout the field test.] The contractor shall obtain the services of a vessel suitable to transport and deploy the system. The estimated time required to perform the field test is: 1 day in port for mobilization, transit time to and from a suitable site, 1 full work day for testing (if the pressure test is part of the field test), and 1 day for demobilization. The Government may send one or two persons to observe the field test and may select a set of waveforms to be transmitted as part of the tests. In addition, the Government may attach small, autonomous test sensors to the tow body for the duration of the tow test.

The contractor shall develop a test plan detailing the measurements that will be made to accomplish the test objectives. The test plan shall be delivered to the COR for approval no later than 60 days prior to start of the field test. It will be the Government's responsibility to obtain any required permissions and/or file any required environmental impact paperwork for low-level source operations during this test.

If the pressure test is conducted as part of the field test, it shall be conducted prior to the tow test as specified in paragraph 10.b above. At a minimum, the tow test shall consist of a single straight-line tow at a nominal depth of 100 meters. The amplifier current and voltage monitors, the monitor hydrophone voltage, and the output of all engineering sensors shall be recorded throughout the duration of the tow test. The tow ship shall execute a straight-line transit beginning at a speed of one knot for 15 minutes. The speed shall be increased to 2 kts, and the device towed at 2 kts for 15 minutes. At the end of this period, the speed shall be increased to 3 kts, and the device towed at 3 kts for 15 minutes. Finally, the speed shall be increased to 4 kts and the device towed at 4 kts for 15 minutes. The Authorized Government Representative observing the test may modify this track at the time the test is conducted depending on local conditions at the time the test is conducted. Pings shall be transmitted (at approximately 1-minute intervals) during the straight-line transit. The Contracting Officer's Representative will approve the waveforms to be transmitted, source levels, and the transmission schedule.

The contractor shall provide a report of results of the tow test described in paragraph 10.c. This report shall include graphs of all engineering sensor outputs versus time for the straight-line transits. It shall also include sound pressure versus time calculated

from the recorded monitor hydrophone voltage and current. Delivery of this report must take place prior to the delivery of the system. The report shall be delivered in electronic format -- either Adobe Acrobat (.PDF) or Microsoft Word (.DOC).

11. Required Documentation.

a. Technical manual(s): One or more technical manuals, describing each contractor-supplied system component in detail, must be provided. Detailed drawings for all contractor-supplied custom hardware in the system must be included. A detailed list of all parts/components manufactured or supplied by third parties must be included. This list must identify the manufacturer, manufacturer part number, manufacturer's address, telephone/fax numbers, and, if applicable, web site. In addition, a separate list of all expendable items required to maintain, deploy, operate, or recover the system must be included. The technical manual must also include all conversion factors needed to convert engineering sensor output voltages to engineering units. Delivery of the technical manual(s) shall take place with the delivery of the system. The technical manual(s) shall be delivered in electronic format -- either Adobe Acrobat (.PDF) or Microsoft Word (.DOC).

b. Operations manual: The contractor must provide one or more operations manuals that describe in detail how to operate all contractor-supplied components of the system. It must contain the procedures to be used for pre-deployment checkout, hardware and system preparation, and provide a checklist for all mechanical and electrical connections for the safe and successful deployment, operation, and recovery of the system. The operations manual must also include information on all required routine maintenance of the system and all procedures that need to be carried out when placing the system in or removing it from storage. Delivery of the operations manual(s) shall take place at least 30 days prior to the tow test (see paragraph 10.c). The operations manual(s) shall be delivered in electronic format -- either Adobe Acrobat (.PDF) or Microsoft Word (.DOC).

c. Deployment and recovery plan: The contractor shall provide a deployment and recovery plan for the system. The plan must detail all hardware, procedures, and specifications for any equipment not supplied with the system that is required to safely deploy, operate, and recover the system. If a block (sheave) is required to deploy the unit, the plan must specify the block characteristics (minimum diameter, groove radius and depth, rim width, throat width and height) that will allow multiple deployments without damage to the electrical and mechanical integrity of the tow cable. Delivery of the plan shall take place at least 30 days prior to the tow test (see paragraph 10.c). The deployment and recovery plan shall be delivered in electronic format -- either Adobe Acrobat (.PDF) or Microsoft Word (.DOC).

12. Options.

a. Longer tow cable. This option provides an additional 100 meters of tow cable -- that is, a 375-meter tow cable ***in place of*** the 275-meter tow cable specified in paragraph 8.a. All specifications in paragraph 8.a apply with the exception of the

length of the cable (8.a.i). If selected, this option would be exercised at the time of contract award.

b. **Spare parts.** For a period of three years from the date of contract award, the contractor shall make available for purchase the following spare parts:

- **i. Projectors.** Individual projectors of each type used in the baseline system. (It is anticipated that this option would be exercised at most twice for each projector type.)
- **ii. Amplifiers.** Individual amplifiers used in the baseline system. (It is anticipated that this option would be exercised at most 3 times.)
- **iii. Hydrophones.** Individual hydrophones of each type used in the baseline system.
- **iv. Engineering sensor modules.** Individual engineering sensor modules of the type used in the baseline system.