UNITED STATES NAVAL ACADEMY
Annapolis, Maryland—21402

IN REPLY REFER TO:

7-2-69

From: Superintendent, U. S. Naval Academy
To: Chief of Naval Personnel

Subj: High Performance Towing Tank

Ref: (a) NavPers ltr Pers-C322-jk of 8 October 1968
(b) COMNAVFACENGCOM memo of 18 September 1968
(c) ENGR DEPT (USNA) INST 11000.2 of 30 June 1968
(d) ENGR DEPT (USNA) Report E-68-5 "The Conceptual Design of a High Performance Towing Tank for the U. S. Naval Academy," 25 June 1968
(e) "Justification for a Hydrodynamics Laboratory at the U. S. Naval Academy," 9 September 1968

Encl: (1) Specific Justification of a High Performance Towing Tank for the U. S. Naval Academy
(2) Procurement of Equipment for a High Performance Towing Tank for the U. S. Naval Academy
(3) Abstract of Reference (d)

1. References (a) and (b) request further and specific justification for construction of a high performance towing tank in the proposed new Engineering Department building. This justification is found in Enclosure (1). References (c) and (d) describe the proposed laboratory, and the required development and design work. Enclosure (2) outlines possible means of reducing initial development costs and procuring the required equipment. Enclosure (3) abstracts reference (d) describing the tank and its equipment.

2. Although clearly recognizing a critical need to save funds, it is my conviction that the proposed high performance towing tank is justified and must be included in the proposed new building. The requirement for, and the utilization of, this facility are completely consistent with the Naval Academy's curriculum and mission, and vital to their realization.

The proposed tank is the minimum facility for its proposed mission. Justification is strengthened by the proposed acoustic capability; the tank will serve a dual function: an educational tool, and a research tool of significance to the Navy. The laboratory must study tomorrow's hydrodynamic problems, if the Naval Academy is to retain its position of leadership in the Navy's increasingly sophisticated technical environment.

3. In reply to questions raised in references (a) and (b), Enclosure (1) states the following:

a. The proposed tank is not beyond the state of the art, rather it employs the latest technology in ways sometimes unique in towing tank design.

b. Development costs, as explained in Enclosure (2), need amount to only $120,000, followed by $285,000 of equipment design.

c. Because uses and requirements are entirely different, duplication between the proposed tank and those at Carderock does not exist, despite physical similarities.

d. Educational need for this tank exists, both with respect to specific courses, and to the general needs of a school of Naval Engineering. The Naval Academy presently has Naval Engineering enrollment comparable to that at the University of Michigan, and greater than any other accredited university.

e. Separation from the first MCON increment is an architectural question, and of little import so long as the tank is built adjacent to the new Engineering building.

f. Separation of the tank and carriage design is feasible, so long as compatability of all components of the total system is guaranteed. A feasible design method is proposed in Enclosure (2).

g. The extended 85-foot tank should, under no circumstances, be omitted from the proposed building.

4. The development costs for such a sophisticated facility will be significant. However, the Engineering Department staff feel it possible to substantially reduce the $500,000 figure quoted in reference (b). Indeed, such reductions would have, and should have, been made had better communication existed. Enclosure (2) indicates a method of reducing and delaying the funds required in Fiscal 1969 from a total of $634,000 to $120,000. This reduction may be followed by considerably more level funding than originally planned.

5. It is requested that funding be authorized in the estimated amount of $120,000 for the accomplishment of Acoustic and System Development described on pages 10-11 of Enclosure (2). This is basic to the development of firm requirements for design.

6. Division IV, pages 18-20, of Enclosure (2) summarizes management decision that must be made to assure orderly progress in planning. Discussions must be held among personnel of NAVFAC, BUPERS, the Architect-Engineer, and the Naval Academy to resolve these problems. Many of the problems are associated with equipment which may or may not be MCON funded. This equipment seems to fall in a grey area as to funding definitions, and solutions to the problems are not readily apparent. These questions can only be resolved by agreement among the commands concerned. This project must not be deferred without expending a great deal more effort in solving the funding difficulties. My staff and I are prepared to discuss this matter further and in depth with you as necessary.

7. It is realized that the crux of the justification of the towing tank in the Hydromechanics Laboratory is the percentage of utilization by midshipmen at the Naval Academy, and the degree to which this tank is an integral part of developing a first-rate engineering program at Annapolis.

a. Courses which are now offered, or are in development as necessary additions to the curriculum, and which will require midshipman use of the tank are as follows (demonstrations to basic courses, which total approximately 40 tank hours per year are not included):

E-610 - Introduction to Ship Systems
E-702 - Systems Engineering
E-715 - Ship Vibrations
E-802 - Naval Architecture II
E-811 - Ship Structures
E-813 - Continuum Mechanics
E-821 - Marine Propulsion I
N-832 - Oceanographic Applications
S-704 - Underwater Acoustics
E---- - Ocean Waves
E---- - Ship Motions
E---- - Marine System Design II
E---- - Ocean Structures
E---- - Advanced Marine Vehicles
E---- - Hydrofoil and Propeller Theory
N---- - Oceanographic Instrumentation

Assuming the tank to be used forty-hours per week during a thirty week academic recitation year, approximately 440 hours or 37 percent will be used for the above courses. This does not include a significant amount of preparation and set-up time on the course connected experiments, which will bring utilization by and for the above courses to something well in excess of 50%.

b. In addition, Trident scholars and individual midshipman projects (E-902) significantly increase tank utilization. During the 1965-66 and 1966-67 academic years, Trident Scholar usage pushed midshipmen utilization of the existing towing tank to virtually 100%.

c. In summary, it is estimated that the new towing tank will be used by midshipmen for the purposes outlined in sub-paragraphs a and b above, from 50 to nearly 100% of the academic year.

Copy to:
NavFacEngCom
Ches Div
ComNavShips

SPECIFIC JUSTIFICATION FOR A HIGH PERFORMANCE TOWING TANK

for

THE U. S. NAVAL ACADEMY

Enclosure (1)

SPECIFIC JUSTIFICATION OF A HIGH PERFORMANCE TOWING TANK FOR THE U. S. NAVAL ACADEMY

Ref: (a) NavPers ltr Pers-C322-jk of 8 October 1968
(b) COMNAVFACENGCOM memo of 18 September 1968
(c) ENGR DEPT (USNA) INST 11000.2 of 30 June 1968
(d) ENGR DEPT (USNA) Report E-68-5 "The Conceptual Design of a High Performance Towing Tank for the U. S. Naval Academy," 25 June 1968
(e) "Justification for a Hydrodynamic Laboratory at the U. S. Naval Academy," 9 September 1968
(f) Procurement of Equipment for a High Performance Towing Tank for the U. S. Naval Academy, 18 December 1968

I. STATEMENT OF PHILOSOPHY

Full understanding of the justification for the proposed laboratory requires knowledge of the guiding philosophy of Naval Engineering education at the Naval Academy. It is impossible to consider only detailed portions of the overall justification; the laboratory is justified not by isolated facts, but as a key facility for a modern undergraduate engineering curriculum. Excellent laboratories are vital to excellent engineering education, be it at an undergraduate school, a graduate school or at the U. S. Naval Academy. The philosophy which holds this to be true is outlined below, and in more detail in reference (e). Much of reference (e) has been repeated below in the format requested by reference (a). The laboratory's justification is based on consideration of the Naval Academy's educational, curriculum, and research needs and on the Navy's need for leadership in hydrodynamics. The Naval Academy must educate and train a man for the Navy of the future, and for the technical problems he will encounter. Such a sophisticated laboratory will contribute significantly to this effort.

Currently, ten existing courses and five planned courses will use the proposed towing tank. By 1974, even greater utilization is envisioned as the curriculum evolves. But in addition to instruction, the tank will be used for an increasingly active schedule of midshipman projects, especially under the Trident Scholar program. Present facilities have been used by fourteen midshipmen engaged in potentially significant hydrodynamic research during the last five years. The existing 85' towing tank is of marginal utility for most of this work and does not allow the proper prediction of much full scale phenomena.

It is incorrect to distinguish between research and educational needs, since in modern engineering education the two are inseparable. Certainly, the midshipmen projects cited above are educational, and our great universities have demonstrated research's ability to generate a dynamic atmosphere conducive to study. In addition, sincere motivation is felt by top flight faculty members toward research, as a primary method of advancement in the academic community outside their own institution. It is a creative outlet for personal involvement in significant engineering projects. First-class schools of engineering have first-class laboratories, laboratories obviously necessary for graduate education. But for reasons stated here, if these schools taught undergraduates only, the laboratories would still be required.

The most important reason for faculty research is its proven capability to keep the faculty, and therefore the curriculum, current. A man, no matter how dedicated a teacher, will lose touch with his profession if allowed no activity beyond the classroom. Even if a great faculty could be assembled at an institution with limited research opportunities, it is doubtful that faculty would remain great.

Many of the Academy faculty are engineers exceptionally well qualified to teach engineering, but with little or no Naval background. When these men are encouraged to pursue research problems of current Naval concern, their knowledge, understanding, and feeling for the Navy inevitably increases. They become more effective teachers of midshipmen. A mission of the Naval Academy faculty must be involvement with the Navy and its problems. In addition, the Naval Academy faculty has other men well qualified to teach Naval Engineering and Naval Hydrodynamics. They will be sorely disappointed if the Naval Academy does not succeed in establishing a first-class hydrodynamics facility; indeed, some of them have joined the faculty with just that expectation. In like manner, a significant facility of this kind will attract outstanding midshipmen in an age in which the top high school graduates have a wide spectrum of excellent institutions from which to choose. The Naval Academy, its faculty, and its midshipmen must remain involved with the Navy and with its problems.

II. RESPONSE TO REFERENCE (b)

A. State of the Art

Reference (b) states that "the tank concept and the carriage to be used in this facility is beyond the state of the art." This statement obviously depends upon definition of the term, state of the art. If the term implies assembly of a unique system, then the proposed tank is beyond the state of the art. However, if it implies the development of new technology, then the proposed tank is not at all beyond the state of the art. The conceptual design, reference (d), proposes a towing tank system of unique and advanced design, but one which utilizes existing technology and many proven components. It would be foolish to design an educational facility whose success did hinge on undeveloped technology.

The proposed tank is of medium length (380'). Forty-eight tanks in various countries are up to 2588 feet longer; the tank at the University of Michigan is only twenty feet shorter. The proposed speed of thirty knots is also moderate when compared to speeds of over sixty knots achieved by tanks intended for high speed. In the proposed facility, the difficult constraint is achieving 30 knots in a short distance. Relatively high carriage accelerations will be required, but will not exceed accelerations found at certain other tanks, nor in a great variety of other non-towing tank equipment. It is considerably less expensive to use high acceleration to achieve speed than it is to use a longer tank.

The proposed hydro-acoustic aspects of the basin are unique. It is hoped that through adequate structural acoustic isolation, and sufficient absorption of model generated noise, a high acoustic signal-to-noise ratio may be achieved for the study of flow noise. Anechoic or zero noise conditions are not required. It is hoped that adequate noise control may be achieved through use of available knowledge and products currently on the market. A study of the available materials, and how they might best be utilized is required. This study will establish the limits of the state of the art, and thus will allow the intelligent writing of specifications. A too stringent specification will be prohibitively expensive; a too loose specification will not achieve the required technical goals.

All of the instrumentation for the proposed tank will be available off the shelf. In some cases, it will be ahead of that found in other towing tanks, simply because it will be new and will reflect the rapid advances being made by instrumentation technology.

B. Development Costs

Reference (b) states that "approximately $500,000 would be required for research and development effort on this tank and its associated towing carriage. In addition, the final design of the tank is estimated at $75,000." While it is true that $575,000, or more, may be spent on development and final design, reference (b) classifies all this work as research and development. Conceptual design studies by the Naval Academy faculty have disclosed no areas requiring research effort. According to estimates made by the faculty, the development costs amount to only $120,000 of the total figure. The necessary final design of the equipment could then be accomplished for an additional $285,000. All other equipment design would then be funded as part of the equipment purchase contracts. The distinction between engineering done as development, final design, and under equipment purchase may be critical.

A detailed discussion of these problems has been prepared, and is available in reference (f). It suggests a division of responsibility which will allow the planning to progress with the expenditure of only $120,000 of Fiscal 1969 funds. Under the original plan, the A and E firm designing the new building held responsibility for the entire tank design, including equipment. This would have required expenditure of the total development and design cost ($500,000+) in 1969. The proposed plan allows more level funding by delaying some design items removed from the architect's responsibility.

Responsibility for procurement of much of the equipment would fall to the Naval Academy, but the exact division between Military Construction and non-technical training (commercial scientific) equipment is not clear. Some of the very specialized equipment is heavy, and is attached to the building structure; it may be MCON equipment, or it may be procured as non-technical training (commercial scientific) equipment. This will govern the division of responsibilities.

The necessity of development, and design independent of procurement contracts, also clouds the division of responsibility. This engineering is absolutely required. The development will confirm the conceptual design, lead to an optimum configuration, and provide vital input to the architect and equipment specification writers. The design of certain items must be accomplished prior to asking for construction bids; again to supply input to the architect, and to allow utilization of fixed-price equipment construction contracts.

C. Duplication of the Carderock Facility

The proposed laboratory will not duplicate the NSRDC Facilities, except in the simplest possible terms. NSRDC has ship model towing tanks, the Naval Academy will have towing tanks; NSRDC has wind tunnels, the Naval Academy will have wind tunnels; NSRDC has a Naval Engineering Library, the Naval Academy will have a Naval Engineering Library. But the uses of these facilities are entirely different at NSRDC and at the Naval Academy.

One Trident Scholar recently used NSRDC's David Taylor Model Basin. Certainly the Naval Academy found these facilities adequate and to a limited degree accessible. However, the mission of NSRDC makes it incompatible with usage by Naval Academy midshipmen and faculty. NSRDC's facilities must be scheduled for maximum utilization and for the achievement of positive results. Projects are scheduled far in advance, but with sufficient flexibility to continue or terminate tests on the basis of their success. The Naval Academy facilities, on the other hand, must be geared to midshipmen schedules and the academic year. Class demonstrations and experiments must be performed on schedule; midshipmen projects must be performed after the midshipmen has had time to prepare, but while sufficient time remains to complete his project within the academic year. Faculty research must often be performed between lectures, instruction, meetings, etc. The Naval Academy must be extremely rigid in some scheduling, while allowing the tank to be used on short notice; NSRDC must schedule well in advance and then be quite flexible. The two needs are obviously incompatible. The recent use of NSRDC was very successful except for scheduling; the scheduling problems were extreme. It is completely impossible logistically to utilize NSRDC for the frequent experiments required by classroom instruction.

These problems cannot help but be aggravated by the growing demands on both NSRDC and the Naval Academy. The Navy's need for the proposed type of high performance laboratory is expected to increase for the foreseeable future. In addition, a very great need is felt by the Navy and by the engineering community for a facility in which to study the problems of flow noise and high speed vessels. Flow noise can render SONAR ineffective above certain speeds; it is the subject of millions of dollars of research and development. Yet no controlled environment facilities exist, in any form in any country, to study the noise generated by the external flow of water about an object. Such study

can never be accomplished in towing tanks presently in existence, for the water basins and the rail systems themselves must receive special acoustic and vibration isolation. Today such tests are run either at sea or on uncontrolled bouyancy or gravity propelled models. Neither technique is satisfactory, both are expensive. With sufficient engineering however, a new tank meeting the requirements could be constructed.

The facilities of NSRDC are presently filled to capacity, and are incapable of the flow noise work described. In addition, a general shortage of towing tanks exists in this country. Even the inadequate 85 foot tank at the Naval Academy is used by organizations separate from the Academy. Chief among these has been the Annapolis Division of NSRDC; in fact the Annapolis Division has asked for more time in the tank than the Naval Academy has been able to allot. Use by the Annapolis Division of NSRDC and other Navy laboratories is of mutual benefit to the laboratory involved and the Naval Academy, and is actively encouraged.

Thus, the Navy has use for a towing tank with flow noise study capabilities; and it has use for a tank in the Annapolis area. A laboratory constructed at Annapolis will serve a dual function: greatly aiding the education of midshipmen, and serving the Navy as a laboratory. For the investment of one facility at the Naval Academy, the Navy will gain the benefits of two facilities, both of which are justified.

If any first rate laboratory is to be located at Annapolis, it seems appropriate that it be a facility capable of studying Naval Engineering and Naval Hydrodynamics, a facility which will greatly extend the already fine capability in existence at the Naval Academy for the experimental study of the turbulent boundary layer.

D. Evidence of Educational Need

The educational needs are, of course, strongly influenced by the educational philosophy stated in paragraph (1) above, and in reference (e). Specific needs may be cited, both in the field of classroom instruction and in midshipman research. Any specific curriculum requirements stated today will certainly have changed by the time the lab becomes operational. A definite trend exists toward greater midshipmen involvement in laboratory work, both in course work and in independent projects.

The degree of midshipman participation in Naval Engineering, and thus in ship hydrodynamics, is reflected in a comparison of the Naval Architecture, Marine and Ocean Engineering enrollments at the Naval Academy and the various other schools offering such courses. The Naval Academy's Naval Engineering program will graduate 57 midshipmen in the class of 1969. The University of Michigan will graduate 38 Naval Architecture and Marine Engineering students during the 1967-68 academic year. No other ECPD accredited school will graduate more than 12.* The present Naval Academy's total Naval Engineering enrollment stands at 167 midshipmen; the University of Michigan's total undergraduate and graduate Naval Architecture and Marine Engineering enrollment is roughly 200.

No other accredited school has total enrollment of much over 100 students. The University of Michigan has a 360' foot towing tank, with features very similar to the conventional features of the proposed USNA tank. The Naval Academy's existing 85' tank is the smallest university towing tank in the United States. It is safe to say that the Naval Academy is one of the two largest schools of Naval Engineering in this country, and yet presently has the smallest hydromechanics laboratory.

The Naval Academy curriculum currently includes a number of courses which will benefit by the presence of a first-class hydromechanics laboratory. Among these are: E-610, Introduction to Ship Systems, in which midshipmen will observe resistance and seakeeping tests, and any research underway; E-802, Naval Architecture - Dynamics, in which students will perform resistance and seakeeping experiments on a number of vessels including submarines, hydrofoils, hovercraft, and self-propelled ship models, and will observe research; E-811, Ship Structures, which will have midshipmen investigate the structural loading of ships in waves; E-702, Systems Engineering, which will study the laboratory data system itself, and will include experiments in the acquisition and processing of random data measured in the tank, emphasis being placed on real-time computer analysis and computer control of the experiment; E-813, Continuum Fluid Mechanics, which will experimentally investigate laminar and turbulent flow and turbulent flow noise; and S-704, Principles of Underwater Acoustics, in which flow noise will be studied. In addition to these, several new courses have been proposed which could make extensive use of the tank. These include: Design of Marine Systems, Ship Motions, Hydrofoil and Propeller Theory,

* State University of New York, Maritime College, is developing an unaccredited program comparable to that of the Naval Academy. It has no towing tank, but uses one at Webb Institute.

Advanced Marine Vehicles, and Ocean Engineering Structures. These courses are indicative of the direction in which the curriculum is moving; Design of Marine Systems, Ship Motions, and Ocean Engineering Structures should be offered in the very near future. All of the subjects mentioned are of direct academic and professional importance to the Navy. The tank will be used for demonstrations to all midshipmen, in the basic engineering courses; and to some midshipmen in Oceanography.

But instruction will not form the majority of the proposed towing tank's usage. The courses E-902 and E-903, Engineering Research, Design or Construction, and the Trident Scholar Program will provide an increasingly active group of midshipmen with need of a first-class hydrodynamic facility. These midshipmen are typified by the 14 Trident Scholars and E-902/903 students of the past five years who have studied Naval Hydrodynamics. Nine of these students have used the existing towing tank, while the remainder used other laboratory equipment. They all could have used the proposed 380 foot tank. Their projects included: a feasibility study of a Deep Submergence Vehicle (DSV); propulsion of swimming fish-like bodies; the resistance of a slender hull; signal analysis of turbulence and flow noise measurements; the effects of polymer additives on boundary layer velocity fluctuations; turbulence intensity, hydrodynamic flow noise, and drag; hot film anemometer calibration techniques; drag reduction on hydrofoils; boundary layer control on submarines; the feasibility of a semi-submersible vessel; the design of a sailing hydrofoil; and a unique method for testing submarine models. These projects were in most cases of graduate quality. The work on polymer additives and turbulent boundary layer measurement has received world-wide attention. The present tank, which is very limited in speed, length, and model size, will not allow many logical extensions of this work.

III. RESPONSE TO REFERENCE (a)

In addition to the above response to reference (b), reference (a) requested comments on the following points.

A. Present State of Knowledge

Paragraph (IIa)(State of the Art) concluded that the knowledge necessary to build the towing tank exists today, but in some cases, has not yet been applied to the design of a towing tank.

B. Separation from the First MCON Increment

If incrementation does occur, the inclusion of the towing tank in one increment or the other is basically

an architectural question. The increment in which the towing tank is funded is immaterial; its inclusion in, and integration with, the new Engineering Department building is essential. The architect must plan the building increments for ease of construction, first increment utilization, etc., and must include or not include the towing tank on that basis.

The towing tank must be integrated with the new building for a number of reasons. Naval Architecture classrooms will be located near the towing tank, so that midshipmen may easily participate in laboratory exercises and may readily observe any research underway in the tank. The midshipmen enrolled in the Naval Engineering program will have a center of activity in their classrooms, design rooms, and the laboratories. They will develop an esprit de corps which will motivate them in their studies, and interest them in current research and Naval engineering advances. The establishment of centers of activity has benefited other schools, and will prove beneficial at the Naval Academy.

In addition to this, the towing tank must take full advantage of the technical support planned for the new building: signal processing, data reduction, computer interfacing equipment, and technical shops. Faculty utilization will be increased if the tank is readily accessible.

C. Separation of Tank Design and Carriage Design

The design of the towing tank and its associated equipment originally was to be by the architect/engineer on a system responsibility basis. This approach has two advantages: it places one organization in control of the entire design, insuring integration and compatability of all components; and it relieves the Naval Academy of a great deal of engineering and administrative effort for which it has the capability but not the capacity.

However, if a total systems approach is not feasible, another approach must be used. An alternative, (reference (f)), has been prepared by the Navy Academy which will provide the minimum requirement for design of a total facility. This minimum requirement includes: (1) preliminary development of the acoustic design, to estimate architectural requirements, (2) a tradeoff analysis of the proposed carriages, in sufficient detail to allow the architect to proceed with the building design; and (3) the generation of performance specifications cost estimates, etc., so that equipment procurement may begin.

Achievement of these goals will allow the architect to proceed, with the assistance of an acoustic consultant, and will allow the appropriate organization to proceed with the procurement of the necessary equipment. The preliminary studies must consider the entire system; the procurement process may separate sub-systems if necessary.

D. Omission of the Existing 85 Foot Tank

The existing 85 foot towing tank is entirely independent of the proposed 380' tank and should under no circumstances be omitted from the new building. It requires no development work, only simple architectural engineering. Approximately $100,000 is presently invested in instrumentation and support equipment for this tank, while the proposed modifications involve only the water basin and rail system. It would be wasteful not to include it in the new building.

The small tank will be utilized extensively in the new building; for it has several unique advantages. The visibility of the model is excellent, making it ideal for teaching the basic principles of ship resistance to the large groups of midshipmen enrolled in the basic Fluid Mechanics course. The proposed tank will be used primarily by smaller groups of midshipmen enrolled in the Navy Engineering programs, although all midshipmen will see it and benefit from it. The small tank will also be used for preliminary investigation of research projects; its small size will be of great convenience. In addition, it will be used for tests which contaminate the tank water; changing the water will be possible.

IV. GENERAL COMMENTS

The importance of Section (I), Statement of Philosophy, cannot be overemphasized, for the proposed tank must not be considered out of context.

In addition, it must be made very clear that the Naval Academy is desirous of cooperating fully in reducing the cost of this facility. Any design and procurement method which furnishes adequate engineering and a product compatible with the total designed system is satisfactory. The facility may very well be developed over several years, but it must at all times be developed in such a way as to allow further development in keeping with the total system plan. It is far more important to figuratively, and

literally, lay a foundation upon which the complete design may be developed, than it is to provide a system which is 100% operational at the time the new building is occupied. Such development will not be possible, however, without careful preliminary engineering.