Statement of Work

Autonomous Underwater Vehicle (AUV)

Phase I – Prototype Development & Demonstration

AUV SOW Rev (-)

HISTORY CHANGE LOG

REV	DATE	ORIGINATOR	USED ON	SUMMARY DESCRIPTION OF CHANGES
-	11/27/2023	Tom G.	X314159-AUV	Initial release.

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SECTION 1.   INTRODUCTION

1.1 Scope

This Statement of Work (SOW) defines the scope of work necessary to develop, build, test and demonstrate a prototype for an autonomous underwater vehicle (AUV) with the following capabilities.

- Surveillance and reconnaissance, e.g. identification of underwater mines and other subsurface weapons.
- Recovery of reusable underwater targets, test torpedoes, etc.
- Manipulative abilities sufficient to attach recovery lines to objects.

1.2 Background

The tasks associated with the AUV to be developed are being performed by dolphins trained by the Department of the Navy. The use of dolphins is to be phased out over the next three years, resulting in a gap in capabilities, to be filled by the AUV. The CONTRACTOR shall develop and demonstrate a prototype AUV to meet the requirements specified in the associated Space and Naval Warfare Systems Command (SPAWAR) contract 645_667-M16-A1A. The AUV shall designed to operate autonomously, with manual control via ultra-high frequency (UHF) communication while on the surface, and low frequency (LF) communication while submerged.

> **Commented [TG1]:** Name has actually changed to Naval Information Warfare Systems Command as of 2019, I believe.

> **Commented [TG2]:** Make up a contract #?

1.3 Period of Performance

The period of performance (PoP) will be a maximum 18 months after receipt of order (ARO), with an objective PoP of 12 months.

> **Commented [TG3]:** Specify the full 18 months?

SECTION 2.   APPLICABLE DOCUMENTS

The following documents form a part of this SOW to the extent specified herein. In the event of a conflict between the documents specified below and the content of the SOW, the SOW shall take precedence. In all cases, SPAWAR shall be notified of any conflicts. Nothing in this document, however, supersedes applicable law and regulations unless a specific exemption has been obtained and incorporated as part of the contract. The following documents of the most recent released issue at the time of the award form a part of this SOW to the extent specified herein.

2.1   Contract Documents

Table 2-1   Contract Documents

Document Number	Title
645_667-M16-A1A	Autonomous Underwater Vehicle (AUV) Prototype

SECTION 3.   PROGRAM TASKS

The CONTRACTOR shall provide all necessary labor, materials, and facilities required to perform the work described by this SOW and to meet all delivery requirements and the terms of the related contract.

3.1   Program Management and Control

3.1.1   Monthly Status Review

The CONTRACTOR and SPAWAR shall conduct a monthly review. The dates for the monthly reviews will be agreed upon by both the CONTRACTOR and SPAWAR a minimum of 14 days prior to the review. These reviews may take place at the CONTRACTOR's facility or virtually at SPAWAR's discretion.

3.1.2   Monthly Status Report

The CONTRACTOR shall submit Monthly Status Reports (MSR) (CDRL-001) by close of business on the fifth working day after the CONTRACTOR's accounting month end during the period of performance. The monthly status report shall be electronically sent to SPAWAR's Contract Manager (CM) and Technical Lead. Content of the MSR will include the following items at a minimum:

1. Contract Status Summary
   a. Programmatic accomplishments
   b. Technical status and accomplishments
2. Issues & Concerns
3. Action Item Review/Status
4. Schedule Update
5. Identification of Long Lead Materials necessary to meet prototype demonstration date

3.1.3   Program Management Reviews

The CONTRACTOR shall hold a Program Management Review (PMR) meeting with SPAWAR's representatives, coinciding with the reviews defined below, to review the progress of the program and discuss technical, status, management status, and discuss the current monthly status report (MSR). The meetings shall be held at the CONTRACTOR's facility or virtually, at SPAWAR's discretion. Program action items shall be agreed upon at the meeting, and the agreements included as part of the monthly program review minutes.

3.1.4 Integrated Master Schedule

The CONTRACTOR shall submit an integrated master schedule (IMS) (CDRL-002) for the duration of the contract phase, as well as a notional schedule for completion of engineering and manufacturing development (EMD) and low-rate initial production (LRIP). The schedule shall show how the CONTRACTOR will meet deliverable dates, program milestones and risk mitigation milestones.

The schedule status shall be provided to SPAWAR's technical representative and CM in conjunction with the monthly status report.

3.1.5 Quality Management

The CONTRACTOR shall plan, implement, and maintain a quality management system. The quality management program (CDRL-006) shall be described as part of the first MSR.

3.1.6 Configuration & Data Management

The CONTRACTOR shall maintain a configuration management system for all items required by this SOW that assures the configuration identification, control, status accounting, reporting, and auditing of all deliverable items. The CONTRACTOR shall maintain a configuration management system that adheres to established CONTRACTOR configuration management Policies and Procedures provided to SPAWAR (CDRL-005), and that is subject to SPAWAR's review and approval. Authorization to proceed with changes to the baseline configuration shall be provided to the CONTRACTOR by means of appropriate contractual direction prior to change implementation.

3.1.7 Drawings

The CONTRACTOR shall provide one (1) legible reproducible set and a soft copy set of all CONTRACTOR drawings for any contractual deliverable units (prototypes, brassboards, etc.) in accordance with any established non-disclosure agreement in effect. Documents shall include all fabrication and assembly drawings and Bill of Materials (BOMs).

3.2 Systems Engineering

3.2.1 Systems Engineering Management Plan (SEMP)

The CONTRACTOR shall develop and maintain a Systems Engineering Management Plan to include the following:

- Development team organization

- Description of Systems Engineering methodology

  o Configuration management

  o Verification and validation methods

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- o Hardware and software development methodology

- o Management of external interfaces

- Compliance matrices

3.2.2 Test and Evaluation Management Plan (TEMP)

The CONTRACTOR shall develop and maintain a Test and Evaluation Management Plan to include the following:

- Identification of test objectives

- Identification of test roles and responsibilities

- Identification facility and/or range requirements for the demonstration test

- Description of demonstration test objectives, entrance and exit criteria

- Description of data collection requirements

3.2.3 Configuration Item Requirement Specifications

The CONTRACTOR shall develop and maintain requirement specifications for the following configuration items:

- Overall AUV

- Propulsion system

- Sensor module

- AUV structural housing

- Power and distribution

- Manipulator module

- Communication module

- Support equipment

3.2.4 Systems Engineering Technical Reviews

The CONTRACTOR shall perform the following systems engineering technical reviews:

- System Requirements Review – to include all specifications listed in Section 3.2.3

- Design and test reviews listed in Section 3.3.8

3.3 Technical Tasks

3.3.1 Hardware Engineering

The CONTRACTOR shall perform all necessary design, engineering, analyses, modeling, and documentation required to define and build a prototype AUV with the capabilities noted in Section 1.1.

The CONTRACTOR shall fabricate and integrate the following modules into a prototype AUV: propulsion and steering, sensor payload, manipulator, communication and control.

The CONTRACTOR shall adapt current dolphin support equipment to construct a launch and recovery system for the prototype AUV demonstration.

The CONTRACTOR shall maintain a complete set of current documentation to allow for a seamless transition to LRIP.

The CONTRACTOR shall identify long lead items and initiate purchase contracts to ensure availability during the Phase II transition to low/full-rate production.

3.3.1.1 Propulsion and Steering

The CONTRACTOR shall perform trade studies to select the following propulsion and steering components:

- Electric motor
- Rechargeable battery
- Steering and depth control

The CONTRACTOR shall integrate the selected components into a propulsion module controlled by signals from the AUV controller. The CONTRACTOR shall develop and maintain interface control documents (ICD) showing the mechanical and electrical interfaces between the propulsion module and the AUV.

The CONTRACTOR shall perform integration testing at the propulsion module level with an AUV controller or AUV controller emulator.

3.3.1.2 Sensor Payload

The CONTRACTOR shall perform trade studies to select the following sensors:

- Sonar – navigation aid and target identification
- Optical – navigation aid, target identification and manipulator control input

- Infrared (IR) – navigation aid, target identification and manipulator control input in low light conditions
- Inertial navigation – primary navigation input

The CONTRACTOR shall integrate the selected sensors into a payload module with interfaces provide inputs to the AUV controller. The CONTRACTOR shall develop and maintain ICDs showing the mechanical and electrical interfaces between the sensor module and the AUV.

The CONTRACTOR shall perform integration testing at the sensor module level with an AUV controller or AUV controller emulator.

3.3.1.3 Manipulator

To decrease development time and risk, the CONTRACTOR shall modify and integrate an existing six degree of freedom (DOF) manipulator arm with the AUV prototype. The manipulator is adaptable to various tasks via changeable end effectors.

The CONTRACTOR shall develop and maintain ICDs showing the mechanical and electrical interfaces between the manipulator and the AUV.

The CONTRACTOR shall perform integration testing at the manipulator level with an AUV controller or AUV controller emulator.

3.3.1.4 Communication Module

The CONTRACTOR shall develop a communication module comprising an ultra-high frequency (UHF) radio and a low frequency (LF) radio, as well as modulator/demodulator (modem) to convert audio signals to data and vice-versa. The communication module will be used to transmit commands to the AUV or receive telemetry from the AUV while on the surface (UHF) or submerged (LF).

The CONTRACTOR shall use the JANUS underwater communication protocol as specified in Allied Naval Engineering Publication 87 (ANEP-87) and ensure that all communication equipment is compatible with the JANUS protocol.

The CONTRACTOR shall develop and maintain ICDs showing the mechanical and electrical interfaces between the communication module and the AUV.

The CONTRACTOR shall perform integration testing at the communication module level with an AUV controller or AUV controller emulator.

The CONTRACTOR shall maintain a minimum volume margin of 8" x 4" x 4" withing the communications module to accommodate an encryption unit. The prototype AUV will use unencrypted communication during its demonstration, however the production AUV will require encryption due to the potentially sensitive nature of some mission types.

3.3.1.4.1 Ultra-High Frequency (UHF) Radio

The CONTRACTOR shall perform a trade study and select a suitable UHF radio transceiver.

3.3.1.4.2 Low Frequency (LF) Radio

The CONTRACTOR shall perform a trade study and select a suitable LF radio transceiver.

3.3.1.4.3 Modulator/Demodulator (Modem)

The CONTRACTOR shall perform a trade study and select a suitable modem capable of operating in both the UHF and LF ranges.

3.3.1.5 AUV Controller

The CONTRACTOR shall perform a trade study and select a controller for the AUV, considering the following parameters at a minimum:

- Size, weight and power (SWaP)
- Ability to run multiple tasks simultaneously without external control
    - Image recognition machine learning models
    - Propulsion and navigation
    - Manipulator control
    - Handle communication interrupts
    - Maintain sensor logs
- Sufficient memory and storage margin
- Sufficient input/output channels
- Network capability to load mission parameters and offload sensor data

The CONTRACTOR shall develop and maintain ICDs showing the mechanical and electrical interfaces between the controller and the AUV.

The CONTRACTOR shall perform individual integration testing of the AUV controller with the propulsion module, sensor module, manipulator and communication module.

THE CONTRACTOR shall perform full integration testing of the AUV controller with the AUV fully assembled.

3.3.1.6 Structural Housing

The CONTRACTOR shall design and fabricate a structural housing to integrate the propulsion, sensor, communication, controller, and manipulator modules into the AUV prototype.

The CONTRACTOR shall perform material compatibility analyses for joined materials and for materials exposed to seawater. The CONTRACTOR shall mitigate the potential for corrosion through the use of e.g. coatings or sacrificial anodes where necessary.

3.3.1.7 Launch and Recovery System (LARS)

The CONTRACTOR shall develop a system to launch and recover the AUV. The LARS shall provide the ability to launch/recover the AUV from a pier or from a support vessel.

To minimize development time and risk, the CONTRACTOR shall:

1. Utilize existing dolphin support equipment to the greatest extent practicable

2. Leverage an existing LARS design developed in conjunction with Maritime Applied Physics Corporation (MAPC)

The CONTRACTOR shall perform testing of the LARS prior to the full prototype demonstration, using either a fully integrated AUV or a mockup with the same size and weight characteristics.

3.3.2 External Interface Definition

The CONTRACTOR shall support SPAWAR in refining required interface definitions from a support vessel to the AUV or support equipment to include physical dimensions, electrical interfaces, connectors, isolation, radio frequencies, and network interfaces.

3.3.3 Software (SW) Design and Development

The CONTRACTOR shall provide a software design document (SDD) for the Mission Planning, AUV, and Data Analysis software to SPAWAR. The initial SDD (CDRL-007) shall be submitted to SPAWAR's Program Manager (PM), CM and Technical Lead as part of the third MSR and updated monthly for each subsequent MSR submittal. The SDD shall include the following artifacts at a minimum:

- Activity diagrams to illustrate the concept of operations for each computer software configuration item (CSCI)

- A failure modes, effects and criticality analysis (FMECA) to show that there are no modules in any CSCI that are single points of failure

- A complete description of each CSCI

3.3.3.1 Mission Planning SW

The CONTRACTOR shall develop a mission planning SW module that establishes mission parameters such as mission type (survey, target retrieval, etc.), area of operations (AO), geofencing coordinates, target information, manipulator end-effector type and manipulator tasking.

To reduce development time and risk, the CONTRACTOR shall leverage mission planning SW previously developed for remotely operated vehicles.

3.3.3.2 AUV Control SW

The CONTRACTOR shall develop AUV control SW that:

- Takes sensor module and communication module information as inputs and controls the propulsion module and manipulator in accordance with the mission tasking

- Logs sensor module data as specified by mission planning parameters

- Transmits telemetry as specified by mission planning parameters

- Performs image recognition for target identification

- Provides manual override via the communication module

The CONTRACTOR shall test each CSCI module, e.g. propulsion control or image recognition, with its associated hardware as the module is completed. The CONTRACTOR shall perform full integration once all SW modules have been completed and all hardware (HW) modules have been fabricated.

3.3.3.3 Data Analysis SW

The CONTRACTOR shall develop software to analyze all data collected during a mission.

The CONTRACTOR shall develop a database to store collected data for future analysis and archival purposes.

3.3.4 Support and Training

The CONTRACTOR shall create technical manuals with the following sections at a minimum:

- Hardware operation – charging, launch and recovery, maintenance

- Software operation – loading mission parameters, offloading sensor data

- Manual AUV operation

3.3.5 Integration and Test

As noted in previous sections, the CONTRACTOR shall perform testing at the subsystem/module level to ensure that each module functions correctly on its own and in conjunction with the AUV controller.

The CONTRACTOR shall perform full system integration testing once all HW modules have been fabricated and a prototype AUV has been assembled.

3.3.6   Reliability Analysis

The CONTRACTOR shall provide a reliability estimate or prediction for the prototype AUV based on planned component quality and stress levels. The CONTRACTOR shall update the reliability estimate upon receipt of an EMD/LRIP follow-on contract. The reliability analysis shall include analyses showing that any limited life components exceed design and operational life requirements. The initial reliability analysis (CDRL-008) shall be submitted to the PM, CM and Technical Lead as part of the third MSR and updated monthly for each subsequent MSR submittal.

The CONTRACTOR shall update the reliability prediction as the design matures.

The CONTRACTOR shall mitigate any Single Point Failures in the AUV design that would prevent the overall system from functioning, including communication, software and hardware faults.

The CONTRACTOR shall track and report all failures occurring during development, integration and test of the prototype units to support SPAWAR's failure trend analysis.

3.3.7   Structural Modeling

The CONTRACTOR shall perform and provide the results of structural modeling that shows the critical stresses and margin to yield for the manipulator and overall AUV design, to include stresses incurred during launch and recovery. Structural analysis results (CDRL-011) are to be submitted in conjunction with System Functional Review package (CDRL-004) to the PM, CM and Technical Lead and updated for Preliminary Design Review Package (CDRL-009).

3.3.8   Milestone Reviews

The CONTRACTOR shall conduct milestone reviews with the BUYER identified below. Minutes of the actions and agreements at each review (CDRL-003) shall be submitted to the SPAWAR PM, CM and Technical Lead with the final review package.

Table 3-1   Milestone Reviews

Review	Due Date
System Functional Review	5.5 Months ARO
Preliminary Design Review	7.5 Months ARO
Demonstration Test Readiness Review	11 Months ARO

3.3.8.1   System Functional Review

The CONTRACTOR shall conduct a System Functional Review (SFR) no later than five and a half months ARO on a mutually agreed date that SPAWAR will attend, virtually or in person. A draft version of the SFR Package (CDRL-004) will be electronically sent to SPAWAR's PM, CM and Technical Lead at least 10 working days prior to the review. Topics covered in the System Functional Review will include the following as a minimum:

1) Establishment of technical baseline
2) Functional specifications of system and subsystems
3) Chassis and mechanical design drawings
4) Software design, including activity and other diagrams to show operational concept
5) Predicted performance estimates
6) Updated schedule
7) CM, quality and risk management processes
8) Draft test plan
9) Action Item Status

The System Functional Review shall serve as a control gate for agreement on proceeding to preliminary design of the AUV. The final presentation package and minutes taken at the System Functional Review shall be prepared and submitted to SPAWAR within 3 working days after the meeting. Program action items shall be agreed upon at the meeting, and the agreements included as part of the minutes.

3.3.8.2 Preliminary Design Review

The CONTRACTOR shall conduct a Preliminary Design Review (PDR) no later than seven and a half months ARO on a mutually agreed date that SPAWAR will attend, virtually or in person. A draft version of the PDR Package (CDRL-009) will be electronically sent to SPAWAR's PM, CM and Technical Lead at least 10 working days prior to the review. Topics covered in the PDR will include the following as a minimum:

1) Chassis and mechanical design drawings
2) Detailed schematics and board layouts
3) Software design, including activity and other diagrams to show operational concept
4) Structural analysis
5) Predicted performance estimates
6) Updated schedule
7) CM process
8) Action Item Status

The Preliminary Design Review shall serve as a control gate for agreement on modifications, performance characteristics and physical characteristics prior to committing to the initial fabrication of the prototype AUV to be demonstrated. The final presentation package and minutes taken at the PDR shall be prepared and submitted to SPAWAR within 3 working days after the meeting. Program action items shall be agreed upon at the meeting, and the agreements included as part of the minutes.

3.3.8.3 Demonstration Test Readiness Review

The CONTRACTOR shall conduct a Demonstration Test Readiness Review (TRR) in conjunction with the completed build of the final prototype unit on a mutually agreed date that SPAWAR will attend, virtually or in person. A draft version of the Demonstration TRR Package (CDRL-010) will be electronically sent to SPAWAR's PM, CM and Technical Lead 10 working days prior to the review. Topics covered in the TRR will include the following as a minimum:

1) Verification Matrix showing traceability of all requirements to demonstration test plans

2) Completed test plans

3) Completed test procedures

4) Identification and description of demonstration setup and demonstration personnel

The Demonstration TRR shall serve as a control gate for the beginning of an abbreviated EMD to update the design based on any findings from the demonstration, followed by low-rate initial production. The final presentation package and minutes taken at the Test Readiness Review shall be prepared and submitted to SPAWAR within 3 working days after the meeting. Program action items shall be agreed upon at the meeting, and the agreements included as part of the minutes.

SECTION 4.   HARDWARE DELIVERABLES

4.1   Delivery Quantities and Schedule

The CONTRACTOR shall adhere to the delivery schedule shown below in Table 4-1. The quantity listed in Table 4-1 represent the quantity required for the AUV demonstration.

Table 4-1.   Demonstration Hardware List

QTY	Description	Due Date
1	AUV with Manipulator	
1	Launch and Recovery System (Simplified)	11 Months ARO
1	Mission Planning & Data Analysis Computer	

SECTION 5.   CONTRACT DATA REQUIREMENTS LIST (CDRL)

The Contract Data Requirements List (CDRL) is shown in Table 5-1.

Table 5-1.   Contract Data Requirements List

CDRL#	Description	Due Date
001	Monthly Status Report	5 working days after accounting month end
002	Master Schedule	Updates with the MSR packages 5 working days after month end
003	Milestone Review Meeting Minutes	3 working days after design change review meeting
004	System Functional Review Package	Draft 10 working days prior to review Final 3 working days after review with minutes
005	CONTRACTOR's Configuration Management Plan	Delivered as part of System Functional Review Package
006	Quality Assurance Program Plan	Delivered as part of System Functional Review Package Update at Preliminary Design Review
007	Software Design Documents	Delivered as part of System Functional Review Package Update at Preliminary Design Review
008	Reliability Analysis	Initial at May MSR Updates as part of subsequent MSRs
009	Preliminary Design Review Package	Draft 10 working days prior to review Final 3 working days after review with minutes
010	Test Readiness Review Package	Draft 10 working days prior to review Final 3 working days after review with minutes
011	Structural Analysis Results	Delivered as part of System Functional Review Package Update at Preliminary Design Review

SECTION 6.   ACRONYMS AND ABBREVIATIONS

Below is the list of acronyms and abbreviations used in this document.

Table 6-1   Acronyms and Definitions

Abbreviation	Definition
ANEP	Allied Naval Engineering Publication
AO	Area of Operations
ARO	After Receipt of Order
AUV	Autonomous Underwater Vehicle
BOM	Bill of Materials
CDRL	Contract Data Requirements List
CM	Configuration Manager/Management
CSCI	Computer Software Configuration Item
DOF	Degree of Freedom
EMD	Engineering and Manufacturing Development
FMECA	Failure Modes, Effects and Criticality Analysis
HW	Hardware
ICD	Interface Control Document
IMS	Integrated Master Schedule
LF	Low Frequency
LRIP	Low-Rate Initial Production
MAPC	Maritime Applied Physics Corporation
MSR	Monthly Status Report
PDR	Preliminary Design Review
PM	Program Manager
PMR	Program Management Review
PoP	Period of Performance
SDD	Software Design Document
SFR	System Functional Review
SOW	Statement of Work
SPAWAR	Space and Naval Warfare
SW	Software
SWaP	Size, Weight and Power
TRR	Test Readiness Review
UHF	Ultra-High Frequency