Deep Ocean Exploration Submersible

An unsolicited proposal submitted to

OceanGate, Inc.

[redacted]

Submitted by

[redacted] **Principal Investigator (APL-UW)**

Technical Contact:
[redacted]
Applied Physics Laboratory
University of Washington
1013 NE 40th Street
Seattle, WA 98105

[redacted] (phone)
(206) [redacted] (fax)
(206) [redacted] (cell)
[redacted]

Administrative Point of Contact:
[redacted]
Office of Sponsored Programs
University of Washington
4333 Brooklyn Ave NE
Seattle, WA 98195

[redacted] (phone)
(206) [redacted] (fax)
[redacted]

Total Funds Requested: $ 4,983,589

Proposal Date: November 7, 2012

Award Instrument: Cost Plus Fixed Fee (CPFF)

Period of Performance: December 1, 2012 – December 31, 2015

Place of Performance: Applied Physics Laboratory, University of Washington

Objective

APL-UW proposes to support work with OceanGate on the development, construction, launch, recovery, test and analysis of a deep ocean, manned underwater vehicle (MUV) (a.k.a., Cyclops).

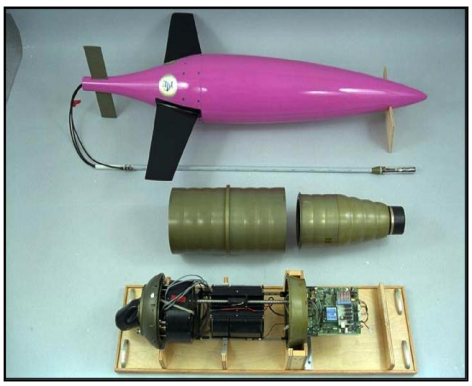
Background

APL-UW has a very broad background in Ocean Engineering to support science, technology development, and new system concepts. This background includes the mechanical, electrical, software, deployment and recovery of fixed and mobile ocean systems for surface operations, shallow water operations, bottom operations, and deep ocean exploration. In addition, APL-UW has had considerable experience at system integration of underwater vehicles from design, to the construction, deployment, recovery, test and analysis. These include remote operated vehicles, but also autonomous vehicles. Examples of such vehicles include one of the first autonomous, unmanned vehicles, the Self-Propelled Underwater Research Vehicle (SPURV). Such a vehicle used on-board auto-pilot controllers for most flight operations with a higher level command and control function that integrated sensors, processors and acoustic communication for operations. Typically missions for such a vehicle include oceanography survey of the water column, surface, and bottom features.

APL-UW experience included a number of extensions to SPURV including small vehicles such as the Mk 38 Anti-submarine target trainer, the Unmanned Arctic Research System (UARS) for exploration under the ice, and more recently, the buoyancy driven, unmanned underwater "Seaglider."

UARS was a derivative of SPURV that added several notable features. Among those features was a flexible architecture of individual components such that it could be expanded for greater payloads or batteries. It also included obstacle avoidance sonar (critical to under-ice operations) and one of the first high resolution imaging sonars integrated into an unmanned underwater vehicle (UUV) for use to determine the topographic structure underneath the ice. It further developed the navigation and acoustic communication to permit under-ice operations.

Seaglider implemented even further innovations. Foremost was the use of variable buoyancy to allow for movement up and down in the water column, along with wings and a mass-shifter to allow for the vehicle to "glide" up and down in the water column to permit forward motion. The advantage of this type of propulsion is the energy savings. Seagliders operate for six to nine months



remotely and can operate completely autonomously for ocean sampling. Given this long duration, APL-UW also had to develop an over-the-horizon satellite communication capability, as well as autonomy behaviors for other than normal operations, to allow for problems in the vehicle and to compensate for adverse weather conditions. The design has worked very well, permitting long endurance (6 to 9 months), long range (3,000 nmi), and deep (1000 m) operations.

In addition to vehicle technology, APL-UW has conducted research in the deep ocean, both for cabled and autonomous systems. APL-UW has also operated autonomous vehicles on the deep ocean floor. Two specific programs are relevant to this project. First, in 1985, APL-UW developed and operated a deep ocean bottom lander for the In-Situ Heat Transfer Experiment (ISHTE). The technology was meant to determine the feasibility of storing nuclear waste in the deep ocean sediments. The lander was designed to operate for a year in the soft clays and exfiltrate data via acoustic modem. This type of deep ocean operation and our experience with Navy acoustic ranges has led to more recent capabilities that are not only being applied to hydrothermal vent exploration, but also to the engineering necessary to support NEPTUNE, the National Science Foundation's regional cabled observatory system. Part of the work-up to NEPTUNE has been the APL-UW development of the MARS node currently in operation by MBARI.

Technical Approach

APL-UW will assist OceanGate, Inc. with a system engineering approach to the development of a new, manned, deep submergence vehicle. The purpose of systems engineering is to produce systems that satisfy the customers' needs, increase the probability of system success, reduce risk, and reduce total-life-cycle cost. APL-UW intends to break the system engineering into seven basic steps spread over three broad tasks. These basic steps are:

1. State the problem. Stating the problem is the most important systems engineering task. It entails identifying customers, understanding customer needs, establishing the need for change, discovering requirements, and defining system functions.

2. Investigate alternatives. Alternatives are investigated and evaluated based on performance, cost, and risk.

3. Model the system. Running models clarifies requirements, reveals bottlenecks and fragmented activities, reduces cost, and exposes duplication of effort.

4. Integrate. Integration means designing interfaces and bringing system elements together so they work as a whole. This requires extensive communication and coordination.

5. Launch the system. Launching the system means running the system and producing outputs -- making the system do what it was intended to do.

6. Assess performance. Performance is assessed using evaluation criteria, technical performance measures, and measures -- measurement is the key. If you cannot measure it, you cannot control it. If you cannot control it, you cannot improve it.

7. Re-evaluation. Re-evaluation should be a continual and iterative process with many parallel loops.

APL-UW shall work with OceanGate to identify the requirements for the vehicle. These requirements will include, at the highest level, the number of people to be deployed aboard the vehicle, for how long, and with what intent in terms of vehicle performance such as depth, speed, maneuverability, control, and expandability. This shall also include an evaluation of what conditions are desirable for launch and recovery including consideration of the economics of the design, construction, and operation for a commercial enterprise.

APL-UW shall work with OceanGate to consider alternatives during the design. Trade-off studies will be provided to look at the basic design and fabrication of the pressure hull, especially the mating of the pressure hull to the exterior viewing port(s) and necessary through-hull connections for power, oxygen, sensors, communication, etc. Trade studies shall be conducted on all sub-systems as to whether or not commercially available systems will fit the requirements of the operational system or whether or not a custom system is desirable. Some elements of a custom system may be fabricated at APL-UW and/or OceanGate, but the long-term impact of custom work on future expansion and maintenance shall also be considered. Trade studies need to ensure that the requirements of the system need to be met, or that the requirements change as necessary to reflect the benefits, costs, risks, and disadvantages of a particular choice.

Some level of modeling of the deep submergence vehicle is necessary. A deep ocean vehicle has a trade-off of size, buoyancy, weight (both in the water and out), and cost. Buoyancy and depth capability can be very difficult but absolutely key to properly model. Vehicle maneuverability needs to be modeled to determine the time to ascend and descend through the ocean. Minimizing the time spent in getting to and from depth is key to commercial success. APL-UW will use a variety of modeling tools, depending on what is needed. Excel spreadsheets have been used successfully to track vehicle weight, buoyancy, center-of-gravity, center-of-buoyancy, and power requirements. Specific hydrodynamic and flow studies will be conducted to evaluate drag as needed. We also need to consider the human element in terms of impact on buoyancy, weight distribution, energy, and oxygen requirements (over time). No attempt will be made to produce a full system model that integrates all aspects of the system, but modeling will be conducted as necessary to support overall system design and component-level trade studies and testing.

There are three levels to the integrated design: hardware, electrical, and software. The hardware will be designed using software, such as Solidworks, to ensure that the hardware components are compatible. An electrical design is required to help define the power and communication requirements between all of the different components and to ensure a proper interface between components, such as the pressure hull and other external components. Finally, there is an overarching software architecture that will need

to be constructed to ensure that the control functions integrate the sensor side (i.e., speed, depth, inertial measurements, heading, temperature, etc.) with the actuator side (i.e., thrusters, fins, buoyancy). In addition, there will need to be integration of the supply and demand for the human support and safety including air, pressure, and temperature.

APL-UW will use existing facilities and work with OceanGate to modify and/or develop new facilities to fabricate and construct the submersible. This will be conducted in a step-wise process that will test individual components and then integrate and test in a "build-test-build" sequence. For individual components, but especially for the final assembled unit, launch and recovery of the system shall be designed, constructed and tested. Testing of the pressure hull will initially be conducted without humans and then turned over to OceanGate for final safety approval and testing. APL-UW will support all aspects of this testing.

Assessment of performance will depend on the integration and data collection of the many individual components, their sensors, and actuators. APL-UW will support OceanGate with creating a configuration managed software and hardware support system. It will also work with OceanGate to generate tools to analyze at-sea test data in order to develop metrics for evaluation of submersible performance.

All of these steps will be conducted in an iterative process that begins at the component level and integrates components sequentially until a fully integrated system is developed. Along the way APL-UW will conduct regular design reviews to gather input on the designs and create alternatives that will need to be evaluated.

Finally, APL-UW shall work to ensure the safety of the submersible, the engineers, and test personnel. Safety will not be compromised in any aspect of the design, fabrication, or test.

Statement of Work

Task 1: Cyclops design support

APL-UW shall work with OceanGate to design a deep manned underwater vehicle (MUV) (a.k.a., Cyclops) and its launch and recovery system that is capable of supporting 5 people up to a 6,000-meter operational depth. The design shall include mechanical engineering, electrical engineering, software engineering, control systems, communication, deployment, recovery, and testing. APL-UW shall provide, as necessary, simulation of sub-system performance under a range of environmental and operational conditions. APL-UW shall work with OceanGate to develop a construction schedule and allocation of tasks to OceanGate, APL-UW, and sub-contractors for Cyclops sub-components.

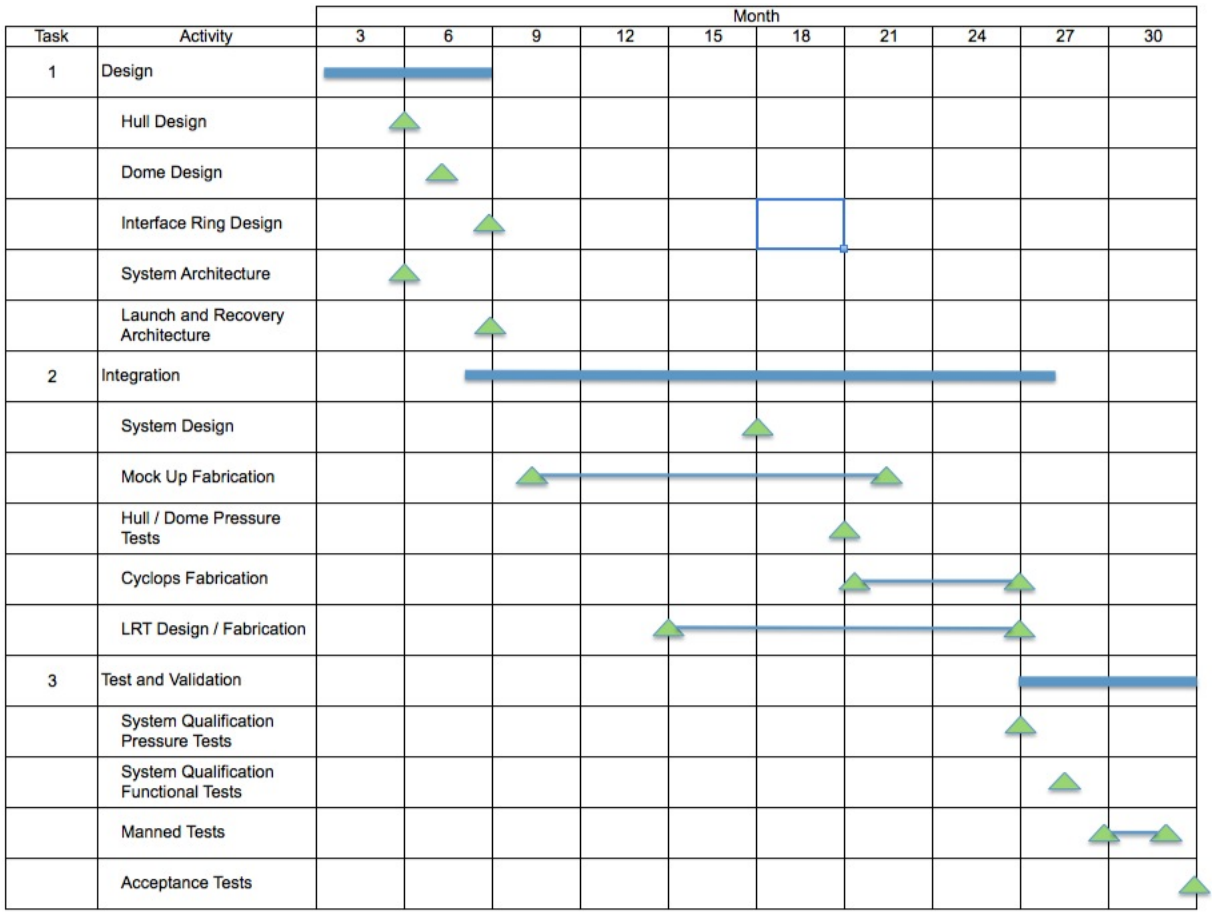
Task 2: Cyclops development support

APL-UW shall work with OceanGate to construct Cyclops. This shall include monitoring schedule and coordinating sub-component construction according to the design in Task 1. APL-UW shall provide, as necessary, areas for fabrication and assembly.

Task 3: Cyclops testing support

APL-UW shall work with OceanGate to provide test and analysis of system components and the integrated system (including launch and recovery). Services shall be provided as needed and may include support of in situ testing systems and remote, on location, depth testing of major components. Testing in UW pressure tanks may also be required.

Schedule



Deliverables

1. Monthly technical and financial reports
2. System Architecture
3. Manned Submersible
4. Launch and Recovery System
5. Operational Documentation
6. Test Plans and Analysis

Risk Management

All on-water testing is subject to weather conditions. APL-UW's foremost goal is to ensure safe operating conditions for all personnel. Within that, the tests will be conducted in the best weather conditions possible, which may be less than optimum given the time of year and the tight timeline for execution of this proposal.

Management Personnel

APL-UW will be led by Robert Miyamoto who will coordinate with OceanGate, Inc. for all tasks. Dave Dyer and Andrew Stewart will support the overall system engineering. Pete Brodsky will provide for the software engineering.

Robert Miyamoto, Associate Director, Applied Physics Laboratory

Robert Miyamoto is Principal Physicist and Affiliate Associate Professor of Electrical Engineering at the University of Washington. He has thirty years of experience in sonar analysis and design, especially environmentally adaptive sonar and most recently in acoustic multistatic systems. He has worked in sonar automation, including human-system integration. He is known for his work in environmental acoustics for a wide range of active and passive systems. He was also the principal acoustician in the DARPA Unmanned Naval Vessel project, which led to the Active Continuous Trail Unmanned Vehicle (ACTUV) project. In Phase 1 of the ACTUV project he led an effort that demonstrated the efficacy of imaging sonars (specifically a P450-130 BVT sonar) for continuous trail of a submarine in the presence of countermeasures, obstacles, and surface ship traffic.

David Dyer, Senior Engineer, Applied Physics Laboratory

David Dyer has over 30 years experience providing mechanical and systems engineering support to a wide variety of projects such as sonobuoys, blue/green laser communication, composite structures for satellites, dynamic analysis of launch vehicles, as well as design and analysis of consumer products. He has worked in a wide variety of industries while employed at Rockwell, Hughes, Boeing, and Precor. He is currently supporting several efforts to develop concepts and prototypes of autonomous underwater vehicles. Mr. Dyer recently provided engineering support for sea testing of high definition sonar performance and capabilities for use in close contact tracking and threat detection, as well as research being conducted to evaluate the potential for energy harvesting of thermal vents.

Andrew Stewart, Senior Engineer, Applied Physics Laboratory

Dr. Andrew Stewart is an Ocean Engineer with the UW Applied Physics Laboratory, where he works to develop new technology for exploring marine environments. He has experience with systems engineering and mechanical design, and his research is in dynamics and control theory. Andrew has worked to develop tools for optimizing decision making in human and co-robot exploration tasks and has developed a number of autonomous underwater vehicles. As a mechanical designer for L-3, he has contributed to several large ONR projects including the Affordable Weapon System UAS and the experimental LCS prototype Seafighter.

Pete Brodsky, Principal Engineer, Applied Physics Laboratory

Peter Brodsky develops command and control software for Autonomous Underwater Vehicles (AUVs). In support of this discipline, he also writes tools for AUV flight prediction, simulation, and underwater navigation. At least five different AUVs are now in his repertoire, of both the propeller and buoyancy-driven varieties. In addition, Mr. Brodsky supports projects in the areas of acoustic simulation, ocean property estimation, and image-processing and automatic target recognition. Two and three dimensional graphical displays of geometric data are another field of expertise. A former Merchant Marine officer, Mr. Brodsky has extensive seagoing experience. He has over 20 years developing scientific and realtime control software in C/C++, Java, Python, and shell scripting. Mr. Brodsky joined the Laboratory's Environmental and Information Systems Department in 1999.

APL-UW IP

APL-UW begins the project with no specific intellectual property intended for use in this project.

Data Rights

No data rights are requested.

APL-UW Capabilities

APL-UW has over forty years of experience developing and transitioning unmanned, autonomous underwater vehicles, including high frequency sonar systems for communications, search, and imaging. From 1960 to 1975 APL-UW built the first unmanned underwater vehicle called the Self Propelled Underwater Research Vehicle (SPURV) with acoustic underwater communications, acoustic and non-acoustic sensors for operations in acoustic research, and ocean properties mapping operational to a depth of 3600 m. In the 1970's APL-UW developed the Unmanned Arctic Research Submersible (UARS) for navigation under the ice using acoustic lens technology. In the 1970's APL-UW built high-speed underwater vehicles as well as the MK-38 mobile sonar training vehicle. In the 1990's APL-UW worked with the Department of Oceanography to develop a buoyancy-driven, underwater glider (Seaglider) that has flown for 6 months and 2000 nautical miles. More recently APL-UW has teamed with the Marine Physical Laboratory at the University of California San Diego to develop and prototype a buoyancy driven underwater flying wing. Therefore, APL-UW has considerable background in building conventional and unconventional vehicles.

APL-UW has also had a number of programs to construct high resolution, multi-beam sonars including the development of the Dual-Frequency Identification Sonar (DIDSON) using acoustic lens technology, and the blazed array imaging sonar now marketed by BLUVIEW Technologies. These sonars are state-of-the-art imaging sonars and are being used extensively in a wide range of applications including underwater vehicles.

APL-UW is located on the campus of the University of Washington with a staff of 300 in five buildings. These facilities include a 57-foot utility boat and a self-propelled, pontoon based, floating laboratory that can serve as an acoustic calibration facility, and where large instrumentation can be deployed and tested. Our machine shops are capable of building advanced prototypes. In addition, APL-UW has instrumentation for underwater testing including pressure tanks, portable tracking ranges, acoustic communications, and Benthos acoustic localization systems.

In addition to its hardware capabilities, APL-UW has considerable software development experience including ongoing programs to provide real-time sensor integration into unmanned vehicles for vehicles as small as an Iver2 (5" diameter) to an ocean-roving 30 foot "X-Ray" glider (http://www.apl.washington.edu/projects/xray/summary.html).

DCAA Accounting System

The University of Washington has an approved Defense Contracting Auditing Agency (DCAA) accounting system. Audit Report #4261-2006S11070001 dated September 27, 2006.

[redacted] Applied Physics Laboratory

Associate Director for Applied Research and Technology — University of Washington
Affiliate Associate Professor of Electrical Engineering

Education

1976 Ph.C. (Candidate for Ph.D.), Department of Oceanography, University of Washington
1973 B.A., Math and Physics, University of California - Irvine

Experience

2001-Present Associate Director for Applied Research and Technology, Applied Physics Laboratory, University of Washington.

2001-Present Affiliate Associate Professor of Electrical Engineering, University of Washington

1995-2002 Department Head, Environmental and Information Systems Department (EIS), Applied Physics Laboratory, University of Washington. Responsible for a department of over thirty professional staff with grants and contracts of approximately $5 million per year. The EIS department is a multi-disciplinary team with expertise in signal processing, statistics, simulation, oceanography, meteorology, optimization, computer science, workflow analysis, multimedia, visualization, and human factors. The department included 10 Ph.D.s, 11 Masters, Bachelors, graduate students, and undergraduate student employees.

1979-Present Principal Investigator/Project Manager, Applied Physics Laboratory, University of Washington

Various projects in underwater acoustics, signal processing, geophysics, simulation, human-systems interaction, multimedia, oceanography, and instrument development funded by US Navy R&D laboratories (Naval Oceanographic Office, Naval Underwater Systems Center, Naval Ocean Systems Center), DARPA, the Office of Naval Research, and the National Science Foundation

Panels, National and International Committees and Societies

Institute of Electrical and Electronics Engineers
National Defense Industrial Association
Clinical Care Advisory Board, Children's Tumor Foundation

Awards

1995 College of Ocean and Fishery Sciences Distinguished Service Award
1995 Jefferson Award (Washington State) from the American Institute for Public Service

Publications

[redacted]

[redacted], "An Autonomous, Closed-Loop, Concept Study for Detecting and Tracking Submerged Objects," *U.S. Navy Journal of Underwater Acoustics*, In Press, JUA Vol 59(2), April 2009.

[redacted], "Incorporating Performance Prediction Uncertainty Into Detection and Tracking," *U.S. Navy Journal of Underwater Acoustics*, JUA 1552, April 2006.

[redacted] "Emerging Technologies: ONR's need for intelligent computation in underwater sensors," in Computational Intelligence: The Experts Speak, edited by David B. Fogel and Charles J. Robinson, IEEE press, pp 57-64 (2003)

[redacted] (2002). Human Systems Study on the Use of Meteorology and Oceanography Information in Support of the naval Air Strike Mission. *APL-UW Technical Memorandum 8-02*. Applied Physics Laboratory-University of Washington, November, pp 146.

[redacted], "Neural network training for varying output node dimension," *Proceedings of the Intl. Joint Conf. on Neural Networks 2001*, Washington, D.C., pp. 1733-38.

[redacted]"Team optimization of cooperating systems: Application to maximal area coverage," *Proceedings of the Intl. Joint Conf. on Neural Networks 2001*, Washington, D.C., pp. 2212-2217.

[redacted], "Stochastic resonance of a threshold detector," submitted to *IEEE Signal Processing Letters*, Feb. 2001.

[redacted]A fuzzy-logic autonomous agent, applied as a supervisory controller in a simulated environment," *IEEE Transactions on Fuzzy Systems*, Volume 12, #1, February 2004, pp. 107-122.

[redacted]Active sonar search for underwater targets utilizing an autonomous agent as the supervisory controller," submitted to *IEEE Journal of Oceanic Engineering*, Dec. 2000.

[redacted]
"Design and Evaluation of Digital METOC Documents to Support Retrieval and Use of Information: User-Centric CDROM Compared to the Traditional Paper Document and its Republished Web Version," NRL-WDC Technical Report TR 9963, October 2000.

[redacted]"Turning Pictures into Numbers: Extracting and Generating Information from Complex Visualizations," International Journal of Human Computer Studies, 53(5) 827-850, November 2000.

[redacted]-
[redacted]
"Inversion of Feedforward Neural Networks: Algorithms and Applications,"

Proceedings of IEEE, (Special Issue--Computational Intelligence) Vol. 87, No. 9; 1536-1549, September 1999.

[redacted], "Self-selective clustering of training data using the maximally-receptive classifier bank," submitted to *IEEE Transactions on Neural Networks*, Aug. 1999.

[redacted] "The Sound," An interactive, multimedia CD-ROM for Puget Sound, published by Washington Sea Grant Program August 1996.

[redacted] "I am Tamra's Father," Father's Voices - Exceptional Parent Magazine (a magazine for parents of children with special needs), August 1996.

[redacted], "Managing Environmental Information to Support Navy Tactical Commanders," U.S. Navy Journal of Underwater Acoustics, October, 1996.

[redacted] "Tactical Environmental Information Agent," American Society of Naval Engineers' Intelligent Ships Symposium, November, 1996.

[redacted] "Environmentally Adaptive Tactical Systems," American Society of Naval Engineers' Intelligent Ships Symposium, November, 1996.

[redacted]," J. Atmospheric and Oceanic Technology, 12(2):367-380, April 1995.

M[redacted]"An autonomous dual-beam acoustics and data telemetry system for time-series study of acoustic backscatter and individual target strengths of oceanic macrozooplankton and micronekton." EOS Transactions of the American Geophysical Union, 71(95).

[redacted] "Shallow water environmental effects on torpedoes (U)" (Confidential). U.S. Navy Journal of Underwater Acoustics (U), Special Feature: Shallow Water Acoustics, 42(4), 1992. (SECRET).

[redacted]. "High frequency environmental acoustic survey data." Proceedings of the Symposium on Shallow Water Undersea Warfare, 1992. The Technical Cooperation Program.

[redacted]. "Probing the fine structure of sound-scattering layers with ROVERSE technology." Liminology and Oceanography, 36(1):193-204, 1991.

[redacted]. "BIOSPAR, a buoy system for acoustic monitoring of biological populations." IEEE Oceans '89 Proceedings, 4:1032-35, 1989.

[redacted] "Some new developments in turbulent diffusion of momentum in a stably stratified fjord." EOS Transactions of the American Geophysical Union, 57(12):934.

APL-UW Reports (partial listing)

[redacted], [redacted] [redacted] "Sonar Environmental Parameters Estimation System (SEPES)," Applied Physics Laboratory - UW Technical Report 0101, 2001.

[redacted] and [redacted] "Preliminary Results from a Human Systems Study of the Use of Meteorological and Oceanographic Data to Support Naval Air Strike" Applied Physics Laboratory Technical Memorandum APL-UW TM 8-00, January 2001

[redacted]., and [redacted] "Introduction to METOC Workflow Analysis for Anti-Submarine Warfare Mission Planning," Project Report submitted by Guide.Net, Inc. , December 31, 1998. Funded by the DARPA CEROS project, Contract number 44404.

[redacted], "Transfer of Navy's Environmental Guides to CD-ROM, APL-UW Technical Memorandum TM 17-91, Seattle, WA: Applied Physics Laboratory, University of Washington.

[redacted]n. 1987. "Simulation inputs for Tsugaru using NAVOCEANO high-frequency acoustic survey data: quick look analysis (U)." (Confidential).

[redacted]. 1989. "Simulation inputs for the approach to the Strait of Juan de Fuca using NAVOCEANO high-frequency acoustic survey data: quick look analysis (U)." (Confidential). APL-UW TR 8821.

[redacted] [redacted] and [redacted]. 1991. "APP volume scattering inputs for the Mediterranean Sea, Sargasso Sea, U.S. Pacific Coast, and Bering Sea (U)." (Confidential). APL-UW TR 9020.

David Dyer – Ocean Engineer
Applied Physics Laboratory, University of Washington
Ocean Engineering Dept.
[redacted]

Professional History

Applied Physics Lab, University of Washington Seattle, Washington 2010 to Present

Ocean Engineer, Ocean Engineering Department

- Develop methods and operational schemes for deployment of sensor platforms for use in deep ocean research.
- Unmanned underwater vehicle design, fabrication and operations.
- Develop concepts for deep ocean vehicles for energy delivery to stationary and mobile sensor nodes
- Provide "at-sea" support of tests and operations
- Produce concepts and co-author proposals for ONR, DARPA, NSF and other DoD agencies.
- Design, analyze and provided fabricated oversight of various hardware platforms to be deployed in ocean environments.

Precor USA Woodinville, Washington 1998 to 2010

Chief Engineer, Cardio Research and Development

- Develop logic, a database structure, and Java code using a business rules engine to provide "intelligent" and specific guidance to exercisers.
- Evaluate biomechanics and user touch points on new line of cardio and strength equipment
- Design components and structure used for preliminary stress analysis of prototype concepts used to evaluate the feasibility of components and design concepts
- Provide oversight of university studies and multiple consultants

Director, Research and Innovation

- Manage a team of multi-discipline engineers in the evaluation of technologies to determine potential uses and how they could achieve specific product capabilities
- Develop and prototype concepts of exercise equipment that provide new exercise experiences through new motions and unique user interaction
- Work with the VP of Innovation to develop the yearly department project plan and provide oversight of an $8M department budget
- Provide leadership to model shop and test engineering group and assist in establishing project and task priorities in support of product development team efforts
- Monitor, direct, and maintain intellectual property disclosure and application processes

Engineering Manager

- Provide technical direction for a cross functional team in the development, test, and launch of cardio exercise equipment
- Design and analyze cardio equipment structures and components using Solidworks and Ansys
- Function as project manager for cardio equipment projects

Senior Engineer

- Perform thermal analysis of control and power systems using Ansys and hand calculations
- Technical lead for heavy commercial, light commercial and home-use treadmill projects

Boeing — Kent, Washington — 1997 to 1998

Principle Engineer, Structural Analyst

- Design and analyze of the ground support equipment used to mate a satellite to the launch vehicle using ProE, PATRAN, and Ansys
- Conceive of a method of stowing on a launch vehicle, and deploying in space, a 30 foot by 60 foot composite phased array antenna resulting in a patent
- Design, analyze, and provide oversight for the prototype build of the composite phased array antenna structure

ENTEC — Renton, Washington — 1996 to 1998

Owner/Consulting Mechanical Engineer

- Independent engineering consultant
- Conceive, design and prototype a bulge water filtration system for small commercial fishing boats to meet newly established USCG bilge water contamination regulations
- Design and fabricate portable sound barriers used in large meeting halls at Puyallup Fairgrounds
- Develop concepts for converting ship motion to electric energy to be used for powering cargo container monitoring systems

Hughes Aircraft — El Segundo, CA and Kent, WA — 1984 to 1997

Senior Project Engineer/Vehicle Engineer

- Provide engineering direction and technical expertise in the fabrication, testing and launch of communications satellites

Section Head/Structural Analysis Section

- Provide organizational and procedural direction to the Space Dynamics Group
- Perform dynamic analysis of satellite systems during Space Shuttle and Titan rocket launches
- Develop and direct spacecraft vibration testing to validate the analysis and structural integrity

Engineer, Dynamic Analyst

- Perform dynamic analysis of satellite systems during Space Shuttle and Titan rocket launches
- Perform dynamic and static analysis of the General Motors solar powered car entered in the first Australia World Solar Challenge

Rockwell International — Fullerton, California — 1981 to 1984

Mechanical Engineer/Ocean Engineering Department

- Design of high pressure seals for cable penetration through pressure vessel bulkheads
- Design and analysis of structure and test samples for a boundary layer control by suction study
- Design and test of sonobuoy components and mechanisms
- Test coordinator for at-sea sonobuoy testing requiring quick retrieval of failed sonobuoys for cause and effect analysis of intermittent failures
- Design and conduct sonobuoy deployment and functional tests conduct in on-site tanks and pressure vessels
- Design of pressure vessels for a blue-green laser communication system and conduct the thermal analysis of the laser receiver platform to ensure a stable platform

Todd Shipyard — San Pedro, California — 1980

Associate Engineer

- Direct main propeller shaft alignment procedures providing analysis support and interpretation of strain gage monitoring

Support sea trials of Perry class fast frigates

- **Education**

Bachelor of Science, Ocean Engineering - Mechanical Emphasis — 1981

CALIFORNIA STATE UNIVERSITY, LONG BEACH

Related Credentials and Skills

Professional Engineer, State of Washington, License Number 35231
Certificate of Technology Management, California Institute of Technology
Agile Product Development – Scrum Master Certified
United States Citizen

Professional Memberships

IEEE - Oceanic Engineering Society

Patents

Exercise Community System; 7,955,219 B2, June 7, 2011
Adjustable Exercise Device; 7,938,755 B1
Weight stack selector; 7,871,357
End of travel stop for an exercise device; 7,833,133
Weight stack selector; 7,815,554
Exercise device visual representation; 7,758,469
Cross training exercise device; 7,731,635
Elliptical exercise equipment with stowable arms; 7,731,634
Incremental weight and selector; 7.708.672
Elliptical exercise equipment with adjustable stride; 7.704,192
Parameter sensing system for an exercise device; 7,507,187
Adjustable exercise device; 7,156,777
Treadmill with adjustable cushioning members; 6,821,230
Treadmill cushion; 6,589,138
Flexible self-actuated structure and associated method; 6,266,030

Patents Pending

Self-powering on-board power generation; 20090200983
Treadmill cushion; 20020010055

[redacted] Applied Physics Lab – University of Washington
Ocean Engineering Dept.
1013 NE 40th St, Seattle WA 08544
[redacted]
[redacted]

Education

Ph.D. – **Princeton University (2012), Princeton, NJ**
Department of Mechanical and Aerospace Engineering
Thesis: *Analysis and Prediction of Decision Making with Social Feedback*
Advisor: Naomi Ehrich Leonard

M.A. – **Princeton University (2008), Princeton, NJ** Department of Mechanical and Aerospace Engineering Dynamics & Control Theory
Advisor: Naomi Ehrich Leonard

B.Sc. – **University of California, San Diego (2006), San Diego, CA**
Jacobs School of Engineering
Mechanical Engineering Advisor:
Miroslav Krstic

Professional Experience

APL-UW - Research Scientist, 2012 to present **Seattle, WA**

- Development of tidal generator environmental monitoring package unmanned docking system.
- Lead Mechanical Engineer for NSF-funded ocean observatory instrument to provide streaming high-definition footage of thermal vents.
- Mechanical Design of instrumentation for deep-sea deployment, measuring seawater velocity using voltage potential induced by earth's magnetic field.
- Analysis of Dynamics of ONR buoyancy-driven glider.

Princeton University - Researcher, 2006 to 2012 **Princeton, NJ**

- Managed lab operations (schedule, budget, hardware procurement), Oversaw undergraduate thesis work, Developed robotic testbed and supporting laboratory equipment
- Modeled human-in-the-loop systems, Predicted performance in teams with social feedback, Performed research in support of Air Force Office of Scientific Research project to study interaction in mixed systems of humans and automata
- Collaborated with psychologists to develop experiments with human subjects

L-3 Communications - Mechanical Designer, 2002 to 2005 San Diego, CA

- Designed and built unmanned air vehicle systems for Office of Naval Research, Tested Prototype to compete with Tomahawk
- Managed mechanical design of *Seeker* - a dual-axis, forward-looking sensor mounted on air vehicle platforms
- Built first modular rocket launch system for deployment of UAVs
- Supported outfit team for US NAVY / US Coast Guard experimental craft SEAFIGHTER

UCSD Independent Research - Project Leader, 2006 San Diego, CA

- Constructed Autonomous Underwater Vehicle
- Acquired funding, managed budget and schedule
- Adapted vehicle for experimental use at UCSD

KK Boat Building - Master Shipwright's Apprentice, 2001 San Diego, CA

- Implemented modern composite hull re-fit on classic wooden sailboats
- Developed project management tool to track labor and materials costs on large contracts

Scripps Institution of Oceanography - Researcher, 1999 San Diego, CA

- Ran field deployments, Tested GPS data acquisition systems
- Researched feasibility of remote station in Baja California, Mexico

Teaching Experience

Princeton University - Assistant Instructor, 2008 to present Princeton, NJ

- **Introduction to Design**

– Professor [redacted]

Delivered special lecture on design methodology, Guided student projects in machine shop and design lab, Assisted students with written reports, Graded final exam.

- **Introduction to Dynamics**

– Prof. N. [redacted]

Held weekly review sessions, Delivered supplemental lectures, Created assignments: midterm and final exam, Graded all student work.

- **Modern Control Theory**

– Prof. [redacted]

Held weekly review sessions, created assignments, and graded all student work.

Publications

Journal Papers

[redacted], "*Towards humans in the loop: Model-based analysis of human decision making in two-alternative choice tasks with social feedback.*" Proceedings of the IEEE, 100:3, 751-775, 2012.

[redacted], "*Convergence in human decision-making dynamics.*" Systems & Control Letters, Volume 59, pp. 87-97, 2010.

Conference Papers

[redacted], "*The role of social feedback in steady-state performance of human decision making for two-alternative choice tasks.*" Proceedings of the IEEE Conference on Decision and Control, Atlanta, Georgia, 2010.

[redacted], "*Steady-state distributions for human decisions in two-alternative choice tasks.*" Proceedings of the American Control Conference, Baltimore, Maryland, 2010.

[redacted], "*Integrating human and robot decision-making dynamics with feedback: Models and convergence analysis.*" Proceedings of the IEEE Conference on Decision and Control, Cancun, Mexico, 2008

Presentations

"Decision making in systems with mixed assets: humans in the loop with automata," *UCSD Controls Group*, July 12, 2011, San Diego, CA.

"Decision making in cyber-physical systems with emphasis on human-supervisory input," *Nonlinear Dynamical Control Systems Lab Seminar*, July 5, 2011, Seattle, WA.

"Realization of Humans and Robots," AFOSR MURI 16 Review, June 13, 2011, Arlington, VA. "Humans in the Loop: Decision-Making Teams for Management of Automated Systems," Dynamical Systems Seminar, March 4, 2011, Princeton, NJ.

"Humans in the Loop: Model-based analysis of human decision making with social feedback," *MAE Graduate Research Day 2010*, September 17, 2010, Princeton, NJ.

"Steady-state distributions for human decisions in two-alternative choice tasks," *American Control Conference*, July 1, 2010, Baltimore, MD.

"Humans in the Loop," *AFOSR MURI 16 Review*, August 13, 2010, Arlington, VA.

"Modelling Human Decision Making in Task Allocation of Autonomous Vehicles," *FAA JUP Pro- gram Review*, April 23, 2009, Princeton, NJ.

"Collective Robotic Foraging," *General Examination Research Comp.*, January 23, 2008, Princeton, NJ.

"Integrating Human and Robot Decision-Making Dynamics with Feedback," *Northeast Control Workshop*, April 27, 2008, University of Maryland, College Park, MD.

Skills

- Applied Math, Dynamics, and Control Theory: Dynamical Systems analysis tools, Stochastic Systems Analysis, Markov Chains, Dynamic Programming, Optimal Control & Estimation, etc.
- Adept in hands-on industrial setting: machine & hand tools /fastening /composites /adhesives /electronics /embedded systems. Intuitive understanding of mechanical systems & material properties: weather ability, corrosion rates, impact/abrasion, etc.
- Proficient with common programming/modeling environments (MatLab, C, Solidworks, ProE)
- Marine-specific skills: SCUBA (20 years experience), Sailboat Racing, Large and small craft boat-handling skills (expert level), Boat-building (2,000 + hours experience), Marine systems repair and maintenance, etc.
- Language: English - Native, Spanish – Fluent

Awards

- Best Paper Presentation in Session, *American Control Conference 2010* - Baltimore, MD
- Best Presentation, *MAE Graduate Research Day 2010* - Princeton, NJ

[redacted]

Senior Engineer
Applied Physics Laboratory, University Of Washington

[redacted]

Skills Summary

- Twenty years experience developing engineering and scientific software.
- Autonomous vehicle control: Design and development of algorithms and software for real-time control of Autonomous Underwater Vehicles (AUVs).
- Acoustic signal processing: Implementation of algorithms for simulation and modeling of underwater acoustic signals, including propagation, scattering, attenuation, and reflection.
- Estimation for dynamic systems: Design and development of Kalman filters and batch estimators for nonlinear parameter determination.
- Image processing: Linear and nonlinear filter design and development, edge detection, segmentation, Fourier and Wavelet filtering/denoising, morphological processing, thresholding, and color mapping.
- Automatic target recognition: Detection/Classification/Identification
- Networks and distributed systems: Experience developing multi-platform distributed systems using Corba, HTTP/Web Services and XML.

Professional Experience

- **1999-Present: Software Engineer, University of Washington Applied Physics Laboratory**
    - Lead engineer for large AUV (“XRay”) flight control software. Designed and developed all onboard subsystem logic including navigation, active control, logging, acoustic and satellite communications, and vehicle health and safety. Directed development of real-time onboard acoustic data processing system. Developed real-time dynamic simulator for testing. Perform at-sea testing for vehicle engineering and participate in joint AUV exercises MB’06 and PN’07.
    - Continuing development of a high-fidelity sonar signal simulation program.
    - Created an image processing system for underwater mine identification.
    - Developed a parameter estimation program for ocean bottom characteristics.
    - Assisted in development of a neural-network program for emulation of a complex underwater acoustic model.
    - Continuing development of a web-based distributed system for oceanographic and meteorological data dissemination.

- **1997-1999: Software Engineer, The Boeing Company**

Developed software comprising a real-time embedded flight simulator. Developed a prototype of an extended Kalman filter for GPS-based satellite orbit determination.

- **1993-1997: Software Engineer, Lockheed-Martin Corporation**

Developed command and control software for commercial satellite systems. Designed multi-satellite constellation orbit control system. Developed and implemented algorithms for ground and antenna control. Led team of developers creating mission analysis software, which modeled propulsion, attitude, and power systems, and flight dynamics and trajectory control.

- **1989-1993: Software Engineer, Space Telescope Science Institute**

Developed planning and analysis software for the Hubble Space Telescope. Created and implemented algorithms for scheduling, locating, and pointing orbiting instrument.

Education

- M.S., Applied Mathematics, The Johns Hopkins University, Baltimore, MD
- B.S., Meteorology and Oceanography, State University of New York Maritime College, New York, NY

APL- UW Estimated Budget

Deep Ocean Exploration Submersible
Principal Investigator: [redacted]
Budget Summary

	YR 1	YR 2	YR 3	TOTAL
A. Salaries [1]	$390,833	$518,795	$304,877	**$1,214,505**
B. Employee Benefits [2]	$238,408	$316,465	$185,975	**$740,848**
C. Equipment	$81,028	$0	$0	**$81,028**
D. Travel [3]	$11,160	$11,220	$39,918	**$62,298**
E. Other Direct Costs				
Services	$337,424	$343,704	$173,464	$854,592
Supplies	$223,165	$144,270	$99,021	$466,456
Subtotal Other Direct Costs	$560,589	$487,974	$272,485	**$1,321,048**
F. Prorated Direct Costs [4]	$200,106	$265,623	$156,097	**$621,826**
G. TOTAL DIRECT COSTS	$1,482,124	$1,600,077	$959,352	**$4,041,553**
H. UW Indirect Costs [4]	$238,187	$272,013	$163,090	**$673,290**
I. Total Direct + Indirect Costs	$1,720,311	$1,872,090	$1,122,442	**$4,714,843**
J. APL Fixed Fee (5.7%) [5]	$98,058	$106,709	$63,979	**$268,746**
K. TOTAL	**$1,818,369**	**$1,978,799**	**$1,186,421**	**$4,983,589**

NOTES

[1] Estimated Staff hours are calculated by multiplying total MM by the hours per month (173.3).

[2] The APL benefit and leave rates are in accordance with the University of Washington's negotiated rates approved by DHHS and UW policy on proposal budgets.

[3] Per diem rates for specific locations are set by the State of Washington.

[4] The University Facilities and Administration (F&A) rate applied to APL-UW is lower than the rate elsewhere on campus (17% vs 54.5%) and does not recover the Laboratory's central costs. These are recovered by app a Prorated Direct Cost to total salaries. Prorated Direct Costs include such expenses as salaries and employ benefits for central service employees, administrative data processing, communications, and some facilities costs. APL-UW's Prorated Direct Costs have been reviewed and accepted by the Navy's Resident Administrative Contracting Officer, [redacted] Office of Naval Research, Seattle Regional Office, per letter dated 28 September 2012, to [redacted] Director, Applied Physics Laboratory.
The current F&A rate agreement with DHHS is dated 22 September 2011.

[5] APL-UW receives a fixed fee on its contracts to cover in-house research and development-related costs, such as costs to improve facilities, purchase equipment, support graduate students, and conduct an independent research and development program. APL-UW does not receive appropriated State funds or University funds for such purposes, and APL-UW has no foundation funds. The U.S. Navy (our primary sponsor), via the Naval Sea Systems Command has authorized payment of a fixed fee. APL-UW abides by the intent of this authorization for all fee received from all sponsors.

The APL-UW may rebudget within the total estimated cost.

Deep Ocean Exploration Submersible
Principal Investigator: [redacted]
By Task

	Amount PM	Rate	Design 6-mo **Task 1**	Build-18 mo **Task 2**	Test-6 mo **Task 3**	**Total**
A. Salaries						
[redacted] Principal Physicist	5.60		$8,128	$44,476	$40,591	$93,195
[redacted] Research Scientist/Engineer-Senior	23.00		$40,000	$141,866	$52,020	$233,886
Pete Brodsky, Research Scientist/Engineer Principal	21.00		$20,794	$147,499	$54,085	$222,378
TBD, Research Scientist/Engineer Principal	23.00		$41,588	$147,499	$54,085	$243,172
TBD, Research Scientist/Engineer Principal	12.00		$10,397	$84,285	$32,451	$127,133
TBD, Field Engineer 2	15.66		$0	$65,383	$31,590	$96,973
TBD, Field Engineer 2	5.34		$0	$33,076	$0	$33,076
Andrew Stewart, Research Scientist/Engineer-Senior	21.00		$15,400	$109,237	$40,055	$164,692
SubtotalPM/Salaries	126.60		$136,307	$773,321	$304,877	$1,214,505
Estimated Staff Hours [1]	21940					
B. Employee Benefits [2]						
Professional		.319	$43,482	$246,690	$97,256	
Subtotal Benefits			$43,482	$246,690	$97,256	
Leave Allowance						
Professional		.291	$39,665	$225,036	$88,719	
Subtotal Leave Allowance			$39,665	$225,036	$88,719	
Total Benefits/Leave Allowance			$83,147	$471,726	$185,975	$740,848
C. Equipment						
Schematic software			$21,900	$0	$0	
Solidworks software			$6,012	$0	$0	
PhotoStress Equipment			$0	$28,150	$0	
Steel Prefab Building			$0	$24,966	$0	
Total Equipment			$27,912	$53,116	$0	$81,028
D. Travel						
Meet with General Dynamics						
RT Airfares: Seattle, WA - Lincoln, NE	4	498	$498	$996	$498	
Per Diem	12	123	$369	$738	$369	
Car rental, gas, parking, etc.	12	65	$195	$390	$195	
Subtotal			$1,062	$2,124	$1,062	
Meet with Corning						
RT Airfares: Seattle, WA - Salt Lake City, UT	4	182	$182	$364	$182	
Per Diem	12	157	$471	$942	$471	
Car rental, gas, parking, etc.	12	65	$195	$390	$195	
Subtotal			$848	$1,696	$848	
Glass Dome Work						
RT Airfares: Seattle, WA - New York, NY	9	557	$557	$4,456	$0	
Per Diem	27	366	$1,098	$8,784	$0	
Car rental, gas, parking, etc.	27	65	$195	$1,560	$0	
Subtotal			$1,850	$14,800	$0	
Meet with Deep Ocean						
RT Airfares: Seattle, WA - Honolulu, HI	8	635	$0	$0	$5,080	
Per Diem	24	278	$0	$0	$26,688	
Car rental, gas, parking, etc.	24	65	$0	$0	$6,240	
Subtotal			$0	$0	$38,008	
Total Travel			$3,760	$18,620	$39,918	$62,298

Deep Ocean Exploration Submersible
Principal Investigator: [redacted]
By Task

			Design 6-mo Task 1	Build-18 mo Task 2	Test-6 mo Task 3	Total
E. Other Direct Costs						
Services						
Contract Services - Hardware Fab			$25,000	$200,000	$25,000	
Contract Services - Test Equip Fab			$10,000	$130,000	$10,000	
Pr Srvcs - Engr Sup - Proto/Human Factors	2,080	$105	$72,800	$145,600	$0	
Vessel Useage -RV Robertson	800	$280	$0	$89,600	$134,400	
FEA yearly maintenance			$1,137	$3,411	$2,274	
CFD yearly maintenance			$895	$2,685	$1,790	
Services Subtotal			$109,832	$571,296	$173,464	
Supplies						
Monitors			$1,700	$0	$0	
Computer			$1,800	$0	$0	
Mock-up supplies			$25,000	$15,000	$25,000	
Test supplies - scope, power supply, etc.			$0	$0	$20,000	
Test monitoring equipment - data loggers, interface boxes etc			$25,000	$50,000	$0	
Fabrication - launch, recover, & transport mock-up			$0	$50,000	$0	
Warehouse lease			$48,999	$149,936	$54,021	
Supplies Subtotal			$102,499	$264,936	$99,021	
Total Other Direct Costs			$212,331	$836,232	$272,485	$1,321,048
F. Prorated Direct Costs [4]						
51.2% of salaries			$69,789	$395,940	$156,097	$621,826
G. TOTAL DIRECT COSTS			$533,246	$2,548,955	$959,352	$4,041,553
H. Facilities & Administration Costs [4] (17% of G less Equip, Grad Op Fees, & Subcontract amounts above $25K)			$85,907	$424,293	$163,090	$673,290
I. Total Direct + F&A			$619,153	$2,973,248	$1,122,442	$4,714,843
J. APL Fixed Fee (5.7%) [5]			$35,292	$169,475	$63,979	$268,746
K. TOTAL			$654,445	$3,142,723	$1,186,421	$4,983,589

NOTES

[1] Estimated Staff hours are calculated by multiplying total MM by the hours per month (173.3).

[2] The APL benefit and leave rates are in accordance with the University of Washington's negotiated rates approved by DHHS and UW policy on proposal budgets.

[3] Per diem rates for specific locations are set by the State of Washington.

[4] The University Facilities and Administration (F&A) rate applied to APL-UW is lower than the rate elsewhere on campus (17% vs 56%) and does not recover the Laboratory's central costs. These are recovered by applying a Prorated Direct Cost to total salaries. Prorated Direct Costs include such expenses as salaries and employee benefits for central service employees, administrative data processing, communications, and some facilities costs. APL-UW's Prorated Direct Costs have been reviewed and accepted by the Navy's Resident Administrative Contracting Officer, [redacted] Office of Naval Research, Seattle Regional Office, per letter dated 28 September 2012, to [redacted] Director, Applied Physics Laboratory.
The current F&A rate agreement with DHHS is dated 22 September 2011.

[5] APL-UW receives a fixed fee on its contracts to cover in-house research and development-related costs, such as costs to improve facilities, purchase equipment, support graduate students, and conduct an independent research and development program. APL-UW does not receive appropriated State funds or University funds for such purposes, and APL-UW has no foundation funds. The U.S. Navy (our primary sponsor), via the Naval Sea Systems Command has authorized payment of a fixed fee. APL-UW abides by the intent of this authorization for all fee received from all sponsors.

The APL-UW may rebudget within the total estimated cost.

APL-UW Estimated Budget

Deep Ocean Exploration Submersible
Principal Investigator: [redacted]
Year 1

	Amount PM	Rate	Task 1	Task 2	Task 3	Total
A. Salaries						
[redacted] Principal Physicist	1.40	16,256	$8,128	$14,630	$0	$22,758
[redacted] Research Scientist/Engineer-Senior	8.67	10,000	$40,000	$46,700	$0	$86,700
Pete Brodsky, Research Scientist/Engineer Principal	6.67	10,397	$20,794	$48,554	$0	$69,348
TBD, Research Scientist/Engineer Principal	8.67	10,397	$41,588	$48,554	$0	$90,142
TBD, Research Scientist/Engineer Principal	3.67	10,397	$10,397	$27,760	$0	$38,157
TBD, Field Engineer 2	5.33	6,073	$0	$32,369	$0	$32,369
Andrew Stewart, Research Scientist/Engineer-Senior	6.67	7,700	$15,400	$35,959	$0	$51,359
SubtotalPM/Salaries	41.08		$136,307	$254,526	$0	$390,833
Estimated Staff Hours [1]	7119					
B. Employee Benefits [2]						
Professional		.319	$43,482	$81,194	$0	
Subtotal Benefits			$43,482	$81,194	$0	
Leave Allowance						
Professional		.291	$39,665	$74,067	$0	
Subtotal Leave Allowance			$39,665	$74,067	$0	
Total Benefits/Leave Allowance			$83,147	$155,261	$0	$238,408
C. Equipment						
Schematic software	2	$10,950	$21,900	$0	$0	
Solidworks software	2	$3,006	$6,012	$0	$0	
PhotoStress Equipment	2	$14,075		$28,150		
Steel Prefab Building	1	$24,966		$24,966		
Total Equipment			$27,912	$53,116	$0	$81,028
D. Travel						
Meet with General Dynamics						
RT Airfares: Seattle, WA - Lincoln, NE	1	$498	$498	$0	$0	
Per Diem	3	$123	$369	$0	$0	
Car rental, gas, parking, etc.	3	$65	$195	$0	$0	
Subtotal			$1,062	$0	$0	
Meet with Corning						
RT Airfares: Seattle, WA - Salt Lake City, UT	1	$182	$182	$0	$0	
Per Diem	3	$157	$471	$0	$0	
Car rental, gas, parking, etc.	3	$65	$195	$0	$0	
Subtotal			$848	$0	$0	
Glass Dome Work						
RT Airfares: Seattle, WA - New York, NY	5	$557	$557	$2,228	$0	
Per Diem	15	$366	$1,098	$4,392	$0	
Car rental, gas, parking, etc.	15	$65	$195	$780	$0	
Subtotal			$1,850	$7,400	$0	
Total Travel			$3,760	$7,400	$0	$11,160
E. Other Direct Costs						
Services						
Contract Services - Hardware Fab			$25,000	$25,000	$0	
Contract Services - Test Equip Fab			$10,000	$25,000	$0	

APL-UW Estimated Budget

Deep Ocean Exploration Submersible
Principal Investigator: [redacted]
Year 1

			Task 1	Task 2	Task 3	Total
Pr Srvcs - Engr Sup - Proto/Human Factors	2,080	$105	$72,800	$145,600	$0	
Vessel Useage -RV Robertson	107	$280	$0	$29,960	$0	
FEA yearly maintenance			$1,137	$1,137	$0	
CFD yearly maintenance			$895	$895	$0	
Services Subtotal			$109,832	$227,592	$0	
Supplies						
Monitors			$1,700	$0	$0	
Computer			$1,800	$0	$0	
Mock-up supplies			$25,000	$5,000	$0	
Test monitoring equipment - data loggers, interface boxes etc			$25,000	$50,000	$0	
Fabrication - launch, recover, & transport mock-up			$0	$16,667	$0	
Warehouse lease			$48,999	$48,999	$0	
Supplies Subtotal			$102,499	$120,666	$0	
Total Other Direct Costs			$212,331	$348,258	$0	$560,589
F. Prorated Direct Costs [4]						
51.2% of salaries			$69,789	$130,317	$0	$200,106
G. TOTAL DIRECT COSTS			$533,246	$948,878	$0	$1,482,124
H. Facilities & Administration Costs [4] (17% of G less Equip, Grad Op Fees, & Subcontract amounts above $25K)			$85,907	$152,280	$0	$238,187
I. Total Direct + F&A			$619,153	$1,101,158	$0	$1,720,311
J. APL Fixed Fee (5.7%) [5]			$35,292	$62,766	$0	$98,058
K. TOTAL			$654,445	$1,163,924	$0	$1,818,369

NOTES

[1] Estimated Staff hours are calculated by multiplying total MM by the hours per month (173.3).

[2] The APL benefit and leave rates are in accordance with the University of Washington's negotiated rates approved by DHHS and UW policy on proposal budgets.

[3] Per diem rates for specific locations are set by the State of Washington.

[4] The University Facilities and Administration (F&A) rate applied to APL-UW is lower than the rate elsewhere on campus (17% vs 56%) and does not recover the Laboratory's central costs. These are recovered by applying a Prorated Direct Cost to total salaries. Prorated Direct Costs include such expenses as salaries and employee benefits for central service employees, administrative data processing, communications, and some facilities costs. APL-UW's Prorated Direct Costs have been reviewed and accepted by the Navy's Resident Administrative Contracting Officer, [redacted] Office of Naval Research, Seattle Regional Office, per letter dated 28 September 2012, to [redacted] Director, Applied Physics Laboratory. The current F&A rate agreement with DHHS is dated 22 September 2011.

[5] APL-UW receives a fixed fee on its contracts to cover in-house research and development-related costs, such as costs to improve facilities, purchase equipment, support graduate students, and conduct an independent research and development program. APL-UW does not receive appropriated State funds or University funds for such purposes, and APL-UW has no foundation funds. The U.S. Navy (our primary sponsor), via the Naval Sea Systems Command has authorized payment of a fixed fee. APL-UW abides by the intent of this authorization for all fee received from all sponsors.

The APL-UW may rebudget within the total estimated cost.

APL-UW Estimated Budget

Deep Ocean Exploration Submersible
Principal Investigator: [redacted]
Year 2

	Amount	Rate	Task 1	Task 2	Task 3	Total
A. Salaries	PM					
[redacted] Principal Physicist	1.80	16,581	$0	$29,846	$0	$29,846
[redacted] Research Scientist/Engineer-Senior	9.33	10,200	$0	$95,166	$0	$95,166
Pete Brodsky, Research Scientist/Engineer Principal	9.33	10,605	$0	$98,945	$0	$98,945
TBD, Research Scientist/Engineer Principal	9.33	10,605	$0	$98,945	$0	$98,945
TBD, Research Scientist/Engineer Principal	5.33	10,605	$0	$56,525	$0	$56,525
TBD, Field Engineer 2	5.33	6,194	$0	$33,014	$0	$33,014
TBD, Field Engineer 2	5.34	6,194	$0	$33,076	$0	$33,076
Andrew Stewart, Research Scientist/Engineer-Senior	9.33	7,854	$0	$73,278	$0	$73,278
SubtotalPM/Salaries	55.12		$0	$518,795	$0	$518,795
Estimated Staff Hours [1]	9552					
B. Employee Benefits [2]						
Professional		.319	$0	$165,496	$0	
Subtotal Benefits			$0	$165,496	$0	
Leave Allowance						
Professional		.291	$0	$150,969	$0	
Subtotal Leave Allowance			$0	$150,969	$0	
Total Benefits/Leave Allowance			$0	$316,465	$0	$316,465
C. Equipment						
Total Equipment			$0	$0	$0	$0
D. Travel						
Meet with General Dynamics						
RT Airfares: Seattle, WA - Lincoln, NE	2	$498	$0	$996	$0	
Per Diem	6	$123	$0	$738	$0	
Car rental, gas, parking, etc.	6	$65	$0	$390	$0	
Subtotal			$0	$2,124	$0	
Meet with Corning						
RT Airfares: Seattle, WA - Salt Lake City, UT	2	$182	$0	$364	$0	
Per Diem	6	$157	$0	$942	$0	
Car rental, gas, parking, etc.	6	$65	$0	$390	$0	
Subtotal			$0	$1,696	$0	
Glass Dome Work						
RT Airfares: Seattle, WA - New York, NY	4	$557	$0	$2,228	$0	
Per Diem	12	$366	$0	$4,392	$0	
Car rental, gas, parking, etc.	12	$65	$0	$780	$0	
Subtotal			$0	$7,400	$0	
Total Travel			$0	$11,220	$0	$11,220
E. Other Direct Costs						
Services						
Contract Services - Hardware Fab			$0	$175,000	$0	
Contract Services - Test Equip Fab			$0	$105,000	$0	
Vessel Useage -RV Robertson	213	$280	$0	$59,640	$0	
FEA yearly maintenance			$0	$2,274	$0	
CFD yearly maintenance			$0	$1,790	$0	
Services Subtotal			$0	$343,704	$0	

APL-UW Estimated Budget

Deep Ocean Exploration Submersible
Principal Investigator: [redacted]
Year 2

	Task 1	Task 2	Task 3	Total
Supplies				
Mock-up supplies	$0	$10,000	$0	
Fabrication - launch, recover, & transport mock-up	$0	$33,333	$0	
Warehouse lease	$0	$100,937	$0	
Supplies Subtotal	$0	$144,270	$0	
Total Other Direct Costs	$0	$487,974	$0	$487,974
F. Prorated Direct Costs [4]				
51.2% of salaries	$0	$265,623	$0	$265,623
G. TOTAL DIRECT COSTS	$0	$1,600,077	$0	$1,600,077
H. Facilities & Administration Costs [4] (17% of G less Equip, Grad Op Fees, & Subcontract amounts above $25K)	$0	$272,013	$0	$272,013
I. Total Direct + F&A	$0	$1,872,090	$0	$1,872,090
J. APL Fixed Fee (5.7%) [5]	$0	$106,709	$0	$106,709
K. TOTAL	$0	$1,978,799	$0	$1,978,799

NOTES

[1] Estimated Staff hours are calculated by multiplying total MM by the hours per month (173.3).

[2] The APL benefit and leave rates are in accordance with the University of Washington's negotiated rates approved by DHHS and UW policy on proposal budgets.

[3] Per diem rates for specific locations are set by the State of Washington.

[4] The University Facilities and Administration (F&A) rate applied to APL-UW is lower than the rate elsewhere on campus (17% vs 56%) and does not recover the Laboratory's central costs. These are recovered by applying a Prorated Direct Cost to total salaries. Prorated Direct Costs include such expenses as salaries and employee benefits for central service employees, administrative data processing, communications, and some facilities costs. APL-UW's Prorated Direct Costs have been reviewed and accepted by the Navy's Resident Administrative Contracting Officer, [redacted] Office of Naval Research, Seattle Regional Office, per letter dated 28 September 2012, to [redacted] Director, Applied Physics Laboratory.
The current F&A rate agreement with DHHS is dated 22 September 2011.

[5] APL-UW receives a fixed fee on its contracts to cover in-house research and development-related costs, such as costs to improve facilities, purchase equipment, support graduate students, and conduct an independent research and development program. APL-UW does not receive appropriated State funds or University funds for such purposes, and APL-UW has no foundation funds. The U.S. Navy (our primary sponsor), via the Naval Sea Systems Command has authorized payment of a fixed fee. APL-UW abides by the intent of this authorization for all fee received from all sponsors.

The APL-UW may rebudget within the total estimated cost.

APL-UW Estimated Budget

Deep Ocean Exploration Submersible
Principal Investigator: [redacted]
Year 3

	Amount	Rate	Task 1	Task 2	Task 3	Total
A. Salaries	PM					
[redacted] Principal Physicist	2.40	16,913	$0	$0	$40,591	$40,591
[redacted] Research Scientist/Engineer-Senior	5.00	10,404	$0	$0	$52,020	$52,020
Pete Brodsky, Research Scientist/Engineer Principal	5.00	10,817	$0	$0	$54,085	$54,085
TBD, Research Scientist/Engineer Principal	5.00	10,817	$0	$0	$54,085	$54,085
TBD, Research Scientist/Engineer Principal	3.00	10,817	$0	$0	$32,451	$32,451
TBD, Field Engineer 2	5.00	6,318	$0	$0	$31,590	$31,590
Andrew Stewart, Research Scientist/Engineer-Senior	5.00	8,011	$0	$0	$40,055	$40,055
SubtotalPM/Salaries	30.40		$0	$0	$304,877	$304,877
Estimated Staff Hours [1]	5268					
B. Employee Benefits [2]						
Professional		.319	$0	$0	$97,256	
Subtotal Benefits			$0	$0	$97,256	
Leave Allowance						
Professional		.291	$0	$0	$88,719	
Subtotal Leave Allowance			$0	$0	$88,719	
Total Benefits/Leave Allowance			$0	$0	$185,975	$185,975
C. Equipment						
Total Equipment			$0	$0	$0	$0
D. Travel						
Meet with General Dynamics						
RT Airfares: Seattle, WA - Lincoln, NE	1	$498	$0	$0	$498	
Per Diem	3	$123	$0	$0	$369	
Car rental, gas, parking, etc.	3	$65	$0	$0	$195	
Subtotal			$0	$0	$1,062	
Meet with Corning						
RT Airfares: Seattle, WA - Salt Lake City, UT	1	$182	$0	$0	$182	
Per Diem	3	$157	$0	$0	$471	
Car rental, gas, parking, etc.	3	$65	$0	$0	$195	
Subtotal			$0	$0	$848	
Meet with Deep Ocean						
RT Airfares: Seattle, WA - Honolulu, HI	8	$635	$0	$0	$5,080	
Per Diem	96	$278	$0	$0	$26,688	
Car rental, gas, parking, etc.	96	$65	$0	$0	$6,240	
Subtotal			$0	$0	$38,008	
Total Travel			$0	$0	$39,918	$39,918
E. Other Direct Costs						
Services						
Contract Services - Hardware Fab			$0	$0	$25,000	
Contract Services - Test Equip Fab			$0	$0	$10,000	
Vessel Useage -RV Robertson	480	$280	$0	$0	$134,400	
FEA yearly maintenance			$0	$0	$2,274	
CFD yearly maintenance			$0	$0	$1,790	
Services Subtotal			$0	$0	$173,464	

APL-UW Estimated Budget

Deep Ocean Exploration Submersible
Principal Investigator: [redacted]
Year 3

	Task 1	Task 2	Task 3	Total
Supplies				
Mock-up supplies	$0	$0	$25,000	
Test supplies - scope, power supply, etc.	$0	$0	$20,000	
Warehouse lease	$0	$0	$54,021	
Supplies Subtotal	$0	$0	$99,021	
Total Other Direct Costs	$0	$0	$272,485	$272,485
F. Prorated Direct Costs [4]				
51.2% of salaries	$0	$0	$156,097	$156,097
G. TOTAL DIRECT COSTS	$0	$0	$959,352	$959,352
H. Facilities & Administration Costs [4] (17% of G less Equip, Grad Op Fees, & Subcontract amounts above $25K)	$0	$0	$163,090	$163,090
I. Total Direct + F&A	$0	$0	$1,122,442	$1,122,442
J. APL Fixed Fee (5.7%) [5]	$0	$0	$63,979	$63,979
K. TOTAL	$0	$0	$1,186,421	$1,186,421

NOTES

[1] Estimated Staff hours are calculated by multiplying total MM by the hours per month (173.3).

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