

# The Role of University Laboratories in Navy Research and Development

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# THE ROLE OF UNIVERSITY LABORATORIES IN NAVY RESEARCH AND DEVELOPMENT

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by

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## I. INTRODUCTION

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This report has been prepared jointly by the Directors of the Applied Physics Laboratory, University of Washington (APL/UW), the Applied Research Laboratory, The Pennsylvania State University (ARL/PSU), the Applied Research Laboratories, University of Texas (ARL:UT), and the Marine Physical Laboratory, Scripps Institution of Oceanography (MPL). It is intended to reaffirm the laboratories' traditional role of contributing technical leadership in ocean science and underwater technology for the Navy. This reaffirmation is motivated by two concerns. One is that the resources and special attributes of university laboratories may be overlooked due to the recent emphasis within the Navy on centralized planning in which the laboratories have little direct participation; the other is over the decline in Technology Base support to university laboratories, which is a concern that has also been expressed at high levels in both the Department of Defense<sup>1</sup> and the Navy.<sup>2</sup> In anticipation of a renewed dedication by the Navy to its research and development programs, which are the "seed corn" from whence new advanced systems evolve, the university laboratories are prepared to contribute to the planning process and identify research opportunities with high potential returns.

The university laboratories constitute a group within the Navy's Technology Base that is unusually well qualified to make recommendations on research and development in underwater technology. As described in Section II of this report, the laboratories share a perspective grounded both in strong associations with the university independent research base and in years of participation in Navy R&D programs. This perspective, resident in a large staff dedicated primarily to Navy activities, has historically proven to be a valuable asset to the Navy's work. Section II also describes the collective resources of the laboratories and summarizes data on our sponsors.

In Section III, the laboratories' current research emphases and Technology Base contributions are summarized in each of the following research areas: ocean environmental acoustics, marine and arctic physics/geophysics, ocean technology, acoustic technology, fluid dynamics, propulsion, signal processing, guidance and control, simulation and modeling, and materials/structures. This information provides an overview of the research interests and capabilities of the laboratories for those unfamiliar with the full spectrum of activities.

<sup>1</sup> "Report of the Defense Science Board Task Force on University Responsiveness to National Security Requirements," Office of the Under Secretary of Defense for Research and Engineering, January 1982.

<sup>2</sup> "NMC R&D Centers Mission Review Panel Report," 12 August 1982, (submitted to The Director of Navy Laboratories, NMAT Code 05).

## II. THE ROLE OF UNIVERSITY LABORATORIES

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The four university laboratories were formed in the World War II era to enroll the scientific and engineering expertise of their respective universities for rapid response to the Nation's defense requirements involving undersea warfare research. The laboratories have continued as Navy-oriented research centers, specifically structured to address selected research, development, and test and evaluation problems in a timely and innovative fashion. These laboratories are distinct in motivation and methods of operation from the usual research functions of academic departments. Academic faculty primarily teach but also conduct research relevant to their teaching responsibilities. In contrast, the university laboratories are mainly dedicated to research and development projects for the Navy while their teaching function is an ancillary one. Further, the Navy-supported university laboratories are sustained by income derived from contract sponsors (on a nonprofit basis) and receive little or no university financial support.

This unique position of the laboratories, with close ties to both the Navy and their parent institutions, allows them to serve as a valuable interface between Navy 6.1 and 6.2 Technology Base programs and the talent, resources, and technology available within their respective universities. This connection affords an institutional framework in which academic researchers, at the forefront of emerging scientific thought and technology, can contribute to Navy programs while maintaining their traditional academic roles. Moreover, university laboratory associations with academic departments involve the laboratories in training students and professionals in Navy-related areas of ocean science, which provides a flow of experienced people into Technology Base programs.

The interface role of university laboratories makes them distinct not only from academic department laboratories, but from Navy "in-house" laboratories as well. The university laboratories, while informed by long involvement with Navy laboratory programs, are characterized by their historical association with the broader technology concerns and views of the university research community. This outlook has often led to novel and independent contributions that have served to strengthen, and to check and balance, the directions taken by Navy R&D programs. Among these contributions are advanced guidance and control systems, powerplants and propulsor concepts for in-fleet torpedoes, and underwater tracking ranges to test weapons and ship sensors. A related role of university laboratory personnel is to act as a nonvested council on technological issues. Indeed, one of our most important missions is to serve on Navy advisory panels and special committees and provide an independent expert view and recommendations. A few examples of recent service on technical panels include the following: MOST Committees and Subcommittees, ALWT Senior Advisory Committees, ALWT and ADCAP Technical Advisory Support Groups, DARPA Sensors Technology Advisory Group, U.S. Navy Underwater Sound Advisory Group, Ocean Science Research Strategy Team, Undersea Weapons Strategy

Team, MASWEPS Target Strength Working Group, the TOMAHAWK Technical Review Committee, the JASON Group, the Naval Studies Board (National Research Council)—Mine Warfare Study, and the USS Assessment Panel.

### **Collective Resources—Staff and Facilities**

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The collective resources of the university laboratories constitute a valuable set of assets within the Navy's Technology Base. The total permanent full-time staff at the laboratories is approximately 1000 employees including research staff, faculty, technicians, and administrative support. Approximately one-third of these employees are faculty members or university-laboratory joint appointees. Among the combined professional staffs of about 500 scientists and engineers, over one-quarter hold Ph.D.'s. Two hundred graduate and undergraduate students are receiving training toward degrees.

Each laboratory maintains special facilities to support Navy programs, and these facilities are augmented greatly by access to university facilities such as computer centers, libraries, research laboratories, and engineering shops. The total building space that houses the university laboratories is approximately 300,000 square feet. Special research facilities include stationary tanks and custom-designed barges for hydroacoustic transducer system development and testing, water tunnels for hydrodynamic research such as the Garfield Thomas Water Tunnel (48-inch diameter) at ARL/PSU, satellite monitoring stations operated by ARL:UT, and sophisticated electronics and machine shops that specialize in converting engineering concepts into hardware for testing and modification on a timely basis. The laboratories operate or lease a wide variety of research vessels, platforms, and associated instrumentation for ocean measurements. Finally, the laboratories have a large and modern set of general and special purpose computers for use in field data collection, analysis, simulation work, and other applications.

### **Sponsors**

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Information on university laboratory sponsors and funding is condensed in a series of tables. Table 1 presents a summary of Department of Defense (DOD) sponsors and their level of funding for FY 82. The total amount for the combined laboratories is over \$48 million, and the largest single sponsor is NAVSEASYSCOM. Table 2 shows total Navy funding divided into the standard categories of basic research, exploratory development, advanced development, and other support activities. Currently, Technology Base activities (6.1 and 6.2) make up 46% of the total Navy funding, which reflects a reduction from more optimal levels above 50%. Since Navy Technology Base work is particularly suited to benefit from university laboratories'

**TABLE 1 Summary of University Laboratory DOD Sponsors for FY 82**

in thousands

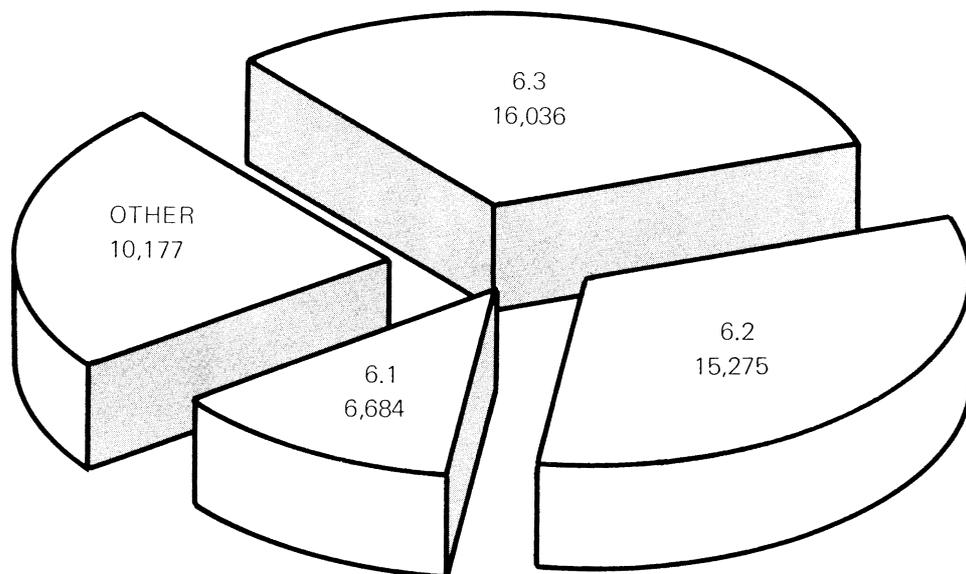
Sponsors	APL/UW	ARL/PSU	ARL:UT	MPL	Combined Laboratories
AIR FORCE			25		25
CNR	250				250
DARPA			100	383	483
DMA			394		394
F/O (ONR/NAVSEA)				600	600
NADC		20			20
NAVELEX	48		25		73
NAVOCEANO			46		46
NAVSEA	5370	12981	8319	260	26930
NAVSEA DET			25		25
NCSC			363		363
NORDA	1012		1974	900	3886
NOSC	600		58	437	1095
NRL	80				80
NSCS			100		100
NSRDC	351	434	350		1135
NSWC		276	2060		2336
NUSC	271	313	460		1044
NUWES	1000				1000
ONR	2434	656	1580	2184	6854
PACFLT			706		706
PSNS	50				50
SPCC	47		350		397
SSPO	305				305
Totals	11,818	14,680	16,935	4,764	48,197

expertise and the interface the laboratories provide with the university research base, this level below 50% in 6.1 and 6.2 categories is a matter of serious concern. A similar concern with the erosion of research and development funding was voiced in the previously cited "Report of the Defense Science Board Task Force on University Responsiveness to National Security Requirements."<sup>1</sup>

Table 3 identifies non-DOD sponsors, who provide a combined additional increment of nearly \$5 million, or roughly 10% of total university laboratory funds for FY 82. This group of sponsors outside the Navy represents an important element of university laboratory work. It signifies recognition of the laboratories' broad areas of expertise by the marine science community and provides a means of applying the technology developed primarily for the Navy to a wide range of civilian and commercial problems.

**TABLE 2 Summary of University Laboratory Navy Funding for FY 82**

in thousands



**TABLE 3 Summary of University Laboratory Non-DOD Sponsors for FY 82**

in thousands

Sponsors	APL/UW	ARL/PSU	ARL:UT	MPL	Combined Laboratories
NASA	179	203	59		441
NMFS	30				30
NOAA	569			105	674
NSF	150			1865	2015
OREGON STATE UNIVERSITY	103				103
SANDIA	545				545
SEA GRANT				100	100
STATE OF CALIFORNIA				370	370
TREASURY DEPARTMENT			88		88
OTHER		277		121	398
<b>Totals</b>	<b>1576</b>	<b>480</b>	<b>147</b>	<b>2561</b>	<b>4764</b>

### III. TECHNICAL CAPABILITIES AND RECENT ACTIVITIES

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The research and development activities performed by the university laboratories for the Navy are, from a broad view, closely related and complementary in that they primarily support basic acoustic research and undersea warfare programs with an emphasis on underwater acoustic system technologies. Strong technical capabilities and recent activities are described below.

#### Ocean Environmental Acoustics

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Experimental and theoretical models of environmental acoustic effects in the oceans at sonar frequencies including shallow water and the marginal ice zone. Results of this work are used to characterize the operating environment in terms required by modern processing technology. These models are applied to help design improved acoustic-based systems such as weapon guidance and control, and are incorporated in sophisticated simulations of the ocean that test, evaluate, and develop new concepts and systems. Examples of modeling work include the following:

Ambient noise and acoustic forward and backscattering for both surface and bottom for the open ocean and marginal ice zone; bistatic and out-of-plane scattering; propagation fluctuations; acoustic absorption in arctic waters and ice. (APL/UW)

The effect of bubbles on sea surface backscatter at weapon frequencies; background noise; explosive communications in shallow water. (ARL/PSU)

Acoustic interaction with the bottom and its effects on long range propagation, surveillance, and tactical sensor and sonar performance; improved understanding of the signal and noise processes in deep water. (ARL:UT)

Ambient noise and its directionality; propagation effects including biological scattering, and horizontal and vertical coherence in various conditions; attenuation and scattering effects in bottom sediments. (MPL)

#### Marine and Arctic Physics/Geophysics

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Basic research on the interrelated dynamic processes of the ocean including air-sea interactions, ocean mixing, hydrodynamics of internal waves, mixed layer phenomena, and the air-sea-ice system. Studies on these and related areas, which are published in the open literature by scientists from each university laboratory, are increasing our general understanding of the acoustic field in which undersea systems must operate. Some recent work includes the following:

Studies of the exchange of energy between air and the sea surface, as during storms, and subsequent energy distribution into the ocean; major aspects of air-sea-ice interaction, such as heat exchange; upper ocean processes including the dynamics of mixing, eddies, fronts, currents, and internal waves. (APL/UW)

Models and data bases for acoustic propagation at the sea floor interface; technical direction of SUBICEX 1-79. (ARL/PSU)

Geoacoustic models for many ocean areas; techniques to extrapolate existing data to new ocean regions; measurements and modeling of the geophysical/acoustic processes in ice zones to predict the acoustic field and its seasonal variations; acoustic properties of ocean sediments. (ARL:UT)

Investigations with the multiple Doppler sonar system to study the upper ocean internal wave field and equatorial undercurrent; use of Deep Tow to examine fine scale aspects of the sea floor and measure oceanic geomagnetic anomalies; sound transmissions through the sea floor. (MPL)

## **Ocean Technology**

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Ocean research equipment, vehicles, and platforms for obtaining a wide range of environmental measurements and testing new systems. Examples of this technology developed at the laboratories include the following:

Underwater tracking ranges to help test and evaluate undersea weapons and ship sensors; sophisticated instruments for measuring ocean microstructure and shear over vertical scales from dissipation lengths (10 cm) to the depth of ocean basins with great accuracy and control. (APL/UW)

Instrumentation system consisting of a deployable underwater acoustics package and a shipboard computer-based data recording system used to collect target strength data on operational submarine hulls. (ARL:UT)

Deep ocean seafloor vehicles such as the Remote Underwater Manipulator (down to 2 km) and Deep Tow (6 km); a stable Floating Instrument Platform (FLIP) with a 91 m draft for taking experimental measurements; the Doppler sonar for remote sensing of ocean hydrodynamics; the oceanographic research buoy (ORB) for handling large equipment in the open ocean. (MPL)

## **Acoustic Technology**

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Development, testing, and integration of acoustic technology for a wide range of undersea systems including anti-submarine warfare (ASW) systems. Areas of expertise include transducers, noise control, audiology, holography, and acoustic materials.

Individual laboratories activities include the following:

Acoustic lens development for data gathering by the fleet, under-ice profiling, mapping of ship radiated noise, and as a receiver in environmental acoustic measurements; transducers for artificial acoustic targets (substitutes for submarines) used to test and evaluate ASW systems. (APL/UW)

Reduction of self-noise in large aperture acoustic transducer arrays; development and testing of prototype Advanced Lightweight Torpedo (ALWT) transducers. (ARL/PSU)

Object detection and classification improvements through development of high resolution broadband sonars and low frequency nonlinear sonar; highly directive high frequency sources used to measure target characteristics; low frequency, forward looking passive capability for submarines; anechoic materials research related to detection and classification. (ARL:UT)

Transducer and hydrophone array development primarily for undersea research instrumentation; acoustic array dynamic beamformer development. (MPL)

## Fluid Dynamics

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Basic research, theory development, computational modeling, instrumentation methods, and laboratory testing in the broad area of fluid dynamics. This area includes design methodologies for high efficiency low noise propulsors, cavitation prediction, drag reduction, turbulence modeling and modeling of the complex flow-structural-noise interactions. Examples of the facilities and research include:

Assessment of hydrodynamic characteristics of a low-drag, laminar flow vehicle body in wind tunnels at the University of Washington and the California Institute of Technology. (APL/UW)

A set of three water tunnels (48, 12, and 6-inch diameter) to aid hydrodynamic research including cavitation prediction and control, design of propulsors and drag reduction; pressure test facilities to evaluate the strength of submersible bodies; extended capability of the laser Doppler velocimeter to conduct flow field measurements between blades of an operating propeller; full-scale retrofit solution to a surface ship sonar dome cavitation program. (ARL/PSU)

Transducer housing design and testing in a new water flow tunnel and its effect on receiver self-noise levels in a parametric acoustic receiving array under development. (ARL:UT)

## **Propulsion**

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Propulsion systems for surface and underwater vehicles, in particular high energy density systems for ASW applications. This work involves expertise in metal combustion physics, thermodynamics, materials, and powerplant modeling.

Propulsion systems for unmanned research vehicles including the Self-Propelled Underwater Research Vehicle (SPURV II) and the Unmanned Arctic Research Submersible (UARS); high energy density systems for mobile underwater artificial targets. (APL/UW)

Propulsion systems based on closed cycle chemical reactions, such as the ARL/PSU Stored Chemical Energy Propulsion System (SCEPS). (ARL/PSU)

## **Guidance and Control, Signal Processing, and Simulations**

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Improvement of weapon detection and homing capabilities, particularly in adverse environments, which is needed to counter significant advances in threat capabilities. Guidance and control (G&C) work, taken broadly, includes the areas of signal processing, development of G&C designs, and the development and use of computer simulations to test the concept designs and systems.

Development of G&C techniques aimed at solving target detection problems in adverse acoustic environments (e.g., shallow water and under ice); creation and use of computer simulations to evaluate G&C concepts for Navy laboratories and industry. (APL/UW)

Development of baseline G&C concepts and experimental hardware for many fleet torpedoes, such as ALWT and the Mk 48 Advanced Capability (ADCAP). (ARL/PSU)

Advances in counter-countermeasure technology, which improves weapon response time in attack/reattack and terminal homing modes; signal processing techniques addressing coherence and non-Gaussian behavior of reverberation, interference, and target signals; development of computer simulations to evaluate design and performance of high resolution and nonlinear sonar systems, countermeasures, and signal processing. (ARL:UT)

Theoretical research on adaptive signal processing and development of techniques for improved reverberation rejection. (MPL)

## **Materials/Structures**

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Development of nondestructive test technology; characterization and development of acoustic materials for Navy applications; theory and model develop-

ment of structural/noise interactions and materials research for high-energy-release metal combustion propulsion systems.

Development of an on-line ultrasonic technique for nondestructive testing of metal matrix composite precursor wire. (ARL/PSU)

Development of anechoic coating material with extended frequency and environmental parameter performance. (ARL/PSU)

While in general the activities of the laboratories are closely related in that they all emphasize marine science and technology, it is also true that each laboratory has developed a unique profile of technical expertise and emphases that is defined by the Navy program areas with which it has been associated over the years. Table 4 indicates the technical emphases of each laboratory with respect to ten scientific/engineering disciplines. The emphases of the four laboratories as an aggregate are also represented.

